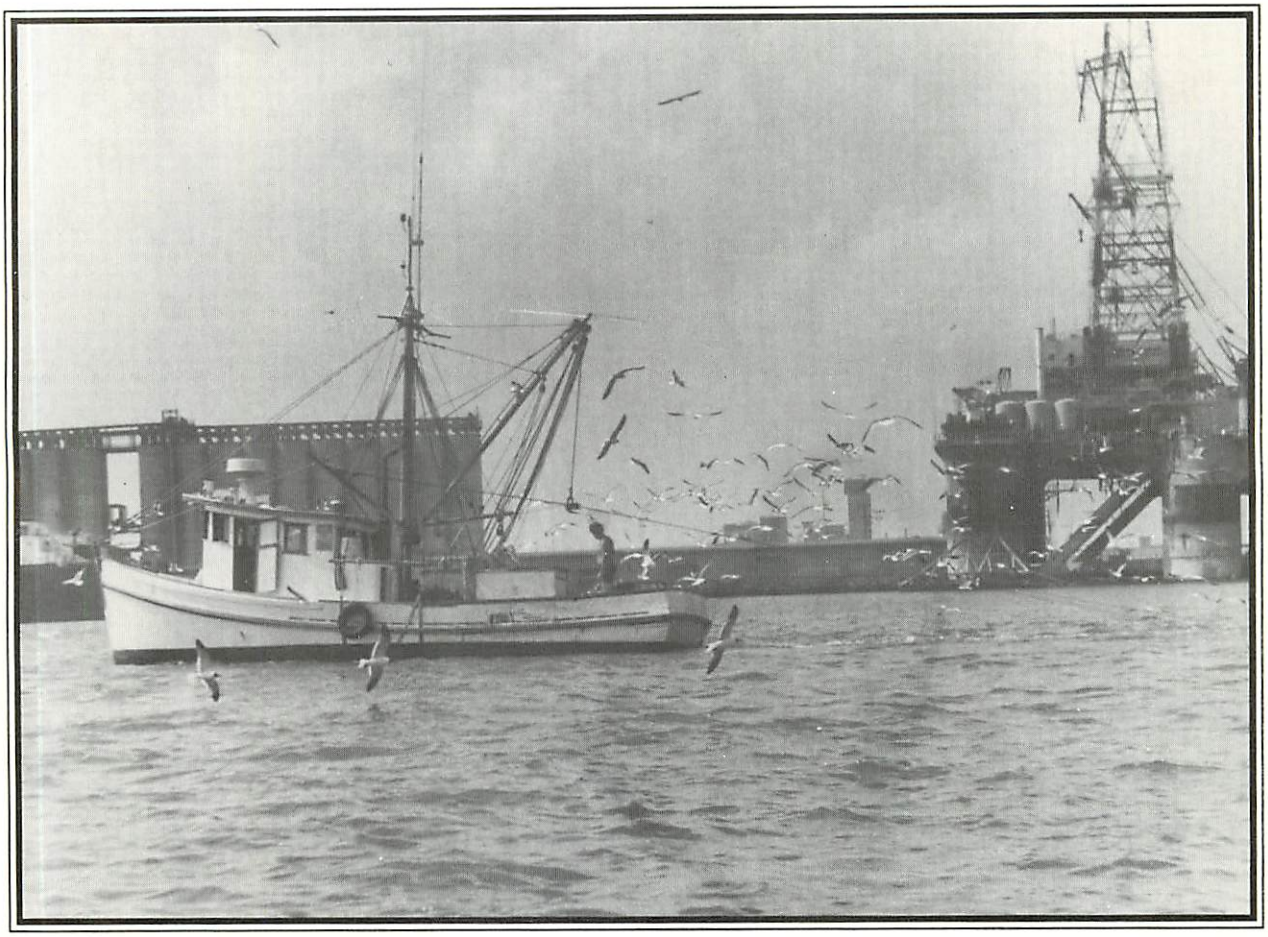
Sea Grant:

Addressing Contemporary Marine and Coastal Issues



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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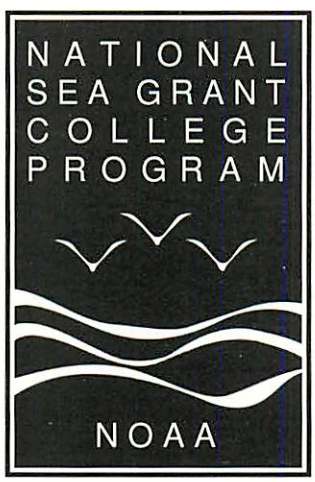
"The National Sea Grant College Program, a unique partnership with public and private sectors combining research, education, and technology transfer for public service, is the national network of universities meeting changing environmental and economic needs of people, industry, and government in our coastal, ocean, and Great Lakes states."



Cover: Multiple uses of limited marine and coastal resources are growing and problems associated with that growth are increasing. Sea Grant supports research to develop the knowledge base needed not only to solve coastal problems but also to seize commercial opportunities.
Photo: Texas Sea Grant/Pat Lowry

Sea Grant:
Addressing Contemporary Marine and Coastal Issues

Contents

Acknowledgments:

Authored by National Sea Grant Office staff, with contributions from the Sea Grant network

Edited by Victor Omelczenko and Susan Borda

Foreword

The National Sea Grant College Program, created in 1966 by the Congress to provide for the understanding and wise use of ocean, coastal, and Great Lakes resources and the environment, now encompasses a network of over 300 institutions nationwide operating through a core leadership of 29 Sea Grant Colleges and Institutions. This network annually draws upon the talents and skills of over 3,000 scientists, engineers, educators, students, and outreach specialists. They work together advancing knowledge and understanding of the marine and aquatic environments in order to achieve the objectives of the legislation. Headquartered in the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), Sea Grant supports coordinated programs of university-based research, education, and technology transfer. In areas where their interests are congruent, Sea Grant and NOAA work together to meet the agency's missions to describe and predict changes in the Earth's aquatic environment and to manage the nation's ocean, coastal, and Great Lakes resources.

Sea Grant mobilizes the resources of both the Federal government and academia in a dynamic partnership to solve urgent coastal and ocean problems. By drawing upon researchers from across the full spectrum of the marine and aquatic sciences, Sea Grant supports research to develop the knowledge base needed to solve coastal problems or seize new commercial opportunities. The program generates information critical to understanding the marine environment and transfers new technologies to coastal and Great Lakes industries and decisionmakers nationwide.

Sea Grant activities in marine ecology and fisheries, coastal processes, environmental studies, seafood science, and the coastal ocean support NOAA's mission. Over the years, Sea Grant has also taken on several missions unique in NOAA such as research and technology transfer in the areas of aquaculture, marine biotechnology, and marine policy. Sea Grant thus enables NOAA to enhance the work of its own government scientists with that of experts in the academic community, all in the national interest of effectively developing and managing marine resources while maintaining stewardship of the marine environment. At the same time, Sea Grant also assists the Commerce Department in its efforts to promote American economic growth and jobs. For the year 1987, Sea Grant was found to have generated an $842 million impact on the national economy by stimulating new business opportunities or helping implement cost-saving productivity improvements.

During the years since 1987, Sea Grant has continued to have a beneficial impact, not only by increasing knowledge but also by creating new jobs and businesses. While looking at the time frame of 1987-1992, this report does not attempt to gauge a new impact figure to the degree done in 1987. Rather it shows that Sea Grant over this time period has continued to produce a variety of results that benefit both the nation's environment and economy. For instance, in the area of creating new industries, jobs and products, Sea Grant programs conducted research and technology transfer that helped the soft-shell crab industry grow. From almost nothing a decade ago, this industry now yields annual gross sales of more than $40 million and provides 4,000 jobs in 12 Atlantic and Gulf Coast states; a growing export market now exceeds $2 million per year. In an example of solving coastal environmental problems, Sea Grant research on nutrient inputs from agriculture into bays led to the adoption of "Best Management Practices" in four states. These new land-use practices resulted in a 25 percent reduction of nitrogen compounds entering bays, with a subsequent improvement in water quality.

Sea Grant: Addressing Contemporary Marine and Coastal Issues focuses on seven themes which permeate Sea Grant's work and underscore its commitment to the environment and to commerce. Each theme includes sections providing background information, examples of recent accomplishments, and a look at the challenges and opportunities Sea Grant faces as the 21st century approaches. Comments on this report are welcome and should be addressed to:

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David B. Duane
January 1993

Wetlands, such as those pictured above, are valuable for many purposes. They provide food and habitat to living marine resources, present a buffer to coastal storms, remove excess nutrients from overlying waters, and are used for recreation. Approximately 41% of the nation's coastal wetlands are found in Louisiana which has lost almost 1,500 square miles of wetlands over the last 60 years.
Photo: Louisiana Sea Grant

Sea Grant: Solving Coastal Environmental Problems

William Graham
and Leon Cammen

As part of NOAA's mission to promote stewardship of the marine environment, Sea Grant plays a major role in identifying and addressing coastal environmental problems. Sea Grant bridges the gap between management and research, creating management approaches that will protect the environment while at the same time encouraging development of coastal resources.

Since many environmental problems are common to large portions of the U.S. coastal zone, Sea Grant's efforts are often regional, interinstitutional efforts that include not only scientific research, but also the transfer of those research results to the general public and to environmental managers. Problems such as the disappearance of the nation's wetlands, the deterioration of coastal water quality, and the increased need for waste treatment caused by coastal industrial development and population growth have all been addressed successfully by the Sea Grant network.

Wetlands

Loss of Coastal Wetlands

Wetlands are valuable for many purposes. They provide food and habitat to living marine resources, present a buffer to coastal storms, remove excess nutrients from overlying waters, and are used for recreation. The average minimum value of coastal wetlands to society has been placed as high as $2,000 per acre.

About 41% of the nation's coastal wetlands are found in Louisiana. Unfortunately, these wetlands have been disappearing at a substantial rate. Since 1932, Louisiana has lost almost 1,500 square miles of coastal wetlands—an area larger than the state of Rhode Island. A combination of restoration programs and wetlands regulations has helped reduce the annual loss rate, but the trend is still alarming.

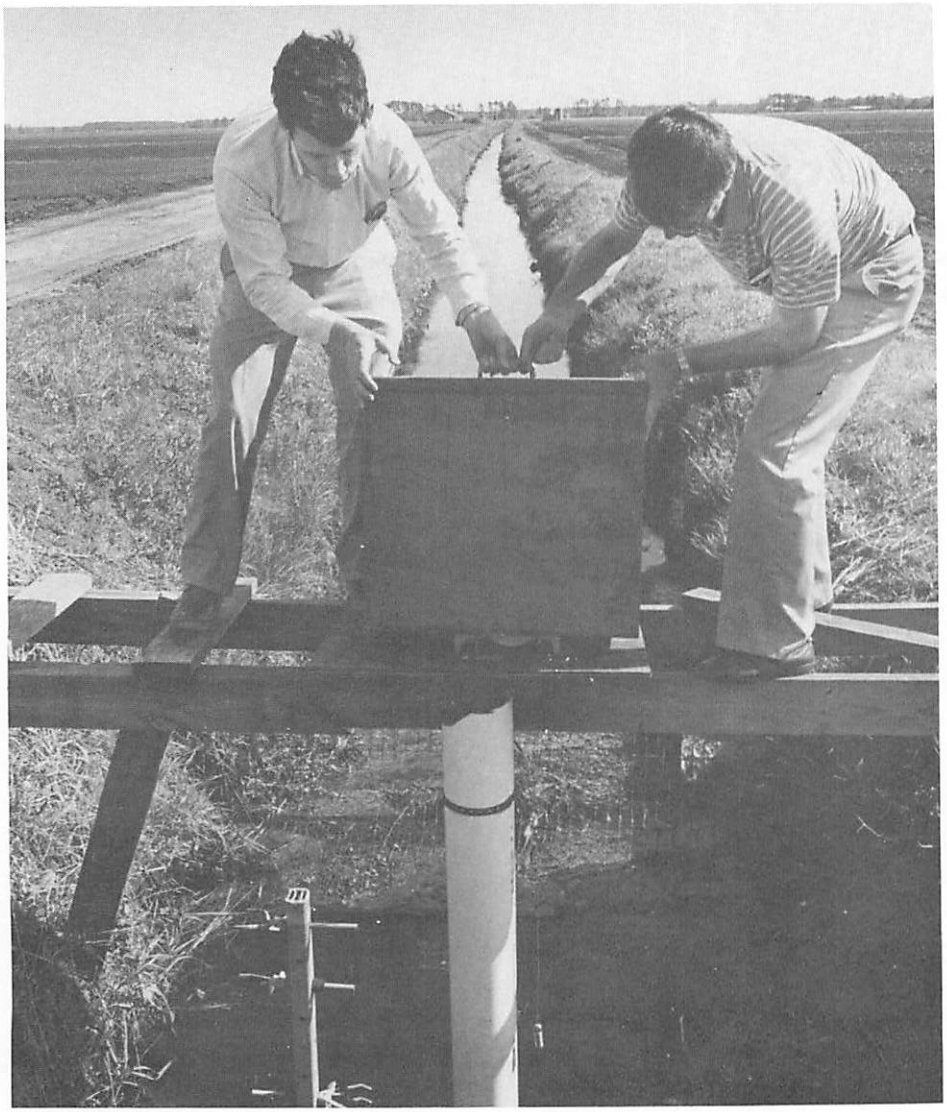
In 1978, Louisiana Sea Grant established the Atchafalaya Research Program to address the implications of this wetland loss and to determine what could be done to prevent further loss. A series of ecological, hydrological, and geological studies began of the wetlands and bays in the Atchafalaya Delta region. Involving 26 faculty researchers from three institutions, the studies culminated in a better understanding of the processes leading to wetlands loss.

The researchers discovered that the construction of flood-control levees had reduced river-borne sediment input to the interior marshes, causing vegetated areas to become submerged. The wetlands were lost. These findings led to a cooperative effort between the Fish and Wildlife Service and the U.S. Army Corps of Engineers to develop computer simulations of the region, based largely on Sea Grant-collected data. The computer modeling clearly showed the effect of existing flood control projects and predicted a large potential wetlands loss from the proposed $150 million Avoca Island levee extension along the Atchafalaya River. The model predictions were well-accepted by the management community in large part because of the quality of Sea Grant research data used to construct the model. Those predictions were instrumental in the decision of the Corps of Engineers to suspend plans to build the levee extension.

Wetlands Restoration

If the nation is to reduce loss of wetlands, it must develop the capability to restore and construct wetlands truly equivalent to natural wetlands. Because 90% of California's original wetlands have been lost, interest in developing methods to effectively restore and construct new wetlands is particularly intense in that state. Thus, California Sea Grant has been highly involved in research to develop techniques for measuring whether a constructed wetland is ecologically equivalent to the natural wetland that was destroyed.

Research results have been published



These researchers are conducting tests to discover how to reduce nutrients entering coastal waters from agricultural uses.
Photo: North Carolina Sea Grant/ Scott Taylor

in *A Manual for Assessing Restored and Natural Coastal Wetlands*. The manual outlines methods for wetlands construction, restoration, and enhancement; proposes methodology for sampling and comparing natural and restored wetlands; and contains recommendations about the minimum follow-up monitoring required to assess the restoration's success over time. The manual's illustrative examples are from southern California marshes but can be applied nationwide. It has been distributed widely to both wetlands scientists and managers in federal and state agencies and to persons involved in wetlands mitigation and restoration.

Water Quality

In an effort to answer questions about the sources and fates of nutrients in estuarine waters, Sea Grant funded a research project on reducing the nutrients entering estuaries from farmland drainage. The researchers knew that non-point source nitrogen is the most serious nutrient input into coastal waters. They also knew that in low-lying coastal areas, land-use activities, particularly agriculture, require drainage before the land can be used, and drainage transports large amounts of nitrogenous nutrients to surface waters. The question researchers needed to answer was: during agricultural activities, how can land nutrient losses be reduced without jeopardizing productivity?

To help answer this question, a well-instrumented field site was installed in coastal North Carolina to test simulation models for predicting movement of nutrients, sediments, and pesticides into surface and groundwaters. The demonstration site also served as an ongoing model to demonstrate to farmers, governmental officials, outreach personnel, and other researchers just how a water management system could maximize production and minimize nutrient and material losses during various land-use activities. Research findings enabled models to be adjusted and expanded to show how certain land-use activities (Best Management Practices [BMP]) could be followed to reduce contamination and improve production.

As a result of this project, nitrogen input into estuarine surface waters receiving drainage from approximately 120,000 acres of controlled land has been reduced by 1.2 million pounds of nitrogen per year. The North Carolina General Assembly enacted a cost-sharing program to entice farmers to follow the BMPs to reduce nutrient outflow. The program is working so well that three other states—Maryland,

A tractor hauls a wildcat device which turns the blue crab compost mixture daily. Photo: Florida Sea Grant

Delaware, and Virginia—require BMPs in a cost–share program. The North Carolina demonstration site serves as the only reference site to test models for specific implementation. Officials from other states and several countries have visited the site to determine application to a wider geography. The three North Carolina Sea Grant researchers who worked on this project were presented the U.S. Department of Agriculture's prestigious Superior Service Award for their contribution to agriculture.

Turning to highly urbanized areas, Southern California Sea Grant researchers examined what happens to treated sewage once it's discharged into the coastal waters off Los Angeles. To determine the fate of the contaminants in the sewage, they studied where and when the sewage effluent or plume dispersed in the water column and in sediments. The researchers mapped the extent of the sewage plume and determined that sewage and contaminants were not coming to the ocean's surface. As a result, the Los Angeles County Sanitation District adjusted its waste and management practices to use less chlorine than it had in the past to treat sewage. Los Angeles is now saving $300,000 each year in reduced chlorination costs.

Waste Disposal

Seafood Waste Composting

Disposing of waste from seafood processing operations is becoming more and more difficult due to increasingly tighter environmental regulations. Novel, affordable solutions to waste disposal problems are needed by the small businesses making up the bulk of the seafood processing industry.

In the state of Florida, about 6,000 tons of blue crab waste are produced by seafood processors each year. For the most part, these wastes have been disposed of in county landfills. This disposal technique is expensive. It uses up landfill space faster than other wastes, because additional soil cover is required to control odors. It is estimated that, in one county where 16 percent of the waste was crab scraps, 25 percent of the landfill costs went to manage this waste. In addition, creating more landfill acreage can cost up to $250,000 per acre.

Florida Sea Grant has recently completed a project to evaluate new methods for disposing of blue crab wastes. The project considered three waste disposal methods: in–plant wet extrusion, compacting and anaerobic bioconversion to methane gas, and large–scale composting.

Using wet extrusion to treat blue crab waste offers the potential to provide feed pellets for aquaculture operations, but additional research is needed to prove the feasibility of this method. Compacting with anaerobic bioconversion to methane gas reduces the volume of crab scrap but does not eliminate the by–products. The liquids resulting from the compacting process have the potential to be used for the biological generation of methane gas as a fuel on site. However, more research is needed to develop practical fuel generating systems, and the capital costs may be beyond the resources of small processors.

Large–scale centralized composting appeared to be the most promising option for treating crab waste. A number of materials such as fresh and aged sawdust, bark, and yard trimmings can be used as the carbon source in composting. Wakulla County in Florida is now composting all its crab scrap and two other counties may soon do the same. Public acceptance of the compost is high based on market tests.

Bioremediation of Waste Streams and Waste Sites

Cleanup of industrial waste discharges and remediation of toxic waste spill and disposal sites are problems of major national concern. In the past, chemical cleanup methods have predominated. Now, it is widely recognized that using naturally occurring microorganisms to degrade toxic chemical wastes can be more effective and less expensive than other approaches.

While significant research into using microbes for toxic remediation in fresh waters has been carried out nationwide, the development of organisms which could be applied in the saline and brackish waters of coastal areas is a major new development. A Louisiana Sea Grant researcher has isolated new microorganisms capable of degrading toxic chemicals in both salt and fresh water environments and has developed new processes to apply these capabilities in the field.

One application of this research is to use these organisms to degrade components of oil waste and a variety of pollutants in industrial waste discharges. Sea Grant, working with the Manville Corporation, developed a highly efficient bioreactor using diatomaceous earth to immobilize microbes in the reactor to prevent their loss into the waste stream. Recent tests of the reactor in cooperation with Exxon Corporation indicate the bioreactor can significantly reduce concentrations of pesticides and chlorine and organic solvent compounds in waste streams.

An additional application of this research is to use these microbes for *in situ* treatment of hazardous waste sites. In this method, the adapted microbes are grown directly in the soil of the waste site, using the toxic wastes as their energy source and degrading them in the process. In cooperation with the EPA, the adapted microbes technique has been successfully applied to a hazardous waste site on the east bank of the Mississippi River. On-site toxic waste degradation significantly saves in remediation costs.

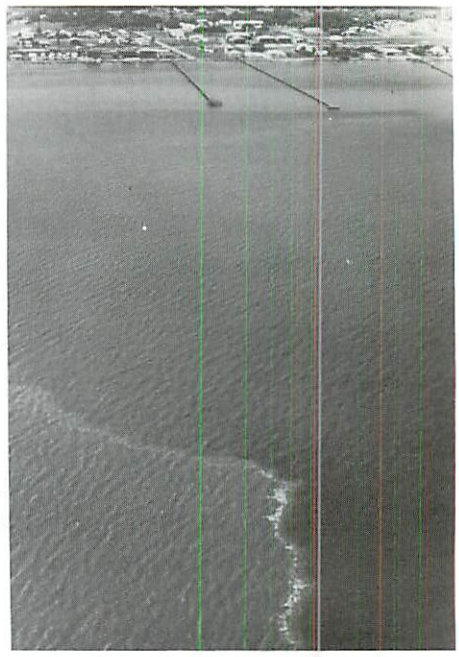
As a result of this research, Environmental Solutions, Inc. and Environmental Remediation, Inc. were formed to license and apply this technology developed by Louisiana Sea Grant.

Outlook

As coastal development pressures increase and coastal population rises, impacts on the environment will become even more severe. Among these impacts are continued degradation and loss of coastal habitats critical for the support of marine and Great Lakes ecosystems and their commercial fisheries, and the continued decline in water quality due to eutrophication and toxic chemicals. Further development of the seafood processing industry and the emergence of mariculture operations may adversely affect coastal water quality. Sea Grant will continue to address these issues with the goal being cost-effective solutions that will protect environmental quality.

Among the future major problem areas Sea Grant scientists will be addressing are the issues of habitat preservation and restoration. There is a great need for information on how the ecosystems of marine and Great Lakes habitats actually function. Without such an understanding, it is not possible to predict habitat loss consequences or to restore or construct replacement habitats with a reasonable chance of restoring the ecological functions that have been lost.

Understanding the impact of toxic chemicals on marine and Great Lakes ecosystems and organisms continues to be a high priority for Sea Grant research.



Harmful algal blooms are expected to be a continuing problem. Some 200 miles of Texas coastline were once blanketed with "red tide" or toxic algal blooms.
Photo: Texas Sea Grant

This understanding is necessary if appropriate water quality and seafood safety standards are to be set by appropriate agencies.

Eutrophication and harmful algal blooms are expected to be continuing problems in our nation's coastal waters. Quantifying the cause and effect linkages between nutrient input quantities and eutrophication is required if realistic and cost-effective nutrient control strategies are to be applied.

Assistance to the seafood industry in coping with ever more restrictive environmental regulations on waste disposal will not only involve researchers but also will be an important mission of Sea Grant's Marine Advisory Service in the coming years.

These issues and others that cannot be foreseen will continue to involve the best university scientists as part of the National Sea Grant College Program in 1993 and into the 21st century.

Sea Grant:
Tackling Fast-Breaking Issues

Bernard Griswold
and Dale Baker

Waist-deep in water, this Detroit Edison worker is using high pressure water to remove zebra mussels from water intake pipes. To prevent this biofouling, Sea Grant provides electric power companies with the best available technology to manage this problem.
Photo: Detroit Edison

Multiple uses of increasingly limited marine and coastal resources are growing. With this growth, conflict among user groups increases: conflicts which frequently result in emotional confrontation and/or abuse of resources. Many of these multiple-use conflicts arise quickly, with little lead time for consideration of resolution. The arena of environmental hazards (both natural and human caused) also creates situations where knowledgeable personnel must react quickly with highly technical information and must do so in a way to energize policy and decisionmakers and, occasionally, the general public to action. Doing this well has been a hallmark of the Sea Grant program and its nationwide network.

Zebra Mussels

In the fall of 1988, a small clam-like organism was found attached to a stick of driftwood in Lake St. Clair between Lakes Huron and Erie. The animal was a zebra mussel, a mollusk native to the Caspian and Azov Sea regions of Eastern Europe. It is now assumed to have been released into the Great Lakes through bilge water exchange from a transoceanic merchant vessel and was the latest in a series of exotic species introduced into the Great Lakes in this manner.

This introduction was recognized as being particularly troublesome. Zebra mussels have a high reproductive capability, attach in large clusters to any hard surface, and have reproductive and survival mechanisms which allow them to spread very rapidly. Furthermore, the zebra mussel's potential as a significant new biofouling organism is recognized as a threat to navigation, power generation, municipal water supplies, industrial use, and irrigation systems. Sea Grant realized this introduction posed a significant threat to the integrity of the entire nation's freshwater ecosystems and to the nation's marine infrastructure such as water intake pipes, docks, locks, and dams.

By fall 1991, zebra mussels were found throughout the Great Lakes and were making their way into the major river systems and some freshwater lakes throughout the northeast quadrant of the U.S. They had reached a density of over 700,000 mussels per square meter in Lake Erie and, from an economic and productivity standpoint, harmed many water users in the Great Lakes.

To address this problem, NOAA was able to turn to the Sea Grant programs of the Great Lakes region (Illinois/Indiana, Michigan, Minnesota, New York, Ohio, and Wisconsin) which brought together agencies to develop research strategies, public awareness, and technology transfer plans. In addition, other federal agencies had specific roles and responsibilities. For example, the Fish and

Wildlife Service was interested in the effect on fishery resources, and the Environmental Protection Agency on the fate and transfer of environmental contaminants.

From the beginning, Sea Grant led the research role to fill knowledge gaps in basic zebra mussel biology so as to allow understanding of ecological disruption, predict areas of future high impact, and identify strategic times in the life cycle when control efforts might be more effective. Research results are preliminary, but it is believed mussel outbreaks can be particularly bad in more eutrophic areas with some water movement. Research results also seem to indicate that some ecological benefits may actually be realized from the zebra mussel's filtering actions which result in increased water clarity.

In assuming the primary responsibility for public awareness and technology transfer, Sea Grant outreach developed standardized monitoring programs, drew upon the long European experience with the mussels, and informed utilities, industry and navigation users about mussel control options. For instance, electric power companies and water treatment plants learned from Sea Grant what the best available technology was for their particular plant configuration. Strategies range from chemical treatment with filters, heat, ultraviolet light, and coatings. In addition, Sea Grant educated the general public on methods to prevent the inadvertent spread of the mussel through boating, fishing or other recreational activity.

An economic study by the U.S. Fish and Wildlife Service has estimated that zebra mussel control will cost the U.S. $5 billion annually by the year 2000. Currently, Sea Grant conducts the only broad-based educational program to alert users to the problems, consequences, and strategies necessary to be ready for this noxious invader in other parts of the country.

Oil Spills

On March 24, 1989, the supertanker Exxon Valdez went aground in Prince William Sound, Alaska, spilling more than 10 million gallons of crude oil into that pristine and productive environment. Oil coated a length of shoreline roughly equal to the entire coast of California. Alaska Sea Grant responded quickly on a few targeted, high priority objectives.

An Alaska Sea Grant Marine Advisory Service (MAS) specialist, based in Cordova, was first on the scene the morning of the oil spill. He recognized the futility of attempting to deal with all aspects of the problem because local resources were limited. The MAS specialist, along with local fishermen and resource managers, recognized that efforts targeted at defending localized, highly important areas could be successful. They devised a strategy to prevent oil incursion into key fish hatcheries and herring catchments, fisheries resources which support the livelihood of most Prince William Sound communities.

The Alaska Department of Environmental Conservation accepted the strategy and gave the Alaska Sea Grant MAS specialist and Cordova fishermen full responsibility for carrying it out. In the next few days, they recruited over 200 vessels, 260,000 feet of booms, tugs, barges, skimmers and other support equipment. This makeshift navy worked day and night to defend the fishery resources from the oil. These sensitive areas were saved. The long-term effect of the spill on salmon and herring runs into the Sound through potential loss of a complete year class of fish was averted.

Also, on the day of the grounding, the Alaska Sea Grant Program coordinated the gathering of environmental samples in critical areas throughout the Sound to which the oil had not spread. Samples obtained proved invaluable as a primary information source to document losses and track environmental recovery. Further, Sea Grant funded research over a two-year period following the oil spill to revisit sampled areas to document the initial impact and the extent and mechanisms of recovery.

Finally, Sea Grant MAS business management education programs informed Alaska fishermen and suppliers about available assistance and how to obtain it, thereby averting further economic hardship. As part of the Sea Grant network, the Alaska Sea Grant Program will be able to share valuable lessons learned from the Exxon Valdez experience when and where the next oil spill occurs.

Amnesic Shellfish Poisoning

In November 1991, domoic acid, a naturally occurring and potentially fatal marine toxin produced by phytoplankton, was detected in razor clams and Dungeness crabs off the Washington, Oregon, and California coasts. Two months earlier, domoic acid had been established as the cause of unusually high brown pelican kills in Monterey Bay. As precautionary measures for human health and safety, regulatory agencies imposed closures and delays on commercial harvesting of crabs, clams and other shellfish.

Information about domoic acid was fragmented. No regional monitoring or research programs existed. It was known that some marine algae of the genus *Nitzschia* produce domoic acid in the Atlantic Ocean. *Nitzschia* algae are common in coastal waters of the Atlantic, Pacific, and Indian Oceans. The algae occasionally multiply rapidly or "bloom" when ocean conditions are favorable. Natural *Nitzschia* populations produce large amounts of domoic acid

only when these blooms occur. During a bloom, filter feeding fish and shellfish can consume large quantities of the algae. The toxin produced by the algae does not harm the fish or shellfish, but may harm birds, animals, and humans that eat the contaminated fish and shellfish.

Although gastrointestinal upset is the most common symptom from eating affected shellfish, it is known this toxin can cause irreversible amnesia or even death in humans. This occurred following a serious outbreak in eastern Canada in 1987 which caused 107 illnesses and four deaths. After that outbreak, Canadian scientists identified the causative organism and helped develop a successful management strategy, allowing the shellfish industry to continue to grow despite the continued annual appearance of the toxic organism.

The outbreak of domoic acid on the U.S. West Coast caught everyone there by surprise. Headlines reported dire risks of consuming seafood. The result was widespread alarm. It was at this point that the Washington Sea Grant Program brought the diverse resources of its researchers and outreach personnel to tackle the issue.

To facilitate state and federal agency efforts, Washington Sea Grant organized forums where representatives could discuss management needs and strategies and coordinate responses. To provide seafood harvesters and processors with critical information to guide their operations, Sea Grant quickly organized an industry workshop. Among others, Canadian scientists and industry officials were brought in to share their experience and knowledge. To address consumer needs, Sea Grant outreach staff issued information releases and fact sheets and worked closely with reporters to provide reliable information.

Subsequently, Oregon Sea Grant sponsored a domoic acid workshop to identify scientific issues which must be addressed in order to establish a successful management program and to protect public health. Priority areas identified during the workshop include:

This form of phytoplankton, *Pseudo-nitzschia australis*, is responsible for the recent outbreak of domoic acid along the West Coast.
Photo: Dr. Rita Horner

identification of the source of domoic acid on the West Coast and the factors governing its production; establishment of a phytoplankton field study examining the processes determining size and distribution of toxin-producing species; and establishment of routine toxicity monitoring in appropriate indicator species. To address these research areas, personnel from Sea Grant institutions in Alaska, Washington, Oregon, and California worked with a myriad of agencies, institutions, and industries to develop coherent strategies for future research.

For the moment, the toxic bloom has passed and the issue has lessened in critical importance. Harvesting of the Dungeness crab was delayed a month. The market is slowly returning—a market worth $43.5 million annually. It has been estimated that the crab industry suffered a $15 to $20 million loss during the domoic acid outbreak. The history of nuisance blooms along the West Coast, and in most other regions of the world, suggests that high concentrations of domoic acid will likely be a recurring problem. Sea Grant researchers provide the capability to help understand the problem, and Sea Grant outreach provides the capability to respond to the information and coordination needs of agencies, industry, and the public.

Outlook

Sea Grant outreach staff are ready to bring the best available technical information to bear on a wide range of issues, whether the information comes from Sea Grant-sponsored research or other worldwide sources. Fast-breaking issues needing Sea Grant responses frequently relate to coastal disasters or contentious resource problems. The need to develop technology and management strategies to reduce fishery bycatch is surely an issue for Sea Grant to address in the near-term. Further, public education related to toxic algal blooms is growing in importance as are issues of resource access and allocation, land use, water quality, coastal zone management, and coastal business regulation. Also, multiple uses of natural resources are generating increasing antagonism among users. Sea Grant outreach personnel are in a unique position to provide forums to bring these antagonistic parties together.

Sea Grant outreach experts will work with many states to develop hurricane preparedness programs and oil spill response plans. As a result, Sea Grant will help provide the basis for large coordinated citizen responses to such potential fast-breaking disasters.

Sea Grant:

Creating New Industries,

During this decade, 15 million jobs need to be added to the United States economy just to maintain the American standard of living. This will need to be accomplished in the face of unprecedented globalization of economic activity. Goods and services produced by U.S. industries must compete in a world economy.

The new world marketplace is causing the restructuring of the traditional industrial base. Coupled with this restructuring, rapid changes in technology permit mature industries to downsize their labor force. Consequently, the needed level of job growth to sustain the American standard of living will come mostly from the emergence of new industries based on new products. Creating these industries is the primary economic challenge for the 1990s.

In meeting this challenge, the National Sea Grant College Program works closely with marine industries and coastal businesses. Over the past 25 years, Sea Grant has established a successful record helping to create new industries, products, and jobs.

The nation's Sea Grant colleges are well-adapted to addressing the industrial competitiveness challenge facing the United States. Through its growth-oriented research agenda, its attention to transforming scientific results into commercial use and its programs to develop human capital, the National Sea Grant College Program is a proven economic development vehicle.

Aquaculture

Aquaculture—the farming of aquatic plants and animals—originated with the Chinese thousands of years ago. Sea Grant has been the driving force in adapting this ancient practice to the U.S. in the 20th century.

Years of Sea Grant research, education and technology transfer on hybrid striped bass hatcheries, nutrition, and pond management have culminated in the creation and expansion of commercial hybrid striped bass farms in the mid-Atlantic states. These farms now produce over 2 million pounds of bass yearly for a growing market, provide new jobs on the many farms, and impact the processing, transportation, and marketing industries. As Sea Grant research continues to make striped bass farming more profitable, the industry should grow even more rapidly.

Recent Sea Grant genetic research in South Carolina has produced a hard-shell clam that grows faster than wild clams. Based on this research, private investors have committed almost $6 million to establish the largest clam farm in North America. Currently, the farm employs 52 workers and is expected to produce enough clams to be equivalent to the present East Coast wild harvest. This approach to clam and bivalve farming will undoubtedly be adopted by other private investors, greatly expanding bivalve production in the United States. To further assist this new industry, the Florida, Georgia, North Carolina, South Carolina, and Virginia Sea Grant Programs jointly produced an investment guide for clam farmers during 1991.

Texas Sea Grant researchers were pioneers in developing shrimp and redfish culture techniques used today. But emphasis is now shifting to technology transfer and commercial production. At the request of the Land Commissioner of the Texas General Land Office (GLO), Texas Sea Grant developed a program to involve GLO in aquaculture. As a result, the first state land-purchase/lease back arrangement was completed for a commercial shrimp farm which is in its third year of operation. With the help of Texas Sea Grant, the GLO now has an active aquaculture program on state-owned lands which is transferring technology, providing jobs, producing high-valued products, and stimulating a fledgling Texas industry.

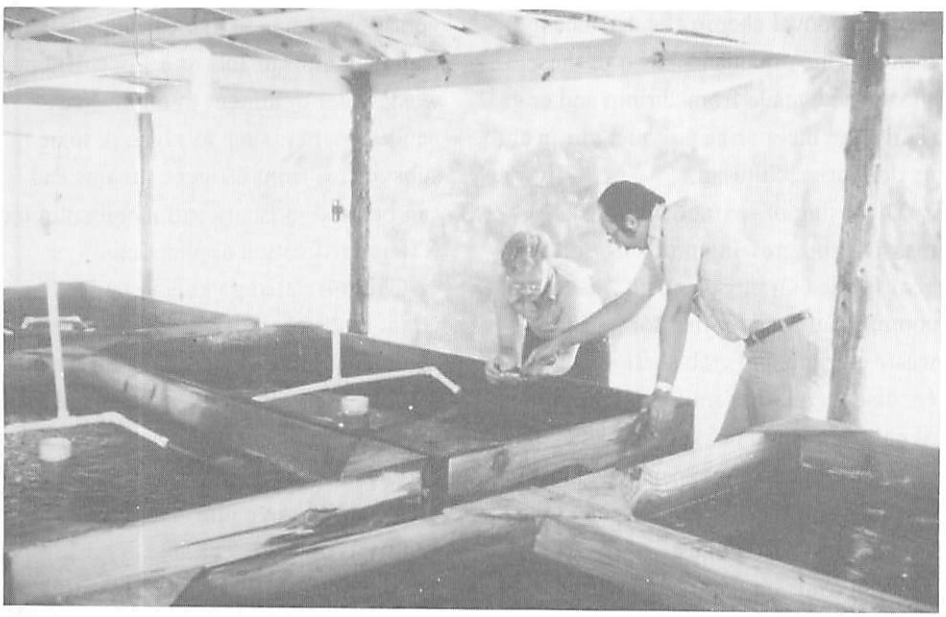
Sea Grant technological research

Jobs, and Products

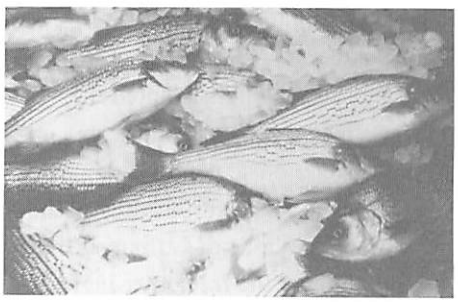
Francis Schuler
and James McVey

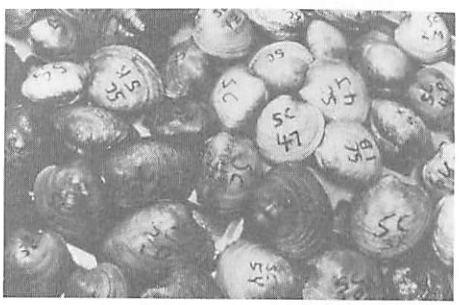
played a major role in developing and expanding the soft-shell crab industry. In the late 1970s, soft-shell crab production was sporadic and subject to fluctuations due to deteriorating water quality. For example, Louisiana estimated the worth of its soft-shell crab industry at only $1,000,000, causing many industry participants to leave the business. To reverse this trend, Louisiana Sea Grant developed flow-through and recirculation systems for land-based operations rather than the float cars traditionally used by the industry. This resulted in improved water conditions and higher production, so that by 1985, the industry was valued at $4-7 million with production coming equally from float car and modified, controlled water quality systems. A 1991 survey in Louisiana shows the value of the soft-shell crab industry to be $6-8.5 million with over 75% of the production coming from the new Sea Grant-developed technology.

The soft-shell crab industry now extends from New Jersey to Texas accompanied by an economic impact in tens of millions of dollars and by the creation of new jobs in businesses that include both the crab industry as well as the packaging and marketing industries. Exports of soft-shell crabs, primarily to Japan, have reached $2 million annually, and the technology has spun off new industries such as soft-shell crawfish

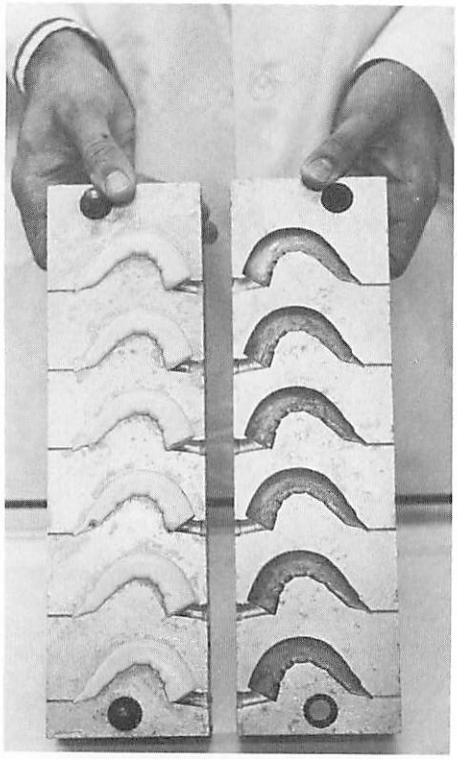


A Sea Grant MAS specialist and a soft-shell crab producer check the shedding tank for peelers. This 16-tank closed recirculating shedding facility is typical of the modern soft-shell crab operations developed through Sea Grant research and outreach efforts.
Photo: Virginia Sea Grant/Gloria Walters





Sea Grant research and technology transfer have created growing industries in hybrid striped bass (top) and hard shell clams (bottom; numbers identify individual broodstock for genetic studies).
Photos: South Carolina Sea Grant



Plentiful domestic fish species are minced, enhanced, flavored, and then molded to produce imitation seafood such as in this "shrimp" mold. Photo: North Carolina Sea Grant.

production which could grow to the size of the soft-shell crab industry.

Surimi

Originated by the Japanese, surimi is a bland, white form of minced fish used to produce imitation seafood. Sea Grant's interest in surimi began many years ago. Researchers adapted the Japanese technology so American processors could use plentiful domestic fish species to make surimi. Researchers also refined methods of gelling surimi and investigated the role other ingredients play in the taste, smell, and texture of surimi-based foods.

Today, business is booming for surimi and surimi-based products. In an interesting turn of events, the United States began exporting surimi to Japan in 1985. Ship-based production of surimi from Alaska pollock has increased 37-fold from 4,000 metric tons in 1986 to over 150,000 metric tons in 1991. In 1989, the production of surimi in the U.S. stood at a dollar value of $466 million coming from 18 offshore vessel plants and five onshore plants. Each offshore vessel plant may employ from 30-50 people and the onshore facilities employ 50-100 people each. Projections of dollar value for 1993 are $600 million, and this is probably an underestimate given the recent increase in the product's value.

Chitin and Chitosan

Since its first investment two decades ago, Sea Grant's marine chemistry program has discovered and isolated scores of novel chemical substances from marine organisms. Two of these substances, made from shrimp and crab shells, are the marine polymer chitin and its derivative chitosan.

Disposing of seafood waste is a massive and growing problem, so the goal for Sea Grant scientists was to find commercial uses for one form of this waste, shrimp and crab shell. Researchers discovered that antifungal properties of chitosan could boost crop yields, so they developed an inexpensive chitosan treatment for wheat seed to protect the crop against soil fungus.

Field trials on the treated wheat showed 10-30 percent higher crop yield with better protein content. With high protein wheat drawing a premium price of 3.5 cents per bushel for each 0.1 percent increase in protein, this could amount to increased income to the farmer of 17.5-35 cents per bushel for a treatment that costs less than two cents per bushel. As a result of the favorable economics, an estimated 300,000 acres of wheat were planted in 1991 using chitosan treated seed.

Although agricultural uses could provide one of the largest returns from Sea Grant's investment in chitosan research, other industrial uses are expected to grow rapidly. For example, scientists found applications for this versatile substance to cleanse polluted waters. Chitosan acts as a flocculant in wastewater treatment to remove suspended matter, such as algae or toxic substances, from effluent streams and can be used in filters and membranes for water clarification applications.

Chitin-related patents issued to Sea Grant researchers have been licensed for medical applications such as for making soluble, non-allergenic sutures and for dressings to promote the healing of burns and wounds. (A violin maker even uses it to improve musical sound quality.) Independent industry analysts say that, by the year 2000, the world market for chitin-based agricultural products, cosmetics, food and beverages will top $700 million annually. Health care uses alone are expected to account for $500 million in sales.

Sea Grant's success in expanding the Great Lakes charter boat industry has had a significant economic impact on that region. Photo: Michigan Sea Grant

Charter Boat Businesses

Tourism and recreation are central to the economy of a growing number of coastal communities. Sea Grant's success in expanding the charter boat industry of the Great Lakes has had a significant economic impact on that region. In the 1960s and 1970s, the ecological health of the Great Lakes was poor. Lake water quality had declined because of erosion and industrial and agricultural chemical runoff, and coastal wetlands, where fish feed and spawn, had deteriorated. Those conditions plus overfishing by commercial concerns caused the decline of the Great Lakes fishery.

As a first step in resurrecting the Great Lakes fishery which is so important to the charter boat industry, Sea Grant scientists began research and educational programs aimed at improving water quality and stopping the input of toxics. Then, with the help of Sea Grant researchers, state and federal agencies instituted management practices to enhance wild fish stocks. The rehabilitation was a success. Sportfishermen flocked to the Great Lakes bringing with them money to pay for goods and services which fueled the creation of new jobs.

To meet this new demand, Sea Grant outreach staff offered training to charter boat operators in business management, hospitality, safety, and biology of the resource. Sea Grant researchers analyzed the growth prospects for charter fishing, the factors affecting angler satisfaction, the perceptions of toxic contaminants in fish, and the best ways to communicate health risks to customers. Beyond the technical help, Sea Grant also convinced charter boat operators to view their interests collectively, as an industry. With this encouragement, charter boat operators formed an association and now have a voice in Great Lakes resource protection and water quality improvement issues.

The Great Lakes charter fleet has grown from several hundred boats in 1975 to over 3,000 today. Charter revenues are now over $35 million annually; the investment in boats and equipment is nearly $120 million. Due largely to Sea Grant's work, the Great Lakes charter boat industry and the Great Lakes themselves are flourishing.

Outlook

A Sea Grant goal is to create new industries, jobs, and products through the wise and equitable use of marine and coastal resources. Sea Grant, through its National Review Panel which is advisory to the Secretary of Commerce, currently is engaged in structuring a "Sea Grant Business Opportunity" initiative. It will delineate Sea Grant's strategy for working more closely with the business community in three areas: research on critical marine technologies, development of human capital, and improvement of the business environment.

The "Sea Grant Business Opportunity" initiative builds on Sea Grant's success as an economic development vehicle in coastal areas and as a source of marine technological innovation. With sufficient funding to make the needed investment, Sea Grant will be able to meet the challenge of putting Americans to work by creating industries and products.

Recently, a panel of the National Academy of Sciences recommended that Congress create a Civilian Technology Corporation to speed commercialization of new products and processes. The report also called for creation of an Industrial Extension Service to speed up technology transfer. The nation already offers such a program for the marine sector through the National Sea Grant College Program.

Sea Grant: Improving Commercial Competitiveness

Richard Kolf
and Francis Schuler

Commercial competitiveness is the degree to which a nation produces goods and services that compete in global markets while raising the standard of living of its citizens. A Presidential Commission on Industrial Competitiveness concluded that to realize national goals for economic security and a rising standard of living, it is essential for both the public and private sectors to base economic decisions on competitive consequences.

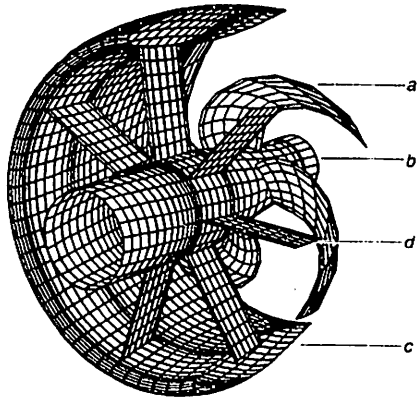
A recent report issued jointly by the National Academy of Science and the National Academy of Engineering, "The Government Role in Science and Technology," considered how to structure the federal research and development role. The Academies concluded that federal support must go beyond basic R&D funding. The argument is made on economic grounds and also because government programs have been successful in stimulating civil technology development and commercialization. The report concluded that the United States needs a better balance in civilian technology policy, one that considers the importance of diffusing best-practice information and adoption of new technology.

To compete in the global marketplace, business and industry need a competitive edge. A competitive edge translates into growth and new jobs. The National Sea Grant College Program has provided that edge through its research and technology transfer programs. Sea Grant, based on the land-grant model, has made substantial contributions of this type across many marine industries—aquaculture, commercial fisheries, water-borne transportation, marine biotechnology, and coastal tourism.

Engineering

Hydrodynamics and Hull Design

Recreational boat sales in 1991 were over $4 billion in the United States with imports accounting for approximately one-fourth of the total. This industry is very competitive. However, present designs are made on the basis of experience, ignoring advances in modern naval architecture. Design deficiencies include rough-riding qualities in choppy seas and dangers from capsizing during high speed turns.



A computer-generated image of a propeller, showing: (a) blades, (b) hub (c) duct, and (d) stators.
Diagram: MIT Sea Grant

Sea Grant has long supported work at all major naval architecture schools. Recently, Michigan Sea Grant studies have focused on improving hull design for the recreational boating industry and on developing Computer Aided Design and Manufacturing (CAD/CAM) systems that are applicable to industry in general. MIT Sea Grant has also developed CAD/CAM systems which are being adopted by the U.S. Navy and several major industries. These systems provide major improvements in design efficiency and are improving the ease and precision of the design process which will help make the U.S shipbuilding industry more competitive. Sea Grant's first phase efforts in using CAD/CAM systems were directed at propeller design and have been successful.

Extending the Life of Marine Structures

California Sea Grant scientists have developed methods for assessing the integrity and remaining useful life of marine structures. These methods are

based on risk–decision analysis and advances in artificial intelligence which combines computer hardware and software systems to execute tasks usually performed by humans. Regulatory agencies will be able to use these methods to evaluate the safety of offshore drilling and production platforms which provide one–third of domestic gas and petroleum.

There are 6,000 platforms in U.S. waters; 35 of these structures are off the California coast. Some of the structures, which were designed for 20 years of useful life, are still in operation after 30, even 40, years. These aging structures are prohibitively expensive to replace—as much as $1 billion apiece.

The California Sea Grant researchers developed a screening process that sorts platforms into three categories on the basis of structural integrity and failure consequences. Healthy platforms can be quickly identified. This is important because a detailed inspection can cost more than $1 million. Other platforms are classified as "marginal" or "unfit for service," and must then undergo additional evaluation to determine the feasibility of maintaining or upgrading the safety level.

A number of major oil companies provided essential information for this project, and the screening process is already being used by the California State Lands Commission and the California Coastal Commission. It is also being applied to platforms in Cook Inlet, Alaska, and offshore New Zealand.

Trade

Science Helps Develop Export Markets for Seafood Products

Seafood products are a major contributor to the U.S. trade deficit. In 1991, the nation imported $5.7 billion and exported only $3.0 billion of fishery products, leaving a trade deficit of $2.7 billion. Sea Grant through its aquaculture, seafood technology, and fishery development programs can reverse this trend. Through research and technology transfer, Sea Grant has had success in working with fishing and seafood processing industries to retain domestic markets and penetrate foreign markets.

Workers process sea urchins to remove the roe, which is exported fresh by air freight to Japan.
Photo: Los Angeles Times

In an effort to penetrate foreign markets, Sea Grant fishery scientists and seafood technology outreach specialists, along with NOAA's National Marine Fisheries Service, are working to develop a sustainable sea urchin fishery. Several sea urchin species are common in intertidal and shallow rocky habitats along the Pacific Coast. These urchins are processed to remove the roe, which is exported fresh by air freight to Japan and sold as "uni," a prized delicacy. The export value to Japan is estimated to exceed $25 million annually.

The soft–shell crab, high in demand and low in natural supply, is the familiar blue crab right after it has molted. Watermen along the Atlantic and Gulf Coasts have long known how to recognize imminent "peelers," but have not had much success in holding the crabs alive until they shed. Sea Grant's successful work from New Jersey to Texas to develop soft–shell crab closed–system shedding tanks has led to a $40 million domestic market and a developing export market now valued at $2 million annually. Sea Grant advanced an industry that has grown during the past decade from almost nothing to one that provides 4,000 jobs in 12 states.

Commercial Products From Fish Genetics Research

Genetic fish research has paid off not only for aquaculture and marine biotechnology commercial development, but also for advancing fundamental scientific research investigating molecular interactions that occur during vertebrate development.

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Natural stocks of oysters in the Pacific Northwest declined to very low levels, thus depressing the job opportunities in that traditional industry. As a result, in 1984, Washington Sea Grant initiated support to develop a unique tool in oyster culturing to create the triploid oyster. This work was designed to build on previous Sea Grant research at the University of Maine.

Triploid oysters are unique because they have an extra set of chromosomes and are essentially sexually sterile. Consequently, they remain firm, meaty, and sweet during the summer months when normal oysters spawn and become unpalatable and, therefore, unmarketable. Another positive characteristic of triploid oysters is that they generally grow faster and larger than the conventional diploid oyster, creating the possibility for higher yields.

Recognizing the potential such research had for enhancing the West Coast oyster industry, Washington Sea Grant first provided small-level support and later full-scale project support which produced an easy-to-use chemical technique for creating triploid oysters. With the cooperation and support of Washington Sea Grant, the Pacific Oyster Growers Association, and the Coast Oyster Company, this technique has been successfully applied on a commercial scale. Seeing the need to make the chemical technique for developing triploid oysters available to a broader sector of the industry, Washington Sea Grant sponsored the publication and production of both a "how-to-make-triploids" manual and an instructional video. Development of triploid oysters and subsequent Sea Grant transfer of technology to shellfish companies have resulted in current production of $2 million per year, creating scores of new jobs. Now that triploid oysters are coming into widespread commercial production on the West Coast, the oyster industry can operate year-round with good potential for export to Asian markets.

The numerous, large, transparent, and externally fertilized eggs of many fish species make them ideal for genetic manipulation, especially for producing transgenic animals (i.e. species that have had foreign genes introduced). Sea Grant scientists from Maryland, North Carolina, Washington, and Minnesota have cooperated in this program. Their research results demonstrate the feasibility of producing fast-growing transgenic fish using carp and catfish as biological models. Now the possibility exists for using this technology to introduce desirable traits in many commercially cultured species such as striped bass and the eastern oyster.

Sea Grant scientists, while working to develop transgenic fish, discovered that researchers using expensive mammal embryos for genetics research should be able to get the same information by using fertilized fish eggs. The cost of medical research to cure and prevent human genetic diseases—such as hemophilia, multiple sclerosis, and some forms of cancer—could drop dramatically as a result of these findings.

The Beta-Actin gene in carp was found to be nearly identical to the similar gene in mice in terms of how genetic material is organized and regulated. This gene is present in all vertebrates and is responsible for maintaining cell structure. The finding means that genetics researchers could use fertilized transgenic fish eggs that cost only about $3 each instead of transgenic mice embryos that can cost $300 to $3,000 each. Fish eggs are much simpler to use in genetics research because they are easier to store, move, and grow than are fertilized mammal eggs. Using fertilized fish eggs for research could also reduce pressure on scientists from animal rights groups asking for biomedical genetics research that does not use mammals.

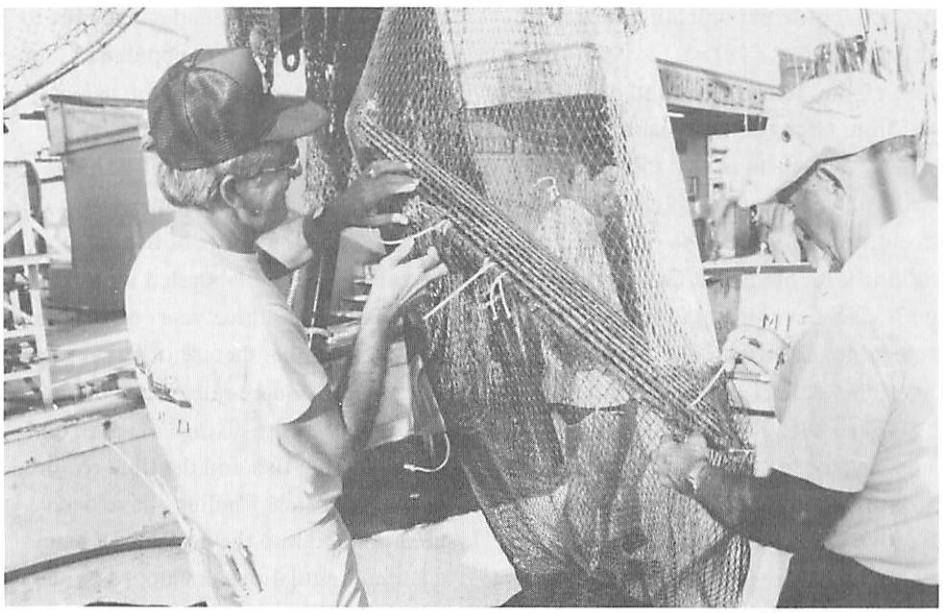
Outlook

Sea Grant will continue to focus on improving commercial competitiveness. A national collegium of industries is being developed to evaluate the potential commercial utility of fundamental Sea Grant research and to suggest the most fruitful directions for continued and collaborative work. For example, advances in microfabrication technology are expected to provide the basis for significant breakthroughs in various sensor designs, reducing the size and power requirements. This will give a stimulus to development of various robotic devices which will benefit science and industry.

Benefits which have been derived for marine industry will be made available to the U.S. industry in general. For example, the computer-aided design work which is benefiting shipbuilding industries is of much more general utility because it is adaptable to design of any complex sculptured surfaces. These design codes will be made available to other significant large industries. Other Sea Grant work which is poised to make a real contribution in the near future includes the application of artificial intelligence to closed system intensive aquaculture systems. Studies have shown that such intensive closed systems are necessary to make the U.S. aquaculture industry competitive.

Sea Grant: Helping Manage and Enhance Natural Resources

Eugene Fritz
and John Ahrens



An outreach specialist helps a commercial fisherman install one of the TED designs certified for use as a result of Sea Grant-conducted tests.
Photo: Georgia Sea Grant

A recent NOAA inventory identified 260,000 square miles of land—the size of Texas—that drain into estuaries and bays. With more than half of the total U.S. population now living within 50 miles of the coast, these estuarine areas are increasingly vulnerable to man-made stress. Yet, scientists know little regarding the amount and types of estuarine environments required to maintain a high-quality life for both man and the living resources inhabiting estuaries.

Responding to the national need for improved management of coastal resources, NOAA, through its National Sea Grant College Program, has developed interinstitutional and interdisciplinary programs in fisheries, ecology, and coastal processes. These programs focus on understanding the natural resources of the coastal and open ocean, estuaries and the coastline itself.

Costs associated with physical impacts, such as property damage caused by coastal erosion, storm surge and subsidence, are conservatively estimated at $1.57 billion. In 1989 alone, over $750 million were spent on beach nourishment projects. Before any headway can be made in reducing these losses and expenditures, coastal managers must have answers to questions about the physical processes at work in nearshore coastal waters. Sea Grant can help provide those answers.

Natural resources include diverse groups of living resources such as shell and fin fisheries and non-living, nonrenewable resources such as minerals, oil or gas, and beaches and coasts. Many of the nation's fin and shellfish resources declined during the 1980s. In its 1991 report on the status of U.S. living marine resources, the National Marine Fisheries Service (NMFS) identified 65 seriously stressed fisheries. Declines among some of these were so great that moratoria were placed on all fishing of striped bass along the Atlantic Coast and of redfish in the Gulf of Mexico.

Reasons for these declines range from groundfish overexploitation to shellfish habitat degradation. Whatever the causes, the long-term health of the nation's fisheries depends on restoring depleted stocks and species. But this restoration requires management actions based upon a thorough understanding of the factors controlling fish productivity.

Conservation Engineering/ Bycatch

At a recent commercial fishing industry-sponsored workshop, industry leaders, for the first time, acknowledged the existence of serious problems caused by bycatch, the unintentional part of any fisheries catch. They also recognized that growing public concern about waste

in some fisheries could threaten the existence of commercial fishing.

Recognizing these serious bycatch problems as early as the mid 1980s, Sea Grant shifted its research from improving fishery gear efficiency to reducing bycatch and joint catch. In cooperation with NMFS, Sea Grant programs in states from North Carolina to Texas took a very active role in evaluating turtle excluder devices (TEDs).

Sea Grant researchers and outreach staff from Georgia, Louisiana, and Texas also took an active role in identifying alternatives to NMFS-developed TEDs. Georgia outreach staff working with other Sea Grant programs and NMFS developed the testing protocol for certifying alternative TEDs. Out of this collaboration, five alternative TEDs have been identified so far, and three have been certified. The alternative TEDs are not only equally or more effective in excluding endangered turtles but also are safer for fishermen to use than earlier models.

To meet certification standards as prescribed by federal law, outreach staff have assisted owners of approximately 6,000 vessels in using the Sea Grant identified and tested TEDs. To facilitate the adoption of these new devices by fishermen, outreach staff have distributed specific design and installation instructions, held workshops on proper installation, and given on-board demonstrations.

More recently, the focus of Sea Grant teams in the Southeast and Gulf has expanded to include developing and testing bycatch reduction devices (BRDs) for the regional shrimp fisheries. Further north, Sea Grant scientists and outreach specialists from Maine to Rhode Island have supported studies instrumental in introducing fish excluders for use in northern shrimp trawls and for developing lobster trap escape doors, devices whose use has either been adopted voluntarily or through regulation in Maine, Massachusetts, and Rhode Island.

Sea Grant is now concentrating on improving the selectivity features of commercial fishing gear. One of these investigations, supported by Oregon and Washington Sea Grant, incorporates population dynamics and economics to estimate the long-term population and economic consequences from using various mesh sizes and shapes. Also supported by NMFS and the fishing industry, this study is unique. An unprecedented number of fishing vessels—120—collaborated with the scientists. After three years of field tests, it was found that the use of larger mesh sizes and of square rather than diamond mesh reduced the discard of small and unmarketable fish and the time required to sort the catch. Findings have been incorporated into the groundfish management regulations developed by the Northwest Fisheries Management Council. State and federal management agencies and the fishing industry agree that such studies are needed for many fisheries in many environments.

Blue Crab

During the past decade, blue crab fisheries along the East and Gulf Coasts have grown to become one of the largest fisheries in state territorial waters. In 1990, dockside value of blue crab was $77.4 million. Since many coastal fin and shellfish stocks have declined, a large number of fishermen have shifted from traditional fisheries to crabs. Today, the blue crab fishery is the mainstay of the former Chesapeake Bay oyster and clam fishing fleets. The growing economic and social importance of the crab fishery has led fisheries managers to recognize the need to develop management strategies and practices to maintain healthy crab populations.

The key to effective fisheries management schemes is to reduce uncertainty caused by natural variability among fin and shellfish populations. Even though catches of blue crab have increased steadily over the past decade, some years the catch is better than others. Sea Grant has focused 12 years of research on identifying and understanding these causes of fluctuation.

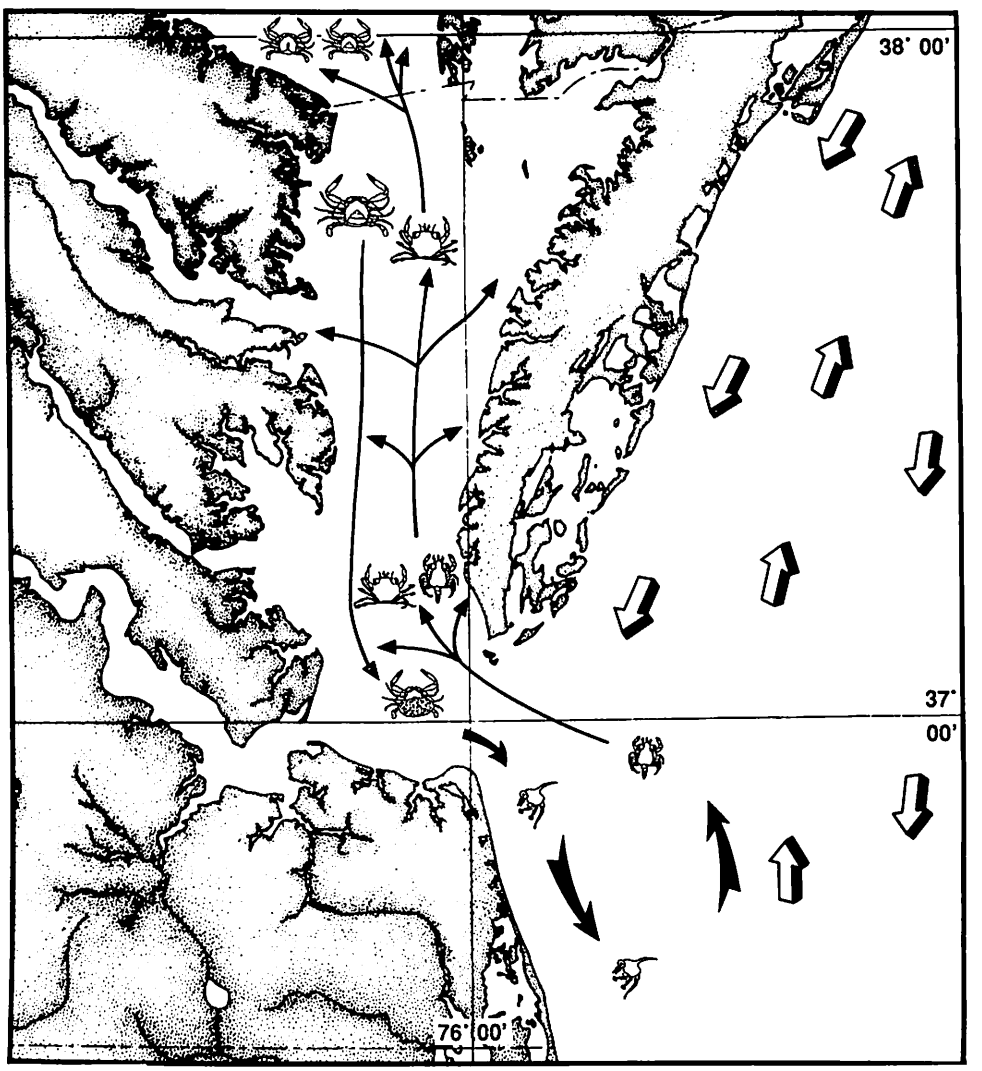
Sea Grant's first blue crab biology efforts focused on the dynamics of early life stages. Sea Grant researchers from Delaware, Maryland, and Virginia discovered adult crabs migrate to the mouths of estuaries to spawn in late spring. The crab eggs then drift offshore where they hatch and the larval stages remain. In the fall, the final larval stages reenter the estuary and metamorphose into juvenile crabs. This information is not only scientifically important, but also helps managers develop practices to protect concentrated spawning populations. Further studies showed that the yearly variations of blue crab population abundance in the Chesapeake and Delaware Bays was linked to events when the late larval stage migrated back into the estuaries and/or shortly after the juveniles settled there.

Following up on these studies, Mississippi and Louisiana Sea Grant scientists showed that though blue crabs in the Gulf of Mexico had similar life cycles, there were substantial differences, particularly with respect to spawning period and settlement sites. Obviously, management practices developed for one area could not be adopted unmodified for use in other areas.

These and other Sea Grant findings led to formation of an informal network of researchers from New York to Texas whose aim is to identify factors control-

ling blue crab populations throughout their range in the United States. Working with support from their local Sea Grant program, this network of over 20 scientists developed a protocol for determining when larvae enter the estuaries and for identifying the physical processes and/or events that facilitate this phenomenon. They also developed a series of independent experiments to identify the life stage(s) most important in establishing year-class strength. The strong links developed by these scientists with state management agencies and fisheries managers promise research results will be quickly adopted.

This body of research has led to at least two major spin-offs. Building on the science developed in these blue crab studies, Pacific Coast crustacean biologists studying the Dungeness crab have identified similar factors that appear to be influencing the population abundance of this economically important species. Recognizing the important role physical oceanography plays in the processes influencing blue crab recruitment was instrumental in developing NOAA's new fisheries oceanography activities. The findings of the early blue crab studies led to the Fisheries Oceanography Cooperative Investigation (FOCI) of the Gulf of Alaska pollock populations. Those studies, in turn, led to NOAA's Recruitment Fisheries Oceanography Program Development Plan which subsequently led to the Coastal Fisheries Ecosystem Element in NOAA's Coastal Ocean Program.



Sea Grant researchers learned that adult crabs migrate to the mouths of estuaries to spawn in late spring. The crab eggs drift offshore to hatch and the larval stages remain. In the fall, the final larval stages reenter the estuary and metamorphose into juvenile crabs. (White block arrows represent coastal currents. Black arrows represent crab migration path.)
Diagram: Virginia Sea Grant

Erosion Control

Sea Grant, recognizing the dilemma posed by coastal erosion, focuses research on the coastal processes that lead to erosion to gain a fundamental understanding of coastal sediment transport. Understanding has been gained through both field and laboratory studies coupled with theoretical investigations.

Sea Grant created and supported the Nearshore Sediment Transport Study (NSTS), the most extensive coastal sediment dynamics field study ever conducted to that point in time. NSTS included detailed observations of waves and currents and the associated sediment movement at two West Coast beaches and one East Coast beach. Important findings from NSTS have led to improvements in the understanding of surf zone hydrodynamics, better quantification of the dependence of transport rates on sediment size, and detailed information on the distribution of transport across the surf zone. Although the field work for NSTS was completed in 1982, this study will provide researchers with valuable information and insight for a long time because of the quantity and complexity of the data collected. To complement field studies, there have been laboratory investigations of sediment movement under waves and wave conditions in the surf zone. From these field and laboratory studies, important conceptual and numerical models have been developed and calibrated. The conceptual models provide clearer physical insight into the process of coastal erosion.

Numerical models are being used by managers to estimate beach and dune erosion for various storm wave- and water-level conditions. Numerical models are also used to explore "what if" scenarios that can evaluate the cost effectiveness of different shoreline protection strategies.

On a recent project in Broward County, Florida, numerical models were used extensively to help design and evaluate the effectiveness of beach renourishment. Sea Grant provided a substantial amount of the support to develop these models. In 1991 slightly over one million cubic yards of sand were placed along a 5.3 mile stretch of beach at a cost of about $6.4 million. This project is estimated to provide over $3.7 million in annual recreational and storm protection benefits. During the project, a large hook groin and 20 smaller groins were removed. The groins, probably never effective as erosion control, had deteriorated over the years to the point that they were a hazard to beach users.

To control erosion, Sea Grant research is causing managers to make a gradual shift away from using hard structures, such as revetments, to using "soft" strategies such as beach nourishment. The soft solution has several advantages over the traditional coastal armoring approach: it is natural and attractive, it allows for recreational use of the shoreline, and it makes a significant contribution to the protection of the hinterland.

In a shift to "soft" strategies to control beach erosion, a project by Sea Grant uses parachutes to absorb wave action and allow smooth cordgrass to take hold.
Photo: Texas Sea Grant

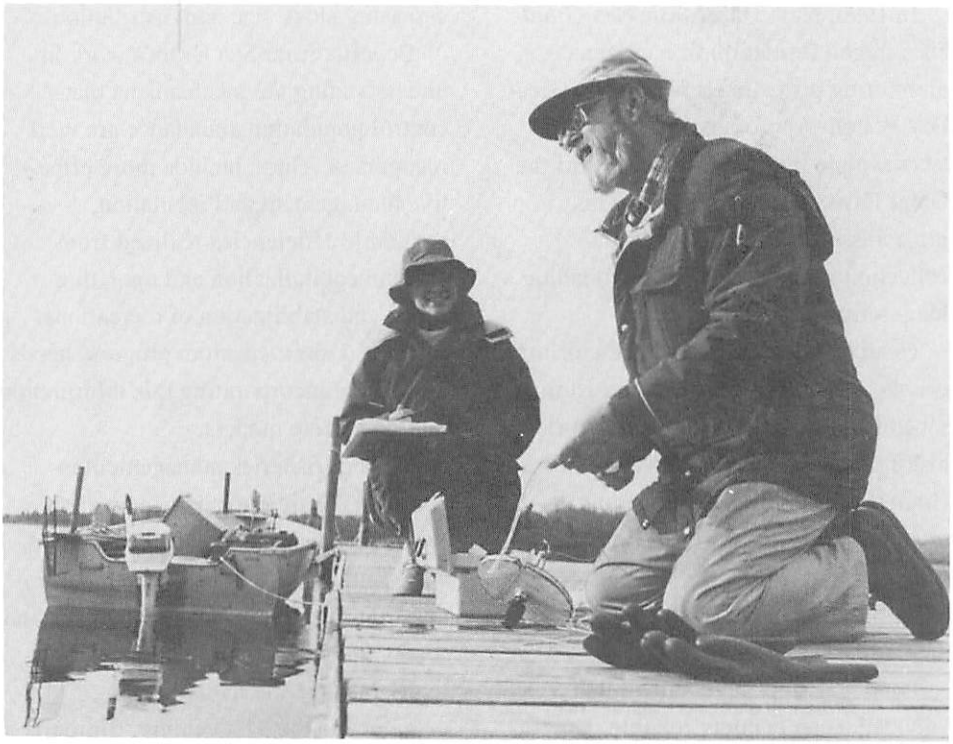
Pond Watchers

New England has a number of shallow estuaries that lie behind barrier beaches. Locally these coastal lagoons are called salt ponds, although the salinity varies widely from pond to pond and over time from almost fresh water to almost open ocean salinities.

In the past, the salt ponds were very productive ecosystems. Today, the ponds support aquaculture, water skiing, commercial fishing, clamming, sport fishing, swimming, bird watching, recreational boating and marinas. Unfortunately, increasing residential and commercial development within the watershed of the ponds has caused water quality in some ponds to deteriorate.

In response to public concern about salt pond water quality, a major five-year, multidisciplinary research effort was launched at the University of Rhode Island with funding provided by NOAA Sea Grant, NOAA Coastal Zone Management, the Environmental Protection Agency (EPA), and local towns in Rhode Island. The purpose of the research was to clarify the major issues and natural processes that are characteristic of salt ponds: erosion of the beaches and sedimentation in the ponds, eutrophication and sources of nutrients from within the watershed, limited flushing or tidal circulation, declining fisheries and waterfowl, and economic costs of outdated land use policies.

The research verified that human activities were causing much of the ecological degradation in the salt ponds. Septic systems located in unsuitable sandy soils were often overloaded or malfunctioned, contaminating groundwater with bacteria and high nitrogen levels. The contaminated groundwater entered the salt ponds where it harmed shellfish habitat, promoted algae blooms, and depleted oxygen in the water. Excess nitrogen was also entering the pond system from fertilizers, stormwater runoff, and animal wastes. In addition, shore inlets had upset estuarine ecology by accelerating sedimentation and altering the circulation patterns and salinity mixtures important to key fish and shellfish species. Volunteers made significant contributions to this early salt pond research. They kept waterfowl counts, made field observations that helped define the nature of the water quality problems, and recorded fishing activity.



Pond watcher volunteers collect water samples and also take physical measurements such as water color, temperature, and light penetration.
Photo: Rhode Island Sea Grant.

As a direct result of this earlier research effort, Rhode Island Sea Grant in 1985 organized 45 volunteers known as "pond watchers" to measure water quality parameters in seven salt ponds. Their goal was to document the current state of pond water quality and to provide the state government with the data necessary to enact management plans and development policies which would not compromise these valuable natural assets. The important role of the Rhode Island Pond Watchers in documenting water quality problems and contributing to solutions is extensively acknowledged by EPA in a 1988 publication *Saving Bays and Estuaries: A Handbook of Tactics.*

Pond watching quickly spread to other Northeast states. In 1987, Woods Hole Sea Grant helped form the Falmouth Pond Watchers organization. Initially only three ponds were involved but now five ponds are being observed and plans are afoot to monitor West Falmouth Harbor. The Falmouth effort has recently been cited as an innovative model by Renew America, a national clearinghouse for environmental information. At the same time, EPA's National Estuary Program at Buzzards Bay in Massachusetts is using the Falmouth Pond Watcher project as the model for initiating a bay-wide citizens monitoring effort.

In 1990, New Hampshire Sea Grant encouraged formation of a citizens monitoring program known as the Great Bay Watch. Approximately 40 volunteers sample the estuarine waters of the Great Bay twice each month. This project is in its third year of data collection with the goal of establishing a long-term data base.

Nearby in Maine, high fecal coliform counts in estuaries forced the closure of several shellfish beds that had no prior history of problems. With Maine Sea Grant support, volunteers began sampling estuarine areas to determine fecal coliform counts, identify sources of contamination, and monitor potential input areas.

Pond watchers have shown that volunteers can conduct reliable data collection studies over a long time period which include water quality measurements beyond simple parameters such as pH or turbidity. An increase in the number of volunteers has permitted even more ponds to be monitored and data to be collected year round instead of just during the summer. The large number of volunteers also makes it possible to sample different ponds simultaneously, under the same conditions of weather and tide, enabling invaluable pond-to-pond comparisons. Data sets of this type have unique scientific value that would be essentially impossible to obtain without volunteers because of the high cost of such labor intensive research.

Outlook

Sea Grant research has improved understanding of the underlying causes of fish population variability, but more work needs to be done. Sea Grant's future objectives in this area are to develop ecologically-based management schemes, cost-effective indexes of abundance, and better methods for assessing stock size and distribution.

Benefits from Sea Grant's work in understanding the mechanisms that control population abundance are well recognized. These include more effective management and regulation, economic efficiencies realized from rational capitalization and operating costs, and stabilization of recreational markets. However, more progress needs to made in incorporating this information into predictive models.

Modern fisheries management is complex. There are human as well as technical issues to consider. Sea Grant will continue providing educational opportunities to resource economists and social anthropologists needed to effectively manage the nation's living resources in the 21st century. Similarly, Sea Grant will continue to play a crucial role in introducing economics and social anthropology into the traditional biologically-oriented fisheries curricula.

There is a growing need for continued Sea Grant participation in understanding the processes influencing the evolution of the nation's shoreline. The coastal population is increasing and sea level is expected to rise. The importance of informed coastal zone management is demonstrated by the loss of life, property damage, flooding, and erosion associated with every northeaster and hurricane that crosses the U.S. coast. Sea Grant will seek to give managers more tools to develop effective strategies to cope with coastal zones under increasing stress.

One particularly promising approach under development to improve understanding of coastal sediment movement uses a Lagrangian model (a technique for measuring sediment movement by following the motion of a particle) which combines both the alongshore and cross-shore sediment transport. The Lagrangian approach to coastal sediment transport represents a more physically realistic description of particle motion which should produce better estimates of shoreline evolution.

More than ever, pressures are mounting from environmental groups concerned with fish and marine mammal interactions, and from others concerned with the catch of undersized or "brood" individuals. Sea Grant will help fisheries managers develop methods to minimize the capture of untargeted species, but at the same time oversee the general well-being of the environment, non-harvested aquatic species, and the fishing industry.

Sea Grant: Ensuring Public Health and Safety

David Attaway
and Richard Kolf

Uses of marine and coastal resources are multiplying and hazards accompanying those uses are increasing. Health-conscious Americans are consuming more seafood and at the same time public concern about seafood safety is growing. Ocean shipping is at an all-time high, so shipping lanes must be kept safe for increased ocean traffic. Coastal construction is skyrocketing putting more people and property in the paths of hurricanes.

One of the mandates of the National Sea Grant College Program is to focus academic expertise on research and education to ensure public and industrial safety as coastal resources are used and developed. From its beginning in 1968, Sea Grant has applied scientific and technological know-how to seafood industry problems. And over the years, it has developed a cadre of academic scientists in coastal states that has proven highly effective in addressing problems for the seafood industry and consumers. Seafood quality and safety are issues of special importance.

Several Sea Grant institutions have developed cutting-edge programs in coastal and ocean engineering that are enhancing safe use of the ocean for transportation and commercial development. Sea Grant's outreach programs provide effective dialogue with the public on these issues.

Photo: Sea Grant programs work as a network to focus outreach and research on minimizing hurricane damage such as that pictured here.
Photo: The Tropic Times

Hurricane Preparedness and Recovery

Sea Grant programs along the Southeast and Gulf Coast as well as in Puerto Rico focus outreach and research efforts on minimizing damage, injuries, and deaths caused from hurricanes. To increase effectiveness and efficiency, these programs work as a network sharing information with and assisting NOAA's National Weather Service and other federal, state, and local agencies in preparing the public for emergencies. Several of the programs have assisted governmental agencies in developing evacuation routes from coastal areas. Printed materials, radio, television, and workshops are used to publicize these routes.

Sea Grant has prepared instructions for coastal residents on what to do at home and what items of food, clothing, and equipment to assemble in preparing either to weather a hurricane or to evacuate to a safer location. These instructions, in the form of checklists, are distributed in leaflets and brochures

and are communicated by mass media. To prepare the public for Hurricane Hugo, South Carolina Sea Grant compiled one of these emergency checklists. Broadcast by local television stations and distributed in grocery stores, the checklist helped minimize storm damage and prevent injury. When Hurricane Bob threatened New England, South Carolina Sea Grant supplied northeast Sea Grant programs from Connecticut to Maine with the checklist, and they used it effectively.

In the aftermath of Hugo, South Carolina Sea Grant with NOAA's National Ocean Service (NOS) organized and conducted a workshop to evaluate response to the hurricane and to identify actions to improve planning for and response to future hurricanes. Workshop participants recognized that better coordination among governmental entities and more accurate data are needed in times of impending emergency. The participants recommended that agencies coordinate data gathering and dissemination, use compatible systems for data management, and develop a common system of geodetic controls and measurements. They also recommended that the Federal Emergency Management Agency's flood zone maps be improved and that participation by state and local governments in coordinated disaster management planning be required as a condition for federal funding.

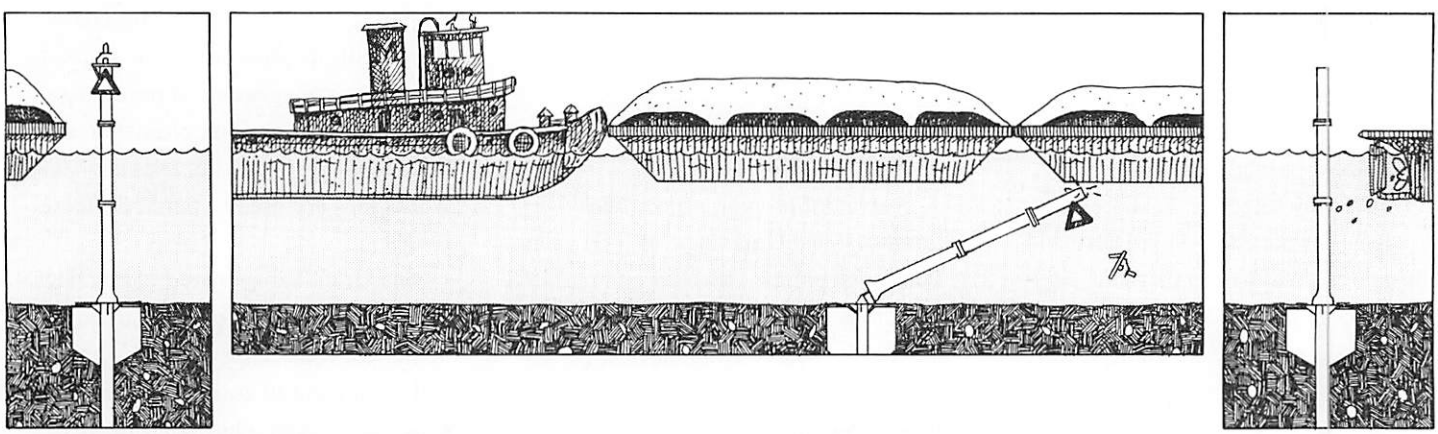
After Hurricane Andrew hit southern Florida, national attention was focused on the devastated inland housing tracts. Florida Sea Grant, however, focused its attention on the waterfront which is so important to southern Florida's economy. Sea Grant along with NOAA/NOS and the Florida Marine Patrol immediately began developing a protocol for removing the hundreds of hurricane-damaged and sunken vessels which were causing navigational, environmental, and health hazards. Also, realizing that jobs were at stake, Sea Grant representatives met with marina and boating industry officials to develop an analysis of economic damage and of recovery options.

To minimize future hurricane damage to homes, South Carolina and North Carolina Sea Grant have developed a computer program that evaluates proposed residential building designs for resistance to wind damage. Now, before construction begins, homeowners can use this program to assess the damage wind might cause to their homes. Other Sea Grant educational programs on how to build protective dunes and on risks from wind and coastal erosion have provided specific and practical information to a spectrum of coastal audiences.

In other approaches to prepare the public for hurricanes, Texas Sea Grant wrote the booklet, *Protecting Your Boat Against Severe Weather*, to provide boat owners a method to test and evaluate emergency plans before a hurricane strikes. Published in English and in Spanish, the booklet is expected to reduce storm-related injuries, deaths, and property damage. To educate the general public about hurricanes, Puerto Rico Sea Grant prepared an effective video "Hurricanes: The Unseen Tragedy."

Collision-Tolerant Navigational Pilings

Ship channels through which precise navigation is required are usually marked with wooden pilings. Ships and barges often collide with and destroy these pilings and are themselves damaged or destroyed. Such destruction leaves navigational channels partially unmarked and creates further danger for

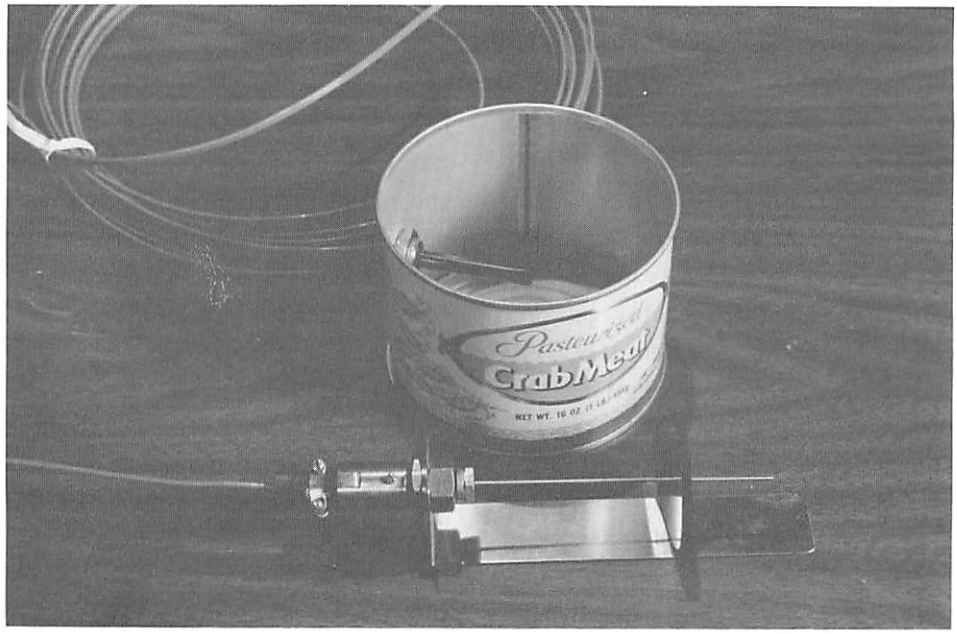


These three drawings demonstrate the workings of a collision-tolerant pile structure (CTPS). In panel one, the CTPS marks a navigational hazard. Panel two shows an off-course tugboat running over the CTPS. The pile bends away from the impact, but the aids to navigation (ATONs) mounted on it can be destroyed, as illustrated here. In the last panel, the CTPS, powered by compression springs and buoyancy, rights itself. The next Coast Guard patrol will note the missing ATONs and arrange to have them replaced.
Diagram: New Hampshire Sea Grant

marine traffic. The U.S. Coast Guard estimates that thousands of these pilings are destroyed annually. Relocation and replacement is a very expensive process.

Recognizing this problem, engineering students and professors at New Hampshire Sea Grant developed a design for collision-tolerant pilings. These low-density pilings have a core of plastic foam. They are hinged at the mud line and have compression springs which return the pilings to an upright position after collision.

Prototypes of this design have been installed in the ship channel near Houston, Texas, and in the harbor of Portsmouth, New Hampshire. The ability to survive harsh weather and serious collisions has convinced the Coast Guard that using the prototype will save millions of dollars a year and will protect ships and barges from accidents, saving life as well as property.



During pasteurization, a thermocouple is inserted into the can's interior to ensure adequate thermal processing.
Photo: Virginia Sea Grant

Seafood Technology

Seafood Pasteurization

Almost all the 130 U.S. plants processing blue crabs in the mid-Atlantic, Southeast, and Gulf Coast states are small and unable to conduct research. As a group, they contribute $50,000,000 annually to the economy. Working as a network, food scientists in Sea Grant programs from Maryland to Texas have been aiding the blue crab industry in upgrading its operations. Of special importance have been efforts to ensure high quality, safe, fresh seafood products including pasteurized crab meat.

When the Food and Drug Administration (FDA) took some improperly pasteurized crab meat off the market, the reputation of crab meat was damaged. Retail and institutional buyers began rejecting it. Producers were alarmed. Industry representatives contacted Sea Grant programs in Georgia, Louisiana, Maryland, North Carolina, and Virginia about the problem. In response, these programs initiated research on crab processing. They worked closely with processors, the National Blue Crab Industry Association (NBCIA), and the FDA to develop industry-supported guidelines for pasteurization. The original NBCIA Blue Crab Pasteurization Standard was completed in 1984 following three years of negotiations.

Sea Grant outreach staff helped develop the standard and continue to provide assistance and training through state and regional workshops designed to train plant operators in proper techniques. Outreach specialists developed computer programs and equipment to standardize pasteurization processes for plants requesting assistance. New container sizes and types have been successfully introduced through Sea Grant assistance. For example, Virginia Sea Grant, in partnership with industry, has developed procedures for using pouches and bags made of clear, flexible plastic for packaging pasteurized crab meat. Flexible plastic packaging offers a number of advantages over the traditional can. Plastic pouches are much cheaper than cans, and energy costs of processing crab meat in pouches is lower. Sea Grant outreach personnel have held workshops to train industry members in the proper procedures for packing and pasteurizing crab meat in these new pouches.

Sea Grant is also aiding in revising NBCIA standards to address additional issues including; determining minimal heating for safe processing; fitting pasteurization standards into the Hazard Analysis and Critical Control Point (HACCP) regulatory framework; keeping adequate records; labeling products; certifying processing conditions; and training and certifying plant operators.

Success with blue crab pasteurization led processors of other types of seafood to adopt the new methods for extending shelf life. Pasteurized products on the market now include shrimp, crawfish, soups, stuffings, and chowders. The new

pasteurization procedures are also used by convenience seafood producers as an effective method to control *Listeria monocytogenes*, a bacterium of recent concern to seafood producers and regulators. The FDA established "zero tolerance" as the ultimate standard for this organism in ready-to-eat seafoods, which means finding a single organism in a product disqualifies it for sale.

Because complete control of micro-organisms in a processing facility through sanitation alone is almost impossible, pasteurization appears to be the most promising solution to this problem. Standard procedures previously developed by Sea Grant are effective in eliminating this pathogen. To facilitate the adoption of its recommended pasteurization process, Sea Grant has produced two video training tapes, a users' manual, and a computer program to help processing plant personnel determine safe processing parameters. Firms using the Sea Grant procedures have reported success in adhering to safety regulations.

However, because size of containers and type of packaging materials are changing rapidly, the Sea Grant network has an ongoing program to aid the industry in determining processing conditions that will result in safe products.

Molecular Assays for Seafood Safety

Many bacteria and viruses are capable of contaminating seafood. Some are native to marine environments, others come from sewage. Contaminated seafood can make people sick, or in rare cases, kill them. Because of the need to move seafood quickly through commercial channels, fast, cheap, and reliable tests for safety are needed. Some traditional methods take days to yield results. Thus, Sea Grant investigators have taken a variety of approaches to make testing more rapid.

Eating seafood contaminated with the cholera bacterium can cause an intestinal infection. Cholera claims up to 50 lives a year in the U.S. and many more in underdeveloped countries. Because the organism can be found in some coastal waters and can contaminate oysters and clams, a quick test to determine its presence is important to ensuring shellfish safety.

Louisiana and Maryland Sea Grant researchers developed a simple dipstick test that can yield results in minutes. The speed and sensitivity of the test, which can be used on any food sample, attracted the interest of New Horizons Diagnostics, a firm that modified the assay for commercial production. New Horizons is manufacturing a hand-held cholera test kit and exporting it to South America to help combat a cholera epidemic.

In a related development, Sea Grant researchers in Hawaii developed an inexpensive dipstick assay for ciguatoxin, a natural substance found in some tropical fishes. Ciguatoxin originates in the food chain and causes poisoning in humans who eat contaminated fish. Ciguatera is one of the primary diseases associated with seafood. While its unpleasant symptoms, including numbness and vomiting, are temporary, it can cause death in extreme cases. Hawaii Chemtect International, Inc. has been licensed to produce a portable ciguatoxin test kit based on the research. The FDA is determining the reliability of the new assay.

The impact of Sea Grant programs on seafood safety and quality can be measured in terms of industry support. During 1991-92, over 30 firms in Florida contributed $800 million dollars to be matched with state funds to build a seafood safety and quality laboratory. This facility will house Sea Grant researchers and outreach personnel and will have an international impact.

Outlook

Because Americans are eating more and more seafood, Sea Grant needs to step-up its efforts to assure seafood safety. Better technology is needed to certify safety of both seafood and shellfishing waters. Research must define effective and reasonable standards of safety. Regulated zero tolerance for some organisms cannot be achieved, is not necessary, and does not serve the public well. Fast and economic methods to promote depuration (self-cleaning) of live shellfish in holding tanks after harvesting are needed. This is particularly important because a high proportion of seafood-associated health problems comes from eating raw shellfish. Seafood processors need to be educated about how to handle, process, and pack seafood safely.

To protect workers in the marine environment, more innovative Sea Grant marine engineering is needed. Working underwater is dangerous. However, underwater studies are necessary to assess the environment or inspect offshore structures for damage or signs of failure. Sea Grant engineering research, in cooperation with industry, is working to produce designs and prototypes for inexpensive robotic vehicles capable of doing work underwater. These robots will bring a new era for work and studies in the ocean.

Sea Grant: Developing Scientific Personnel and Literacy

Robert Shephard
and Shirley Fiske

Once the global leader in scientific and engineering educational achievement, the United States is now seeing its level of scientific literacy imperiled. Little science is taught in elementary school, and enrollment in high school science classes is declining. Science teachers are in short supply, and many of those now teaching need opportunities to update their skills and knowledge. Recent comparisons of world-wide educational achievement scores have shown United States students falling behind other nations for the first time. Published research on science education concludes that science teaching and learning need to be improved nationally.

Whether formal or informal, Sea Grant educational efforts have provided the impetus for individuals from kindergarten to graduate school as well as those outside of school to experience the excitement and reality of scientific study in a way that whets the appetite for more. During the 1960s and '70s, Sea Grant was one of the few organizations supporting marine education. Some of this support helped start the National Marine Educators Association (NMEA). Officially formed in 1976, the NMEA is now an independent organization with 15 regional chapters and more than 1,500 members.

Formal and Informal Education

Students from kindergarten to 12th grade represent not only the nation's future citizens but also its future scientific professionals. Sea Grant programs have played a prominent role in developing marine and aquatic science curricula and accompanying materials for use in schools throughout the country. The curricula developed were then implemented through Sea Grant-sponsored workshops and short courses which covered marine- and aquatic-related concepts and activities for teachers not accustomed to teaching these topics. These workshops and short courses have taken teachers into the marine environment where they acquired knowledge through a "hands-on" approach.

At the university level, under the mentorship of faculty scientists, graduate as well as undergraduate students are involved in Sea Grant research projects. These research assistants obtain training not only in the classical fields of oceanography, but also work on research projects related to ocean law, marine policy and economics, pharmacology, and engineering. Between 1980 and 1991, a total of 5,982 graduate students received Sea Grant support while working on marine-related research and honing their skills for future jobs.

A graduate student separates chemical metabolites from marine organisms using high-performance liquid chromatography.
Photo: Delaware Sea Grant

How Sea Grant-supported graduate education strengthens American business and economic development is illustrated by the career of just one

researcher. While he was a Sea Grant–funded graduate research assistant at Louisiana State University, this scientist began investigating microbes that break down toxic chemicals. After receiving his Ph.D. in 1982, he became a faculty member, and his interest in microbes continued. For over a decade, he worked to develop a collection of several hundred bacterial strains, each adapted to breaking down a particular toxicant, such as PCB. He began collaborative efforts with industry to develop systems for the mass culture and application of these bacteria in the treatment and cleanup of toxic wastes which resulted in several patents and licensing agreements. Four licenses are with new companies formed to apply this technology to industrial effluent cleanup, superfund sites, and oil spills. For his innovative work leading to the creation of new American businesses, this former Sea Grant–supported researcher has received many honors, including an invitation to the White House.

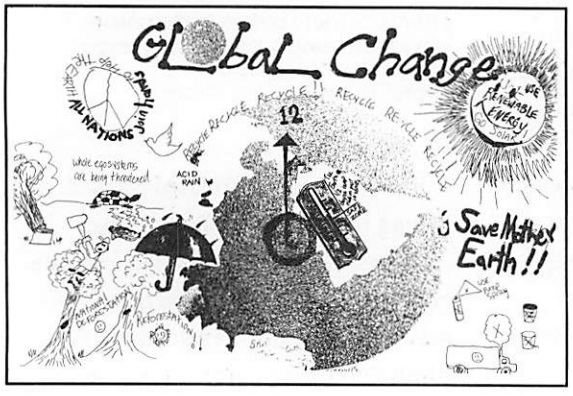
Reaching beyond the classroom to citizens out of school, Sea Grant provides marine and aquatic education through a wide spectrum of activities from public lectures, conferences, and media programs to beach walks, poster contests, and 4–H and Scout projects. For example, Connecticut Sea Grant, working with the 4–H, has a summer program that introduces inner–city youth from New Haven and Ansonia, Connecticut, to coastal resources and the marine environment. The educational materials used are specifically adapted to the program and followed up by a field trip to the ENVIRO–LAB, an educational vessel.

It has been estimated that over the years Sea Grant has informed at least 2.7 million people through education programs at science centers, museums, aquaria, environmental camps, interpretative centers, sanctuaries, and parks. For the past 10 years, Sea Grant programs have provided organizational and educational leadership for a nationwide beach cleanup. These annual cleanups have saved millions of dollars in lost tourism revenue and thousands of dollars in municipal cleanup costs.

Fellowship Program

The Sea Grant Dean John A. Knauss Marine Policy Fellowship program was established in 1979 to provide a unique educational experience to students who have an interest in marine/ocean/Great Lakes resources and in the national policy decisions affecting those resources. This competitive program selects graduate students from a pool of highly qualified candidates and matches them with "hosts" in the Legislative or the Executive Branch, or appropriate associations and institutions in the Washington, DC, area for a one–year fellowship. The Knauss Fellows further their education as they learn about and work on activities such as researching or drafting new legislation, writing policy papers, organizing hearings, or interpreting scientific data to resolve resource management issues.

To date, 215 graduate students have participated in this educational program. Of these, about one–third have gone on to jobs in the federal government. The remainder work in industry and trade associations, in state government as managers, or in academia as teachers and university researchers.



Sea Grant provides marine education through a wide spectrum of informal activities. This award–winning poster, designed by a fourth–grader, was just one of nearly 300 submitted to Rhode Island Sea Grant's global warming poster contest.
Photo: Rhode Island Sea Grant

Special Focus Education Activities

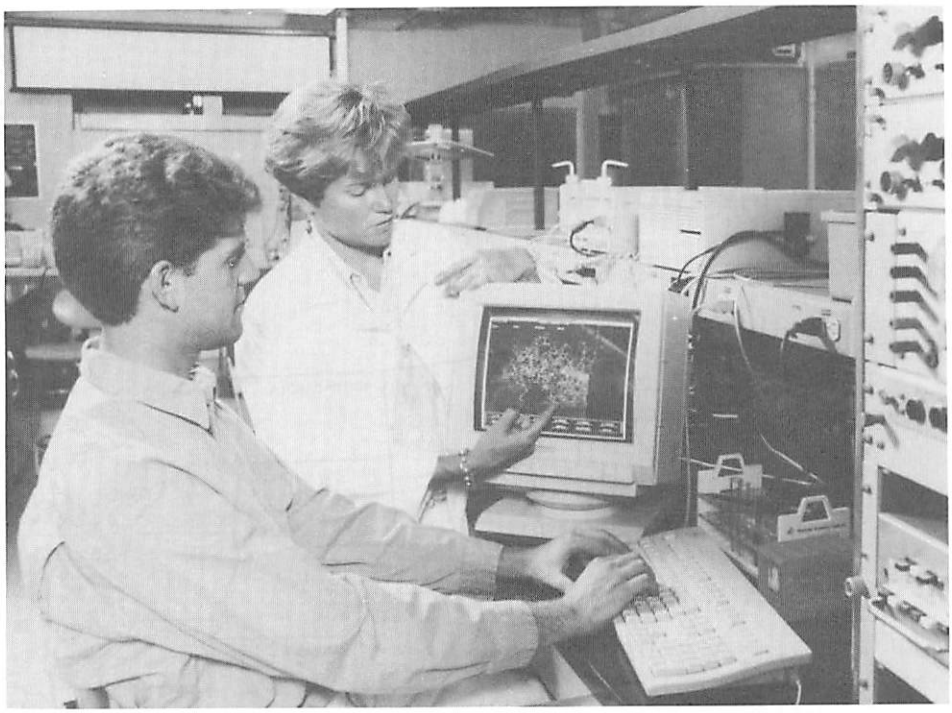
Global warming, acid rain, coastal pollution, the greenhouse effect, droughts, and flooding from sea–level rise are environmental problems facing citizens in both developed and developing countries. Most global change problems arise from the imperfect application of technology, but they also result, to some degree, from the freely made choices of individuals. Thus, to be successful, governmental policies or programs will need the strong support and endorsement of the general public.

Sea Grant continues to be in the forefront in responding to the national need for education on global change. In 1988, members of the Sea Grant network formed the Sea Grant Global Change Task Force. This task force now has members from 11 Sea Grant programs. In cooperation with NOAA's Office of Global Programs, this group coordinates ongoing global and climate change educational efforts and identifies new education needs and funding sources.

Sea Grant programs nationwide are developing a global change education curricula. The Mississippi/Alabama Sea Grant program was awarded a major grant from the National Science Foun–

dation to develop middle school curricula on global change issues for the Gulf Coast region. This pilot effort is expected to become a nationwide activity in the future. And Ohio Sea Grant is developing a variety of educational aids for classroom teachers including fact sheets, case studies, and data bases on global environmental change in the Great Lakes. This information will be made available to teachers and professionals throughout the Great Lakes region.

To reach even more teachers, Sea Grant has conducted a number of regional workshops on global change. With various state and federal agencies, Washington Sea Grant held two regional conferences on global change issues which instructed 400 classroom teachers and educational professionals. Hawaii Sea Grant has been particularly active in educating teachers about global change, sponsoring the Pacific Science Congress and the National Marine Educators Association Conference. These global change educational programs reached scientists from the Pacific Rim region and 500 educators from throughout the nation.



A Sea Grant research associate and pharmacology computer instructor assists an undergraduate student in three-dimensional molecular modeling.
Photo: California Sea Grant

Outlook

Sea Grant's Global Change Task Force, assisted by other NOAA line organizations, is developing for the agency a Strategic Plan on Global Change Education. Sea Grant is also participating in an additional interagency global change planning effort through the Committee on Earth and Environmental Sciences which is a subcommittee of the Federal Coordinating Council for Science, Engineering, and Technology. These efforts will provide direction for future Sea Grant activities in education through NOAA and other agency funding.

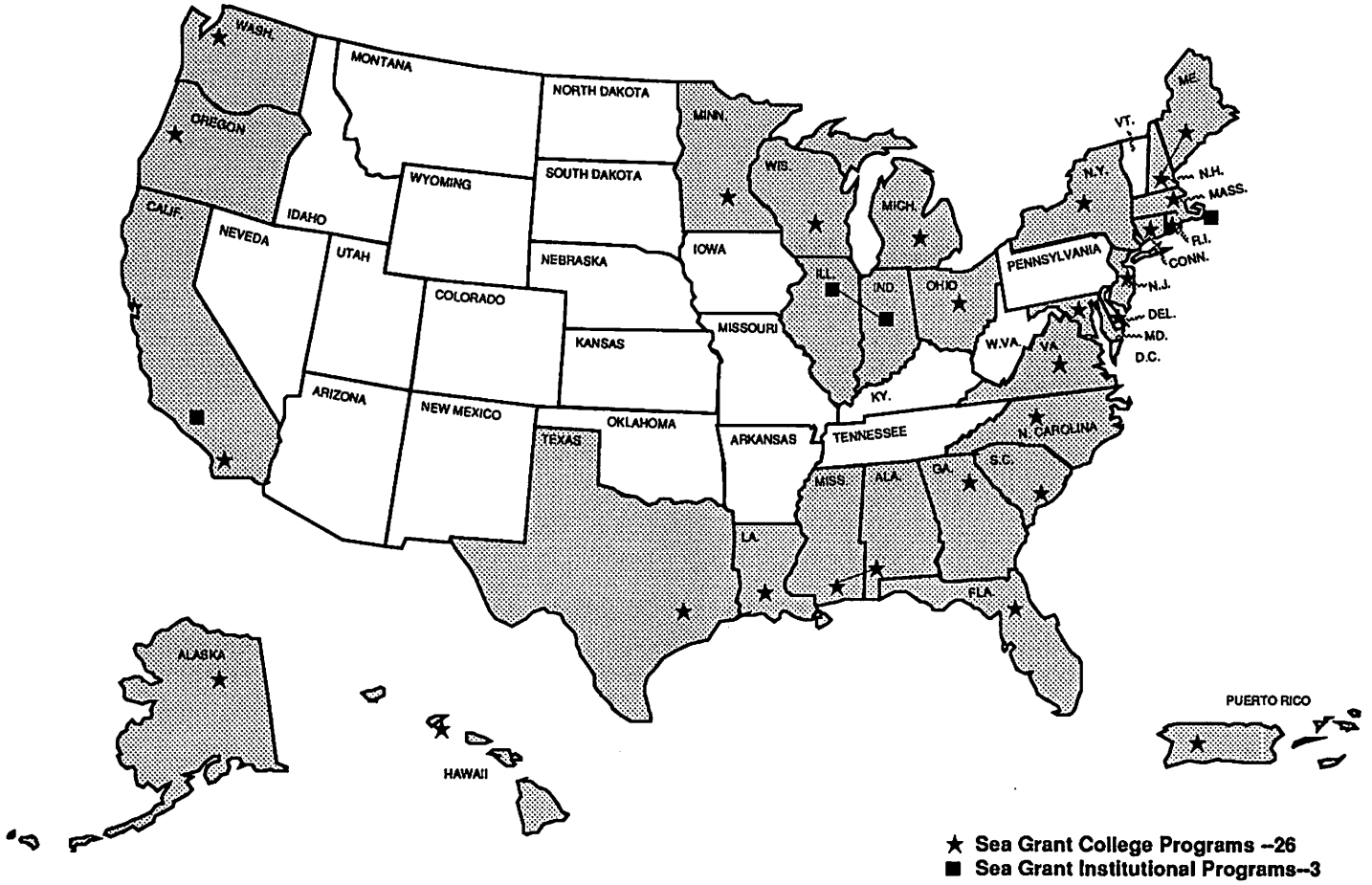
By fostering cooperation between teachers and scientists, Sea Grant will find ways to teach science as it is practiced—with wonder and excitement—in order to attract and retain more students in scientific careers. Training the teachers will be a national priority, since such training lets teachers acquire new knowledge and skills for use in the classroom.

New electronic communications technologies are available for formal teaching strategies. For example, satellite systems now exist that beam instruction directly into classrooms. Sea Grant marine educators are developing programs for these systems and will provide leadership in incorporating this modern technology into new teaching experiences.

A challenge for the nation which Sea Grant can help meet is to provide further educational opportunities to replenish the nation's scientific work force. The number of Sea Grant–supported college students graduating with marine specialties will soon number 10,000. At the graduate school level, it's expected that at least 500 students per year will be offered Sea Grant assistantships and fellowships. These students will work alongside faculty mentors in conducting cutting-edge research designed to better understand coastal and marine issues.

In offering educational programs to the public, Sea Grant will maintain its non-advocacy position, striving to present the best currently available information to the nation's citizens, so they can make educated decisions about issues such as global change, coastal development, and ocean and Great Lakes resources.

National Sea Grant College Program Network



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