

ONE OCEAN, ONE HEALTH NOAA IN THE LEAD

A REPORT FROM THE NOAA SCIENCE ADVISORY BOARD

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EXECUTIVE SUMMARY

The ocean¹ provides many health benefits, from low fat, high protein food sources and therapeutic drugs to regulation of global temperature. The ocean also poses many hazards, such as hurricanes, pathogens, animal attacks, toxins and contaminants that can cause loss of life or impair health. The potential impact of these threats is enhanced because more than half of the US population lives along the coast. Even those living inland are not immune to the ocean's effects, as ocean-driven climate patterns have been linked to inland outbreaks of several pathogens. These and other threats are likely to increase with predicted changes in climate.

NOAA has multiple programs intended to promote health, but has struggled to define its role in relation to the many other agencies that also have health-related responsibilities. To help NOAA more clearly define its role and actions needed to fulfill that role, the NOAA Science Advisory Board (SAB) established an Oceans and Health Working Group (OHWG) that includes experts in the fields of epidemiology, toxicology, public health, environmental modeling, veterinary science, marine biotechnology, economics, and ocean sciences. The OHWG was charged with identifying opportunities to enhance NOAA's ongoing health-related efforts, including all relationships between the ocean and the physiological well-being of organisms. This report from the NOAA Science Advisory Board presents the Working Group's findings and recommendations.

Finding 1: There is an urgent need for action

Changes in ocean acidity, temperature, and salinity are affecting the balance of risks and benefits from the sea:

- The geographic range of pathogens is changing associated with changes in ocean temperature
- Harmful algal blooms are increasing in frequency and intensity
- The increased intensity of tropical storms has placed coastal regions at increased risk of catastrophic flooding
- Decreased availability of domestic seafood has led to increased importation from countries with lower public health and food handling standards
- The frequency of epidemics and number of new diseases in corals, sea turtles, and marine mammals has increased, with many linked to climate change effects

Given the close linkage between human and animal health, the negative impact of oceanic changes on aquatic organisms offers early warning about the potential for human health risks. This linkage is the foundation for the One Health Initiative, a movement to create collaborations among multiple health-related disciplines, including physicians and veterinarians. The One Health Initiative recognizes the interdependencies among human, wildlife and ecosystem health and recognizes that efforts to protect human, animal, and ecosystem health should be coordinated to benefit all.

¹ In this report, "ocean" is defined as the open ocean, U.S. coastal waters, and the Great Lakes

In contrast to health threats, the ocean also provides great promise for health benefits through high quality food sources and development of new pharmaceuticals. Marine habitats offer underexplored opportunities for discovery of novel chemicals with therapeutic potential. Scientists have already isolated more than 20,000 biochemical compounds from sea creatures, leading to several new classes of drugs for treating an array of diseases.

Finding 2: NOAA is well positioned to meet this need

NOAA is the nation's leader in oceanographic, meteorological, and atmospheric predictive science. More importantly, NOAA is leading development of early warning systems to identify and forecast ocean conditions that can threaten human, marine organism, and marine ecosystem health. NOAA has incorporated these predictive capabilities into identifying how climate change may affect the extent and diversity of ocean-related public health impacts. NOAA also leads the nation's efforts to monitor and preserve marine mammal health, which is closely linked to and serves as an important sentinel for human health. In addition to these technical skills, NOAA has legislative mandates to implement and coordinate ocean-related health activities. NOAA has the partnering skills to unify the activities of the many other agencies with programs that address ocean health threats and opportunities. NOAA is uniquely positioned to manage these diverse resources to protect those who use, eat, or otherwise enjoy the ocean's bounty.

Finding 3: NOAA has a diverse health portfolio in place, but the pieces need to be linked together to form a more comprehensive, coordinated program

NOAA already possesses many excellent programmatic elements that promote health and well-being, but they are scattered across many parts of the agency and lack a unifying structure. The programs also appear to result from the interests and skills of the individual research centers, rather than from a cohesive planning effort. During this review, NOAA was asked to list all of its activities intended to increase understanding of, and prevent health risks from, ocean-related hazards. The list largely reflected a focus on biological research programs centered on the Oceans and Human Health Initiative and did not equally represent operational or research programs focused on protecting health from physical oceanographic hazards. Social science assessments of risk perception, management and response similarly were absent. There appears to be no entity within NOAA responsible for linking these pieces into a coordinated program to promote and protect public health.

Finding 4: NOAA needs to better quantify and communicate the benefits of its investment in health-related activities

NOAA's activities save lives and enhance health, but the agency doesn't effectively quantify and communicate its successes and their societal impact. NOAA has developed hazard screening systems for fish and shellfish contamination, coastal flood warning systems, and predictive models for search and rescue, among many other products that benefit the public, but these contributions have not drawn an appropriate level of public recognition and support. The agency needs to develop metrics that quantify its relevance to public well-being, including the number of lives saved and illnesses prevented, as well as economic gains upheld or losses prevented. NOAA should quantify its achievements and proactively leverage this information to increase public awareness about the important societal benefits of its health programs.

Based on these findings, the OHWG advances three core recommendations:

Recommendation 1: NOAA should establish health protection, preservation and enhancement as an agency-wide goal

NOAA should acknowledge that identification and protection of ocean-health linkages are critical to the agency's core mission and commit at the highest administrative level to a national leadership role appropriate to the agency's unique skill sets and capabilities. NOAA's Next Generation Strategic Plan provides an opportunity for the agency to incorporate health concerns into the agency's mission in a meaningful way. The newly-formed Climate Service will also allow NOAA to highlight products useful to individuals who must make decisions on the long-term effects of climate change on health of humans and organisms.

Recommendation 2: NOAA should develop a comprehensive plan for its health programs

NOAA needs a plan that ties its health efforts into a comprehensive program and links NOAA's efforts to other federal agencies with complementary skills in environmental and public health. The plan should be based on a systematic risk characterization that identifies and quantifies potential health benefits and threats. This type of prioritization should identify which threats and benefits can best be addressed with short-term operational programs versus those that will require longer-term research investments. Such planning will ensure that agency investments provide the greatest societal benefit.

Recommendation 3: NOAA should focus initially on several priority projects

The OHWG recognizes that a comprehensive plan for NOAA's health program may take several years to develop, particularly if NOAA conducts a thorough risk prioritization and coordinates its planning with that of complementary agencies. As such, the OHWG identified a number of immediate priority projects that are logical extensions of ongoing NOAA investments that will yield significant societal benefit, including: 1) Forecasts of impending threats; 2) Surveillance systems for emerging pathogens, contaminants, and toxins that affect health; 3) Climate change effects on ocean-related health; and 4) Health benefits from the sea.

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CHAPTER 1: BACKGROUND

The ocean covers 70% of our planet and directly or indirectly impacts every organism on earth. It provides numerous health benefits to humans. Billions of people depend on fish and shellfish as primary sources of protein. More than 20,000 biochemical compounds have been isolated from marine organisms, many of which have become important pharmaceutical products. New health applications for marine-derived compounds continue to evolve, and methods for optimizing yield continue to be fruitful. Some coastal communities rely on the Great Lakes or desalination of ocean waters as their primary source of drinking water. Coastal transportation, energy, and recreation sectors create jobs and improve health by allowing communities to flourish. The ocean improves the quality of life, with more than half of the US population choosing to live along the coast.

On the other hand, the ocean poses many health risks, including those resulting from severe storms, marine toxins, pathogens, and animal attacks. Hurricane Katrina in 2005 and the Indian Ocean tsunami in 2004 are recent reminders of the devastating potential of the ocean. Even those living inland are not immune to ocean effects on health and well-being. Malaria epidemics, tied to ocean and atmospheric climate variability, kill approximately one million people each year. Ocean-driven climate patterns have been linked to inland outbreaks of Hantavirus in the southwest United States and cholera in Bangladesh.

Addressing ocean-mediated health threats is a federal priority. The US Commission on Ocean Policy called for a coordinated effort to understand links between the oceans and health. Concerns about beach closures, seafood contamination, harmful algal blooms, and occurrence of toxic chemicals and pathogenic microorganisms in coastal waters have led Congress to pass several pieces of legislation, including the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2004 and the Oceans and Human Health Act of 2004.

The National Oceanic and Atmospheric Administration (NOAA) is the nation's ocean stewardship agency and has been directed by Congress to address ocean health related issues through the above-mentioned legislation. These Acts require NOAA to increase understanding through research of how the ocean influences health, and to use the findings to develop management, control, and mitigation strategies. Given the implementation of the legislation, the NOAA Science Advisory Board (SAB) established an Oceans and Health Working Group (OHWG) to evaluate NOAA's overall ocean health science portfolio and assess the agency's contributions to public safety and societal well-being.

The SAB provided six charge questions to the OHWG, a group composed of eleven experts in the fields of epidemiology, toxicology, public health, environmental modeling, veterinary science, marine biotechnology, economics, and ocean sciences. These questions focused on defining NOAA's role and steps that the agency will need to take in order to support the preservation of human and organism physiological health in the oceans and Great Lakes (See *Charge to the Working Group*, highlighted below, and responses, in Appendix A). The OHWG considered "oceans and health" in a broad context, including all relationships between the ocean and the physiological well-being of organisms.

Charge to the Working Group

The Working Group (WG) will explore opportunities to enhance NOAA's ongoing ocean health efforts and their impacts on ecosystem and public health and well-being through consideration of the following questions and any others that the WG may decide to entertain:

- 1) What are NOAA's unique and important scientific roles in addressing ocean health issues?
- 2) What are the right ocean health science questions, products and services for NOAA?
- 3) Are there additional ocean health science issues that should be included in the NOAA research portfolio? If so, what are these?
- 4) What are the appropriate steps for NOAA to incorporate and advance ocean health as part of its core mission?
- 5) How could NOAA more systematically develop ocean health products and services to enhance ecosystem, organism, human, and community health?
- 6) How can NOAA better integrate among its major programs, including activities conducted within the agency and those supported in the external community, to better define and assess ocean health issues?

This document is organized in six sections: an executive summary; two main chapters that summarize the OHWG's Findings and Recommendations to NOAA; Appendix A, which provides detailed responses to the specific charge questions provided by the SAB in the OHWG Terms of Reference; Appendix B, which includes biographies for the OHWG members; and Appendix C, which contains agendas from the OHWG meetings.

CHAPTER 2: FINDINGS

Over the past few decades, society has placed increasing demands on ocean resources, and many new challenges have arisen, ranging from global climate change impacts to increases in synthetic organic chemicals. There are also many new opportunities for cultivating ocean resources to improve or sustain healthy communities and ecosystems. While many organizations work on issues related to ocean and health interactions, they usually focus on small parts of the whole, and often fail to combine their successes to advance a broader global knowledge. NOAA's unique, multi-disciplinary capabilities are needed now more than ever to integrate disparate efforts and address the ocean's overall effects on health, ensuring that people who use, eat, or otherwise enjoy ocean resources do not become ill or die as a result of normal responsible use.

Finding 1: There is an urgent need for action

Ecological changes are affecting the balance of ocean-related risks and benefits. Scientists have documented increases in ocean acidity from the absorption of atmospheric carbon dioxide, increases in sea surface temperature, and decreases in salinity from melting glaciers. These physical changes interact to make the ocean increasingly hazardous to aquatic and land-dwelling organisms alike. Emerging health threats include:

- **Pathogens:** The geographic range of pathogens is changing associated with changing ocean temperature. Methicillin-resistant *Staphylococcus aureus* (MRSA) bacteria, which kills 25% more people in the United States each year than the AIDS virus (www.avert.org/usa-statistics.htm), have been discovered in beach sand.
- **Toxins:** Harmful algal blooms are increasing in frequency and intensity worldwide. In the US, inhalation of toxins from *Karenia brevis* blooms cause human illness and economic losses of \$50 million per year from effects on tourism and shellfish industries.
- **Coastal flooding:** Climate induced changes in sea level combined with an increase in intensity of tropical storms has placed coastal regions at increased risk of catastrophic flooding and resulting loss of life.
- **Food safety:** Seafood is increasingly being imported from countries where public health and food handling standards are lower than in the US. One alternative to importing seafood is aquaculture: a technology which provides an increasing portion of consumable fish sold in the US and is accompanied by a different set of health concerns. Cultured organisms are more disease prone than wild stocks and the

Promoting Healthy Seafood

With greater awareness of the health benefits of seafood, demand for fish and fish oil supplements has led to exponential growth in the aquaculture industry and further depletion of the world's oceans. NOAA is conducting research to enhance the health benefits of fish and to understand how seafood production could become more sustainable. For example, they are testing whether wild fish-derived omega-3 aquaculture feed might be used primarily as a late-stage supplement rather than continuously throughout growth. Studies are also being performed to quantify the minimum omega-3 requirements for fish diets, and to track the distribution of these fatty acids in fish tissues. Development of an appropriate diet for farmed fish would promote more efficient use of marine resources and optimize the benefits of seafood consumption for humans.

pharmaceuticals often used to protect against disease outbreaks may contaminate surrounding waters or accumulate in organisms consumed by humans.

- Marine mammal morbidity: The number of marine mammals admitted to rescue centers has climbed in the past few years. Half of diagnosed sea otter mortality cases in the US derive from terrestrial runoff of land-based pathogens. The frequency of epidemics and number of new diseases in corals, sea turtles and marine mammals has increased, with many of these outbreaks linked to climate change effects.

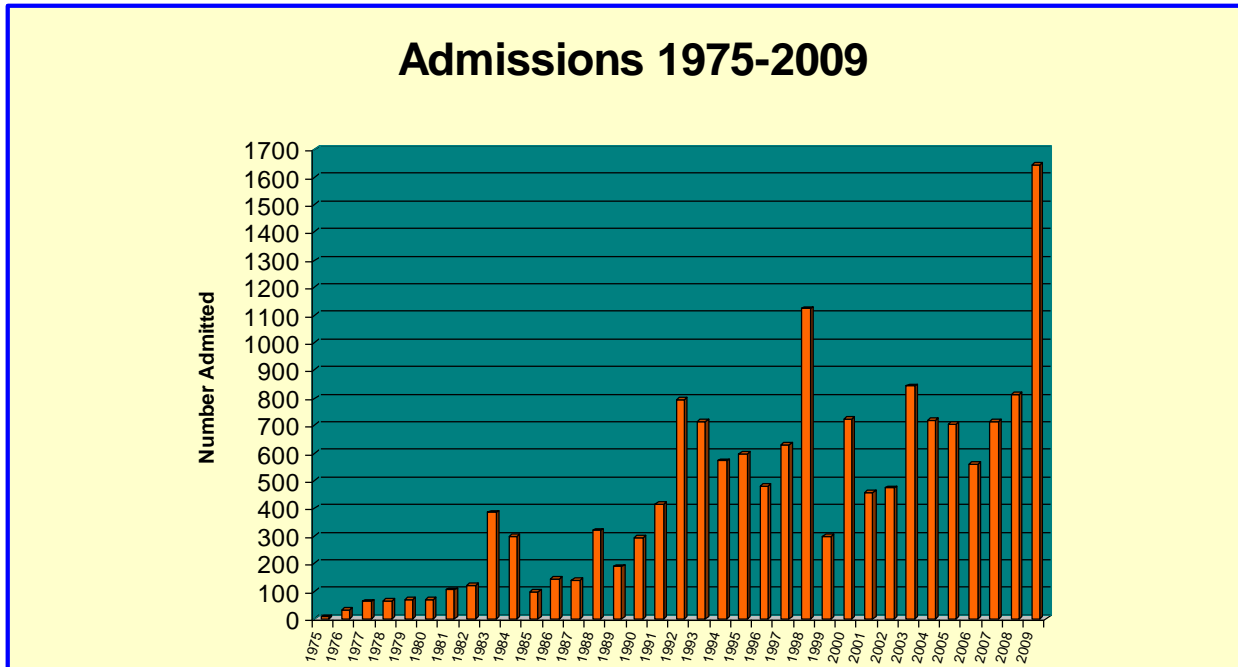


Figure 1. Number of stranded marine mammals admitted to The Marine Mammal Center from 1975-2009. Source: The Marine Mammal Center.

The risks to aquatic organisms resulting from changes in the ocean serve as an early warning signal for humans because of the close linkage between human and animal health.

Approximately 60% of all human pathogens are zoonotic, meaning that they can be transmitted from animals to humans. This number is even higher for emerging diseases, about 75% of which come from animals. Regardless of cross-species transmission of pathogens, the molecular and metabolic processes of higher animals, including man, are very similar, so that aquatic organisms serve as effective sentinels for how ocean anomalies can affect human health.

This underlying linkage is the basis for the “One Health” approach in which scientists have recognized that human health and animal health are inextricably linked (www.onehealthinitiative.com). The One Health initiative seeks to promote the health of all species by enhancing cooperation and collaboration among physicians, veterinarians, and other scientific health professionals. This paradigm of interdependence among human, wildlife and

ecosystem health has been well accepted for the terrestrial biosphere and now needs to be applied to the water-based biosphere, creating a “One ocean - One health” perspective. The concept of the combined health of people and wildlife – one health – when combined with the concept of the ocean as an essential modulator/caregiver of all life on Earth, inexorably leads to the prime tenet that the health of the “one ocean” is essential to the “one health” of all life on earth, including that of humans.

In addition to health threats, the ocean provides promising opportunities for health benefits through development of new pharmaceuticals that must be cultivated. The National Research Council report “Marine Biotechnology in the Twenty-First Century” concluded that the exploration of marine habitats offer underexplored opportunities for discovery of novel chemicals with therapeutic potential. Many medicines come from nature, but historically they have come mostly from land-based organisms. As scientists are exhausting the supply of terrestrial biota with interesting medical properties, the ocean provides a new frontier for natural products. New sources of novel molecules with medicinal value are increasingly important as acquired drug resistance reduces effectiveness of present- use antibiotics. Scientists have already isolated more than 20,000 biochemical compounds from sea creatures, leading to new classes of drugs that treat cancer and viral diseases. These include Zidovudine (AZT) used to fight the AIDS virus and cytosine arabinoside used in the treatment of leukemia. Acyclovir speeds the healing of eczema and some herpes virus inflammations. Chronic pain is treated by Prialt, a neurochemical isolated from gastropods. Equally important is the sharper focus on specific molecular events that underlie the general diseases, such as apoptosis inducers, cytotoxic agents, and enzyme activators or inhibitors. These are but a few examples of the potential for the study of marine organisms to enhance human health, which is enhanced by the close collaboration between ocean and health scientists and programs that support that type of interdisciplinary science.

Marine Natural Products and Pharmaceuticals

Natural products and pharmaceutical research at NOAA is focused on exploring how naturally produced chemicals from marine biota can be used to enhance human health and well-being. NOAA has partnerships with the National Institutes of Health and the US Dept of Agriculture to develop products such as:

- Next generation antibiotics derived using bacteria isolated from corals.
- Chemicals from marine sponges that re-sensitize antibiotic-resistant bacteria to current use antibiotics.
- Toxins isolated from algae for their anti-cancer properties. Recent studies with euglenophycins have demonstrated phenomenal success against renal cancer cells, an otherwise difficult-to-treat cancer.
- Compounds used to fight AIDS, which are developed from a Caribbean sponge.
- Chemicals isolated from the Florida red tide that show promise as therapeutic agents against cystic fibrosis and asthma.

Finding 2: NOAA is well positioned to meet this need

NOAA is the national leader in oceanographic, meteorological, and atmospheric predictive science. More importantly, NOAA is taking the lead in development of early warning systems, which can identify and forecast ocean conditions that may threaten human, marine organism, and marine ecosystem health. NOAA has also incorporated these predictive capabilities into identifying how climate change may affect the extent and diversity of ocean-related public health consequences. Finally, NOAA leads the nation’s efforts to monitor and preserve marine mammal health, which is closely linked to and serves as an important sentinel for human health.

NOAA has the mission

Congress has passed several pieces of legislation that specifically give NOAA responsibilities with respect to oceans and health (see *Legislative Mandates*). These include research into the impacts of oceans on human health, defense from HABS, protection of marine mammals and their habitat, coral reef conservation and research, and ocean ecosystem stewardship. In fulfilling these responsibilities, NOAA is positioned to close the gap among separate federal programs through development of a comprehensive approach to ocean-related health science and management. Integrating NOAA's diverse efforts under a common set of priorities will multiply the benefits that these programs have on public welfare.

In addition to legislative mandates, there are a number of executive branch and external advisory reports recognizing NOAA's important role with respect to oceans and health. For example, recommendations 25-2 to 25-4 in the US Commission on Ocean Policy Report specifically call for NOAA to develop a coordinated national research effort to better understand links between the oceans and human health. In addition, Theme 6 from the President's 2006 Ocean Policy document "Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan (ORPP) and Implementation Strategy" focuses on enhancing human health and details NOAA's role with respect to studying health hazards associated with contaminated seafood, polluted waters, HABS, and emerging pathogens. The "Interagency Oceans and Human Health Research Implementation Plan: A Prescription for the Future" calls for NOAA to work collaboratively with other agencies in developing a national oceans and health research program. In addition, NOAA has trust responsibilities to ensure health of endangered and threatened organisms through the Endangered Species Act.

NOAA's Legislative Mandates

Some examples of specific legislative mandates related to NOAA's stewardship of oceans and health include:

- The Oceans and Human Health Act (H.R.4818), which authorizes the Secretary of Commerce to establish an Oceans and Human Health Initiative to coordinate and implement research and activities as they relate to the role of oceans in human health. This Act specifically calls for 1) program and research coordination, 2) an advisory panel, 3) one or more National Oceanic and Atmospheric Administration national centers of excellence, 4) research grants, 5) distinguished scholars and traineeships, and 6) public information and outreach.
- The Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (16 U.S.C. 1451 note), which requires NOAA to develop tools for "prediction of the onset, course, and impacts of harmful algal blooms including evaluation of their accuracy and utility in protecting environmental and public health."
- The Marine Mammal Protection Act (16 USC 1421), which calls on NOAA to lead the Marine Mammal Health and Stranding Response Program, and address the health of marine mammal populations, the ecosystems that sustain them, and public health implications.
- The Coral Reef Conservation Act (16 USC 6401), through which NOAA leads coral reef conservation and natural product discovery biomedical research.
- The National Marine Sanctuaries Act (16 U.S.C. § 1431), which mandates NOAA to "prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man."
- The Magnuson-Stevens Fishery Conservation and Management Act mandates NOAA's fishery management responsibilities that include organismal health provisions for essential fish habitat.
- The Agricultural Marketing Act of 1946 (7U.S.C.1621-1626) authorizes NOAA authorized to inspect, certify, and identify the class, quality, quantity, and condition of fish and fishery products

These mandates are also consistent with NOAA's mission statement "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." Protecting human health is the

foundation of NOAA's economic and social construct, which extends to all NOAA line offices. NOAA traditionally addresses health hazards associated with hurricanes, air and water quality, and seafood. A better understanding of the complex interrelated issues surrounding coastal development, climate change, infectious disease transmission, toxins, chemical contaminants, and management of diverse ocean resources for health benefits have recently become part of NOAA's charge under the Oceans and Human Health Initiative.

NOAA has the necessary scientific and technical expertise

Many federal, state, and local agencies have programs that address a subset of ocean health threats and opportunities, but NOAA is the only federal agency equipped to integrate the diverse range of scientific disciplines related to ocean health concerns and benefits. NOAA's areas of expertise include the following:

- **Observation and characterization of atmospheric and ocean system dynamics:** NOAA is the national leader in observation and prediction science for oceanographic, meteorological, and atmospheric phenomena. The agency's Integrated Ocean Observing System (IOOS) provides characterization, modeling and prediction of climate, weather, ocean and coastal conditions. Such systems provide the necessary foundation to allow characterization of ocean and coastal systems necessary for understanding the connections to human and marine animal health. IOOS is presently focused primarily on physical parameters, but NOAA is taking the natural extension of this activity to lead development of early warning systems that identify and forecast ocean conditions that threaten health of humans, aquatic organisms, and aquatic ecosystems. This extension will provide managers and decision makers an opportunity to take action, either immediate or longer-term, to reduce risks and address fundamental coastal problems.
- **Integration and prediction:** NOAA has a distinguished history of integrating data from a wide range of sources and agencies into predictive tools to issue forecasts and warnings. The best known example of NOAA's accomplishments are its routine weather forecasts, hurricane and tornado predictions promulgated by the National Weather Service (NWS). NOAA has already begun to adapt these forecasting capabilities to ocean health applications. NOAA has developed a forecasting system that supplies information on the location, extent, and potential for development of harmful algal blooms in the Gulf of Mexico, and is working on a similar system for the Great Lakes. A daily rip current outlook is included in the Surf Zone Forecast, issued by many coastal NWS offices. NOAA's Oceans and Human Health Initiative (OHHI) has developed a model to predict pathogen transport into the Great Lakes, and an integrated risk map for *Vibrio parahaemolyticus* in the northern Gulf of Mexico.
- **Unparalleled marine mammal expertise:** NOAA has paramount expertise in the ecology, biology, health and management of marine mammals. With some of the world's leading veterinary experts, NOAA, in collaboration with the US Fish and Wildlife Service, is responsible for marine mammal permits, management, and enforcement in US waters and aquaria. NOAA maintains the Marine Mammal Health and Stranding Response Program, with a comprehensive network of marine mammal experts and volunteers to address unusual mortality events and disease surveillance. Correspondingly, NOAA is an active and leading participant in the International Whaling

Commission and other international forums involved with the management and protection of marine mammals. As such, NOAA is often called to assist other countries in die-off investigations and other management and enforcement issues.

- **Climate effects on health and oceans:** NOAA has internationally recognized expertise in climate science, including applications related to effects of elevated water temperatures, coastal inundation and sea level rise. NOAA's activities in these areas have helped to establish links between changes in ocean temperature and the northward movement of *Vibrio parahaemolyticus* (a bacterium that can cause gastro-intestinal illness when consumed by eating contaminated shellfish) to Alaska, as well as how changes in the Pacific Decadal Oscillation affects HAB occurrences in coastal waters of Washington State. NOAA's understanding of how ocean systems drive changes in precipitation and temperature have led to forecasts for managing coastal hazards, mosquito vectors, and agricultural production. NOAA has recently formed a Climate Service that will transition the results of research into products that can be used by decision-makers for mitigation and adaptation to climate change. Routine seasonal and interannual forecasts and other tools will be available for long-term use by coastal resource managers, local zoning boards, water and agriculture boards, and infrastructure planners, all of which have implications for health.

NOAA partners well with other agencies that have complementary missions

While NOAA possesses the technical expertise necessary to address many of the ocean's effects on health, complementary capabilities lie in numerous other agencies with which NOAA must forge effective and enduring partnerships if they are to be successful in addressing health issues. Partnerships are also essential because NOAA formally engages only a subset of the potential clients for health products and services. For instance, NOAA tracks the presence of harmful algal blooms, but lacks direct communication with physicians who should be alerted to watch for toxic effects of those blooms on their patients. Consequently, NOAA needs good relationships with the Centers for Disease Control and Prevention, as well as with State Health Departments, which have the formal relationship with physicians and can effectively communicate such information. Similarly, NOAA is developing new tools for monitoring the presence of pathogens on beaches, but it is the Environmental Protection Agency that runs the Healthy Beaches program and has formal relationships with the County health departments that issue beach closures. NOAA also develops storm surge and tsunami models that define coastal areas most likely to be flooded, but it is the Federal Emergency Management Agency that is responsible for coordinating with

Partnering to Reduce Health Risks From an Ocean-dwelling Bacterium

Vibrio parahaemolyticus (Vp) is an ocean-dwelling bacterium which causes seafood-borne gastroenteritis and can be lethal for immunocompromised individuals. An estimated 4,500 cases of Vp infection occur in this country each year and is increasing worldwide. NOAA is engaged in a cooperative project to predict real-time health risks associated with Vp in oysters from the Gulf of Mexico using satellite remote sensing of sea-surface temperature (SST) and other environmental factors. Partners include the FDA, CDC, NASA, Gulf Coast Research Laboratory, Mississippi Department of Marine Resources, and University of Maryland. Maps will be made available on the internet so that fisherman, harvesters, processors, managers, and consumers can determine potential Vp health risks associated with consuming raw oysters harvested at a particular site at a particular time.

States about evacuation orders and other disaster preparedness. Effective partnerships with these other agencies are imperative if NOAA is to make its products and services of greatest use for societal benefit.

During the course of this review, the OHWG interviewed leaders from other federal agencies that have responsibility for ocean-related health issues. In each case, the OHWG requested feedback about whether NOAA is a good partner and if they would be welcomed in a leadership role for addressing health effects from the ocean. The response was uniformly positive. This high regard and acceptance of NOAA reflects recognition of its broad mission and a history of supporting other agencies. NOAA has also demonstrated a number of partnership successes, such as its efforts with NASA in developing US satellite capabilities and participation with EPA and USGS in developing the National Coastal Condition report. NOAA also successfully co-chaired the Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health, which produced a federal implementation plan for Oceans and Human Health Research in 2007.

One of the reasons that the other agencies perceive NOAA as a good partner is that NOAA is a science agency and many of its products are developed to support the activities of other agencies. For example, predictions of extreme rainfall events or drought conditions benefit emergency preparedness and response entities, public and environmental health agencies, drinking water utilities, and resource managers. Similarly, private technology development companies utilize NOAA research to improve value-added products and services. NOAA's role as a service provider that enables the mission of other entities brings increased focus on translational application of its research products.

Partnering Agencies at the Federal Level

The principal agencies that possess skill sets necessary for the development of a comprehensive oceans and health strategy include:

- *National Oceanic and Atmospheric Administration* - monitoring, forecasts, HAB research, marine mammal and fish health and population dynamics, climate change, etc.
- *US Environmental Protection Agency* - Monitoring tools and methods to ensure healthy beaches and public water supplies
- *Centers for Disease Control and Prevention* - Disease surveillance, outbreak response, and epidemiologic expertise
- *US Food and Drug Administration* - Seafood safety and analytical laboratory expertise
- *US Geological Survey* - Monitoring methods and GIS tools to promote wildlife health
- *US Department of Agriculture, Animal and Plant Health Inspection Service* - Diagnostic support and emerging diseases in marine animals
- *Federal Emergency Management Agency* - Response planning for natural disasters
- *National Science Foundation* - Scientific research
- *National Institutes of Health*
- *US Fish and Wildlife Service*
- *US Marine Mammal Commission* - Monitoring and research on marine mammal health
- *National Aeronautics and Space Administration* – Satellite monitoring of oceans and atmospheres
- *US Department of Agriculture* - Aquaculture and seafood safety

Finding 3: NOAA has a diverse health portfolio in place, but the pieces need to be linked together to form a more comprehensive, coordinated program

During the OHWG review, NOAA was asked to list all of its activities that are intended to increase understanding of, and prevent health risks from, ocean-related hazards and threats. The list is impressive and clearly demonstrates NOAA's substantial knowledge, resource investment, and skill base. In addition to the Oceans and Human Health Initiative, there are at least 20 other NOAA programs that have activities in this area, ranging from forecasting weather and climate patterns that impact disease, to prediction and monitoring of harmful algal blooms, and monitoring of seafood to ensure safe human consumption. However, these programs are scattered across many parts of the agency and lack a unifying structure. The programs also appear to result from the interests and skills of the individual research centers, rather than from a cohesive planning effort. Moreover, the list largely reflects biological research programs centered on the Oceans and Human Health Initiative and does not equally represent operational or research programs focused on protecting health from physical oceanographic hazards, the role of health changes in marine animal population dynamics or social science assessments of risk perception, management and response.

Finding 4: NOAA needs to better quantify and communicate the benefits of its investment in health-related activities

NOAA develops screening systems for fish and shellfish contamination, coastal flooding warning systems, and predictive models for search and rescue, among many other products that benefit the public. NOAA also promotes nutritional, pharmaceutical, and quality of life benefits of a healthy global ocean. These and other NOAA activities save lives and promote health, but they are poorly quantified and communicated. NOAA has not created a sense of urgency among the public regarding ocean-related health issues. The lack of a unified program with clearly defined goals and benchmarks contributes to NOAA's difficulty in communicating its successes to, and obtaining funding from, Congress.

Table 1. Distribution of NOAA health programs among line offices.

| National Ocean Service (NOS) | NOAA Fisheries (NMFS) | NOAA Research (OAR) | NOAA Satellite and Information Services (NESDIS) | National Weather Service (NWS) |
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| <p><u>Oceans and Human Health Initiative (OHHI)</u> <u>NCCOS</u> <u>Center for Human Health Risk (CHHR) & Center for OHH at HML</u> <u>-Center for Coastal Environmental Health and Biomolecular Research (CCEHBR)</u> <u>-Center for Sponsored Coastal Ocean Research (CSCOR)</u> <u>-ECOHAB</u> <u>-MERHAB</u> <u>Center for Coastal Monitoring and Assessment:</u> <u>-Mussel Watch Program</u></p> <p><u>Office of Coastal Resource Management (OCRM)</u> <u>- Coral Reef Conservation Program</u></p> <p><u>Integrated Ocean Observing System (IOOS)</u></p> <p><u>Office of Response and Restoration</u> <u>- Marine Debris Program</u></p> <p><u>National Marine Sanctuaries</u></p> <p><u>Coastal Services Center (CSC)</u></p> <p><u>CO-OPS</u></p> | <p><u>Aquaculture</u> <u>Office of Protected Resources:</u> <u>-Marine Mammal Health and Stranding Response Program (MMHSRP)</u> <u>- Cooperative Center for Marine Animal Health (CCMAH)</u></p> <p><u>Fisheries Science Centers -</u> <u>- Southeast Fisheries Science Center</u> <u>- Southwest Fisheries Science Center</u> <u>- Northeast Fisheries Science Center</u> <u>- Northwest Fisheries Science Center</u> <u>- West Coast Center of Excellence in Oceans and Human Health</u> <u>- Alaska Fisheries Science Center</u> <u>- Pacific Islands Science Center</u> <u>Fisheries Regional Offices</u></p> <p><u>NMFS Office of Science and Technology</u></p> <p><u>FishWatch</u></p> <p><u>National Seafood Inspection Laboratory</u></p> <p><u>Seafood Inspection Program</u></p> | <p><u>Health Research</u> <u>- - Atlantic Oceanographic and Meteorological Laboratory (AOML)</u> <u>- Pacific Marine Environmental Laboratory (PMEL)</u> <u>- Great Lakes Environmental Research Laboratory (GLERL)</u> <u>- Center of Excellence for Great Lakes and Human Health (CEGLHH) at GLERL</u> <u>-Geophysical Fluid Dynamics Laboratory (GFDL)</u></p> <p><u>Climate Program Office</u></p> <p><u>National Sea Grant</u></p> <p><u>Office of Exploration and Research (OER)</u></p> | <p><u>National Climate Data Center (NCDC)</u></p> <p><u>National Ocean Data Center</u></p> <p><u>Coral Reef Watch</u></p> <p><u>NOAA Cooperative Institute for Climate Studies</u></p> | <p><u>National Center for Environmental Prediction</u></p> <p><u>NOAA Cooperative Institute for Climate Studies</u></p> |

CHAPTER 3: RECOMMENDATIONS

The Ocean and Health Working Group advances three core recommendations and supporting sub-recommendations that NOAA should implement if it is to fulfill the leadership role envisioned in this report. A number of additional recommendations appear in Appendix A in response to specific questions posed to the OHWG.

Recommendation 1: NOAA should establish health protection, preservation and enhancement as an agency-wide goal

NOAA should acknowledge that ocean-health linkages are a critical need within its core mission and commit at the highest administrative level to the leadership role that the OHWG believes is appropriate for the agency. The remaining recommendations of this report are based on NOAA's acceptance of a leadership role and recognition of an important biological dimension for the agency. NOAA is in the process of developing its Next Generation Strategic Plan, which will revise and update NOAA's mission areas of emphasis for the next decade. This effort provides a timely opportunity to incorporate the recommendations from this report into NOAA's existing organization in a meaningful way.

The time to accept this role is now. Many new challenges are arising, ranging from climate change impacts to increases in use of synthetic organic chemicals. There are also many new opportunities for cultivating ocean resources to improve or sustain healthy communities and ecosystems. While many agencies have programs that address a subset of ocean health threats and opportunities, no individual organization takes a holistic approach to protecting lives and promoting health from ocean-related activities. NOAA's unique, multi-disciplinary capabilities are needed now more than ever to integrate disparate efforts and address the ocean's overall effects on health, ensuring that people who use, eat, or otherwise enjoy ocean resources do not become ill or die as a result of normal responsible use.

NOAA is poised for success in accepting this role. New opportunities abound to measure the means by which the ocean affects health and to use this information for preserving and promoting health. Advanced sensors now allow real-time monitoring of ocean conditions and are beginning to be deployed through ocean observing systems. Genetic sensors will soon allow more sensitive and specific pathogen detection. Similar technology will also allow for more accurate, cost-effective methods for identifying toxins in seafood, especially for difficult-to-detect toxins from algae. NOAA's investment to date in their OHHI program has started them down the path of capitalizing on these opportunities. Moreover, OHHI has developed substantial partnerships with the academic centers funded through the National Science Foundation that will allow them to leverage additional development opportunities. The newly-formed Climate Service will allow NOAA to highlight products useful to individuals who must make decisions on the long-term effects of climate change on health of humans and organisms.

Recommendation 2: NOAA should develop a comprehensive plan for its health programs

NOAA already possesses many excellent elements that can be employed to promote health and well-being, but these are scattered throughout the agency. NOAA needs a plan that ties its health efforts into a comprehensive program and links NOAA's efforts to other federal agencies with

complementary skills. NOAA has already engaged in some strategic thinking as a leader in developing the Interagency Oceans and Human Health Research Implementation Plan. This plan highlights a subset of NOAA activities that deal primarily with pathogens and contaminants, but does not address many life-saving activities in which NOAA is engaged, such as those associated with natural disasters (e.g., coastal flooding) and trauma (e.g., ship strikes on marine mammals). It also fails to emphasize how NOAA's core strengths of forecasting and modeling could be used to promote health. A holistic NOAA Oceans and Health plan should acknowledge the totality of related efforts and organize them strategically. The development of the NOAA Next Generation Strategic Plan provides an opportunity to identify this issue at a high level and make it a priority in the next decade and beyond.

The comprehensive health plan should be based on systematic prioritization of hazards and risks

The plan should rely on a systematic risk characterization with an ultimate goal of risk reduction. NOAA should identify all potential ocean-related health threats and then quantify the present and potential loss of life, rates of illness, and health-related economic loss from these threats. Only through careful and comprehensive strategic planning can the agency ensure that investments will be directed to those activities that provide the greatest societal benefit. In developing a risk prioritization and reduction model, NOAA must consider potential risks, not just current losses. Positive health benefits derived from ocean resources should also be quantified. The plan should identify which threats and benefits are best addressed via operational programs in the short term, versus those that require longer-term research investment. Such strategic planning focused on risk characterization and reduction will also provide quantitative measures of performance and outcome success that will allow the agency to track progress on an ongoing basis. This tracking can provide a means for continuous internal evaluation of spending, and for identifying areas with the greatest potential societal benefits.

The plan should include provisions for technology transition

A large part of the NOAA's health portfolio involves research to develop new tools and products, with half of their OHHI funds and a substantial partnership with NSF/NIH dedicated toward external research grants. OHHI does a good job of interacting with these grant recipients, but does not have a clear plan for transitioning scientific discoveries from their research activities into applications for protecting and preserving health. The program plan needs to include a transitioning approach, which might involve incorporating the potential for practical applications into proposal review, tracking progress of projects toward application throughout their lifespan, and increasing incentives for projects that produce applications. Success should be viewed not just in publishing research, but in how well NOAA applies research translationally to address real-world issues and meet societal needs.

One of the challenges associated with technology transition lies with addressing intellectual property issues. NOAA does not have a clear process within its health programs for developing and assigning patent rights, even though it is developing new products from ocean materials. The absence of policies and procedures that clarify and expedite the patenting process can complicate working with academic partners, who often have interest in monetizing the value of their discoveries. This can further complicate NOAA's ability to work with private companies to

commercialize these products, as the private sector wants clarity about their revenue streams before investing. Streamlining the patenting process is critical to ensure that products with commercial potential make it to the testing arena and achieve their maximum ability to save lives or /promote health. This should be addressed in the program plan and funds should be made available for NOAA scientists to protect discoveries for further development. Policies to protect innovation, information and data early in its development will foster smooth research interactions and promote easier disclosure of research findings in public venues.

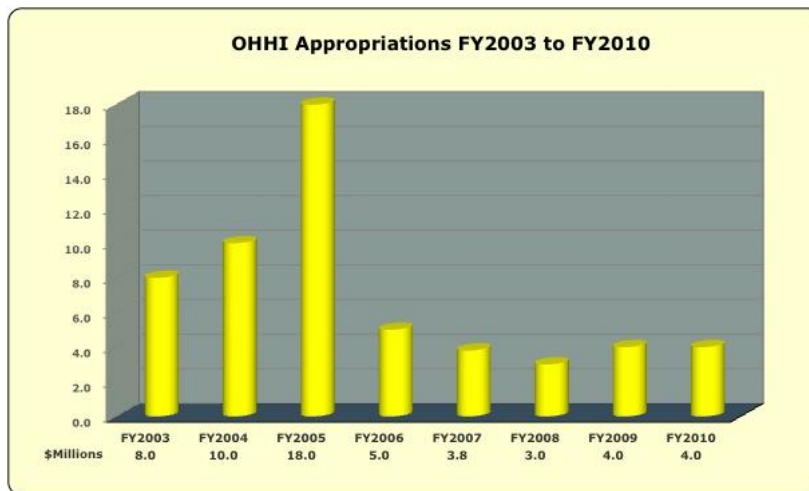
The plan must be incorporated into agency planning

After developing the comprehensive plan, NOAA needs to ensure that it is used in agency actions and decisions. As a first step, NOAA should incorporate short- and long-term oceans and health goals into agency planning documents. For example, the comprehensive health plan should be reflected in documents such as the NOAA Next Generation Strategic Plan, the NOAA 5-Year Research Plan, and the Annual Guidance Memorandum. This step will increase awareness of health activities both internally and externally. Another vital step in adoption of the comprehensive health plan involves creation of a coordinating entity responsible for implementation of health activities. NOAA currently supports health related programs across its many operating branches and directed by a variety of different mission goals. This coordinating entity should serve as a focal point for partnership with other organizations and have responsibility to ensure transition of new technologies developed from NOAA research into operational programs. The coordinating entity should be established at a high enough level in the organization to contribute to agency strategic planning and have sufficient budgetary authority for implementation of priorities outlined in the comprehensive health plan.

Provide a funding level commensurate with the comprehensive health plan

The OHWG has been impressed with the scope and depth of the projects that NOAA has accomplished, particularly under the OHHI, despite fluctuating and diminishing resources. However, continued success is dependent on a stable and adequate budget. NOAA's budget allocations for OHHI have averaged \$4M/yr in recent years. The President's FY11 budget request of \$1M for the OHHI program is inconsistent with an agency commitment to a health mandate. The OHWG

supports an increase in the President's budget request that will at least fund the Oceans and Human Health Initiative at a stable level adequate to support productive intra- and extra-mural activities required by the Oceans and Human Health Act. At a minimum, this allocation should be \$12M/yr, consistent with the Act's original authorization, although greater initial



funding may be needed to initialize the health plan recommended here. The OHWG further recommends that future budgetary requests beyond the initial investment should be dependent on the program's ability to justify its requests through quantification of achievements. It is anticipated that when the benefits from investment in health issues are precisely quantified, the return on investments will amply justify the funding that is recommended.

Recommendation 3: NOAA should focus initially on several priority projects

The OHWG recognizes that development of an effective comprehensive health plan may take several years to develop, particularly if NOAA develops a comprehensive risk prioritization and coordinates its planning with that of complementary agencies. As such, the OHWG identified a number of priority projects that are logical extensions of ongoing NOAA investments that will yield significant societal benefit.

Forecasts of impending threats

NOAA's expertise in forecasting weather and development of early warning systems has transformed preparedness planning and emergency response strategies. As an established leader in developing early warning systems, NOAA should extend its skills in forecasting to predict emerging diseases, pathogens, toxins, and contaminants likely to have an impact on health. To more fully understand relationships between oceans and health, oceanographic and climate data should be collected on spatial and temporal scales that are more effectively integrated with ecological parameters.

Surveillance systems to recognize emerging diseases, pathogens, contaminants, and toxins that affect health

NOAA should be the lead agency for surveillance of ocean organismal physiological health, as well as mitigation of factors causing change in health. A formal interdisciplinary framework for ocean health should incorporate: 1) Surveillance strategies for identifying novel diseases, biotoxins, contaminants, and emerging pathogens; 2) Diagnostic laboratories to provide real-time processing of organism samples during mortality or morbidity events, and 3) Emergency response plans to address animal die-offs, reproductive failure and, disease outbreaks.

Climate change effects on ocean-related health

As part of the mandate for the new NOAA Climate Service, NOAA should identify the ocean-related health impacts from climate change, anticipate their potential consequences, and develop prevention, mitigation, and adaptation measures. In addition to assessing health effects from disease vectors and coastal flooding, NOAA should also characterize the impacts of climate change on water supplies, which are intricately tied into healthy communities and ecosystems. NOAA should monitor and report any large-scale water cycle changes, such as precipitation patterns and intensity, drought incidence, snow and ice melt, atmospheric water vapor, evaporation, water temperatures, soil moisture, and terrestrial runoff. NOAA should develop more refined forecast models to describe the impacts that climate change will have on surface water and ground water, especially for severe events such as floods and droughts.

Health benefits from the sea

NOAA should make human health benefits from the ocean more accessible by encouraging and supporting the development of healthful seafood and other ocean-derived products.

Development spans sustainable foods, essential nutraceuticals, nutritional additives, and health-related drugs. This might include providing information on sustainable replacements for currently used items that negatively impact ocean ecosystems or public health. In addition, NOAA could develop cost-benefit comparisons between healthful seafood and competitive products.

**APPENDIX A: RESPONSES TO THE QUESTION IN THE NOAA
SCIENCE ADVISORY BOARD OHWG TERMS OF REFERENCE**

Question 1: What are NOAA's unique and important scientific roles in addressing ocean (and) health issues?

NOAA is a preeminent leader in scientific research associated with oceanic dynamics, atmospheric conditions, ecosystem interactions and health issues. Given the agency's diverse range of capabilities and extensive areas of expertise, NOAA is uniquely positioned to address a complex array of ocean and health issues. Although the Oceans and Health Workgroup (OHWG) has a number of suggestions for ways in which NOAA can better integrate its efforts into a more comprehensive program, the Workgroup was overwhelmingly impressed by the quality of NOAA research and leadership related to oceans and health and sees tremendous potential to build upon that competency.

NOAA is the nation's leader in observing/characterizing atmospheric and ocean systems dynamics

NOAA is the national leader in observation and prediction science for oceanographic, meteorological, and atmospheric phenomena. The agency's Integrated Ocean Observing System (IOOS) provides characterization, modeling and eventual prediction of climate, weather, ocean and coastal conditions. Such systems provide the necessary foundation to allow characterization of ocean and coastal systems necessary for understanding the connections to human and marine animal health. Presently, the IOOS is focused primarily on physical parameters, but NOAA is taking the natural extension of this activity to lead development of early warning systems that identify and forecast ocean conditions that threaten the health of humans, marine/aquatic organisms, and marine/aquatic ecosystems. This extension will provide managers and decision makers an opportunity to take action, either immediate or longer-term, to reduce risks and address fundamental coastal problems relevant to health.

NOAA has unique integrative and predictive capabilities

NOAA has a distinguished history and demonstrated capabilities to integrate data from a wide range of sources and agencies, and use these data to develop predictive tools and issue warnings. The best known example of NOAA's accomplishments is the National Weather Service (NWS), which excels in weather forecasts, hurricane predictions, and tornado predictions. In addition, the NWS also produces seasonal to inter-annual forecasts of rainfall and temperature and El Nino conditions. These forecasts are often then downscaled in collaboration with regional partners to meet sector-specific needs. For example, the NOAA-led National Integrated Drought Information System integrates basic and applied research conducted by NOAA and other agencies into an adaptive decision-support environment for providing early warning about emerging and anticipated droughts to resource managers, farmers, and other water users.

NOAA has begun to adapt these forecasting capabilities to ocean health applications. NOAA has developed a forecasting system that supplies information on the location, extent, and potential for development of harmful algal blooms in the Gulf of Mexico, and is working on a similar system for the Great Lakes. A daily rip current outlook is included in the NWS Surf Zone Forecast, issued by many coastal National Weather Service offices. NOAA's Oceans and Human Health Initiative (OHHI) has developed a model to predict pathogen transport from a

river into the Great Lakes, and an integrated satellite and in-situ observations risk map for *Vibrio parahaemolyticus* in the northern Gulf of Mexico.

Unparalleled marine mammal expertise

As the Nation's lead agency for marine mammal protection, NOAA has paramount expertise in the ecology, biology, health and management of marine mammals. With some of the world's leading veterinary experts and a wealth of experience at its disposal, NOAA, in collaboration with the US Fish and Wildlife Service, is responsible for marine mammal permits, management, and enforcement in US waters and aquaria. NOAA maintains the Marine Mammal Health and Stranding Response Program, with a comprehensive network of marine mammal experts and volunteers to address unusual mortality events and disease surveillance. Correspondingly, NOAA is an active and leading participant in the International Whaling Commission and other international forums involved with the management and protection of marine mammals. As such, NOAA is often called to assist other countries in die-off investigations and other management and enforcement issues.

Climate effects on health and oceans

NOAA has internationally recognized expertise in climate science, including applications related to effects of elevated water temperatures, coastal inundation and sea level rise. The agency's capabilities include monitoring, modeling, forecasting, prediction, development of climate change scenarios and dedicated data-management resources. NOAA's activities in these areas have helped to establish links between changes in ocean temperature and the northward movement of *Vibrios* to Alaska, as well as how changes in the Pacific decadal oscillation affect HABs occurrence in coastal waters of Washington State. In a broader context, the ocean system drives changes in climate, which in turn affects precipitation and temperature patterns around the world. Correspondingly, seasonal forecasts are used to manage coastal hazards, mosquito vectors, and agricultural production. Ultimately, linking NOAA's climate expertise with its health capacity will help researchers achieve a more comprehensive understanding of how climate change may affect the extent and diversity of ocean-related public health impacts and their potential consequences, thereby allowing further development of prevention, mitigation and adaptation measures.

Training and outreach capacity

NOAA has an established national and regional research, outreach, training and operational infrastructure, as well as capabilities that could be utilized to accomplish Oceans and Health goals. As such, NOAA's capacity to enhance training and outreach includes:

- National Sea Grant Program extension agents and a number of topic-specific training opportunities conducted jointly with other NOAA programs.
- The OHHI has strong outreach to users, training capacity for graduate and post doctoral students, and opportunities for training early- to mid-career professionals.
- The National Marine Sanctuaries Program, which has strong outreach to local communities.

- The regional fisheries management councils and National Marine Fisheries Service
- The Coastal Services Center, which has a network of regional service centers.
- The NOAA Regional Teams, which provide a conduit to regional partners, help set agency priorities, and plan adaptation and mitigation responses relevant to health and environmental protection.

Question 2: What are the right ocean health science questions, products and services for NOAA?

NOAA has unique expertise and strengths that distinguish the agency as a leader in science, products, and services for ocean effects on health. NOAA's experience with translational research has potential for leading to health improvements in a variety of ways. However, the agency does not have the resources to pursue all directions with equal effort. The primary Oceans and Health questions, products, and services that are most appropriately addressed by NOAA are described below.

Forecasts to provide early warning of impending threats and prediction of long-term health impacts

NOAA's expertise in forecasting weather and development of early warning systems has transformed preparedness planning and emergency response strategies for individuals, communities, and governments. As an established leader in developing early warning systems, NOAA should extend its skills in forecasting and prediction to address human health concerns related to coastal waters. This type of service could evaluate, predict, and help to mitigate both immediate and long-term impacts to human and ecosystem health.

Forecasting must embrace the concept of "One Health" to predict long term impacts. To more fully understand relationships between oceans and health at ecosystem, population, organism, and genetic levels, oceanographic and climate data should be collected on spatial and temporal scales that are more effectively integrated with ecological parameters. Additionally, NOAA's forecasting ability should be expanded to predict emerging diseases, pathogens, toxins, and contaminants likely to have an impact on public health.

Intensified data integration is an important focal area, as it is required to forecast high-priority immediate threats. Although NOAA already partners with several organizations for data acquisition, interpretation and use, data transfer is a slow process, with the lag between collection of data and response often measured in years. NOAA should lead the way in streamlining processes and developing technology for receiving data from organizations to ensure that it is accurate and accessible in real time.

Surveillance systems to recognize emerging diseases, pathogens, contaminants, and toxins that affect health

NOAA should be the lead agency for surveillance of ocean organismal physiological health, as well as mitigation of factors causing change in health. A formal interdisciplinary framework for ocean health should incorporate surveillance, emergency response, and research for protected species. This program should convey a sense of urgency about threats to ocean health, have a clear surveillance strategy capable of acting as an early warning system for health threats, and include an efficient emergency response system.

In addition, NOAA should coordinate research relevant to ocean organismal health threats based on successful regional partnerships that currently exist between NOAA and other agencies focusing on ocean health. These partnerships need to be expanded and developed on a national scale, and should include collaborations among agencies including NIH, NSF (the existing

Oceans and Human Health program), USDA-APHIS, USGS Wildlife Disease Program, CDC, state diagnostics laboratories, academia, and the private sector. Correspondingly, NOAA should establish an efficient and coordinated network that builds on existing programs and collaborations, strengthening partnerships to include protected species health in addition to human health.

Climate change effects on ocean-related health

NOAA should identify the extent and diversity of ocean-related health impacts from climate variability and change, anticipate their potential consequences, and develop prevention, mitigation, and adaptation measures. Research related to this investigation will help society to understand, plan for, and respond to climate variability and change. NOAA-provided services might include the development and delivery of climate information, the implementation of a global observing system, and modeling to understand key climate processes.

NOAA will also need to characterize the impacts of climate change on water supplies, which are intricately tied into healthy communities and ecosystems. NOAA should monitor and report any large-scale water cycle changes, such as precipitation patterns and intensity, drought incidence, snow and ice melt, atmospheric water vapor, evaporation, water temperatures, soil moisture, and terrestrial runoff. NOAA should also proceed with additional development of more refined forecast models to describe the impacts that climate change will have on surface water and ground water, especially for severe events such as floods and droughts.

Health protection systems for protected biota

NOAA must expand health protection systems for protected biota, such as marine mammals, birds, turtles, fish, and coral. NOAA should establish a surveillance program for detecting health changes, as well as emergency response and mitigation measures for individual ocean species. Such a program for ocean species would resemble the marine organism equivalent of the CDC. NOAA's health surveillance program should include established health baselines and the ability to detect changes in health, as well as the emergence of novel pathogens, contaminants, and toxins on a real-time basis. NOAA's expanded health protection program should include the following components:

- *Surveillance Strategies* - Surveillance should include identification of novel diseases, biotoxins, contaminants, and emerging pathogens, as described above. Pathogen tracking should not be limited to monitoring of pathogens vectored by protected species and threats to human health, but should also include pathogens that can cause declines in protected species.
- *Dedicated Diagnostic Laboratories* - Regional laboratories with consistent funding for real-time response and surge capabilities during emergencies are needed to evaluate samples from aquatic organisms. Also, consistent quality assurance programs and data sharing abilities amongst laboratories are needed.
- *Emergency Response Plans* - Changes in health parameters that result in animal die-offs, reproductive failure, or disease outbreaks should include established emergency response protocols and mitigation measures. Development of appropriate responses requires

routine communication and collaboration with research programs in emerging disease management. Strong partnerships among federal and state agencies, academia, and the private sector should be fostered.

Health benefits from the ocean

NOAA should make the benefits of ocean health on human health more accessible by encouraging and supporting the development of healthful seafood and other ocean-derived products. Development spans sustainable foods, essential nutraceuticals, nutritional additives, and health-related drugs. This service might include providing information on sustainable replacements for currently used items that negatively impact ocean ecosystems or public health. In addition, NOAA could develop cost-benefit comparisons between healthful seafood and competitive products. Comparative cost-benefit analysis between terrestrial and ocean-derived resources would be beneficial. Comparison of drug type, efficacy, and spectrum of function between ocean- and land-derived sources would also be an important analysis.

Question 3: Are there additional ocean health science issues that should be included in the NOAA research portfolio?

This question differs from Question 2 in that it focuses on science issues, rather science products. This is a subtle, but important, difference that provides the OHWG the opportunity to address the larger strategic thinking that is a necessary foundation for the program. The most prominent issues currently impairing NOAA's ability to comprehensively address ocean-related health issues are explained below.

Develop a risk characterization process to direct resource allocation

NOAA needs a strategic plan that links existing efforts into a comprehensive program that will ensure that resources are allocated to the highest priority issues. The plan should be based on a prioritization process that identifies and ranks the urgency of both current and emerging threats and hazards on a risk probability basis. Such a systematic risk characterization process should identify all potential health threats and then quantify the current and potential loss of life or economic cost of illness associated with each and the likelihood of occurrence. The prioritization process should produce a list of ranked hazards, based on the integration of multiple factors, and using a probabilistic risk assessment approach. The specific process for risk identification and prioritization should be modeled after a rigorous method such as NASA's NSTS Hazard Prioritization. This undertaking will need to incorporate social scientists, as well as public health and medical professionals. In developing the risk prioritization model, NOAA must be prospective in considering relative "*potentials for harm*" from hazards and threats that extend beyond current or past loss/harm scenarios.

Risk characterization will not be a simple process. There will be many data unknowns and a need for policy discussions about how to weigh different aspects of health and well-being. However, such a systemic approach in strategic planning is necessary to set priorities. NOAA's efforts in risk characterization and other forms of strategic planning would be more fruitful if the position of social science within the agency were strengthened. While social science is sometimes applied to calculate the value of scientific programs within NOAA, it is less often used to help identify the scope of those programs, to evaluate the degree to which NOAA products are satisfying constituent needs, or to develop a more informed and participatory constituency through education and outreach programs.

Develop health indices and a supporting monitoring system

Currently, NOAA lacks a means for quantifying and communicating its progress in addressing health issues. This deficiency appears to be one of the factors that impair the agency's ability to obtain adequate and stable funding. NOAA activities save lives and preserve health, but the extent to which is unknown because the agency does not measure it. If the risk characterization described above is conducted properly, it will give the agency quantitative measures of performance and outcome success that will permit tracking and reporting of agency progress on an ongoing basis.

NOAA should develop health indices and a supporting monitoring system that allows them to quantify and track changes in ocean-related health over time. Although the Oceans and Human

Health Initiative has initiated a health monitoring system, its scope is limited to health parameters of species relevant to human health. A more comprehensive program is needed. The development of health indices will put NOAA's expanded research and monitoring efforts to use in addressing pathogens, contaminants, and toxins that could cause a loss of protected species and subsequent loss of ocean resources and biodiversity.

Integrate wildlife, domestic animal, and human health surveillance, research and management

NOAA should adapt the emerging concept of "One Health", which was developed for terrestrial health issues, to ocean health activities and take the lead in cross-species health issues in the ocean using this approach. The One Health (www.onehealthinitiative.com/) concept represents a strategy for expanding collaborations in order to address health issues for both humans and animals. It encourages interdisciplinary relationships among physicians, veterinarians, and other health professionals. The value of these relationships depends upon efficient surveillance, data sharing, and communication. Currently, NOAA supports a variety of excellent health-related programs, but lacks a framework for unifying the projects. Disparate projects result in competition for funding and lack of synergy to stimulate research, which leads to an inability to identify the scale of problems and develop successful mitigation programs.

To develop a holistic One Health program, NOAA will need diagnostic laboratories for testing health parameters and identifying pathogens and toxins, so that data on emerging threats and changes in health can be generated in real-time. The agency will also need to promote data reporting and sharing among key partners, including federal (CDC, NIH, USGS and USDA-APHIS), state, academic, and private sector collaborators, developing a reliable and systematic approach rather than an *ad hoc* network. A holistic One Health approach will rely upon a clear communication structure for collaboration among multiple disciplines on local, regional, national, and international scales.

Facilitate exchange of data across environmental and health disciplines

Because NOAA alone cannot address the full range of data collection and processing needs for a One Health approach, the development of a strategic network of partnerships between NOAA and other relevant organizations or professional fields will be required. These partnerships should encompass all ocean and health related communities, including other federal agencies, international health groups, research institutions, health officials, local community leaders, citizen monitoring groups, animal rescue operations, and veterinarians. Putting an emphasis on collaboration will improve the breadth of data availability and speed of data integration, positioning NOAA to better address issues that impact health at local, regional, national, and global scales.

Question 4: What are appropriate steps for NOAA to take to incorporate and advance ocean health as part of its core mission?

NOAA has a congressionally-mandated trustee role to assess and protect ocean environmental health and quality. The agency has been charged with the fundamental mission "to understand

and predict changes in Earth's environment and conserve and manage coastal and ocean resources to meet our Nation's economic, social, and environmental needs." Under this charge, much of NOAA's core activity has focused on ecosystem health, with less attention to human and organismal health. However, these two areas are inextricably linked. Ocean health is of key importance to human health and the well being of all living organisms. While there is no specific use of the word "health" in NOAA's core mission, NOAA still has a clear mandate to protect and promote human health where ocean systems are concerned.

NOAA is already directly engaged in many ocean health activities of high impact and value to society. Correspondingly, the agency provides significant support to other federal agencies in accomplishing their respective health related missions (see Question 6). NOAA's current activities span monitoring the health of fishery stocks and marine species to the assessment of water quality, predicting/tracking hurricanes, predicting/responding to sea level rise, responding to chemical spills, evaluating seafood safety, and responding to HABs. NOAA also maintains massive amounts of environmental data relevant to health for use by both the public and private sectors.

Own the role

NOAA should take immediate steps to "own" ocean health in the broadest sense, encompassing wildlife, ecosystem, and human health. The agency should accept and embrace its mandate to serve as the premier federal agency responsible for maintaining healthy ocean ecosystems, for protecting human health and safety during extreme weather events, and, in the longer term, from global climate change. NOAA is already addressing some public health needs directly through the OHHI, and indirectly via its roles in predicting extreme weather events and protecting/managing fishery stocks and sensitive species. However, the agency lacks holistic organization with regard to Oceans and Health. There is a distinct need for a coordinating entity within NOAA to firmly define its mission, communicate its mission as a priority, and take steps toward fulfilling this role.

Some issues of immediate concern and priority might be identification, tracking and mitigation of harmful algal blooms; promoting seafood nutritional quality, quantity, and safety; and identifying/mitigating negative fate and effects of ocean pollution. Longer-term concerns for which NOAA could establish a much needed leadership role with regards to health include:

- Ocean climate (e.g., alterations of ocean circulation and extreme weather events);
- Coastal inundation (both extreme and gradual change associated with loss of life and biodiversity);
- Increasing rates of arboviral, zoonotic, and bacterial infectious diseases accompanying coastal development, coastal inundation, and global warming;
- Ocean's role in carbon sequestration and implications for ocean acidification and carbon cycling; and
- Identification of emerging contaminants of concern (e.g., pharmaceuticals/personal care products, brominated and perfluorinated compounds and nanomaterials).

Articulate a sense of importance

NOAA should create a sense of urgency among the public regarding ocean-related health issues. The needs and potential for research in this arena should be quantified and activities marketed in order to increase awareness of the importance of this work. The key message is that NOAA saves lives and promotes a healthy population. An outreach strategy to publicize this concept should include parameters that describe the economic and societal costs of compromised ocean health. These parameters should convey the hazards that oceans can pose to human societies, especially at-risk populations. It is also important to communicate the nutritional, pharmaceutical, and quality of life benefits of a healthy global ocean.

NOAA would be best served by following proven models of effective health communication. This effort might require professional hazard/risk communication specialists. The American Public Health Association has many useful examples of effective public communication of environmental health hazards, such as those related to climate change and health (www.apha.org/programs/environment/).

As an example, with the help of the OHHI and partnerships with the CDC, NOAA could support the acquisition of scientifically valid morbidity/mortality rates for ocean-borne illness and disease, and promote dissemination of this information to the public. Incidence statistics for acquired infections (e.g., *Vibrio*, *Enterobacter*, and *Staphylococcus*) from coastal waters, beaches, and shellfish are available for some states, but these data may be incomplete and are often not subjected to strict epidemiological quality assurance/control standards. NOAA might also investigate and communicate the frequency, extent, and economic costs of recreational beach and shellfish bed closures associated with ocean-borne diseases. In addition, NOAA should perform work to identify the economic and social benefits resulting from better knowledge of these parameters.

Encourage an agency culture where translational research of economic and public health importance is valued and rewarded

Translational research, typically applied in the field of medical research, is defined as the process of using novel laboratory findings to develop clinical applications and practical advancements in health care as quickly as possible. This best practice could also be employed by NOAA's oceanic and atmospheric scientists, with researchers encouraged to focus on applied endpoints that achieve the greatest benefit to health. Priority structures, incentives, and rewards for translational research should be communicated to NOAA's staff and partners.

Remote sensing is one area in which translational research might be pursued. NOAA's technical researchers should collaborate with academic engineers to develop new tools for sensing and predicting ocean/atmospheric changes linked to health, and for detecting biological and chemical indicators of ocean-health processes (i.e., contaminants, toxins, pathogens, and anoxia/hypoxia). Another much needed application involves ocean health database management, as well as data sharing among state and local health departments to monitor changes in health, and to inform early warning systems.

Create an interdisciplinary culture, including cross-sector training

NOAA can best demonstrate its recognition of the One Health concept by taking strong action to expand its interdisciplinary culture. NOAA should become the lead agency supporting cross-sector training of a workforce aimed at finding transnational solutions to health issues. The agency should also sponsor international conferences and symposia that address concerns about coastal, climate, and emerging health hazards. NOAA could leverage these efforts by developing student and post-doctoral training and educational partnerships jointly with other agencies charged with promoting global public health (e.g., WHO, USAID). At the university level, NOAA cooperative agreements in ocean health should be encouraged and developed with special attention to those universities training the public health workforce through the national networks of accredited Schools of Public Health (www.asph.org). The agency could also significantly impact cross-disciplinary training in oceans and health by becoming the lead agency to support and coordinate federal staff rotations. This would create opportunities for other agencies' (e.g., CDC and HHS) public health professionals to rotate through NOAA facilities, and for NOAA scientists to rotate to partnering facilities.

Question 5: How could NOAA more systematically develop ocean health products and services to enhance ecology, organism, human, and community health? What characteristics are required for success? What methods must be employed to be successful?

These questions address organizational behaviors that would lead to a well-conceived, integrated, and innovative Oceans and Health program. The OHWG recognizes that NOAA, particularly through its Oceans and Human Health Initiative, has begun to create a cross-discipline, transformative program that substantially integrates the external oceans and human health community with NOAA efforts. The OHWG has been impressed with the scope and depth of the projects accomplished under the OHHI, despite rather limited and diminishing resources. Still, NOAA and other federal agencies tend to treat strategic planning as a way to mold existing products and skills to fit into an externally mandated program. The OHWG believes that the program could succeed at an even greater level by escalated interdependent planning.

Engage in effective strategic planning

NOAA already does a great deal of work related to ocean effects on health, but lacks a unified direction; commonly themed programs are scattered across many parts of the agency. Moreover, while NOAA funds an impressive research portfolio at several academic research centers (and interacts with academic research centers funded through other federal agencies); these activities have only a marginal connection to corresponding research at its own facilities. A strategic plan is needed to link related efforts into a comprehensive program.

An integrative plan would help guide NOAA's activities in directions that would provide the greatest return on investment in terms of health benefits. The plan should be based on a systematic risk characterization, identifying all potential health threats and then quantifying the present and potential loss of life or economic cost of illness associated with each. Threats can potentially be identified and ranked through a rigorous method such as NASA's NSTS Hazard Prioritization process. Regrettably, NOAA's current spending in the area of Oceans and Health is not backed by such data.

Enhance transparency during planning and execution

Effectiveness of the strategic plan will depend upon strong partnerships and effective communication with other Federal agencies that need to be aware of and able to provide input on NOAA's planned undertaking, as well as how NOAA intends to partner with them. The academic community needs to be informed of NOAA's priorities as well, so that it can effectively target research to assist NOAA in achieving its objectives. Finally, NOAA staff should have an opportunity for input into agency priority development for health related activities.

Provide an investment commensurate with the imperative

A stable and adequate budget is vital for protecting the long-term integrity of health efforts. It is essential that NOAA take steps to secure a sufficient budget by quantifying and marketing the

value of investments in health initiatives. NOAA needs to gather the data necessary to quantify its achievements, and then utilize this data in pursuit of reliable funding.

Balance intramural and extramural funding portfolios

NOAA needs to involve outside expertise in its health efforts. The agency has done a good job of this within the OHHI, where it has provided 50% of agency funding to external institutions and encouraged academic participation through graduate and postdoctoral training and distinguished scholar programs. There is a need to continue these types of activities and expand them to other parts of its health portfolio not already included in the OHHI.

Participation from the academic community is especially important because NOAA's research tends to be application driven, whereas university research is mostly discovery driven. An effective Oceans and Health initiative requires a mix of both types of research. Likewise, academic partners are important in garnering political support, because often it is the extramural community that champions NOAA's valuable contributions to ocean research. Knowledgeable leaders in the scientific community can profoundly help NOAA program managers in communicating with and educating elected officials.

In addition to academic partners, there is a need to engage commercial partners. Engaging the private sector will enhance opportunities for bringing new products into widespread application. Nearly all of the translational elements (putting research into practical products and processes) of scientific discovery occur in collaboration, licensing, or partnering with private sectors companies.

Incorporate paradigms of permanent innovation

NOAA's success in health efforts will be bolstered by its ability to incorporate innovative ideas and practices into agency programs. This can be achieved through the art of permanent innovation. Adopting a specific method to regularize innovation will allow the process to become more institutionalized and more permanent. Multiple innovation models exist, all of which are based on risk, inclusiveness, and recognition of innovation when it occurs. One useful case study might be the innovative research environment promoted by NOAA's Cooperative Institutes, as these established partnerships foster a truly interdisciplinary approach to complex problems. A specific action that NOAA should consider is a call for "innovation proposals" to supplement the calls issued for very specific topic areas. These proposal guidelines would be purposefully amorphous, as stricter guidelines often narrow focus and similarly limit innovative potential.

Question 6: How can NOAA better integrate among its major programs, including activities conducted within the agency and those supported in the external community, to better define and assess ocean health issues?

While NOAA conducts many activities relevant ocean effects on health, it does not possess all of the capabilities necessary to comprehensively address cross-discipline needs. The agency's activities would be better served through an integrated effort in which the lines of communication are opened amongst various entities with differing strengths, skills, and foci. Cooperative partnerships are a valuable mechanism for filling the gaps among programs and between NOAA and other organizations with a shared vision. Leadership is essential to bring the diverse participants together and there are a number of steps that NOAA can take to make this vision a reality.

Establish an Oceans and Health coordinating entity within NOAA

NOAA currently supports health-related programs and projects that are scattered across its many operating branches and directed by a variety of different mission goals. While it is not necessary to bring these activities under a single program, it is vital that NOAA establish some type of coordinating entity for its health programs and Health. An internal coordinating unit would enhance the visibility and contributions of health programs by accepting responsibility for strategic planning, creating consensus on common goals, and communicating results across programs. The coordinating entity should also serve as a driver for transitioning products.

To accomplish these tasks, the coordinating entity should be at a sufficiently high level to contribute to goal-setting and strategic planning activities. It should also have budgetary authority across NOAA's mission goals and operating branches.

Develop and enhance strategic partnerships

NOAA must commit to leading the development of a robust Oceans and Health community. To successfully lead this integrated endeavor, it is critical that NOAA actively seek partnerships that both augment agency strengths and fill gaps in NOAA's current capabilities. Partnerships will include various types of relationships, such as those enhancing a specific skill base or allowing access to new data or clients. While associations among federal agencies are valuable, agreements should also be forged with other complementary organizations. Collaborations might be expanded to engage all ocean-related communities, including scientists, lawmakers, community leaders, resource managers, health officials, and citizens. In addition, NOAA's partnerships should extend beyond our shores to international entities with common interests. Specific potential partnerships are highlighted below.

Potential Strategic Partnerships

Strategic partners that could contribute relevant Oceans and Health experience and expertise include:

International Agencies

- *World Health Organization and International Health Ministries* for disease surveillance, emerging diseases, and species migrations associated with climate change
- *World Organization for Animal Health (OIE)* for disease surveillance, diagnostic capability, and emerging diseases

Federal Agencies

- *US Environmental Protection Agency* for monitoring tools and methods to ensure healthy public water supplies and beaches
- *Centers for Disease Control and Prevention* for disease surveillance, outbreak response, and epidemiological expertise
- *US Food and Drug Administration* for seafood safety
- *US Geological Survey* for monitoring, GIS tools, and wildlife health
- *Department of the Interior* for ecosystem health
- *Animal and Plant Health Inspection Service, US Department of Agriculture* for diagnostic support and emerging diseases in animals
- *Federal Emergency Management Agency* for planning and emergency response
- *National Institutes of Health*
- *National Science Foundation*

State Agencies

- *State Public Health Laboratories* for diagnostic support and emerging diseases
- *State Public Health Agencies* for surveillance, planning, and response
- *State Environmental Laboratories* to augment monitoring and prediction capabilities

Veterinary Community

- *Veterinarians* for disease surveillance, emerging infections, and zoonotic diseases

Academic Community

- *Universities* for basic research, and ocean pharmacopeia
- *University Diagnostic Laboratories* for animal health

Nongovernmental organizations

- *American Public Health Association*
- *American Medical Association*
- *Social services organizations* for developing, evaluating, and implementing Oceans and Health education and outreach

NOAA has had some success in the past at applying inter-agency partnerships to address specific issues. One example is the cooperative relationship between the NOAA Fisheries Seafood Inspection Program and the U.S. Food and Drug Administration in which the NOAA Administrator recently signed a Memorandum of Understanding to share information that leverage limited inspection resources. Another example is the *Interagency Oceans and Human Health Research Implementation Plan* developed to address harmful algal blooms, hypoxia, and human health. However, these types of partnerships often come via government mandate, rather than an internal initiative. The value of partnerships – in terms of extending program capacity,

cost-sharing, and promoting application of products – should encourage NOAA to proactively pursue these relationships.

Partnership enhancement activities should start with improving communication and activities among NOAA's regional laboratories. Integrating region-based monitoring, modeling, and scientific expertise would demonstrate the agency's effectiveness in coordinating disparate activities.

Lead development of a robust oceans and human health community working across disciplines and institutions to improve public health

A new field of scientific and social endeavor is emerging as we learn more about the interactions between the ocean and living communities. NOAA is in prime position to accept the responsibility to integrate health activities across many associated disciplines. NOAA should take an official role -- outlined in a strategic plan and implementation strategy -- that coordinates short- and long-term activities across agencies to address current health research needs, that identifies gaps in present understanding, and that develops research strategies relevant to ocean health promotion, protection and preservation globally.

In addition, NOAA should take a leadership role in identifying projects with practical application to the Oceans and Health community, including new environmental monitoring and health assessment tools and improved capability to predict changes in ocean characteristics, food and pharmaceutical resources, harmful algal blooms, weather, and climate. The coordinating entity discussed above would be responsible for developing and nurturing an agency-wide environment that encourages and supports the transition and translation of research to NOAA and other agency operations. Such an entity is presently absent domestically or internationally even though ocean-health issues are transdisciplinary and of critical multinational concern.

APPENDIX B: BIOGRAPHIES OF WORKING GROUP MEMBERS

Dr. Stephen B. Weisberg, Chair

Dr. Stephen Weisberg is Executive Director of the Southern California Coastal Water Research Project Authority (SCCWRP), a research agency that serves as the interface between science and water quality management in California. Dr. Weisberg's research emphasis is in design of environmental monitoring programs and developing next generation assessment tools. He is Chair of the Southern California Bight Regional Monitoring Steering Committee and sits on the Governing Boards of the California Ocean Science Trust and the Southern California Coastal Ocean Observing System. He serves on numerous advisory committees, including the State of California's Clean Beach Task Force, the California Ocean Protection Council Science Advisory Team, California's Water Quality Monitoring Council, and the US EPA Board of Scientific Counselors. Dr. Weisberg received his undergraduate degree from the University of Michigan and his Ph.D. from the University of Delaware.

Dr. Lorraine C. Backer

Dr. Lorraine Backer is Team Lead for the Applied Epidemiology Team, at the Centers for Disease Control and Prevention. Since 2000, Dr. Backer has served on Oceans and Health-related committees, including the Science Advisory Board for NOAA's OHH Initiative; the Science Advisory Board for the Hollings Marine Lab, Charleston, South Carolina; and the Science Advisory Committee for the University of Miami Oceans and Human Health Center. She was a member of the National Harmful Algal Bloom Committee and is currently HHS Representative and co-chair of the Ocean Science and Technology Policy, Joint Subcommittee on Ocean Science and Technology Interagency Working Group on HABs, Hypoxia, and Human Health. She is currently a board member for International Society for the Study of Harmful Algae and is a member of the National Ocean Policy Working Committee. Dr. Backer holds a Ph.D. from the University of Kansas and an M.P.H. in Epidemiology from the University of North Carolina, Chapel Hill.

Dr. Daniel G. Baden

Dr. Daniel Baden is the Director of the Center for Marine Science at the University of North Carolina Wilmington. Concurrently he is the Executive Principal of MARBIONC, Marine Biotechnology in North Carolina. He also is the William R. Kenan Jr. Distinguished Professor of Marine Science in North Carolina. Formerly he was Professor of Marine Biology and Fisheries at the Rosenstiel School of Marine and Atmospheric Science at the University of Miami, and Director of the NIEHS Marine and Freshwater Biomedical Sciences Center at RSMAS. Dr. Baden has served on a variety of advisory panels, working groups, and review panels for the NIH, NOAA, and NSF. Dr. Baden holds a Bachelor's degree in Chemistry from Hamline University (MN) and a PhD in Biochemistry from the University of Miami, School of Medicine (FL). His research work focuses on the molecular mechanisms by which natural marine toxins from red tide affect living systems. His most recent work is in the area of marine-derived human disease therapeutics and he is inventor on patents in the areas of cystic fibrosis and other mucociliary diseases, neurotoxic shellfish poisoning, and ciguatera fish poisoning.

Dr. Shannon Briggs

Dr. Shannon Briggs is a Senior Toxicologist and manages the beach monitoring program for the Water Bureau of the Michigan Department of Environmental Quality. She has been a member of the Toxicology Steering Group for the State of Michigan since 1998 and served as Chair from 2005 to 2006. She is a member of the Great Lakes Human Health Network hosted by the United States Environmental Protection Agency (USEPA) and the Beach Health Steering Committee for the United States Geological Survey (USGS). She is co-founder of the Great Lakes Beach Association (GLBA) that began in 2001. She served as President of the GLBA from 2005 to 2007 and currently serves as an advisory member. She was a contributor to the Coastal Health Chapter of the Great Lakes Regional Collaboration Strategy that provides the framework to restore and protect the Great Lakes. She also served on the Pre-Pilot Beach Sanitary Survey Workgroup led by the USEPA in 2006. Dr. Briggs has a Ph.D. in Pharmacology and Toxicology from Michigan State University.

Dr. Thomas Chandler

Dr. Thomas Chandler is Dean of the Arnold School of Public Health at the University of South Carolina. The Arnold School has a unique history among Schools of Public Health of making significant contributions with the ocean sciences community in ecosystems and human health. He completed baccalaureate work in biology and marine sciences at UNC-Wilmington in 1979, he received the Ph.D. in zoology in 1986 from LSU, and he was a Fulbright postdoctoral fellow at the University of Hamburg in 1987. He joined the Arnold School in 1990 and holds professorships in environmental health and marine sciences. His area of expertise is estuarine ecotoxicology with special emphasis on fate, bioaccumulation and effects of sediment-associated PAHs, pharmaceuticals, pesticides and nanomaterials in marine ecosystems. He serves on the Organization for Economic Cooperation and Development Environmental Directorate expert advisory group for aquatic toxicity testing, and recently has developed the marine copepod lifecycle test for evaluation of endocrine and reproductive toxicity by xenobiotics.

Dr. Rita Colwell

Dr. Rita R. Colwell is Distinguished University Professor, University of Maryland and Johns Hopkins University. Rita Colwell served as the 11th director of the National Science Foundation (NSF) from 1998 to 2004. Currently, she is Chairman Emeritus of Canon US Life Sciences and President/CEO of CosmosID. She obtained a B.S., Bacteriology and M.S., Genetics, from Purdue University, and Ph.D. from the University of Washington. Dr. Colwell was president of the University of Maryland Biotechnology Institute from 1991 to 1998. Dr. Colwell has held many advisory positions in the federal government, nonprofit science policy organizations, private foundations, and international scientific research societies. She is a nationally-respected scientist and educator, and has authored or co-authored 17 books and more than 750 scientific publications. She produced the award-winning film *Invisible Seas* and has served on editorial boards of many scientific journals. The recipient of numerous awards, Dr. Colwell has received 54 honorary degrees from institutions of higher education. A geological site in Antarctica, Colwell Massif, was named in recognition of her work in the polar regions. Dr. Colwell has previously served on the National Science Board, as chair of the Board of Governors of the

American Academy of Microbiology, and also as President of the American Association for the Advancement of Science (AAAS), the Washington Academy of Sciences (WAS), the American Society for Microbiology (ASM), the Sigma Xi National Science Honorary Society, and the International Union of Microbiological Societies. She is a member of the National Academy of Sciences, the Royal Society of Sweden, the Royal Society of Canada, and the American Academy of Arts and Science. She was awarded the Order of the Rising Sun by the Emperor of Japan and the 2006 Medal of Science by President George W. Bush.

Dr. David Fluharty

David Fluharty is an Associate Professor at the School of Marine Affairs and Wakefield Professor of Ocean and Fishery Sciences, University of Washington where he has been employed since 1976. His doctoral degree is from the University of Michigan, School of Natural Resources in the interdisciplinary field of Natural Resource Conservation and Planning. His research and teaching interests are in natural resource policy and management at national and international levels, ecosystem approaches for management of marine resources, watersheds, coastal zones, fisheries, marine protected areas, and regional effects of global climate change. Significant professional activities include: Chair, NOAA Science Advisory Board 2006-; Chair, External Ecosystem Research Team for NOAA-wide Ecosystem Science and Research 2005 - 2006; Advisor of National Center for Ecosystem Analysis and Synthesis [NCEAS] study groups on Marine Protected Areas, Models for Fisheries Ecosystems 2002-2005, and Ecosystem Management Feasibility in Tropical Areas 2006- ; Member, North Pacific Fishery Management Council 1994-2003; Associate Editor, Coastal Management Journal; Chair, Editorial Board, Marine Protected Area News and Marine Ecosystems And Management; Member, National Research Council, Study on Evaluation, Design and Monitoring of MPAs and Reserves for the United States; Chair, Ecosystem Principles Advisory Panel 1997-2000 reporting to Congress on Ecosystem-Based Fishery Management.

Dr. Frances M.D. Gulland

Frances Gulland is the Director of Veterinary Science at The Marine Mammal Center in Sausalito, California. The Marine Mammal Center is a non-profit hospital for stranded marine mammals, and works closely with the West Coast Center for Excellence in Oceans and Human Health, using marine mammals as sentinels for ocean changes that can impact human health. She has been actively involved in the veterinary care and rehabilitation of stranded marine mammals and research into marine mammal diseases there since 1994. She has provided medical care for thousands of seals and sea lions, has published over 100 peer reviewed articles, and is coeditor of the *CRC Handbook of Marine Mammal Medicine*. She chaired the NMFS Working Group on Marine Mammal Unusual Mortality Events for 6 years, sits on Recovery Team for the Hawaiian monk seal, and is a member of the Committee of Scientific Advisors to the Marine Mammal Commission.

Dr. Frank Kudrna, Jr.

Dr. Frank Kudrna is the chief executive officer of Kudrna & Associates, Ltd., a Chicago civil engineering consulting firm. Formerly he was president of Epstein Civil Engineering Company, and prior to that he was director of the Illinois Division of Water Resources and supervising

engineer of flood control and planning with the Metropolitan Water Reclamation District of Greater Chicago. Dr. Kudrna has served for over 25 years on the Great Lakes Commission. He is former vice-chairman of the Upper Mississippi River Basin Commission and the Ohio River Basin Commission. Dr. Kudrna holds a Ph.D. from the Illinois Institute of Technology and an MBA from the University of Chicago. During 2000, Dr. Kudrna served on the eight-member team that conducted an intensive review of the National Sea Grant College Program's extension efforts that resulted in the report A Mandate to Engage Coastal Users. Dr. Kudrna also serves on NOAA's Science Advisory Board.

Dr. David Letson

David Letson is Professor of Marine Affairs and Economics at the University of Miami, where he has worked since 1995. He currently serves as Chair of the Division of Marine Affairs. As an educator and researcher, he promotes economic understanding of coastal and marine resource use. Letson has worked extensively with NOAA to strengthen its social science research, for example serving as editor on a recent NOAA coastal resource economics monograph. His research focuses on the economics of extreme weather and climate variations. He is interested in the value of predictions from the geosciences and in how those predictions are interpreted and used. Letson serves as a member of NOAA's Hurricane Forecast Socio-Economic Working Group, convened by NOAA and the National Center for Atmospheric Research to develop a hurricane social science research agenda. Letson obtained his Ph.D. in economics from the University of Texas at Austin and has over 40 publications to his credit.

Dr. Carolyn A. Thoroughgood

Carolyn Thoroughgood, Professor of Marine Biosciences, is Special Assistant to the Provost for Program Development at the University of Delaware. Until July, 2008 she held the positions of Vice Provost for Research and Graduate Studies at the University of Delaware and President of the Delaware Technology Corporation. From 1984 to 2004, she served as Dean of UD's College of Marine Studies and Director of the Delaware Sea Grant College Program. Dr. Thoroughgood joined the UD faculty in 1968 as a nutritional biochemist and conducted Sea Grant research on the nutritional needs of bivalves reared in closed-environment systems. She was one of the organizers and officers of the Council on Ocean Affairs, a national organization of marine academic institutions that preceded the Consortium for Oceanographic Research and Education (CORE) and the Consortium for Ocean Leadership (COL). She served as CORE's first Chair of the Board of Governors and was CORE's Acting President from December 2001 to August 2002, when she also became the principal investigator on the first Centers for Ocean Sciences Education Excellence (COSEE) Central Coordinating Office proposal to the National Science Foundation. She served on the Science Advisory Panel to the U.S. Commission on Ocean Policy and currently is on the Science Advisory Board of the National Oceanic and Atmospheric Administration. Additionally, she is on the Southeastern University Research Association (SURA) Executive Committee and Chairs SURA's Coastal Research Committee. She also is the P.I. for the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA) and is an active participant in implementation of the nation's Integrated Ocean Observing System (IOOS). Dr. Thoroughgood cares deeply about the ocean sciences and is honored to be the president of The Oceanography Society (TOS).

APPENDIX C: OHWG MEETING AGENDAS

**Oceans and Health Working Group and NOAA Science Advisory Board
March 24 and 25, 2009
Silver Spring, Maryland**

Tuesday, March 24, 2009

- 8:30 AM Opening Statement by *Science Advisory Board (SAB) Chair David Fluharty* and Introduction of *Oceans and Health Working Group (OHWG) Chair Steve Weisberg*
- 9:00 AM Overview of the NOAA SAB and Review of the OHWG Charge
Cynthia Decker, Executive Director, NOAA SAB

NOAA's Oceans and Human Health Initiative (OHHI)

- 9:30 AM Overview of the OHHI
Paul Sandifer, Senior Scientist Coastal Ecology, NOAA/National Ocean Service(NOS)
- 10:00 AM OHHI Highlights, Achievements, and Partners
Juli Trtanj, Program Manager, OHHI

10:30 AM Break

- 10:45 AM OHHI Distinguished Scholar Program
Rita Colwell, OHWG member, University of Maryland.
- 11:10 AM OHHI Traineeship Consortium
Juli Trtanj, Program Manager, OHHI
- 11:35 AM OHHI External Advisory Panel
Jay Grimes, Panel Chair, University of Southern Mississippi

12:00 PM Lunch

Other NOAA OHH-Related Programs

- 1:15 PM Marine Mammal Health and Stranding Response Program (MMHSRP) and Other Protected Resources
Teri Rowles, MMHSRP Manager, NOAA National Marine Fisheries Service Office of Protected Resources, and Frances Gulland, OHWG member, The Marine Mammal Center.
- 2:00 PM OHH Activities at NOAA's National Centers for Coastal Ocean Science (NCCOS)
Geoff Scott, Director, Coastal Center for Environmental Health and Biomolecular Research; and Acting Director, Hollings Marine Laboratory
- 2:45 PM Sea Grant – Ocean Drug Discovery and Outreach
Leon Cammen, Director, National Sea Grant College Program

3:30 PM Break

- 3:45 PM National Aquatic Animal Health Plan
Michael Rubino, Director, NOAA Aquaculture Program
- 4:30 PM OHWG Discussion
- 5:30 PM Adjourn for Day

Wednesday, March 25, 2009

- 8:30 AM Opening Remarks/Review of the Day
Steve Weisberg, Chair, OHWG
- 8:45 AM NOAA Harmful Algal Bloom Programs
Quay Dortch, ECOHAB Program Coordinator, NOAA NOS/NCCOS
- 9:30 AM National Science Foundation and National Institute of Environmental Health Sciences
Don Rice, Chemical Oceanography Program Director, National Science Foundation
- 10:15 AM Break**
- 10:30 AM Centers for Disease Control and Prevention
Lorraine Backer, Member of OHWG and OHHI Advisory Panel
- 11:15 AM Environmental Protection Agency
Kevin Summers, USEPA Gulf Ecology Division
- 12 Noon Interagency Working Group on Harmful Algal Blooms, Hypoxia and Human Health and
Institute of Medicine Roundtable-Climate Change and Health Research Agenda
Paul Sandifer, Senior Scientist Coastal Ecology, NOAA/NOS
- 12:30 PM Lunch**
- 1:30 PM Discussion of Next Steps for OHWG/Next Meeting
- 3:00 PM Adjourn**

**Oceans and Health Working Group and NOAA Science Advisory Board
Second Meeting
June 23-24, 2009
Silver Spring, Maryland**

Tuesday, June 23, 2009

8:30 Opening Statement and Review of the Past Meeting
Steve Weisberg, Chair, OHWG

9:00 Results from the data call regarding NOAA's Oceans and Health Programs
Paul Sandifer, Senior Scientist Coastal Ecology, NOAA/NOS

9:30 OHHI External Advisory Panel Advice Regarding OHWG's Charge Questions
Jay Grimes, Chair, OHHI External Advisory Panel

10:30 Break

Response to the Charge Questions

10:45 What are NOAA's Unique and Important Scientific Roles in Addressing Ocean Health Issues?
David Fluharty, SAB Chair

12:00 Lunch

1:15 What are the Right Ocean Health Science Questions, Products and Services for NOAA?
Shannon Briggs, Michigan Department of Environmental Quality, and Frances Gulland, The Marine Mammal Center

2:30 Break

2:45 Are there Additional Ocean Health Science Issues that should be Included in the NOAA Research Portfolio? If so, What are These?
Shannon Briggs, Michigan Department of Environmental Quality, and Frances Gulland, The Marine Mammal Center

4:00 What are the Appropriate Steps for NOAA to Incorporate and Advance Ocean Health as Part of Its Core Mission?
Thomas Chandler, University of South Carolina, and Carolyn Thoroughgood, University of Delaware

5:15 Adjourn for the Day

6:30 Group Dinner

Wednesday, June 24, 2009

8:00 Opening Remarks/Review of the Day
Steve Weisberg, Chair, OHWG

8:15 Oceans and Health Initiatives within the US Geological Survey (USGS)
Herb Buxton, Toxic Substances Hydrology Program Coordinator, USGS

Response to the Charge Questions

9:15 How could NOAA more systematically develop ocean health products and services to enhance ecosystem, organism, human, and community health?
Daniel Baden, Center for Marine Science, University of North Carolina Wilmington

10:30 Break

10:45 How can NOAA better integrate among its major programs, including activities conducted within the agency and those supported in the external community to better define and assess ocean health issues?
Lorraine Backer, Centers for Disease Control and Prevention, Member of OHWG and OHHI Advisory Panel

12:00 Lunch

1: 15 Integrating answers from the individual charge questions into an overall assessment
Steve Weisberg, Chair, OHWG

2: 45 Discussion of next steps, assignments and planning for the next meeting
Steve Weisberg, Chair, OHWG

3:30 Adjourn

**Oceans and Health Working Group and NOAA Science Advisory Board
Third Meeting
August 19-20, 2009
Costa Mesa, California**

Wednesday, August 19

- 8:00 Review of the past meeting, comments from the SAB and goals of this meeting.
Steve Weisberg, OHWG Chair
- 8:15 What are NOAA's unique and important scientific roles in addressing ocean health issues?
David Fluharty, SAB Chair, and Lorraine Backer, Centers for Disease Control and Prevention
- 9:30 What are the right ocean health science questions, products and services for NOAA?
Shannon Briggs, Michigan Department of Environmental Quality; and Frances Gulland, The Marine Mammal Center
- 10:45 Are there additional ocean health science issues that should be included in the NOAA research portfolio? If so, what are these?
Shannon Briggs, Michigan Department of Environmental Quality; and Frances Gulland, The Marine Mammal Center

12:00 Lunch

- 1:00 What are the appropriate steps for NOAA to incorporate and advance ocean health as part of its core mission?
Thomas Chandler, University of South Carolina, and Carolyn Thoroughgood, University of Delaware
- 2:15 How could NOAA More Systematically Develop Ocean Health Products and Services to Enhance Ecosystem, Organism, Human, and Community health?
Dan Baden, Center for Marine Science, University of North Carolina Wilmington; and David Letson, Marine Affairs and Economics, University of Miami

3:30 Break

- 3:45 How can NOAA Better Integrate Among Its Major Programs, Including Activities Conducted within the Agency and Those Supported in the External Community to Better Define and Assess Ocean Health Issues?
Lorraine Backer, Centers for Disease Control and Prevention; and Dan Baden, Center for Marine Science, University of North Carolina Wilmington

5:00 Adjourn for the Day

6:00 Group Dinner

Thursday, August 20

8:00 Opening Remarks/Review of the Day
Steve Weisberg, OHWG Chair

8:15 Executive Summary
Steve Weisberg, OHWG Chair; David Fluharty, SAB Chair; and Carolyn Thoroughgood, University of Delaware

9:45 Break

10:00 Introduction to the Report
Steve Weisberg, OHWG Chair; David Fluharty, SAB Chair; and Carolyn Thoroughgood, University of Delaware

11:00 Discussion of Next Steps
Steve Weisberg, OHWG Chair

12:00 Adjourn