Restoring & Conserving America's Coastal Ecosystems & Habitats

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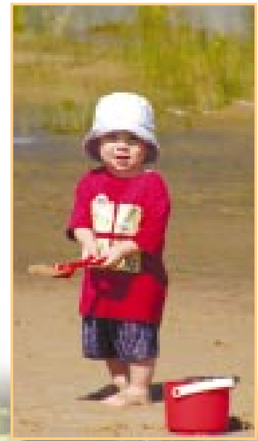
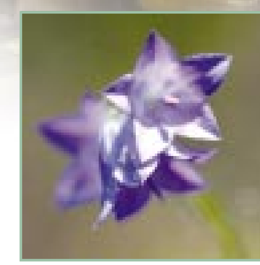
The nation's life-support system and economy depend heavily on the essential goods and services provided by aquatic ecosystems.

Aquatic ecosystems are part of the natural capital that provides useful goods or services ("ecosystem services") to society. Among the benefits are food, the maintenance of clean air and water, and the purification of society's wastes. The current economic value of 17 measured ecosystem services has been estimated to be over $16 trillion per year, which easily exceeds the current total global gross national product.[1] Wetlands, for example, provide the following benefits to society:



- *Flood Control*: Slow and retain flood flows, reducing their size and destructiveness
- *Water Quality and Quantity*: Filter pollutants that could degrade groundwater, rivers, lakes, and estuaries, and recharge aquifers that provide urban and agricultural water supplies

- *Biological Diversity*: Provide important habitats for diverse communities of plants and animals, including over 50 percent of the federally listed threatened or endangered species
- *Fisheries and Waterfowl Habitats*: Provide the spawning and rearing habitats that support productive commercial and recreational fisheries and the principal habitats for migratory waterfowl



- *Recreation and Tourism*: Support a multibillion dollar fishing, hunting, and outdoor recreation industry


Sea Grant

Why Is Sea Grant Working in Coastal Ecosystems and Habitats?

Sea Grant has a long history of interdisciplinary research on ecosystems and habitats. It also is the only university-based federal program that integrates coastal research, education, and outreach needs. The Sea Grant network has a strong research base that includes education and extension programs needed to apply scientific understanding to critical coastal environmental issues. University-based research makes fundamental linkages among ecological processes, habitats, and ecosystem integrity.

Understanding coastal ecological processes, ocean dynamics, and the impacts of natural and human-induced changes is fundamental to the management and restoration of coastal ecosystems and habitats. Coastal areas throughout the United States have been altered by shoreline development, agricultural and industrial runoff, flood control and dredging, to name just a few factors. Human impacts on estuarine systems, for example, have the greatest potential to negatively influence populations of marine species. Scientists don't adequately understand how habitat alterations within these primary nurseries affect the functional control and cumulative impacts on estuarine ecosystems.

Sea Grant is well poised to mobilize its considerable academic talents to aid ecosystem management in sustaining coastal, marine, and Great Lakes resources. While some ecosystems and habitats are well managed and are producing positive benefits, others are severely stressed and must be restored if they are to realize their long-term potentials.

Youth receive hands-on education in habitat restoration

Sea Grant sponsors many activities designed to engage young people in the various components of coastal habitat restoration. For example, a Louisiana Sea Grant project called "Marsh Maneuvers, Coastal Roots, and Ocean Commotion" provides hands-on education and coastal resource stewardship opportunities to thousands of students across Louisiana.

To better manage coastal ecosystems and habitats, we must:

- Develop better qualitative and quantitative understanding of how coastal ecosystems and habitats function, the importance of the various individual components within these systems, and how humans impact these systems.
- Understand how humans are impacted by the changes we have caused in aquatic ecosystems.
- Develop new technologies and strategies to prevent future adverse impacts and reverse the effects of our past transgressions.
- Convey scientific knowledge and information—the results of our research—to the public in a way that makes it easily understandable, plus use a variety of new tools to empower the private sector and the general public to take action to protect and improve coastal ecosystems and habitats.

The National Sea Grant College Program has proven expertise in all of these areas. Sea Grant has a local program in every coastal and Great Lakes state, and thus has the ability to cover every mile of America's coastline. Sea Grant provides the multidisciplinary science, including the social and economic sciences, needed to understand and predict the impacts of societal and natural changes on coastal ecosystems. The program enjoys direct access to world-class scientists at over 300 of the country's best colleges and universities, strong relationships with government and the private sector, and a peer-reviewed research structure that results in support of only the best research for direct public benefit. The Sea Grant outreach network is an invaluable asset present on the docks and in the town halls of America's coastal communities, transferring research findings and encouraging informed decision-making about the future of coastal ecosystems. Sea Grant's state-based regional and national communications network plays a key role in transmitting new information to the policymakers and the public. And Sea Grant's education network delivers formal and informal education programs to students and marine educators across the country.

Shoreline modifications that result from a myriad of human activities...

Threats to Coastal Ecosystems and Habitats

Physical Alterations

One of the greatest challenges we face today is managing and ameliorating physical changes to aquatic ecosystems. Physical alterations to aquatic ecosystems through such processes as erosion, siltation, and hydrologic modification are among the leading causes of water quality impairment in the United States[2] and are a key to understanding avenues for restoration.[3] Although many physical disturbances are the direct result of specific actions (e.g., channelization, shoreline hardening, and dredging), many processes leading to habitat degradation, such as siltation, are the result of less specific, nonpoint activities that result from land use. For example, storm water from urban watersheds often carries sediment-laden water that settles in nearshore zones. Increased impervious surfaces that result from the conversion of rural lands to suburban and urban uses alter hydrologic regimes and increase erosion from watersheds. The same difficult issues we struggle with on land—suburban sprawl, loss of green space, deforestation—have dramatic impacts on aquatic habitats. Reductions in freshwater flows needed to sustain watersheds and coastal habitats could endanger biodiversity and entire aquatic ecosystems. In one striking case from coastal Louisiana, freshwater diversions have caused major changes to the ecosystems of the northern Gulf of Mexico. Reinforced levees and addition of navigation channels provided flood protection, increased development along the Mississippi River, and provided greater access to inland communities, but these measures also prevented the flow of land-building sediments needed to replenish coastal wetlands and they accelerated saltwater intrusion. Combined with sea level rise, natural subsidence, and hurricanes, an estimated 1,000 square miles of Louisiana's coastal wetlands have eroded in the last 70 years. There is an urgent need for applied research and more comprehensive planning for such ecosystem changes that will occur with future water withdrawals for coastal cities and urbanizing watersheds. Water issues and nonpoint pollution problems exemplify the importance of understanding the integral relationship between land-use planning and the physical integrity of aquatic resources.

Sea Grant plays role in restoring the Mississippi River estuary

The most widely advocated strategy for stemming Louisiana's coastal land loss crisis involves returning the Mississippi River estuary to coastal marshes. Conflicts have emerged over the short-term implications of restoration on estuarine fisheries. Louisiana Sea Grant waded directly into these controversial issues by sponsoring "An Interpretive Topic Series on Coastal Restoration."

Shoreline modifications that result from a myriad of human activities are pervasive physical alterations to our coastlines that have significant biological and economic ramifications. Breakwaters and jetties, shoreline armoring and other stabilization methods, tide gates, and other coastal structures are common in most populated areas and often account for a large fraction of available coastline. Such alterations have distinct effects on aquatic ecosystems through a variety of physical mechanisms, including simplification of shoreline habitats, changes in current patterns, changes in regional hydrology, and alteration of sediment characteristics. Shoreline alterations may also lead to changes in the physical and biological characteristics of nearshore zones. Research is needed to quantify the impacts of habitat alterations and to evaluate an array of habitat protection, mitigation, and restoration techniques to compensate for past and future shoreline alteration activities.

Water withdrawal from streams and lakes can also have significant impacts on coastal regions. Common water diversions, such as those for agriculture, domestic, and industrial uses, can alter water levels and flow patterns, strongly affecting the biological processes in aquatic ecosystems. Impacts of water diversions from one basin to another need more attention. Water diversion from the Great Lakes, for example, is an important binational issue. Such alterations can change the subregional availability of water and may have profound influences on biotic resources. As the need for water becomes greater in coastal regions, more information is needed on the biological and economic ramifications of such actions.

Harmful Algal Blooms

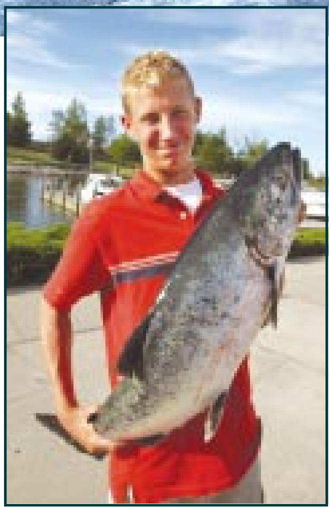
Harmful algal blooms (HABs) have been increasing in prevalence in the United States for the past 30 years to the point where they occur along most of our coastlines.[4] Impacts of these blooms are felt in many ways: Human health is placed at risk, ecosystems are altered, marine mammals are injured or killed, and fishing, aquaculture, and recreation industries suffer substantial economic losses. Economic impacts of HABs in the United States for the period 1987 to 1992 have been conservatively estimated at $49 million annually.[5] Other single HAB events may approach or even exceed those costs; for example, the 1976 red tide event in New Jersey is estimated to have caused losses of about $1 billion (in 2000 dollars). The 1997 outbreak of *Pfiesteria* in the Chesapeake Bay is estimated to have cost the local seafood industry $46 million in lost sales, with greatest losses occurring mostly from sales of species that were not even affected by *Pfiesteria*.

HABs can have major impacts on natural resources and strongly influence utilization of those resources by humans. The most obvious example is the occurrence of human illness and death from consumption of shellfish tainted by HABs. To protect human health, state agencies are required to regulate harvesting of shellfish. But decisions are often made in the absence of information about a particular toxic event, or how shellfish accumulate and reduce toxins. Similarly, HABs cause mortalities of fish, birds, and marine mammals and turtles. Little is known about the mechanisms by which toxins cause mortalities, the impacts these toxins have on fisheries or protection of endangered species, and the way impacts can be minimized. Human activities may cause the occurrence and persistence of HABs by increasing nutrient inputs through changes in land-use patterns or changes in the hydrology of an area. Cells and/or resistant resting cysts of HAB species may be transported to new areas in ballast water or in live shellfish, where they may thrive and threaten human and ecosystem health. Thus, natural resource managers, elected officials, and the public must have an understanding of the causes and impacts of HABs to help prevent or minimize these threats to the economy, public health, and marine systems.

HABs are not only a problem for the nation's marine coasts. Recent research has linked health and ecological problems to blue-green algae (also known as cyanobacteria) blooms that occur in the Great Lakes. These algal

New probe can rapidly detect brown tide

Major brown-tide blooms have damaged the shellfish industries in several states. Brown tides have impacted shellfish populations along the East Coast from Rhode Island to Florida. Delaware Sea Grant researchers have developed a molecular probe that can rapidly detect the microscopic organisms that cause brown tides. The probe is so sensitive it can detect just a few cells per milliliter, advancing the capability to predict waters at risk well before blooms occur.

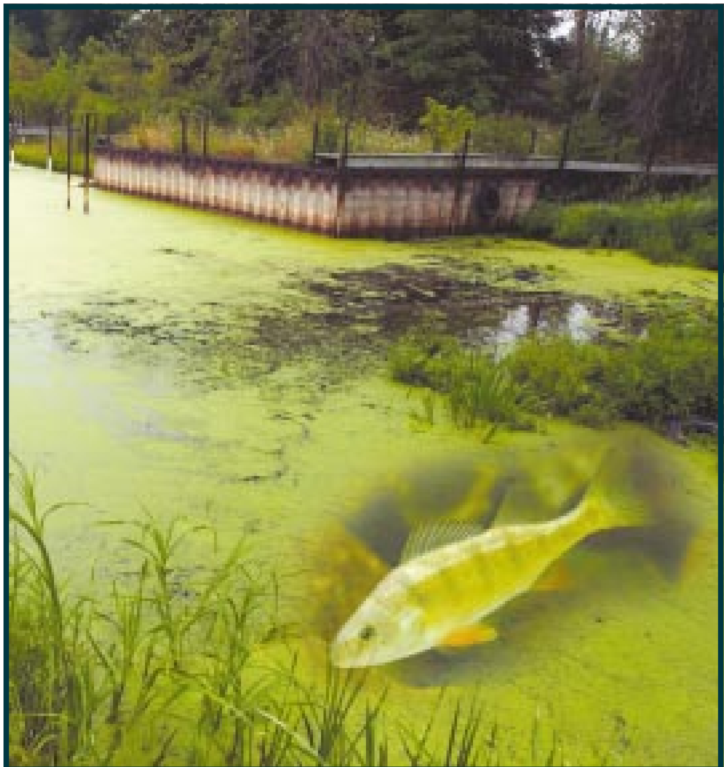


blooms are most frequently associated with eutrophication and nutrient enrichment from sewage treatment plants and agricultural runoff. Blue-green algae are frequently linked to taste and odor problems at water treatment plants. However, they can also produce toxins that, in high concentrations, have caused deaths worldwide. In the United States they have been associated with various human health problems and waterfowl kills.

The social and economic costs of HABs range from short to long term. For example, closure of a water body or beach due to a HAB-related fish kill can have substantial effects on tourism and fishing. A recent study reported that about one-third of visitors planning to visit a coastal area would stay home or go to another coastal location if a *Pfiesteria* outbreak were to occur.[6] In some cases, the negative public reaction to HABs has been severe and prolonged, and misinformation has caused unnecessary scares, placing heavy pressure on management agencies and increasing economic losses.

Over the last 20 years, HABs have been observed more frequently and have extended their geographic range. Many HABs have species with multiple strains, which may complicate detection. Moreover, the movements of blooms are difficult to predict since they are subject to changing environmental conditions. State and local agencies that did not need to monitor, or only monitored their waters for one or two potentially dangerous species, have been forced to expand monitoring efforts as new species have inexplicably appeared. These efforts have increased the costs of monitoring and analysis. Agencies are under pressure to act, often on limited information and funding. Under the National Shellfish Sanitation Program of the Interstate Shellfish Sanitation Commission, states have conservative measures in place for closing shellfish waters in order to protect human health from problems associated with the consumption of contaminated shellfish. However, the inability to predict the onset of many blooms before they occur can be detrimental to commercial harvesters, aquaculturists, recreational fishermen, seafood handlers, and the tourism industry. Clearly, there is a need for a monitoring and detection system that will enable local, state, and federal agencies to work together in developing early warning systems and providing accurate forecasts on bloom occurrence, development, and transport. Such capabilities may make it possible to develop realistic mitigation strategies that minimize the risks to human health and reduce the economic impacts.

Human efforts to control insects, diseases, and fungi are common agricultural practices on land. Control of freshwater HABs has been a significant component of public utility management of drinking, agricultural, and recreational water supplies, but similar attempts to control unwanted plants or animals in the ocean have been rare.[7] Other than one unsuccessful attempt to control a red tide bloom in Florida 45 years ago, field testing of methods to control major blooms in the marine environment has not been seriously considered in the United States.



Action plan development under way for Great Lakes areas of concern

Development of a remedial action plan process to clean up the 43 most seriously polluted areas of concern in the Great Lakes required a new cooperative approach among local citizens, government, and industry. Great Lakes Sea Grant programs provided invaluable assistance to develop a new constituency, identify impaired uses of aquatic resources, and seek pathways to the cleanup of contaminated harbor sediments.

Chemical Contamination

The environmental quality of our nation's coastal areas is declining in many areas in response to increasing coastal population density. Increased loading of a diverse array of chemicals is pervasive, resulting in changes to coastal ecosystems. Such changes can be obvious, such as loss of underwater grasses or increases in algal blooms, or more subtle, such as decreases in the reproductive rates of some aquatic species. Several recent national studies, including the National Research Council reports, *Managing Troubled Waters: The Role of Environmental Monitoring*[8] and *Priorities for Coastal Ecosystem Science,*[9] have highlighted these problems.

Toxic substances are a critical problem in many coastal areas, especially in the Great Lakes. A large number of chemicals have been identified as "critical pollutants" based on their use, loadings, toxicity and/or bioaccumulation in aquatic food webs. The accumulation of organic chemicals in fish, especially polychlorinated biphenyls (PCBs) and mercury, poses threats to both humans and wildlife up the food web. Nationwide, impacts on aquatic organisms have been identified, especially on early developmental stages of sensitive species. The resulting economic impact on commercial and sport fishing and the associated recreational industry has been enormous. Cleanup of toxic pollutants, particularly contaminated sediments, represents an enormous economic liability for the nation. Trade-offs between environmental and social/economic concerns are inevitable and decision-makers will look to scientists to provide answers to cost-benefit questions. Analyses will require assessment of the impacts of toxins in natural systems. Major management decisions underscore the urgent need for quantitative information on contaminant sources, trends, transport, fate, and effects.

Among the most pressing issues are:

- The need to understand the effects of point and nonpoint sources on contaminant loadings, and the linkages between contaminant loading and contaminant movement through coastal ecosystems. It is particularly important to improve our ability to assess contaminant trends in coastal ecosystems so we can evaluate the success of management actions.
- Identification of the effects of contaminants and complex mixtures of contaminants on aquatic organisms, wildlife, and human health. Many of these effects are detrimental to the organism but not lethal (nor

readily observable). Advances in biotechnology will enhance our ability to monitor these effects before they have major impacts on ecosystems.

- Determination of the effects of food web structure and dynamics on contaminant cycling and bioaccumulation with the realization that aquatic nuisance species can completely alter food web structure and dynamics. Development of appropriate models to predict the effects of contaminant reduction on ecosystem function and living marine resource health will increase our ability to take management actions that will have the greatest benefit.
- Development of techniques for remediation of contaminated areas. Innovative approaches are needed to reduce the impact on living resources and human health through physical, chemical, or biotechnological means. We need research to produce new cleanup technologies that are both more effective and less expensive.
- Development of best management practices to prevent contaminants from entering coastal waters and extending this information to communities.

Long Island Sound ecosystem receives helping hand

With more than 24 million people living within 50 miles of its shores, the Long Island Sound ecosystem is among America's most heavily used coastal areas. Many of the sound's coastal wetlands have been degraded by overuse. Nitrogen has been identified as the major cause of recurring hypoxia. Connecticut and New York Sea Grant programs are helping to restore the ecosystem by conducting joint research on improving water quality and habitats, providing information for drafting policy guidelines, and offering public outreach and education programs.

Eutrophication

Eutrophication of coastal waters due to excessive nutrient inputs has affected coastal ecosystem productivity, caused loss of dissolved oxygen in waters as diverse as Chesapeake Bay, Lake Erie, and the Louisiana shelf, and may have accelerated the frequency of HABs. The nation is faced with spending billions of dollars to eliminate nutrient inputs from sewage treatment facilities—by improving sewage treatment and by eliminating nutrients from combined sewer systems—and from nonpoint sources. While the relationship between nutrient inputs and eutrophication is well understood for lakes (too much phosphorus), the same is not true for coastal waters where too much nitrogen is the problem. We are just beginning to understand the importance of dissolved organic nutrients to coastal ecosystems and the potential implications for sewage treatment facilities that may have been designed to optimize removal of inorganic nutrients. In addition, freshwater treatment systems that concentrate on phosphorus removal may be allowing substantial nitrogen to be transported downstream, creating the potential for problems in marine waters. Given the limitations on our current level of understanding of nutrient cycling and food web dynamics, it is difficult for managers to predict with confidence the outcome of potentially very costly programs of nutrient reduction on coastal ecosystems.

Among the most pressing issues are:

- Determination of the relative importance of riverine, terrestrial, atmospheric, and oceanic sources of nutrients in shaping and controlling estuarine and coastal production.
- Understanding the respective impacts of anthropogenic nutrient inputs and natural variability on productivity, biodiversity, and living marine resources in estuarine and coastal ecosystems.

The challenge is to provide the science necessary to identify the full magnitude of the impacts of nutrients on coastal ecosystems, and then to work with coastal managers to develop and implement solutions.

Invasive Species

The introduction of species to areas outside their geographic range is a worldwide event that is difficult, if not impossible, to prevent and is a challenge to manage. Today, invasive species are considered second only to habitat destruction as a threat to plant and animal extinctions and conservation of biodiversity.[10] Our understanding of the ecological and economic impacts of marine bioinvasions lags behind our understanding of introduced species in terrestrial and freshwater ecosystems. Regulations for aquatic species focus on ballast water management with little emphasis on non-ballast water vectors, especially the emerging unregulated Internet trade in live marine organisms.

Shipping (ballast water and fouling, even with the use of antifouling paint) is considered a significant vector responsible for introductions, including HABs, bacteria, attached organisms such as the Asian green alga, *Codium fragile tomentosoides*, and the zebra mussel, *Dreissena polymorpha.*[11] There are no formal surveys of introductions from the early explorations of the seas; however, a recent study of the fouling community of a replica 16th century sailing vessel demonstrated the survival of common fouling organisms as the ship traveled slowly from Yaquina Bay, Ore., to San Francisco Bay, Calif., via the Coos and Humboldt bays.[12] Present-day ships move faster and carry upwards of 14 million gallons of ballast water that is home to hundreds of species of organisms. It is estimated that 405 million gallons of ballast water are discharged daily worldwide, and 7,000 species are transported in ballast each day.[13]

Biological fence may keep Phragmites *out of marshes*

In many marshes *Phragmites* has become an aggressive plant whose fast-growing underground stems enable it to quickly take over a marsh, crowding out native plants that support a balanced ecosystem. Delaware Sea Grant researchers are working to find a way to stop *Phragmites* by evaluating plant varieties and assessing their ability to form a multiple species “biological fence” to block *Phragmites*. Researchers are evaluating wetland plants that can halt the spread of *Phragmites* by shading their shoots, physically blocking their rhizome growth, or releasing chemicals that inhibit their growth.

A national ballast water management program mandates ballast water exchange for ships entering the Great Lakes and compliance with a ballast water reporting system along with voluntary ballast exchange for vessels entering outside the U.S. Exclusive Economic Zone, but compliance is generally low. Pacific coast states have more aggressive approaches and are achieving a 90 percent compliance in reporting.[14] Other efforts are focused on encouraging development of new technologies to achieve reductions in the volume of ballast water exchange.

Coastal managers are challenged to prevent new introductions and to quantify the risks and impacts associated with each vector for invasive species. Non-shipping vectors include aquaculture, live seafood trade, research and education, public aquaria, home aquaria, bait, recreational boating, and commercial and recreational fishing. Although the importance of these vectors has changed over time, critical information on the potential risks from such releases is lacking. The opportunity to purchase live marine organisms through the Internet without oversight poses an even greater challenge to identifying sources of introductions and sources of new releases.

The rate of introductions in San Francisco Bay has increased from one every 55 weeks (1851 to 1960) to one every 14 weeks (1961 to 1995)[15] and may reflect a worldwide trend. Determining the rates of introductions depends on accurate records, taxonomic specialists, and access to reliable information. Making databases and inventories of invasive aquatic species available and documenting the spread of invasives and responses to treatments should assist with documenting impacts and providing opportunities for rapid responses to contain new introductions.

Although increased shipping and non-shipping vectors suggest increased releases, research is needed to document the strength of inoculums, survival of the released organisms, and the receiving environment. The prediction that stressed or species-poor communities are more susceptible to invasions than healthy and species-rich communities has not been consistently supported by the scientific data. The spread of aquatic species depends not only on the primary vector, but also on secondary pathways that may assist dispersal. For example, the mussel *Mytilus galloprovincialis,* which is normally a temperate zone species, becomes established in a tropical environment. Ballast water taken from the region thus could be a potentially important secondary pathway

to the spread of mussels worldwide. A list of characteristics of what makes a successful invader is insufficient to predict which species will become invasive. Furthermore, some species appear to lie dormant for a prolonged period before becoming invasive. Others expand their range very quickly as exemplified by *Hemigrapsus sanguineus*, the Asian shore crab, on the Atlantic coast, and the European shore crab, *Carcinus maenas*, on the Pacific coast. Multidisciplinary, science-based assessments are needed to evaluate the impacts of new introductions, such as proposals to introduce the Asian oyster *Crassostrea ariakensis* into Chesapeake Bay.

Realization of the close link between the oceans and human health has sparked the interest of scientists, health care professionals, and other stakeholders.[14] Biological contaminants such as bacteria, viruses, protozoans, and other pathogens cause the deterioration of coastal water quality, prompt beach closures, contaminate seafood, and render water unfit for human consumption. Wild and cultured fish and shellfish are lost to harvest, sale, and use. In order to address this problem, there is a need to improve our ability to detect and identify the sources, characteristics, and survivability of pathogens—both native and exotic—in the marine environment. Sea Grant is developing biosensors for improved detection, identification, and control of specific viruses and bacteria in water and seafoods. Detecting and quantifying the organisms present and improving the accuracy and communication of risk assessments will enhance the ability of coastal managers to protect human health while limiting the negative impacts on America’s coastal economy.

Sea Grant has played a major role in supporting research, outreach, and education projects on invasion science. In 1999–2000, Sea Grant dedicated over $8 million dollars to invasion science; approximately one-third was spent on outreach and education. However, given the national and global scope of the problem, this funding is inadequate to provide timely solutions. Sea Grant has been a leader in developing educational materials and convening a series of regional and international scientific conferences on aquatic bioinvasions that have advanced the knowledge of range expansion, competition and predation, direct and indirect effects of species introductions, the use of new molecular probes to identify species, and the effectiveness of treatment technologies. As a result, a more comprehensive picture is emerging. The future should offer improved predictive models, risk assessments, and economic analyses to assist managers to adopt prevention, management, and control mechanisms.

Sea Grant prepares New York City for sea level rise

In its report, *Assessment of Sea Level Rise in Response Scenarios in New York*, Sea Grant identifies areas potentially impacted by sea level rise and identifies opportunities for policy refinement to facilitate community responses to rising seas that will impact coastal property.

Climate Change and Variation

Large scale natural processes, such as climate change, impact coastal habitats and marine systems over extensive areas, often with dramatic effects. These processes range from singular events, such as hurricanes, typhoons, violent storms, and seismic-caused tsunamis, to periodic yet unpredictable events like *El Niño*, changes in deep ocean circulation, and shifts in the jet stream to global-scale processes, such as sea level rise, lake level changes in the Great Lakes, and climate change.

Impacts of large-scale events can include devastating changes to coastal habitats following a hurricane or other violent storm. Tsunamis caused by undersea seismic events can inundate coastal areas, changing coastlines and eliminating habitat. *El Niño* and other periodic events cause shifts in ocean temperatures and rainfall patterns that significantly alter the sediment deposition that defines many coastal features. As ocean temperatures and salinities change, the mix of organisms and food webs change. Global climate change may have the slowest yet most profound process effects, changing the balance of organisms, sediment flow, and fringing habitats of the world's oceans. As sea level rises, low-lying coastal areas, including significant portions of the eastern seaboard and Pacific islands, will be flooded. Large-scale events may also act synergistically with human activities, mobilizing land-based nutrients and chemical contaminants, allowing invasive species to colonize scoured areas or intensifying the impacts of freshwater withdrawals.

Additional research is needed that explains the connections between large-scale processes and habitat degradation to better plan for, and mitigate, losses of coastal habitats and the surrounding watersheds. As ecosystems change due to climatic shifts, our ability to forecast the rates at which marine organisms will adapt will allow fisheries managers to work towards sustainable—albeit different—fisheries.

Sea Grant researchers collaborate with the National Oceanic and Atmospheric Administration (NOAA) and other university researchers on global climate change, *El Niño* events, and impacts of hurricanes to bring the necessary expertise in large-scale oceanographic processes to managers, policymakers, and the public. Sea Grant outreach specialists work with coastal managers, land-use planners, fisheries managers, and teachers to bring the results of research on these processes to the practical level.

Opportunities

Restoration Science

Three National Research Council studies, *Priorities for Coastal Ecosystem Science*;[9] *Research to Protect, Restore, and Manage the Environment*;[17] and *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy,*[18] have concluded that the restoration of coastal ecosystems should be a national priority. Authors of *Priorities for Coastal Ecosystem Science* concluded that, "Federal science agencies should encourage rapid advancement of the science and engineering of ecosystem restoration and rehabilitation." The Clean Water Action Plan; the Coastal Wetlands Protection, Planning, and Restoration Act; the Estuaries and Clean Waters Act; and the Beaches Environmental Assessment and Coastal Health Act provide the needed legislative framework to accelerate the restoration of coastal ecosystems. But restoration of coastal ecosystems is one of the greatest challenges facing natural resource managers today because managers don't understand unaltered coastal sites, to which they are attempting to restore degraded coastal areas.

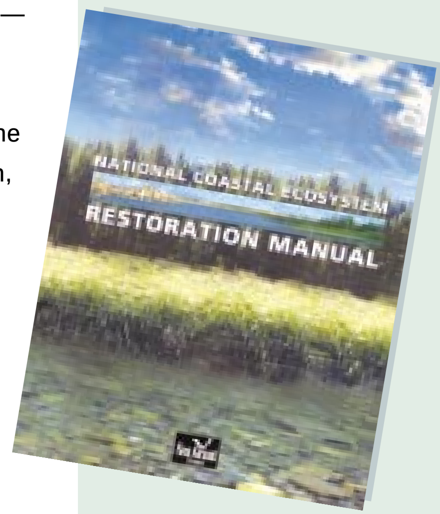
Restoring ecosystems also requires an understanding of how ecosystems respond to stress. Coastal and Great Lakes ecosystems are affected by a wide variety of natural and human-induced stressors, including land-use changes, accelerated nutrient delivery, and invasions of exotic species—stressors that often interact with each other in ways that affect ecosystem integrity.

Some of the urgent needs in restoration science are:

- Understanding the contribution of biological diversity to ecosystem resilience, especially the relationship of natural diversity to ecosystem function, impacts of landscape fragmentation, and implications of introducing exotic species.
- Quantifying the cycling of nutrients, water, metals, etc., through intact coastal ecosystems, including integrated modeling of the processes associated with biota, soil/sediment, water, and air.

Sea Grant produces landmark coastal ecosystem restoration manual

Oregon, New York, and Louisiana Sea Grant programs produced the *National Coastal Ecosystem Restoration Manual.* The manual is designed to help community groups plan effective restoration projects, providing methods to help groups work together to improve coastal habitats and water quality. Its three major sections are watershed ecosystems, best management practices, and effective group interaction.



Eelgrass restoration

Efforts to restore valuable eelgrass beds by harvesting and transplanting shoots from donor beds have been expensive and have achieved limited success. With funding from NOAA's Cooperative Institute for Coastal and Estuarine Environmental Technology, Rhode Island Sea Grant researchers have developed methods to harvest, prepare, and store large quantities of viable eelgrass seeds. They are currently field-testing their new mechanized underwater seed planter "sled" capable of efficiently planting large areas with eelgrass seed.

- Planning for restoration by developing scientific criteria for setting priorities, and balancing these criteria with those derived from engineering, social, economic, and political viewpoints.
- Identifying optimal locations to prioritize the areas in need of, and likely to respond to, restoration.
- Developing and applying evaluation criteria to restoration by setting scientific objectives and performance targets.
- Improving the understanding of the ways that policy and management actions accelerate the restoration of coastal ecosystems.
- Elucidating responses of ecosystems to change resulting from human and natural disturbances, extreme events, and management actions.
- Modeling to simulate restored ecosystem processes, complex environmental changes, and socioeconomic factors at different temporal and spatial scales.
- Building an information infrastructure to support restoration science, management, and policymaking.

At the core of restoration ecology is the desire to return an ecosystem to a close approximation of its condition prior to disturbance. Restoration science takes full advantage of the self-organizing principles of ecosystems, recognizes the importance of scientifically determined monitoring programs, and emphasizes the selection of appropriate reference sites. Restoration projects require approval by society, significant funding, a long-term commitment to goals, and substantial human and biological resources. As a result, the restoration process requires close examination of our relationship with natural systems so that the underlying mechanisms of destruction and repair can be understood. Communication among scientists, engineers, practitioners, decision-makers, and the general public is crucial to long-term success in restoring coastal ecosystems.

Rapid advances in restoration technology, remote sensing, biotechnology, and information science allow Sea Grant to help guide the ecological research community towards an increased focus on coastal ecosystem restoration. Sea Grant can provide critical reviews of existing information, summarize what we know about various restoration sites, and develop important performance measures for restoration using Sea Grant's peer-review process for planning and evaluation. Sea Grant can also facilitate development of partnerships among restoration scientists, practitioners, and the public.

Essential Fish Habitats

For more than a century, the nearshore has been classified as important habitat for coastal fish populations and their young. Up to 80 percent of recreationally and commercially valuable marine species, and many of their prey, are believed to be estuarine-dependent during some period of their lives. Substantial legislation has been enacted to protect coastal ecosystems and habitats. Despite the importance of pathways that link high coastal primary production with high secondary production, it is still unclear how various nutrient sources are utilized by consumers and the degree of importance attached to such sources. In addition, the potential role of coastal habitats as refuges from predation has not been demonstrated. And only recently has there been recognition of the importance of habitats in the fisheries recruitment process.

One of the greatest threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat alterations within primary nurseries have poorly understood effects on young finfish and shellfish. Adults of many species appear to be overexploited, yet subtle factors operating on recruitment of early life stages may be equally important in sustaining healthy stocks. Located in the transitional area between land and sea, estuaries and the adjacent coastal zone are particularly susceptible to environmental degradation, which can harm juvenile marine species that depend on estuaries for food and shelter. Federal and state agencies must identify and map the habitats of all managed species in their various life stages. It also is important to assess the functions and relative values of estuarine habitats (seagrasses, salt marshes, mangroves, oyster/mussel reefs, shoals and flats, open water) and coastal habitats (rocky shores, kelp forests, “live-bottom,” sand ridges, coral reefs), and the interactions between them.

The latter half of the 20th century taught us that the nation’s fisheries cannot be viewed as a “commons” to be exploited by all, but rather that these resources are a fragile commodity, easily overexploited using modern technologies. The fishing industry, managers, and scientists have come to

Sea Grant restores essential fish habitats

New York Sea Grant is working in partnership with many groups to restore essential fish habitats in the Beaver Dam Creek watershed on Long Island. The project is restoring wetland areas damaged by dredging and dikes, removing invasive *Phragmites*, and aiding residents and businesses in the watershed to adopt best management practices to protect water quality. The project serves as an invaluable model for restoring damaged watersheds throughout the urbanized eastern United States.

Model defines fish habitat needs

Using a computer-controlled aquarium system, Delaware Sea Grant researchers are monitoring how juvenile fish respond to varying oxygen conditions found in healthy and polluted estuaries over a range of temperatures and salinities. Regional fisheries models are being developed that can predict impacts of changing oxygen conditions on the distribution, growth, and survival of major fish species, including young weakfish, summer flounder, Atlantic menhaden, and spot. The effort will produce a valuable framework for quantifying the complex relationships between water quality and fish populations.

view individual fish stocks as part of a complex system. Essential habitat is an obvious component of such a system. In amending the original Magnuson-Stevens Act, Congress noted that certain stocks of fish are threatened as a consequence of direct and indirect habitat losses that result in diminished capacity to support existing fishing levels. The collection of "reliable data" was found essential "to the effective conservation, management, and scientific understanding of the fishery resources of the United States." Following Congressional lead, the National Marine Fisheries Service (NMFS) was tasked with promoting conservation and enhancement of essential habitat to prevent future depletions of managed species and to help restore overfished stocks. NMFS is to provide fishery management councils with ecologically sound guidance that is both feasible and "scientifically defendable." This is a tall order given our rudimentary understanding of the relationship between habitat and successful recruitment for most marine transient species. Four "levels" are used to organize the information necessary to describe and identify essential fish habitat (EFH): Level 1: distribution data; Level 2: habitat-related densities; Level 3: growth, reproduction, or survival rates; and Level 4: production rates. There is a notable paucity of data, especially at EFH levels 3 and 4. Reliable data eventually must be collected in these areas if fishery management plans are to be meaningful.

Sea Grant's Strategic Plan[19] includes a vision for the next decade to enhance sustainable fisheries that support fishing industry jobs, safe and wholesome seafood, and recreational opportunities. These needs can be best accomplished by forging partnerships among university scientists, stakeholders, resource agencies, and private groups.

Protected Areas and Sanctuaries

The last three decades have witnessed an intense search for effective coastal resource assessment and management tools. Scientists have argued that better science will improve the standard models that have been used to manage resources. However, the trail of management failures has led to skepticism about when these models will be able to reduce the uncertainties surrounding model predictions. In addition, it has become clear that management must deal with multiple species, communities, and ecosystems rather than just single populations. Given these challenges, regulation of human activities by creation of protected areas has gained substantial momentum during the last decade.

Protected areas have long been used in freshwater, estuarine, and marine environments. Aquatic protected areas can be defined as areas of an aquatic environment that have been reserved by federal, state, territorial, tribal, or local laws to provide lasting protection for part or all of the natural and cultural resources they contain. Existing protected areas range from sanctuaries that are focused on protection of one or a number of resources to wilderness areas where natural conditions and biodiversity are maintained.

There are two general classifications of protected areas based on their goals. Establishment of the protected area can be a goal in itself—for example, a reef, coastal marsh, or other habitat that is deemed worthy of protection or restoration. Or, a protected area can be designed to achieve another goal, such as fisheries management. In that case, the protected area would be a means to an end. This differentiation is important for considering the types of questions to ask about protected areas. In the former case, critical questions concern the characteristics of the specific site and how they affect the costs and benefits of establishing the protected area. In the latter case, questions would range more broadly and focus on comparisons of the efficacy, costs, and benefits of protected areas versus other management tools.

Protected areas have substantial support in coastal aquatic resource management. However, questions remain about whether there has been ample demonstration that protected areas have been effective management tools. In fact, the first reserves in a biogeographic region will be experiments. Thus, each protected area will need to be evaluated carefully after inception and be considered part of an adaptive management strategy. Substantial questions also remain about efficacy with respect to size, location within a biogeographic region, juxtaposition to other similar areas, and the dependence of these questions on the species and/or communities of interest. Assessing the costs and benefits of

Detroit River designated an International Wildlife Refuge

The Detroit River on the Michigan-Canadian border is a binational Waterfowl Habitat Area of Concern, having lost over 95 percent of its wetland habitats. In 2001, President Bush signed a law declaring the Detroit River the first International Wildlife Refuge in North America. Michigan Sea Grant served as master of ceremonies at the opening that featured Congressman John Dingell, who authored bill H.R. 1230, establishing the refuge. Legislation provides resources to restore over 400 acres of habitats and enhances public-private partnerships for conservation. Michigan Sea Grant chaired the Greater Detroit American Heritage River Steering Committee that brought together Canadian and U.S. researchers, managers, policymakers, students, and concerned citizens to develop a 10-year conservation vision for the lower Detroit River ecosystem.

Size of marine protected area doubled in Chesapeake Bay

Using a scientific assessment conducted by Virginia Sea Grant, the Virginia Marine Resources Commission decided to expand by 200 percent the size of a 172,000 hectare marine protected area established to protect the spawning grounds of female blue crabs during their reproductive season in the lower Chesapeake Bay.

specific protected areas is critical. According to William Hogarth, NMFS assistant administrator, protected areas are "not a panacea for improved marine resource management," but "an additional tool that places an emphasis on spatial parameters" that "can be effective in some cases and for some purposes, while in other situations they cannot achieve success without significant resource commitments or complementary conservation measures in surrounding waters."

Once it has been determined that a protected area is appropriate as part of an integrated management protocol, there are many roadblocks to its establishment. Involvement of the full range of stakeholders in the entire process of considering the ecological, sociocultural, and economic issues related to the proposed protected area is crucial. The list of potential stakeholders is diverse, from fishermen to farmers, property owners to tourism representatives, energy producers to the military, and many others. Those not involved in the process will be critics or opponents of the process. But where involvement has been carefully cultivated, protected areas have been successfully negotiated even in situations of strong conflict.

Sea Grant is well placed to contribute to future decisions about marine protected areas. Sea Grant facilitates stakeholder meetings to consider specific protected areas and to develop consensus. Sea Grant outreach specialists have the knowledge and experience to lead such discussions and/or to teach others to do so.

Sea Grant's Role in Decision-making

Maintaining the sustainability of coastal ecosystems and habitats under conditions of unprecedented growth and development is putting severe demands on our regulatory infrastructure. Knowledge critical to the management of coastal ecosystems, and the synthesis and rapid transfer of that knowledge into public policy, must be given high priority.

Coastal ecosystems are highly dynamic and continue to be subjected to prolonged and escalating human disturbance. Consequently, the current state of coastal ecosystems in the United States reflects, to varying degrees, those cumulative anthropogenic impacts. From a management perspective, we are already dealing with perturbed systems. Sea Grant is well positioned, because of its infrastructure and capability, to play a significant role in supporting the science base for institutional decision-making. Sea Grant can contribute knowledge about current ecosystem states and acceptable limits and address how and at what cost ecosystems can be maintained or restored. And if this does not prove economically feasible, Sea Grant can assist in reducing or containing the extent of degraded ecosystems. The fate of our coastal ecosystems and habitats into the next century will depend on the management we practice today.

Footnotes

1. Constanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. O'Neill, J. Paruelo, R. Raskin, P. Sutton, and M. van den Belt. 1987. The value of the world's ecosystem services and natural capital. *Nature* **387**: 252–259.
2. Environmental Protection Agency. 2000. *Water Quality Conditions in the United States*. Environmental Protection Agency Report 841-F-006. Office of Water, Environmental Protection Agency, Washington, D.C.
3. National Research Council. 1992. *Restoration of Aquatic Ecosystems: Science, Technology and Public Policy*. National Academy Press, Washington, D.C.
4. Committee on Environment and Natural Resources. 2000. *National Assessment of Harmful Algal Blooms in U.S. Waters*. National Science and Technology Council, Washington, D.C.
5. Anderson, D., P. Hoagland, Y. Kaoru, and A. White. 2000. Estimated annual economic impacts resulting from harmful algal blooms (HABs) in the United States. Woods Hole Oceanographic Institution Technical Report 2000-11, Woods Hole, Mass.
6. Falk, J., F. Darby, and W. Kempton. 2000. Understanding mid-Atlantic residents' concerns, attitudes, and perceptions about harmful algal blooms: *Pfiesteria piscicida*. Report DEL-SG-05-00. University of Delaware Sea Grant College Program, Newark, Del.
7. Anderson, D. 1997. Turning back the harmful red tide. *Nature* **388**: 513–514.
8. National Research Council. 1990. *Managing Troubled Waters: The Role of Marine Environmental Monitoring*. National Academy Press, Washington, D.C.
9. National Research Council. 1994. *Priorities for Coastal Ecosystem Science.* National Academy Press, Washington, D.C.
10. Wilcove, D., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. *BioScience* **48**: 607–616
11. Carlton, J., D. Reid, and H. van Leeuwen. 1995. *Shipping Study: The Role of Shipping in the Introduction of Non-Indigenous Aquatic Organisms in the Coastal Waters of the United States (Other Than the Great Lakes) and an Analysis of Control Options*. Connecticut Sea Grant College Program, University of Connecticut-Avery Point, Groton, Conn.
12. Carlton, J. and J. Hodder. 1995. Biogeography and dispersal of coastal marine organisms: Experimental studies on a replica of a 16th century sailing vessel. *Marine Biology* **121**: 721–730.
13. Carlton, J. 2001. *Introduced Species in U.S. Coastal Waters: Environmental Impacts and Management Priorities.* Pew Oceans Commission, Arlington, Va.
14. McDowell, K. 2002. Ballast water education and management on the West Coast of the United States. *Aquatic Invaders* **13**: 1–5.
15. Cohen, A. and J. Carlton. 1998. Accelerating invasion rate in a highly invaded estuary. *Science* **279**: 555–558.
16. National Research Council. 1999. *From Monsoons to Microbes: Understanding the Ocean's Role in Human Health.* National Academy Press, Washington, D.C.
17. National Research Council. 1992. *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy*. National Academy Press, Washington, D.C.
18. National Research Council. 1993. *Research to Protect, Restore, and Manage the Environment.* National Academy Press, Washington, D.C.
19. National Sea Grant College Program. 1995. *Network Plan, 1995–2005*. National Oceanic and Atmospheric Administration, Washington, D.C.

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