

Guest Editorial

The Oceans and Human Health

For millennia, the oceans have been perceived by mankind as a producer of essential protein, a vital transportation artery, a source of great danger (from storms, hurricanes, typhoons, tsunamis, and venomous and predatory animals) and the greatest mystery on the planet, inspiring untold realms of poetry and prose. The oceans are the world's most important sources of biological activity, water, biodiversity, and biomass production. They supply food, oxygen, and other natural products critical for human existence, and interactions between the oceans and atmosphere shape our climate and weather. Today, we recognize the oceans for all these attributes and also for their marvelous, incredible, and almost infinite diversity of life forms and life processes, as well as the extraordinary potential for many of those life forms, biological and physical processes, and other resources to be harnessed for human welfare. We are just beginning to understand the numerous and complex ways in which humans can affect the oceans, and the oceans, in turn, can affect human health, including the discovery of new pharmaceuticals to fight human illnesses.

Although not truly an island, the United States is bordered on all sides by seas, and the lands immediately adjacent to the coast annually contribute over \$1 trillion to the U.S. economy. In addition, our coastal waters provide invaluable waste processing and other ecologic services for free. Approximately 25% of the country's land area lies within coastal counties, which provide homes and workplaces for > 50% of our population. In addition, ocean-based tourism is the fastest growing component of the coastal economy, with hundreds of millions of Americans and international guests visiting our coasts annually. Not surprisingly, coastal population densities are several times higher than in the rest of the nation, and coastal sprawl is consuming land at ≥ 3 times the rate of population growth. These trends are projected to continue and may accelerate, resulting in permanent alterations to a large portion of the coastal landscape and potentially serious impacts on marine ecosystems and public health.

Estuaries—those places where freshwater rivers meet and mix with the saltwater of the ocean—are dynamic environments renowned for their ecologic complexity, biological productivity, and seafood harvests and for the critical nursery habitat they provide for many ecologically and economically important species. Linking the land to the sea, the shallow tidal creeks and embayments along the shores of larger estuaries are the first zone of impact for many of the chemical and microbial pollutants washed or released into estuaries. As nurseries for the early and generally most sensitive life-history stages of many species of fish and invertebrates, these areas may provide early warnings of ensuing harm to the environment and to humans. In addition, the continental shelf and even the open ocean show increasing evidence of human-derived pollutants, such as occurrences of pathogens and persistent organic pollutants in offshore marine mammals.

Estuarine and coastal processes are increasingly being affected by humans, with consequent impacts on coastal ecosystems and the humans who live, work, and play there. Principal sources of pollution are urban and agricultural runoff, municipal sewage discharges, atmospheric deposition of airborne pollutants, and industrial wastewater. Other causes of degradation include shoreline modification, overfishing, introduction of invasive species, and high-density recreational use. Increasing incidences of beach closures, fish and shellfish consumption advisories, harmful algal blooms, and occurrence of toxic chemicals and pathogenic microorganisms in coastal waters, sediments, and biota are indicative of the extent of the problem. Changes in marine ecosystems due to global warming and other stressors also pose



Left to right: Paul A. Sandifer, A. Frederick Holland, Teri K. Rowles, Geoffrey I. Scott

increased threats to human health from microbial agents transmitted via water, food, or other vectors, or which may be harbored in animal reservoirs.

The safety and economic risks of extreme weather events, climate change, and rising sea levels to those who live on or visit our coasts are reasonably well known. However, while cases of human illness linked directly or indirectly to stressed estuarine and coastal environments are being documented with increasing frequency, the risks to human health from continued and expanded impairment of coastal and ocean environments remain very poorly understood. Globally, nontraumatic human illnesses documented in relation to coastal processes typically are associated with *a*) consumption of pathogen-contaminated or chemically contaminated seafood; *b*) spread of human pathogens (e.g., cholera) via the release of poorly treated or untreated sewage into coastal waters; *c*) exposure to toxins from harmful algae; and *d*) effects of weather and climate on the rates and means of transmission and severity of infectious diseases. Other associations are more elusive, probably because we have not looked in the right places using the right technologies. Existing national and regional monitoring and assessment programs have focused on the measurement of persistent chemicals, particularly in deeper estuarine sediments. Much more attention should be paid to assessing known or potential human pathogens and contaminants and emerging contaminants of concern such as newly registered pesticides, pharmaceuticals, and fire retardants in shallow estuarine and marine waters, coastal retention ponds, continental shelf environments, and the open ocean.

New approaches and collaborations are required if we are to understand and resolve the large-scale environmental and public health problems facing the United States' predominantly coastal population. As the U.S. Commission on Ocean Policy (2004) stated in its preliminary report, "Significant investment must be put into developing a coordinated national research effort to better understand the links between the oceans and human health" The interdisciplinary Oceans and Human Health (OHH) initiatives now being undertaken by the National Oceanic and Atmospheric Administration and jointly by the National Science Foundation and National Institute of Environmental Health Sciences provide the first steps toward a coordinated effort to transcend traditional disciplines and boundaries and focus a broad array of scientific intellect on developing regional and national solutions to environmental and public health issues of increasing complexity involving cumulative impacts from multiple stressors. Deriving such solutions will require a sustained and concentrated effort of scientific talent from multiple disciplines and institutions, development of new technologies and new understanding of ecosystem dynamics, and effective transfer of critical information to natural resource and public health managers and to the public at large. These new OHH initiatives should help

the nation build a foundation for forecasting environmental and human health risks across estuarine habitats, watersheds, and coastal and ocean regions and an enhanced capacity to design and implement future estuarine monitoring and assessment programs that will include early warning indicators of threats to public, organism, and ecosystem health. Ultimately, we believe the OHH initiatives will help the United States better address three key questions the public frequently asks about virtually every estuary and coastal area: *a)* Are the fish and shellfish safe to eat? *b)* Is it safe to swim in the water? *c)* If not, what can we do to make them safe?

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Teri K. Rowles was a faculty member at Virginia Maryland Regional College of Veterinary Medicine and the University of Tennessee before moving to NOAA's National Marine Fisheries Service in 1995. At NOAA, she coordinates the Marine Mammal Health and Stranding Response Program and works on the impacts of diseases on marine protected species and on zoonotic diseases from marine organisms. She is currently on detail at the Hollings Marine Laboratory.

Geoffrey I. Scott is the director of NOAA's Center for Coastal Environmental Health and Biomolecular Research. His primary research areas include environmental toxicology and physiological ecology, and he holds faculty appointments at the University of South Carolina, the Medical University of South Carolina, and the College of Charleston.

REFERENCES

U.S. Commission on Ocean Policy. 2004. Preliminary Report of the U.S. Commission on Ocean Policy. Governors' Draft. Washington, DC:U.S. Commission on Ocean Policy.

Guest Editorial

Connecting the Oceans and Human Health

Life on Earth is and has always been inextricably associated with the oceans that occupy greater than 70% of the planet's surface. The origins of life as we know it began in the depths of the oceans, and human life is still unreservedly dependent on the same oceans. As of 1994, more than 2 billion people lived within 60 miles of a coastline (Cohen et al. 1997); today, 14 of the world's 17 largest cities lay on or near coasts (United Nations Population Division 2002).

The proximity of human populations to ocean coasts is not surprising when our past, current, and future dependence on coastal waterways for food, commerce, travel, and recreation are taken into consideration. The largest source of protein in the world is fish, and more fish are harvested throughout the world than cattle, sheep, poultry, or eggs (Srinivas 1999). Billions of dollars are generated annually from fishing alone (National Marine Fisheries Service 2003), and other commercial ventures include travel and recreational use of coastal waterways. In addition to human dependence on the oceans for life, work, food, travel, and fun, human health is also associated with the oceans.

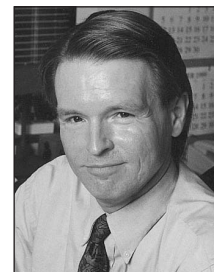
The oceans are teeming with life and serve as the world's greatest reservoir of biodiversity, including marine mammals, fish, crustaceans, mollusks, and countless species of zoo- and phytoplankton. It is this marvelous biodiversity that will allow us to take advantage of the oceans' bounty, and identify and develop marine-derived biopharmaceuticals to improve human health outcomes. Recent work from a number of investigators' laboratories has shown that marine



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invertebrates produce compounds that have potential for development as pharmaceuticals, with applications in treatment of neurodegenerative disorders, cardiovascular and infectious diseases, and certain cancers.

Human health outcomes related to the oceans have been documented as far back as 800 B.C., when illness resulting from consumption of contaminated fish was recorded in Homer's *Odyssey* (Halstead 1988). In present times, ocean-related human illnesses are still primarily caused by consumption of contaminated seafood, but are also caused by inhalation of aerosolized toxins. Worldwide each year, more than 60,000 cases of poisoning by exposure to harmful algal blooms (HABs) are reported (Van Dolah 2000). HABs release marine toxins that are frequently associated with kills of fish, birds, and marine mammals. Adverse health outcomes in humans range from acute neurotoxic disorders such as paralytic shellfish poisoning, neurotoxic shellfish poisoning, and ciguatera fish poisoning to more chronic diseases such as chronic liver disease caused by microcystins and amnesic shellfish poisoning from

domoic acid exposure. Presently it is not known what is responsible for or triggers outbreaks of HABs. Methodologies for early detection or remote sensing of outbreaks would provide a major mechanism for reducing and preventing exposures to marine toxins released by HABs.

Worldwide, human activities associated with point and non-point sources of pollution result in the discharge of billions of gallons of wastewater into oceans and coastal waterways. In the United States alone, 2.8 billion gallons of industrial wastewater are released into the oceans annually (U.S. Environmental Protection Agency 1994). These activities represent human patterns and behaviors that exacerbate the adverse impact that oceans and coastal waterways can have on human health through exposure to water- or vectorborne pathogens. It is clear that the oceans are a life-sustaining, reinvigorating resource that demands proper stewardship, because human well-being and public health outcomes are at risk. Greater resources should be brought to bear in terms of scientific research on pathogen growth patterns and detection in the oceans. This would greatly facilitate reduction of hazardous human exposure and disease.

The oceans have unfortunately become conduits for a number of environmental threats to human health. In order to guard against health threats, and at the same time to take advantage of medicinal benefits that the oceans might provide, the impact of oceans on human health must be more fully explored. Programmatic development in oceans and human health research originated in 1998, when the NIEHS participated in interagency activities, workshops, and Institute of Medicine panels as part of the International Year of the Ocean. That same year, the NIEHS cosponsored the U.S. Pavilion with its theme of Oceans and Human Health at the World's Fair in Lisbon. A 1998 presidential National Ocean Conference in Monterey, California, and subsequent workshops at the Bermuda Biological Station for Research and elsewhere assisted in providing the framework for a research strategy. Through multiple discussions, the NIEHS and the National Science Foundation (NSF) Division of Ocean Sciences decided to create one oceans and human health research program that would combine NSF expertise in ocean biology, chemistry, and physics with NIEHS expertise in environmental health and prevention research. This program would also take advantage of the institute's ties to the public health community.

The four new Centers for Oceans and Human Health collaboratively sponsored by the NIEHS and the NSF (and described on p. A468 of this issue) have established a new paradigm for linking the health and the rich resources of the Earth's oceans with the health outcomes of the Earth's population. By harnessing the various talents, disciplines, and expertise of scientists supported by the collaborating agencies; by combining the tools of genomics, proteomics, and metabolomics with physical oceanography; and by stimulating intercenter cooperation and coordination, this program offers tremendous promise for developing more comprehensive linkages between oceans and human health as the world's population continues to depend on one of our greatest natural resources for food, commerce, transportation, and recreation. Supported by the physical and biological science resources of the NSF and the NIEHS, the centers also demonstrate the capacity of

federal research agencies to collaborate and leverage resources to foster high-quality interdisciplinary research.

This novel, groundbreaking interagency effort fulfills one of the key recommendations of the recent *Preliminary Report of the U.S. Commission on Ocean Policy* (U.S. Commission on Ocean Policy 2004): to encourage interdisciplinary marine biomedical research to improve our understanding of the links between oceans and human health. In the coming years, these NIEHS–NSF Centers for Oceans and Human Health will serve as models both of life–physical sciences interaction and of federal coordination.

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REFERENCES

- Cohen JE, Small C, Mellinger A, Gallup J, Sachs J, Vitousek PM, et al. 1997. Estimates of coastal populations [Letters]. *Science* 278(5341):1209–1213.
- Halstead BW. 1988. *Poisonous and Venomous Marine Animals of the World*. Princeton, NJ:Darwin Press.
- National Marine Fisheries Service. 2003. *Fisheries of the United States 2002*. Silver Spring, MD:National Marine Fisheries Service, Office of Science and Technology, Fisheries Statistics and Economics Division. Available: <http://www.st.nmfs.gov/st1/fus/current/index.html> [accessed 17 May 2004].
- Srinivas H. 1999. Coastal Area Management: Integrating Environmental Objectives into Harbour Planning. Available: <http://www.gdrc.org/oceans/cam-continuum.html> [accessed 17 May 2004].
- United Nations Population Division. 2002. *World Urbanization Prospects: The 2001 Revision*. New York, NY:United Nations. Available: <http://www.un.org/esa/population/publications/wup2001/WUP2001report.htm> [accessed 17 May 2004].
- U.S. Commission on Ocean Policy. 2004. *Preliminary Report of the U.S. Commission on Ocean Policy*. Governors' Draft. Washington, DC:U.S. Commission on Ocean Policy. Available: <http://www.oceancommission.gov/> [accessed 17 May 2004].
- U.S. Environmental Protection Agency. 1994. *Report to Congress on Inventory of 403(c) Ocean Discharges*. Washington, DC:U.S. Environmental Protection Agency.
- Van Dolah FM. 2000. Marine algal toxins: origins, health effects, and their increased occurrence. *Environ Health Perspect* 108(suppl 1):133–141.