Chapter 23: Connecting the Oceans and Human Health

While marine animals and plants are most commonly used as sources of food, they also produce a vast array of chemical compounds that can be developed into products with beneficial medical and industrial uses. However, marine organisms such as bacteria, algae, and viruses can also be sources of human illness. Although these microorganisms exist naturally in the ocean, human actions can lead to ocean conditions that greatly increase their growth, harming the health of humans, marine species, and ecosystems. Significant investment must be put into developing a coordinated national research effort to better understand the links between the oceans and human health, with research aimed at discovering new drugs and other useful products derived from marine organisms, and detecting and mitigating outbreaks of disease and other harmful conditions. Efforts must also be aimed at improving public awareness about how pollution and waste can contribute to the spread of seafood contamination and disease and can decrease the diversity of species that provide new bioproducts.

Understanding the Links between the Oceans and Human Health

While the topics generally included under the umbrella of Oceans and Human Health, such as harmful algal blooms and pharmaceutical development, may at first seem to be unrelated, they are actually inextricably linked. The health of marine ecosystems is affected by human activities such as pollution, global warming, and fishing. But in addition, human health depends on thriving ocean ecosystems. A better understanding about the many ways marine organisms affect human health, both for good by providing drugs and bioproducts, and for bad by causing human ailments, is needed.

The oceans sustain human health and well-being by providing food resources and absorbing waste from areas of human habitation. For many years the ocean's carrying capacity for meeting both these needs was assumed to be limitless. As we know today, this is not true. Scientists have reported that excessive human releases of nutrients and pollution into the ocean, and a subtle, yet measurable, rise in ocean surface temperatures are causing an increase in pathogens, primarily bacteria and viruses.[1,2] These environmental conditions can also cause certain species of microscopic algae to become concentrated in specific areas. Some of these organisms are capable of producing toxins that are released into the water and air, and become concentrated in tissues of fish and shellfish. When these toxins are ingested or inhaled by humans, they present health risks ranging from annoying to deadly.

On the other hand, thousands of new biochemicals have been discovered in marine organisms such as sponges, soft corals, mollusks, bacteria, and algae. Furthermore, scientists believe only a fraction of the organisms that live in the ocean have been documented, underscoring the vast potential of the oceans as a source of new chemicals.[3] These natural products can be developed not only as pharmaceuticals, but also as nutritional supplements, medical diagnostics, cosmetics, agricultural chemicals (pesticides and herbicides), enzymes and chemical probes for disease research, and many other applications. Based on existing pharmaceutical products, each of these classes of marine-derived bioproducts has a potential multibillion-dollar annual market value.

A 1999 National Research Council (NRC) report recommended a renewed effort to understand the health of the ocean, its effects on human health, and possible future health threats.[4] In a 2002 report, the NRC also emphasized the beneficial value of marine biodiversity to human health, noting that underexplored environments and organisms – such as deep-sea environments and marine microorganisms – provide exciting opportunities for discovery of novel chemicals.[5]

Currently two national programs exist that are designed to enhance our understanding of the ocean's role in human health. The first is a joint program between the National Institute of Environmental Health Sciences (NIEHS) and the National Science Foundation (NSF) called the Centers for Oceans and Human Health. The centers promote interdisciplinary collaborations among biomedical and ocean scientists, with the goal of improving knowledge about the impacts of the oceans on human health. The second is the National Oceanic and Atmospheric Administration's (NOAA's) Ocean and Health Initiative, which will coordinate agency activities and focus funding on ocean and health issues such as infectious diseases, harmful algal blooms, environmental indicators, climate, weather and coastal hazards, and marine biomedicine.

In addition to these broad interdisciplinary programs, several other existing programs are focused on one or more specific subtopics. For example, ECOHAB (Ecology and Oceanography of Harmful Algal Blooms), a program created by NOAA and NSF, provides a scientific framework designed to increase our understanding of the fundamental processes leading to harmful algal blooms. Other agencies, including the Centers for Disease Control (CDC), U.S. Environmental Protection Agency (EPA), and Food and Drug Administration (FDA), administer programs that address different aspects of the links between the oceans and human health.

MAXIMIZING THE BENEFICIAL USES OF MARINE-DERIVED BIOPRODUCTS

The marine environment constitutes the greatest source of biological diversity on the planet. Representatives of every phylum are found in the world's oceans, and more than 200,000 known species of invertebrates and algae have been documented. With so many organisms competing for survival in the challenging ocean environment, it is not surprising that many organisms produce chemicals that provide some ecological advantage. Animals and plants synthesize natural biochemicals to repel predators, compete for space to grow, and locate potential mates. Scientists have shown that these chemicals can also be developed as human pharmaceuticals and used for other biomedical and industrial applications.

Despite the potential benefits, the U.S. investment in marine biotechnology is relatively small. Japan, the world leader in marine biotechnology, has spent between $900 million and $1 billion a year for the last decade and has said it intends to significantly increase this investment in the future. About 80 percent of the Japanese investment comes from industry, with the remainder from government. By contrast, U.S. public investment in marine biotechnology research and development in 1996 was around $55 million, and U.S. industry investment is estimated at approximately $100 million annually. Yet even with this limited funding, U.S. marine biotechnology efforts since 1983 have resulted in more than 170 U.S. patents, with close to 100 new compounds being patented between 1996 and 1999.[6]

Specific Applications

Pharmaceuticals

Since the 1970s, scientists have been isolating and characterizing molecules from ocean organisms that have unique chemical structures and bioactivities. In recent years, several of these compounds have undergone clinical testing in the United States as potential treatments for cancer. Progress has also been made in finding treatments for other human ailments, such as infectious diseases, multiple sclerosis, Alzheimer's, chronic pain, and arthritis (Table 23.1).

Table 23.1 Drugs from the Sea

This table highlights some of the chemicals and biological materials isolated from marine organisms that are already in use or are being developed.

Application	Original Source	Status
Pharmaceuticals		
Anti-viral drugs (herpes infections)	Sponge, *Cryptotethya crypta*	Commercially available
Anti-cancer drug (non-Hodgkin's Lymphoma)	Sponge, *Cryptotethya crypta*	Commercially available
Anti-cancer drug	Bryozoan, *Bugula neritina*	Phase II clinical trials
Anti-cancer drug (mitotic inhibitor)	Sea hare, *Dolabella auricularia*	Phase I clinical trials
Anti-cancer drug (tumor-cell DNA disruptor)	Tunicate, *Ecteinascidia turbinata*	Phase III clinical trials
Anti-cancer drug	Tunicate, *Aplidium albicans*	Advanced preclinical trials
Anti-cancer drug	Gastropod, *Elysia rubefescens*	Advanced preclinical trials
Anti-cancer drug (microtubule stabilizer)	Sponge, *Discodermia dissoluta*	Phase I clinical trials
Anti-cancer drug	Sponge, *Lissodendoryx* sp.	Advanced preclinical trials
Anti-cancer drug	Actinomycete, *Micromonospora marina*	Advanced preclinical trials
Anti-cancer drug (G2 checkpoint inhibitor)	Tunicate, *Didemnum granulatum*	In development
Anti-cancer drug	Sponge, *Jaspis* sp.	In development
Anti-inflammatory agent	Marine fungus	In development
Anti-fungal agent	Sponge, *Trachycladus*	In development
Anti-tuberculosis agent	Sea whip, *Pseudopterogorgia*	In development
Anti-HIV virus agent	Ascidian (tunicate)	In development
Anti-malarial agent	Sponge, *Cymbastela*	In development
Anti-dengue virus agent	Marine crinoid	In development
Molecular Probes		
Phosphatase inhibitor	Dinoflagellate	Commercially available
Phospholipase A_2 inhibitor	Sponge, *Luffariella variabilis*	Commercially available
Bioluminescent calcium indicator	Bioluminescent jellyfish, *Aequora victoria*	Commercially available
Reporter gene	Bioluminescent jellyfish, *Aequora victoria*	Commercially available
Medical Devices		
Orthopedic and cosmetic surgical implants	Coral, mollusc, echinoderm skeletons	Commercially available
Diagnostics		
Detection of endotoxins (LPS)	Horseshoe crab	Commercially available
Enzymes		
Polymerase chain-reaction enzyme	Deep-sea hydrothermal vent bacterium	Commercially available
Nutritional Supplements		
Polyunsaturated fatty acids used in food additives	Microalgae	Commercially available
Pigments		
Conjugated antibodies used in basic research and diagnostics	Red algae	Commercially available
Cosmetic Additives		
Cosmetic (anti-inflammatory)	Caribbean gorgonian, *Pseudopterogorgia elisabethae*	Commercially available

Source data combined from:
Pomponi, Shirley A. "The bioprocess-technological potential of the sea." *J. Biotechnology*, 70 (1999): 5-13.
Pomponi, Shirley A. "The oceans and human health: the discovery and development of marine-derived drugs." *Oceanography*, 14 (2001): 78-87.
Dr. David J. Newman, NIH, National Cancer Institute, Natural Products Branch, Frederick, MD.
Jordan, M.J. and Leslie Wilson. "Mining the Ocean's Pharmacological Riches: A Lesson from Taxol and Vinca Alkaloids." In *Marine Biotechnology in the 21st Century*. Washington, DC: National Academy Press, 2001.

Molecular Probes

Several marine-derived compounds, explored initially as potential pharmaceuticals, are available commercially as molecular probes. These probes are special chemical compounds that researchers can use to study important biochemical processes. Their value in resolving the complexities of diseases has often outweighed their economic and medicinal value as commercial pharmaceuticals. Moreover, molecular probes often offer attractive opportunities for commercialization, with revenues generated in a shorter time than pharmaceuticals because lengthy regulatory approvals are not required for research that does not involve human subjects.

Nutrients

Marine-derived nutritional supplements, or "nutraceuticals," present a relatively new opportunity for research and development in the application of natural marine products to human health issues. Nutritional supplements from plants have been used for years, including commonly known products such as St. John's wort, ginseng, and echinacea. A few products from marine sources are also commercially available such as xanthophylls from algae, which are used in nutritional supplements and vitamins for their antioxidant properties. Although the use of marine natural products in nutritional supplements is limited at this time, it represents a large potential market.

Special Focus on Microbial Diversity

Microorganisms comprise a larger biomass than any other form of life on Earth. In addition, they are the most diverse group of organisms on the planet, having evolved to be able to survive in almost all environments. In the ocean they are the basis for food webs, even in areas that would not normally be capable of sustaining life.

For example, in the deep ocean environment with no light and few nutrients, chemosynthetic bacteria thrive on the methane present in frozen gas hydrates. Near deep-sea hydrothermal vents where temperatures can rise to over 300 degrees Celsius, bacteria are capable of using hydrogen sulfide and carbon dioxide as their only nutrients and producing enough organic compounds to support whole vent communities, including tubeworms, fish, crabs, shrimp, clams, and anemones.

However, microorganisms have not evolved simply to synthesize molecules for food; they have also been shown to produce a wide array of chemicals for other purposes. Understanding how these organisms survive, both individually and symbiotically, and why they produce such unique chemistry is essential to understanding their therapeutic and technological potential. Yet, only a small percentage of these organisms have been documented, largely due to difficulties in culturing organisms from such unique habitats. An expanded search for new microbes in the ocean based on cooperation among a number of multidisciplinary government programs could yield exciting results.

Industrial Uses

In additional to medicinal uses, chemicals produced by marine organisms have a wide array of industrial applications. For example, marine organisms, such as limpets, produce adhesive proteins that hold them strongly to surfaces against the pull of tides and waves. Currently, researchers are examining the chemistry of these adhesives to produce new glues that work in wet environments. Some cold water marine microorganisms are being studied because of chemicals they produce that can be used as detergents. These chemicals could help produce commercial detergents that are more effective in cold water. Many sedentary marine organisms produce anti-fouling chemicals that prevent algae and bacteria from clinging to their surfaces. Researchers are investigating these chemicals as potential paint additives for ship hulls. If effective, these chemicals could reduce the need for traditional anti-fouling paints that contain high levels of tin and other heavy metals, which can contaminate bottom sediments. Several other applications of marine-derived substances are currently in development, such as reaction enzyme catalysts and biochemicals used for detoxifying chlorinated hydrocarbons and other pollutants.

Encouraging Interdisciplinary Marine Biomedical Research

Past U.S. efforts to discover marine biomedicines were of the collect-and-test type, with little attention given to the evolutionary, environmental, and molecular biology of the species being tested. However, to realize the greatest rewards for research investments, each species' ecological, genetic, and physiological information should be examined to understand how they adapt to environmental conditions. The unique diversity and adaptations of marine life can help scientists understand the evolutionary development of biochemical signals that regulate cell cycles and control resistance against diseases and infections.

Historically, structural limitations inherent in the federal agencies made it difficult to undertake truly multidisciplinary science. NSF restricted funding for biomedical research because it is covered by the National Institutes of Health (NIH), creating difficulties in establishing combined environmental and biomedical research programs. Likewise, NIH has generally supported direct medical research, thus precluding ancillary studies of systematics, ecology, and species distributions. Until a few years ago, the NIH's ocean pharmaceutical programs had been very narrow, focusing almost exclusively on discovering and developing new anti-cancer drugs. Thus, the very structure of the federal scientific support system has been counterproductive to establishing the type of multidisciplinary programs required to advance the broader field of marine natural product discovery and development.

Based on recommendation from the National Research Council and others, in the last two years new approaches for supporting marine bioproduct development have been established that allow the necessary cross-disciplinary research to occur, including the NIEHS–NSF and NOAA programs mentioned earlier. However, increased participation and cooperation from other federal agencies, including EPA, the Office of Naval Research (ONR), the National Aeronautics and Space Administration (NASA), CDC, FDA, and the Minerals Management Service (MMS), each of which brings particular expertise and perspectives, will also be helpful.

Recommendation 23–1. The National Oceanic and Atmospheric Administration, National Science Foundation, National Institute of Environmental Health Sciences, and other appropriate entities should support expanded research and development efforts to encourage multidisciplinary studies of the evolution, ecology, chemistry, and molecular biology of marine species, discover potential marine bioproducts, and develop practical compounds, through both competitively awarded grants and support of federally designated centers.

These efforts should include:

- *a strong focus on discovering new marine microorganisms, visiting poorly sampled areas of the marine environment, and studying species that inhabit harsh environments.*
- *encouragement for private-sector investments and partnerships in marine biotechnology research and development to speed the creation of commercially available marine bioproducts.*

Managing Marine Bioproduct Discovery and Development

Based on the potentially large health benefits to society, the federal government should encourage and support the search for new bioproducts from marine organisms, known as bioprospecting. However, before wide-scale bioprospecting proceeds in federal waters, requirements need to be established to minimize environmental impacts. Planning and oversight will help ensure that public resources are not exploited solely for private gain and will help protect resources for future generations.

Individual states can regulate the collection of marine organisms quite differently, sometimes requiring an array of research permits to collect organisms, and licenses to gain access to particular areas. Regulations that ban the removal of specific organisms, such as corals and other sensitive species, often exist in both state and federal protected areas. In protected federal waters, such as national marine sanctuaries, research permits are required for all collections. However, bioprospecting outside state waters and federal protected areas is unrestricted, except for certain species subject to regulation under existing legislation, such as the Endangered Species Act. Both U.S. and foreign researchers, academic and commercial, are free to collect a wide range of living marine organisms without purchasing a permit and without sharing any profits from resulting products.

On land, the National Park Service has successfully asserted the government's right to enter into benefit sharing agreements in connection with substances harvested for commercial purposes in Yellowstone National Park. The National Park Service is in the process of conducting a full environmental impact statement on the use of such agreements for benefit sharing in other parks. This practice could serve as a model for the management of bioprospecting in U.S. waters.

A comprehensive national ocean policy should contain appropriate permitting and licensing regulations for bioprospecting in federal waters to protect public resources while encouraging future research. Furthermore, when allocating use of federal ocean areas for bioprospecting, it is important that consideration be given to the other potential uses of those areas, including oil and gas exploration, renewable energy, aquaculture, or mining. (The governance and coordination of offshore uses is discussed in detail in Chapter 6.)

REDUCING THE NEGATIVE HEALTH IMPACTS OF MARINE MICROORGANISMS

A host of microorganisms exist in marine waters, filling their roles in the ecosystem and generally causing no problems to humans. However, environmental factors such as climate change can affect the number and distribution of marine pathogens and human activities can produce even greater fluctuations that threaten the human health and the marine ecosystems they depend on for food, medicine, and other products.

Harmful Algal Blooms

The term harmful algal bloom (HAB) is used to describe destructive concentrations of particular algal species in ocean waters. These blooms are sometimes called red tides because the high algal density can make the ocean surface appear red, but the surface may also be green, yellow, or brown, depending on the type of algae present.

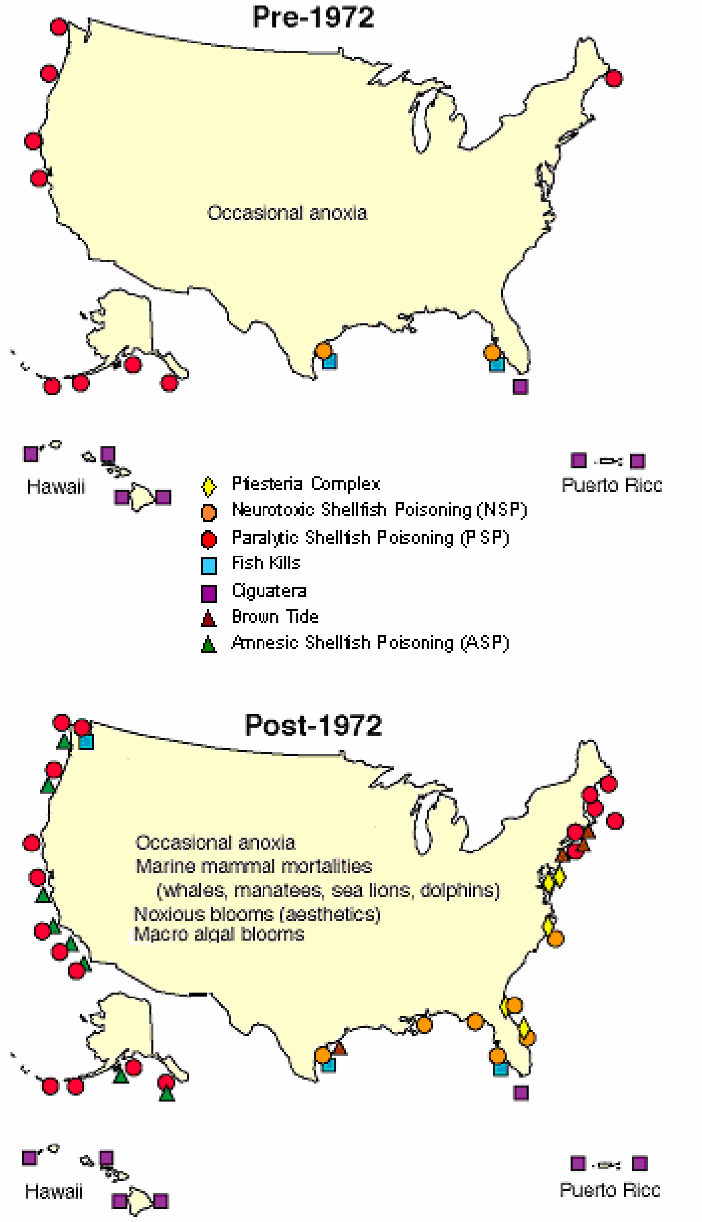
The Nature of the Problem

The underlying physical, chemical, and biological causes for most harmful algal blooms are not well understood, but an increase in distribution, incidence, duration, and severity of HABs has been documented within recent decades (Figure 23.2). Research is needed to understand why blooms form in a specific area, how they are transported, and what causes them to persist. In many areas, increases in nutrients in coastal waters, from point and nonpoint sources of pollution, and higher numbers of invasive species released from ships' ballast water mirror the increase in HAB events, suggesting a possible causal connection.[7, 8] However, others have suggested that the apparent increase in HAB events is simply a result of more frequent and effective monitoring.

HABs can produce high concentrations of potent toxins in ocean waters. When these toxins are concentrated in fish and other seafood consumed by humans, they can lead to paralytic, diarrhetic, neurotoxic, or amnesic shellfish poisoning. Most of these toxins cause harm only if ingested; however, some enter the air from sea spray and can cause mild to severe respiratory illnesses when inhaled. These health effects are not restricted to human populations; fish, birds, and marine mammals often fall victim to red tide poisoning.

Annually, HABs are believed to cost the nation's fishing and tourism industries more than $50 million directly, with a likely multiplier effect that pushes the total economic loss to $100 million.[9, 10] This effect can be catastrophic to low-income fishing communities, as witnessed in Maryland in 1997 during an outbreak of *Pfiesteria piscicida* (a species of dinoflagellate) associated with widespread fish kills.[11] Tourism was hurt by news coverage of seafood poisonings, and reports of red tides had a swift and chilling effect on oceanside resort visits, beach-going, and boating. Aquaculture can also be severely damaged by HABs, which can cause rapid fish kills and result in harvesting moratoria.

Figure 23.2 Harmful Algal Blooms Are on the Rise in All U.S. Waters



Harmful Algal Bloom outbreaks have become more prevalent over the past thirty years, almost tripling the number detected prior to 1972.

Map courtesy of the National Office for Marine Biotoxins and Harmful Algal Blooms, Woods Hole Oceanographic Institution, Woods Hole, MA.

HABs are of particular concern in areas where the water contains high concentrations of dissolved nutrients. These areas are incubators for many types of algal blooms, nontoxic as well as toxic. The nutrients create conditions for rapid growth of large and dense algal blooms. When the algae die, their decomposition consumes the dissolved oxygen that other organisms need for survival.

Improving Understanding, Detection, and Prevention

HABs constitute significant threats to the ecology and economy of coastal areas. While the preferred course of action is prevention, effective treatments will often be needed and the current availability of biological, chemical, or physical treatments is extremely limited. The ecology of each bloom is different, and the required environmental conditions are not completely understood for any algal species.

The most likely and immediate solution for reducing the number and severity of HABs is to control nutrient inputs to coastal waters. (Nutrient pollution is further discussed in Chapter 14.) Prevention may also be strengthened through careful facility siting decisions and tighter controls on invasive species. However, for better long-term management, a comprehensive investigation of the biology and ecology of HABs will be needed to increase our understanding of options for prevention, prediction, and control.

Better coordination would help leverage the relatively few but successful HAB research programs currently being supported by the federal government (such as ECOHAB; MERHAB—monitoring and event response for harmful algal blooms; NOAA's National Marine Biotoxin program and HAB sensor development and forecasting programs; and efforts supported by the CDC, states, and others).

Improved monitoring techniques are also essential in mitigating the harmful impacts of HABs. Sampling directly from the natural environment can help researchers compile an overall HAB picture, laying the foundation for predictive modeling and forecasting. Numerous monitoring programs already exist, many of which are funded by state governments. However, routine field sampling, combined with laboratory analysis, is expensive and time consuming, and becomes more so as greater numbers of toxins and pathogens are discovered over greater geographic areas. A well-coordinated federal effort is needed to support the state and regional implementation of monitoring and mitigation capabilities as they are developed. (See Chapter 15 for a broader discussion of water quality monitoring needs.)

To cover larger areas, monitoring data collected from remote sensing platforms will become essential. NOAA is currently developing and testing techniques to forecast HAB occurrence and movement using satellite sensors. The complementary development and deployment of satellites and moored sensors will provide even greater coverage, cross-referenced groundtruthing, and more frequent site-specific sampling. These elements will add up to better data sets for monitoring of HABs. As more data is collected on HAB occurrences, researchers will be able to more accurately predict future outbreaks by using advanced computer models and taking into account the physical and biological conditions leading to HABs.

Marine Bacteria and Viruses

Bacteria and viruses are present everywhere in the ocean; in fact, each milliliter of seawater contains on average 1 million bacteria and 10 million viruses. While only a small percentage of these organisms cause disease in humans, they pose a significant health risk. Humans become exposed to harmful bacteria and viruses primarily by eating contaminated seafood (especially raw seafood) and by direct intake of seawater.

Many, if not most, occurrences of high concentrations of pathogens in the ocean are the direct result of land-based human activities. Pollution and urban runoff lead to nutrient-rich coastal and ocean waters that provide ideal conditions for the growth and reproduction of these microorganisms. With ever-increasing numbers of people living in coastal areas, along coastal watersheds, or inland along rivers that ultimately drain into the ocean, waste and pollution has increased to a level that creates negative environmental and human health-related consequences.

A comprehensive and integrated research effort is needed to further explore the relationship between human releases of inorganic and organic nutrients to coastal waters and the growth of pathogenic microorganisms in the ocean. Rapid monitoring and identification methods need to be developed so officials can warn populations at risk when unhealthy conditions are present. Integration of these new methods into moored biological sensors and the Integrated Ocean Observing System (IOOS) would allow for continuous data collection, and be especially helpful in areas of high recreational or seafood harvesting activity. This effort must include the participation of state, regional, tribal, and local organizations to implement localized monitoring programs and address public education issues associated with marine bacteria and viruses.

Contaminated Seafood

Contaminated seafood is one of the most frequent causes of human diseases contracted from the ocean, including both pathogenic contamination and chemical contamination. Chemicals such as mercury and dioxins, that exist as environmental contaminants and are concentrated in fish through bioaccumulation, continue to be a health concern for humans, especially in terms of reproductive and developmental problems. In addition, harmful algal blooms and pathogen outbreaks are becoming more common in local waters, increasing the risk of seafood contamination.

Aside from domestic sources, Americans are importing more seafood than ever before.[12] These imports often come from countries whose public health and food handling standards are lower than in the United States. Although the Food and Drug Administration requires that importers to the United States meet federal standards, there is evidence that foreign counties do not always comply with these agreements, increasing the risk of spreading disease through improperly processed and handled seafood.[13] Federal law also bars seafood containing drugs from entering the country, but the FDA currently only screens about 2 percent of the four billion pounds of seafood imported each year, and screens for only five chemicals out of the more than thirty used in foreign aquaculture. While other countries have barred salmon shipments that test positive for such drugs as malachite green (a fungicide) and oxytetracycline (an antibiotic), the United States does not currently test salmon imports for these chemicals.[14]

Domestic aquaculture may provide a way to decrease U.S. dependence on imported seafood. However, cultured organisms are generally exposed to more diseases than wild stocks due to over-crowding in the fish pens. The use of antibiotics and other drugs to protect farmed fish against disease is a problem that will also need to be addressed in the United States. (The potential and problems of aquaculture are discussed further in Chapter 22.)

To protect the safety of the nation's seafood, rapid, accurate, and cost-effective means for detecting pathogens and toxins in seafood are needed. As these techniques are developed they can be incorporated into seafood safety surveillance efforts, particularly inspections of imported seafood and aquaculture products.

Implications of Global Climate Change

In addition to the direct effects of human activities, marine microorganisms' survival and persistence are also strongly affected by environmental factors. In particular, global climate change has the potential to significantly alter the distribution of microorganisms in the ocean. Pathogens now limited to tropical waters could move toward the poles as sea-surface temperatures rise.

For example, the bacterium that causes cholera (*Vibrio cholerae*) has been implicated in disease outbreaks fueled by the warming of coastal surface water temperatures. The intrusion of these warmer, infected waters into rivers can eventually lead to mixing with waters used for drinking and public hygiene. An indirect relationship has also been noted between climate change phenomena associated with the Bay of Bengal and the incidence of cholera in Bangladesh. As the temperature in the Bay of Bengal increased, plankton growth accelerated, which in turn created ideal growth conditions for bacteria such as *Vibrio cholerae*.[15]

Mass mortalities due to disease outbreaks have already affected major life forms in the ocean. The frequency of epidemics and the number of new diseases in corals and marine mammals have increased. It is hypothesized that some of these outbreaks are linked to climate change. Not only are new pathogens possibly present due to changes in water temperature, but temperature changes can also stress marine organisms, making it harder for them to fight infections.[16] More research is needed to understand the links among climate change, pollution, marine pathogens and the mechanisms of disease resistance in marine organisms.

Progress through Research and Education

Research Needs

Better understanding about the links between oceans and human health will require a commitment of research funds to discover the fundamental processes controlling the spread and impacts of marine microorganisms and viruses. In addition, closer collaboration between academic and private sector scientists and federal agencies (including NIH, NSF, NOAA, EPA, ONR, NASA, CDC, FDA, and MMS) will be needed to better examine these issues.

Recommendation 23–2. The National Oceanic and Atmospheric Administration, National Science Foundation, National Institute of Environmental Health Sciences, and other appropriate entities should support expanded research efforts in marine microbiology and virology.

These efforts should include:

- *the discovery, documentation, and description of new marine bacteria, algae, and viruses and the determination of their potential negative effects on the health of humans and marine organisms.*
- *the elucidation of the complex inter-relations, pathways, and causal effects of marine pollution, harmful algal blooms, ecosystem degradation and alteration, emerging marine diseases, and climate change in disease events.*

New knowledge and technologies are needed to detect and mitigate microbial pathogens. These methods must be quick and accurate so that information can be communicated to resource managers and the coastal community in a timely manner. As they are developed, technologies need to be integrated into biological and biochemical sensors that can continuously monitor high-risk sites. It is important that site-specific sensor data and satellite sensor data be incorporated into the IOOS. (The development of chemical and biological sensors and their integration into the IOOS is further discussed in Chapters 26 and 27.) Furthermore, federal and private support will be needed for developing monitoring and mitigation technologies to be implemented at the state level.

Recommendation 23–3. The National Oceanic and Atmospheric Administration, National Science Foundation, National Institute of Environmental Health Sciences, and other appropriate entities should support the development and implementation of improved methods for monitoring and identifying pathogens and chemical toxins in ocean waters and organisms.

This should include:

- *developing accurate and cost-effective methods for detecting pathogens, contaminants, and toxins in seafood for use by both state and federal inspectors.*
- *monitoring and assessing pollution inputs, ecosystem health, and human health impacts.*
- *developing new tools for measuring human and environmental health indicators in the marine environment.*
- *developing models and strategies for predicting and mitigating pollutant loadings, harmful algal blooms, and infectious disease potential in the marine environment.*
- *developing* in situ *and space-based sensing methods and incorporating them as a sustained operational component of the national Integrated Ocean Observing System.*

Public Education and Outreach

Pollution education campaigns have generally focused on the impacts of pollution on marine animals. Signs stenciled on storm drains remind people that dolphins live downstream. However, additional attention should be given to the fact that human food supplies and recreational areas are also downstream. Reductions in pollution from urban area runoff, sewage outflows, agricultural pesticides, and many other sources are needed to avoid creating harmful conditions in the oceans and the best way to start is with a higher level of public education.

Education campaigns should also continue to inform people of the potential risks some fish and shellfish pose to their health because of the bacteria, viruses, or chemicals they carry. These programs should incorporate messages that seafood may be contaminated even when no visible algal bloom is present and conversely that some unattractive algal blooms are not harmful.

Increasing Federal Coordination on Oceans and Human Health

Several existing programs, including the NIEHS–NSF and NOAA programs, could form the nucleus of a fully integrated, national oceans and human health program. Most of these programs already involve significant interagency cooperation, which is essential for effectively addressing issues that cross federal agencies' jurisdictional lines and for coordinating multidisciplinary biomedical research. Any truly national effort to address the varied roles of the oceans in human health will cross many federal jurisdictions, including environmental regulation, coastal management, basic and applied research, biosecurity, and homeland security.

Recommendation 23–4. Congress should establish and fund a national, multi-agency Oceans and Human Health Initiative to coordinate, direct, and fund research and monitoring programs.

The National Ocean Council should oversee the interagency Oceans and Human Health Initiative, and should review existing interagency programs and suggest areas where coordination could be improved. The NOAA Ocean and Health Initiative should be coordinated with the NIEHS–NSF Centers for Oceans and Human Health program as the basis of the federal program and should be permanently funded. To achieve the goals set forth in this chapter, funding should be double the current combined funding level for the NIEHS-NSF Centers for Ocean and Human Health program and the NOAA Ocean and Health Initiative, resulting in total funding of at least $28 million a year for the new initiative.

NOAA should be the lead agency in charge of coordinating interagency public information, outreach, and risk assessment efforts. Research funding awarded through the national program should be subject to a stringent peer review process with federal, state, academic, and private-sector investigators eligible to compete for funding.

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