VOLUME 3 • NUMBER 1 • SPRING 1991

NOR'EASTER

MAGAZINE OF THE NORTHEAST SEA GRANT PROGRAMS

COASTAL CONFRONTATIONS

ALSO INSIDE:

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NOR'EASTER

MAGAZINE OF THE NORTHEAST SEA GRANT PROGRAMS

CONNECTICUT • MAINE • MIT • NEW HAMPSHIRE • NEW YORK • RHODE ISLAND • WOODS HOLE

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FRONT COVER: Walkway to ocean, South County, Rhode Island. *Photo by Larry Pearce.*

OPPOSITE: Broad-clawed hermit crab, *Pagurus pollicaris*, in shell of a channeled whelk, *Busycon canaliculatum*. Hermits reuse shells of dead snails and recycle shells to smaller hermit crabs as they outgrow them. *Photo by Harold Wes Pratt.*

FEATURES

DEPARTMENTS

MARINE BULLETINS

CONNECTICUT

Growing Strong—Kelp in Long Island Sound

Sea Grant researcher Charles Yarish recently mapped the geographic distribution of *Laminaria longicruris*, the brown kelp often cast up on the beach after a nor'easter. He found the kelp is at the southern limit of its distribution in Long Island Sound. This species grows in rocky subtidal habitats and cannot tolerate very warm temperatures. It begins to die back in late summer.

Yarish, a professor of evolutionary ecology and biology at the University of Connecticut at Stamford, found that even at the limit of its range, the brown kelp equals or exceeds the productivity of other kelp species. Field experiments showed that *L. longicruris* plants in Long Island Sound grow slowest in August and September, then the growth rate increases until reaching its maximum in May. When new young plants are recruited to the population, density can reach 1,000 individuals per square meter.

Although the Atlantic Ocean kelp never grow as large as giant kelp in the Pacific, some plants grow to 30 feet by late spring and can grow an inch and a half per day even in the dead of winter.

The Nitty Gritty on Clams

Could the size of lowly grains of sand have a significant effect on the abundance of clams for your chowder? Diane Brousseau, professor of biology at Fairfield University, thinks so.

The life history of an organism is usually studied in the laboratory, where it is possible to control conditions. But field observations are also important for predicting the survival and reproductive success of commercially valuable species such as the soft-shell clam. Brousseau's Sea Grant–supported research on the life history of *Mya arenaria* shows that environmental factors can significantly impact clam survival.

Brousseau conducted field studies at two intertidal sites on Long Island Sound, comparing populations from the eastern end of Connecticut (Barn Island, Stonington) and the western end (Saugatuck River, Westport). For clams older than one year, age-specific fecundity and survival were both greater at the Stonington site.

Brousseau believes that the difference may be attributed to different sediment types. The Westport site has coarser sediment (gravel or cobble) than the Stonington site. Clams in the large-grained sediment grow slowly and have more spherical shells, resulting in reduced body size. The reduced body size may restrict egg production, causing lower fecundity. In addition, the clams in coarse sediment work harder to burrow, depleting energy that would otherwise be available for reproduction, body maintenance, and survival.

Photo by Peg Van Patten

MAINE

Lobster Model in the Works

The lobster industry, one of the principal fisheries in the northeastern U.S. and Atlantic Canada, employs more than 30,000 people in harvesting, distribution, and related activities.

Currently, the industry faces a number of difficult regulatory and economic problems compounded by multiple regulatory agencies, the international border, and the tendency of all involved to view the fishery from a local perspective.

With funding from Sea Grant and the Lobster Institute, UM economists James Wilson and Ralph Townsend are spearheading a project to develop a community model of the lobster fishery. A model, or *aggregate simulator*, will first be developed to address large-scale biological and economic phenomena.

This simulator will then provide a context in which submodels of particular regions, harvesting policies, or marketing activities can be developed. Submodels will, in turn, be used to help refine the aggregate model.

As Wilson points out, "This effort becomes a community model in the sense that a number of potentially independent models and a group of otherwise independent researchers are brought together in a coordinated way."

Salmon Aquaculture Studies

The economic viability of salmon net-pen aquaculture in Maine is threatened by public perception that it could endanger the state's coastal marine environment. Sound scientific information is needed to develop effective strategies for preventing possible environmental degradation.

With joint funding from Sea Grant and the Maine Aquaculture Innovation Center (MAIC), UM researchers Robert Findlay and Les Watling are measuring the amount of organic carbon found in sediments near farm sites and are examining how microbenthic and macrobenthic communities respond to this organic enrichment.

With funding from the U.S. Environmental Protection Agency, Findlay and Watling are developing a monitoring program to detect all types of organic pollution in estuarine environments.

On another project, funded by a Saltonstall-Kennedy grant from the National Marine Fisheries Service, Findlay and Watling are working with MAIC's Robert Blake and UM researchers Robert Steneck and Larry Mayer to develop and assess a benthic threshold model to help maintain conditions near salmon net-pens that are mutually beneficial to aquaculture and traditional fisheries.

These projects will provide the scientific basis needed for management strategies that will protect the marine environment, providing for the continued health of all fisheries.

MIT

A Deep Explorer

The deep oceans are the least known places on earth—shrouded from surface and satellite observation.

If oceanographers had deep-diving, unmanned submersibles to scatter over the ocean, the murky depths could become much clearer. However, constraints of size, expense, engineering, and software have thus far kept such a vehicle out of reach.

The MIT Sea Grant College Program is now developing an autonomous submersible capable of diving to 6,000 meters. A team of students led by James G. Bellingham, MIT Sea Grant Underwater Vehicles Laboratory manager, has been working to define the vehicle's possible missions. Based on those missions, the team will decide what the vehicle will need for maximum reliability at minimum cost.

Critical design components include the vehicle's external shell, watertight and pressure-resistant compartments, acoustic sensors, a propulsion system, and control mechanisms. Many systems will be derived from those aboard *Sea Squirt*, MIT Sea Grant's shallow-water autonomous submarine, but others will be developed specifically for deep-ocean deployment.

The team expects to begin testing a prototype vehicle in 1991, launching the first deep-ocean explorer that is simple, cheap, and reliable enough for routine scientific missions.

Sniffing Pollution

In the event of oil or chemical spills, environmental officials need to know what chemicals they face. However, some pollutants evaporate quickly, hampering measurement by conventional methods.

"What we need," according to Harold F. Hemond, a professor in MIT's civil engineering department, "is to be able to get rapid analysis of a chemical by simply placing a probe in the environment and sniffing for vapors."

An instrument called a mass spectrometer can do the sniffing, but a typical mass spectrometer weighs hundreds of pounds—far too much to carry to remote sites.

Hemond, with support from the MIT Sea Grant College Program, has built a mass spectrometer that is small, light, energy efficient, and ready to travel.

"We had to reduce the weight and volume to where you can backpack it, and reduce the power consumption so you don't have to carry a generator around with you," he says.

Hemond was able to reduce the weight and power requirements of his mass spectrometer to a 70-pound box mounted on a backpacking frame. With the addition of a portable computer, the instrument is ready to carry into the field.

NEW HAMPSHIRE

Ocean Disposal of Solid Waste

The 2.5 to 4 million tons of municipal solid waste (MSW) generated each year in the United States may grow to 17 million tons by the year 2000. In landfills, MSW incinerator ash containing heavy metals threatens surface and groundwater quality, so four University of New Hampshire researchers are reevaluating the ban in force on disposal of wastes in U.S. waters.

Nancy Kinner, David Gress, Robin Collins, and Berry Lyons teamed for a Sea Grant study on the feasibility of burying stabilized/solidified MSW in ocean bottom sediments. They mixed MSW incinerator ash with cement to create a monolith, sliced test wafers from it, and placed them in centrifuge tubes packed with intertidal organically rich marine sediment. They submerged these, along with sediment-filled tubes containing concrete control wafers and tubes filled with sediment alone, in seawater flowing through tanks at UNH's Coastal Marine Lab. Once a month they processed specimens of each type, monitoring changes in the sediment, the porewater, and the biofilm on the wafers. Over the first 10 months, no statistically significant amounts of arsenic, copper, lead, or cadmium were detected in the sediments adjacent to the MSW ash specimens. It is possible that this research will produce a feasible alternative to land disposal.

Extra Steroids Harm Juvenile Salmon

The Atlantic salmon, an important biological, economic, and cultural resource once widespread in the northeastern United States, is now restricted to a few New England rivers. Dams, overfishing, and pollution are among the causes of decline. Over the last 20 years, government agencies have spent at least $250 million to reestablish the species in New England. One method used to improve seawater survival rates is enhancing juvenile growth by feeding of steroids. It now appears that side effects may actually reduce the juveniles' chances for survival and reproduction.

In a Sea Grant project, UNH endocrinologist Stacia Sower compared the effects of various commercial fish feeds containing steroids and feeds from which the steroids had been removed. The impacts on the development, fitness, and seawater survival of juvenile salmon were documented. Commercial fish diets without added steroid supplements contain meal and oil derived from mature fish that often have high levels of male sex steroid hormones. Sower has found that even these levels of steroids can influence physiological responses and reproduction. She concludes that diets should exclude the steroids completely.

NEW YORK

Seaweed and Agriculture

Stress can have long-lasting effects on plants, causing a variety of limitations later in life. A Sea Grant study by Valrie A. Gerard, associate professor of marine environmental studies at SUNY Stony Brook, plans to determine the long-term (or persistent) effects of environmental stress on the productivity and growth of marine algae.

By simulating stressful situations such as low light, low nutrients, or high temperature on common kelp (*Laminaria saccharina*) during its early developmental stages, Gerard will determine whether the seaweed's later growth and physiological characteristics are affected. The identification of stresses that influence seaweed production could help to manage stress in aquaculture and mariculture settings.

Gerard's research could have valuable applications in agriculture as well. "In agricultural crops, young plants that are subjected to stress ultimately have low harvest yield," Gerard explains. The results will also contribute to understanding in basic biology and ecology.

Climate Impact on Fish Growth

In his latest New York Sea Grant study, David O. Conover, associate professor of marine sciences at SUNY Stony Brook, will examine whether the growth capacity of striped bass (*Morone saxatilis*) increases at northern latitudes due to what he terms the "countergradient effect." According to Conover, the capacity for growth should increase with latitude. Based on comparisons of body size and length at the end of the bass' first growing season at different latitudes, Conover found that the shorter the growing season, the faster the growth rate within the growing season. If this countergradient pattern has a genetic basis, it could prove useful for aquaculture and fishery management.

For Conover's study, native striped bass embryos will be taken from hatcheries in Florida, South Carolina, North Carolina, Maryland, and New York. The young will be reared under identical laboratory conditions through the larval period. During the postlarval juvenile period, the five populations will be raised at three different temperatures that span the range that striped bass are likely to experience in nature, and growth rates will then be compared. During these experiments, all the fish will be provided with unlimited food.

If Conover's countergradient model proves accurate, it will provide an easily applied technique for predicting which natural stocks will have the highest growth rate capacity.

RHODE ISLAND

The Coastal Institute on Narragansett Bay

A worldwide reputation in marine programs has long been enjoyed by The University of Rhode Island. But those programs are scattered across two campuses and a dozen separate departments. Government agencies, citizen groups, and researchers can get lost in the university maze. To address this problem, Rhode Island voters in 1990 allocated $7 million toward constructing a building at the Narragansett Bay Campus for a Coastal Institute, mandated to bring together faculty, local government, citizen groups, and the public.

The Institute has a triple mission: to promote excellence in basic and applied research, to act as a resource for decision makers on management and policy issues, and to educate the public. The new building will include laboratories and classrooms, as well as a visitor center and bookstore.

Scott Nixon, director of the Rhode Island Sea Grant College Program, is chair of the Coastal Institute organizational committee. "We hope that the Coastal Institute will provide an unbiased forum," he says, "a place to organize multidisciplinary research teams, to stimulate new ideas and creative solutions, and to make people aware of problems they may not have known existed."

Although Narragansett Bay and Rhode Island Sound will be the primary laboratory for Coastal Institute research, the results will be useful for the management of similar coastal zones around the world.

Oceanic Microbes and Greenhouse Gases

When waste products from the tiny microorganisms that thrive in the upper oceans decay, gases are released, including carbon dioxide, hydrogen sulfide, and methane—all contributors to the atmosphere's greenhouse effect. According to conventional scientific wisdom, this decay takes place after the detritus sinks to the ocean floor, trapping the gases in deep sediments.

But Sea Grant researcher John Sieburth, a professor of oceanography at The University of Rhode Island, questions this assumption. Based on his data from Rhode Island's Pettaquamscutt Estuary, Sieburth suggests that detritus can remain suspended near the surface in stagnant or thermally stratified layers. As much as 90 percent of the ocean's productivity may decay in the upper zones, where the greenhouse gases produced by the decay process can escape into the atmosphere, possibly hastening global warming and sea level rise.

Sieburth and his research team plan to continue their investigations on the Pettaquamscutt and at URI's Marine Ecosystems Research Laboratory.

WOODS HOLE

Crossing Borders in the Gulf of Maine

While a small group of scientists in Nova Scotia study lobster populations in the Gulf of Maine, other researchers hundreds of miles down the coast on Cape Cod may be undertaking similar studies. Both groups are gathering data that will result in management policies by which local lobstermen will be legally bound, and both groups could benefit by sharing information and resources across the borders of states, nations, and provinces.

Researchers and environmental managers operate within the boundaries of their local area, but the Gulf of Maine ecosystem stretches from Cape Cod to Nova Scotia, disregarding any artificial "lines across the water." Ideally, the Gulf of Maine should be managed as a single ecosystem, instead of being carved up into local jurisdictions. A regional, international management strategy would require gathering scientific data collected in the two provinces and three states bordering the Gulf of Maine, sharing the data, and translating the research results into technical information that can be used effectively by resource managers.

In a long-range attempt to do just that, a planning conference, "The Gulf of Maine: Sustaining Our Common Heritage," was held in Portland, Maine, in December 1989. At that meeting, an agreement was signed by the three U.S. governors and two Canadian premiers establishing an international Council on the Marine Environment. The council is charged with developing a 10-year Action Plan by June 1991 to protect Gulf of Maine resources against common threats such as coastal development and pollution.

As a follow-up to this initial meeting, the Gulf of Maine Scientific Workshop was held in January 1991 at the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, Mass. Hosted by WHOI's Coastal Research Center and cosponsored by a variety of organizations, the meeting provided an opportunity for Gulf of Maine researchers to learn about each other's work. More than 250 scientists and resource managers from government, research, and academia attended the workshop. A workshop report will be available from the Urban Harbors Institute at the University of Massachusetts/Boston Harbor Campus.

For additional information about the Gulf of Maine Scientific Workshop, contact the Maine Sea Grant College Program or WHOI Sea Grant (see back cover for addresses).

The Fall 1991 issue of *Nor'easter* will contain a special double feature on the Gulf of Maine, a joint contribution of the Maine and Massachusetts Sea Grant programs and the Maine State Planning Office.

MARINE ADVISORY

CONNECTICUT

Long Island Sound Status Report

Low dissolved oxygen levels have occurred extensively in the western part of Long Island Sound in recent years. As a result, fish and invertebrates have suffered increasing mortality from hypoxia, or inadequate oxygen. Sea Grant/Marine Advisory Program (SGMAP) staff in late 1990 released the Long Island Sound Study's first major management document, *Status Report and Interim Actions for Hypoxia Management.* The status report summarizes hypoxia research findings to date, and lists management actions that are being taken now by Connecticut and New York. The study's final plan will be released in 1992.

SGMAP staff are working closely with federal and state regulatory agencies to publicize the release of the status report and educate citizens on its findings. An issue paper on hypoxia management (available from Connecticut Sea Grant) was developed, and 14 public meetings were held throughout the bistate Long Island Sound area in early 1991. The open forums, organized by SGMAP staff and their colleagues in New York Sea Grant Extension, served to explain the status report to the public and facilitate public input on the interim actions and general direction of the Long Island Sound Study.

Public Trust Tidelands Workshops

The Public Trust Doctrine is a traditional legal concept holding certain resources in trust for all mankind. The doctrine has been the basis of several recent state and federal Supreme Court decisions addressing the titles and ownership rights of both present tidelands and former tidelands that were filled. In Connecticut, with a long history of tidelands development and privatization, the court decisions have raised questions. But many coastal property owners and the concerned public have either never heard of the Public Trust Doctrine, or been misinformed about it.

To provide accurate information, the Connecticut Sea Grant Marine Advisory Program held three workshops in cooperation with the Connecticut Coastal Resources Management Division. Municipal officials and property owners in waterfront communities learned why certain regulatory requirements exist. Follow-up information is being prepared, and Connecticut residents are hopeful that the Public Trust Doctrine will prove to be a useful tool for protecting the environment.

For more information, write Heather M. Crawford, Hamden Extension Office, 43 Marne St., Hamden CT 06514; or call (203) 789-7865.

MAINE

Monitors' Workshop

Although Maine's water resources are still relatively pristine, sound stewardship is essential to avoid environmental crises in the years ahead. Local citizens' groups are increasingly taking on the responsibility for protecting their rivers and bays from pollution through the creation of water quality monitoring programs.

A one-day conference to inform and train volunteers in monitoring methods was held March 9 at the University of Maine at Augusta. Participants from all over northern New England learned how to conduct sanitary shoreline surveys, collect field samples, and analyze data.

Esperanza Stancioff, a marine programmer with the University of Maine Cooperative Extension, coordinated the Water Quality Monitoring Fair, which was cosponsored by the University of Maine Sea Grant Marine Advisory Program and several state marine agencies.

According to Stancioff, who helps local organizations in mid-Maine coordinate volunteer monitoring efforts, environmental agencies such as the Department of Environmental Protection cannot afford to engage in both monitoring and cleanup. Forced to choose, agencies usually choose cleanup.

"That makes the work these [volunteer] groups do all the more important," Stancioff concludes. The data provided by volunteer citizen monitors helps educate the public about the health of local ecosystems.

Scallop Dragging vs. Lobster Habitats

Videotapes of the seabed off Swans Island, Maine, indicate that controversial scallop dragging equipment causes minimal bottom damage, according to Phil Averill, director of the Maine Department of Marine Resources' Fisheries Technology Service.

Averill, a cooperator in Maine's Sea Grant Marine Advisory Program, reports that impacts of dragging are not long-lived and do not seem to affect lobster distribution. Lobsters appear to sense the approach of scallop drags and quickly scuttle out of the way or into burrows, allowing the drag to pass over them.

According to Averill, small rocks and sea cucumbers on the bottom are moved by drags, but major habitat changes seem to restore themselves in a very short time.

The videotapes were filmed shortly before and after the scallop season in 1985, 1986, and 1990. Averill chose 38 study sites in the Swans Island area. Interested parties can review the videotapes, available by mail from the Department of Marine Resources librarian in Boothbay Harbor, Maine, and draw their own conclusions about the results.

MIT

Interactive Learning

Pushing computer buttons to see new underwater worlds appear: What could be a more appropriate way for the Nintendo generation to learn about robot submarines? Robot submarines—remotely controlled and autonomous—are the stars, along with the MIT human-powered submarine, of a new interactive computer exhibit created by the MIT Sea Grant College Program.

Although designed for visitors to MIT Sea Grant's laboratory in the Charlestown Navy Yard, the exhibit will debut this spring at the New England Aquarium. Children and adults will have a chance to explore the Amiga computer-based exhibit. With color drawings, photos, and animation of various underwater vehicles to choose from, MIT Sea Grant hopes visitors will leave with a sense of the frontiers in underwater exploration.

Suppressing Smells

Revere, Mass., has an algal problem. A rapidly-growing algae named *Pilayella littoralis* has chased away swimmers and disgusted residents by blanketing the beach with debris and a smell like rotten eggs. *Pilayella* has hit Revere before, but it's never been so bad.

Last spring Revere's mayor, George V. Colella, called for help. Norman Doelling, executive director of the MIT Sea Grant College Program and Sallie W. Chisholm, a pro-

fessor in MIT's civil engineering department, teamed up with Robert T. Wilce to attack the creeping algal threat.

On the basis of earlier investigations, Wilce, a botany professor at the University of Massachusetts, believes the only certain way to get rid of the algae is to remove it from the area. Scraping it off the beach and tossing the dried algae back in the water just provides nutrients to feed more algae.

John C. Springsteen, an MIT civil engineering senior, joined the effort, and is exploring two plans. First, he is investigating refinement of an algal vacuum cleaner—a suction device with a skimming head and low flow rate. "We'll shoot all the stuff onto a barge and ship it out to a deeper sea zone, where it won't come back," Springsteen says. Alternatively, he is considering draping the bay in nets, letting the algae pile up, and then towing the nets far away to a deep ocean site.

Although neither plan offers a permanent end to *Pilayella*, both would pull biomass and nutrients out of the local system, discouraging future explosive algal growth in the area.

NEW HAMPSHIRE

Great Bay Watch Begins Second Year

UNH Sea Grant's Great Bay Watch completed a highly successful first year of volunteer water quality monitoring last November and embarked on its second year in February.

In early 1990, coordinator Ann Reid, Sea Grant Extension educator Sharon Meeker, and others trained more than 40 volunteers. Teams monitored eight sites on the shores of the Great Bay Estuary and collected water samples twice a month. At monthly meetings they turned in the data, reviewed procedures and difficulties, replaced equipment, replenished supplies, and heard professionals speak about environmental topics relevant to their monitoring mission. At the public meeting closing the watch year, volunteers said they enjoyed being part of a large, ongoing effort.

Meeker, who has developed a manual for the model program, says the volunteers helped to focus attention on Great Bay and to educate the public about environmental issues. The data will be used by many, including researchers at UNH's Jackson Estuarine Laboratory, who have been monitoring the bay for many years. Rich Langan, research supervisor at the lab, says volunteer monitors are essential to much scientific research because funding is scarce for the endless data-gathering needed to study long-term trends.

Funding for the first year was provided by NOAA, and the 1991 program is supported by various sources including UNH's Undesignated Gifts Fund, UNH Cooperative Extension, and UNH/UM Sea Grant Marine Advisory Program.

Mayday Stickers May Save Lives

One of the crucial elements of surviving an emergency at sea is making a clear, accurate radio distress call. Unfortunately, this doesn't always happen. When a vessel starts taking on water or catches fire, the captain, who normally does most of the radio work, usually goes to handle the emergency and tells someone else to make the distress call.

To address this problem, Roland Barnaby, New Hampshire's Sea Grant agent, has devised a "Mayday sticker," a small form designed to be mounted next to the radio in the wheelhouse. Clear, concise, and straightforward, the 6-inch-square sticker lists the 14 steps involved in making a Coast Guard–approved distress call.

The free stickers are available from the following Sea Grant programs: New Hampshire/Maine, Rhode Island, New York, Delaware, South Carolina, Mississippi/Alabama, and Puerto Rico.

NEW YORK

Helping Reduce Coastal Water Pollution

Materials such as pesticides and fertilizers that gardeners routinely handle can pollute coastal and ground waters if used improperly. With this in mind, an educational program designed to teach gardeners about the hazards of such pollution is being developed by New York Sea Grant, Cornell Cooperative Extension, the University of Connecticut Cooperative Extension, and Connecticut Sea Grant.

The Sound Gardening Program aims to increase the awareness of gardeners in watershed areas generally, and around Long Island Sound in particular, about the serious threat of coastal and groundwater pollution.

The program will consist of a series of educational fact sheets including "Your Garden and the Sound," "Pest Management," "Soil Erosion by Water," "Herbicides and Water Quality," and "Garden Wastes."

For further information write Robert Kent, New York Sea Grant's Marine District Program Coordinator, Cornell University Lab, 39 Sound Ave., Riverhead NY 11901-1017; or call (516) 727-3910.

Different Ports, Common Interests

Charter and party boat fishing is big business along New York's marine coast, with direct expenditures by marine anglers totaling $185 million per year. But charter and party boat owners and operators from the area's eight major ports have rarely worked cooperatively regarding fishery management measures, transportation policies, fuel taxes, and other issues affecting the industry.

With assistance from Sea Grant specialist Mark Malchoff, port association representatives have formed the Long Island Commercial Passenger Fishing Vessel Association. LICPFVA represents nearly 300 small businesses and can present a unified industry perspective when opportunities to change public policy arise.

New York Sea Grant first offered assistance to industry leaders in 1989 as they worked to protect winter flounder from overharvest while minimiz-

ing the impact of restricted harvest regulations on the industry. These initial meetings proved that differences of opinion between ports could be resolved.

In Spring 1990, New York Sea Grant Extension hosted a meeting for industry leaders, highlighting ways trade associations in California have successfully addressed numerous challenges. The guest speaker was Roger Thomas, president of the Golden Gate Fisherman's Association and member of the National Sea Grant College Program Review Panel. As a result of this meeting, the ad hoc group involved in Long Island commercial passenger fishing vessel issues was formalized into a multi-port umbrella organization. LICPFVA has since adopted bylaws, elected officers, and begun day-to-day operations on behalf of the local industry.

Sea Grant will continue to offer assistance to LICPFVA, now in its second year, as it interacts with legislative and regulatory agencies affecting the industry, and educates and informs owners of small businesses along New York's marine coast.

RHODE ISLAND

Harbor Management Planning

Following a national trend, Rhode Island's 21 coastal cities and towns are rapidly gaining population. If not properly managed, growth can quickly overstress local facilities. Conflicts arise as the shore becomes clogged with piers, moorings, and residential and commercial development.

In 1988 Rhode Island's Coastal Resources Management Council (CRMC) initiated a program to promote local management of waterfronts. The project tapped into the expertise of the Rhode Island Sea Grant Advisory Service and URI's Coastal Resources Center (CRC) for help in developing a strategy for harbor management planning.

Four towns were selected as prototypes, and management principles for integrating water activities with adjacent land uses were developed. Citizen participation was encouraged, and contentious issues were hashed out in the public forum and incorporated into the final plan. So far, six coastal communities have submitted their harbor management plans to CRMC. The Advisory Service/CRC team is now implementing their strategy in another New England state, and designing a management plan for Nantucket, Mass.

URI Photo

Fisheries Conservation Engineering

How do fish react when confronted by a moving trawl net? Can finfish be chased away from a shrimp net by electrical impulses, while the same impulse encourages shrimp to jump *into* the net?

Nonselective nets capture everything they encounter in the sea, from valuable fish species to seaweed, turtles, and "trash" fish of poor quality or small size. This wasted catch costs fishermen time and trouble and needlessly depletes fisheries. Research on net design aims at eliminating this unwanted catch.

A workshop to explore new research findings on net design and engineering was organized last spring by Rhode Island Sea Grant Advisory Services and attracted about 75 participants from Scotland, Canada, Alaska, and around the U.S.

The conference proceedings are now available from R.I. Sea Grant. To order, see the Marine Publications section in this issue of *Nor'easter*.

CASE Award

Rhode Island Sea Grant's "Fish of Narragansett Bay" poster won a bronze medal in a regional Council for Advancement and Support of Education (CASE) competition.

The medal, awarded in the development category, was one of only three awards given in this category to universities and colleges throughout the northeastern United States and Canada.

WOODS HOLE

Planning Ahead for Oil Spills

In early February, several local groups joined for a one-day "Massachusetts Oil-Spill Contingency Planning Workshop." The workshop, sponsored by the WHOI Sea Grant Program and the Massachusetts Maritime Academy, was designed for town officials and the concerned public, and dealt with plans and procedures to be implemented in the event of a local coastal spill. Existing contingency plans are nearly 20 years old, and local communities are concerned with oil-spill preparedness.

After hearing presentations on topics that ranged from the impact of oil on the environment to spill-related laws and regulations, participants separated into working groups to discuss improved contingency planning. Official contingency plans are produced by the U.S. Coast Guard Marine Safety Offices in Providence and Boston, with assistance from the Massachusetts Coastal Zone Management Office, one of the cosponsors of the workshop. The MIT Sea Grant College Program also participated as a cosponsor. The meeting, which paved the way for future collaborations, attracted approximately 150 people from coastal communities around the state.

Proceedings from the workshop will be available from the WHOI Sea Grant Program.

Coastal Communication

WHOI Sea Grant recently organized a seminar series designed to serve as an information exchange for researchers, scientists, and resource managers concerned with Cape Cod's coastal environment. These "All-Cape Coastal Science Seminars" focus on specific topics and are held at central locations on the Cape.

The first seminar in the series, held in February at the Cape Cod National Seashore's Visitor Center in Eastham, featured Charles Seymour of the Department of Microbiology at the Boston University School of Medicine. His subject, "Health Implications of Bacterial Contamination from Animal Sources in the Pamet River System," was of special interest to area shellfish wardens and health department officials. On March 22, John Portnoy, a biologist with the Cape Cod National Seashore, presented a talk on "Salt Marsh Diking and Restoration." This topic attracted an audience concerned with habitat management and restoration issues.

Additional seminars are planned, and a collection of seminar abstracts will be published at a future date. For further information about this series, please contact WHOI Sea Grant at (508) 457-2000, ext. 2665.

COASTAL CONFRONTATIONS: WHOSE SHORE IS IT, ANYWAY?

"The shores are not understood to be the property of any man, but are compared to the sea itself, and to the sand or ground which is under the sea."

Institutes of Justinian, 533 A.D.

ACCESS to the shore has been a common expectation and, to varying degrees, a legal right for generations of Americans. However, the ability to exercise that right has been gradually eroded by extensive private coastal development, traffic congestion, lack of public facilities, and a variety of legal and logistic hurdles.

Eighty percent of the United States population lives within 50 miles of the coast. With coastal population and development projected to increase dramatically into the next century, the demand for public access to the shore will grow. In some locations, the limited supply of public access is already placing intense stress on these portions of the shore. The overcrowding damages the shore and reduces the pleasure of a typical beach day.

Rhode Island has one of the most densely populated coastal zones in the country. Ninety percent of state residents live within a 20-minute drive of the coastline, and have enjoyed a long-standing tradition of public access to the shore for fishing, swimming, birding, and boating. But during the economic boom of the 1980s, undeveloped coastal lots all but disappeared and coastal real estate prices skyrocketed. Purchasing coastal land for public use was considered too expensive for government budgets. The result has been a marked increase in the exclusivity and privatization of the shore.

Environmental organizations, conservation and land trusts, and citizens' activist groups are but a few of the advocates fighting for public access. One Rhode Island citizens' activist group, Friends of the Waterfront, has been aggressively battling for public access rights in Newport for many years. During a recent walk along the waterfront one member commented, "You can see firsthand the damage that can be done to an historic seaport while speculators squeeze all the profits they can out of the waterfront. This uncontrolled waterfront development has resulted in a wall of condos, hotels, parking lots, and time-shares that have grown topsy-turvy, with traditional public access to the harbor blocked by 45-foot-high buildings, wooden barriers, chain link fences, and guards."

Private landowners also hold strong views about their rights to protect their property against public intrusion. One waterfront homeowner bitterly remarked, "I am paying tens of thousands of dollars annually in property taxes. Why should I allow [the public] to use my land?" Yet, coastal property owners are not alone in paying high property taxes; inland residents of coastal communities also typically pay high taxes to live in these desirable areas. Frustration mounts when attempts to get to the coast in their own city or town prove difficult. According to one citizen, "It is a fundamental right

Above: Without signs like this one, beachgoers may find shoreline public access sites difficult to locate. *Photo by Pam Pogue*

by PAM POGUE
URI Coastal Resources Center

as a taxpaying citizen to be able to look out to the sea, watch the shorebirds, and walk along the shore." But shorefront property owners complain about public abuse of these coastal areas. "If the public wants access to the shore they should first learn to respect this fragile environment."

Because Rhode Island's economy depends on tourist dollars, public access to the shore is vital. Although there are more than 500 public coastal access sites in the state, most of these sites are difficult to locate because they lack signs. Last summer a frustrated tourist trying to locate a secluded beach area in southern Rhode Island angrily commented, "How can you take a vacation at the beach when you can't even find the shore?"

What Is Public Access?

Coastal public access can be defined as the ability of the public to get to the tidal waters of the shore and, once there, to walk along the shore. Common law upholds the states' ownership of submerged lands, tidal waters, and their living resources to be held in trust for the public. Access *to* the shore is not guaranteed, but access *along* the shore and *over* the coastal waters, subject to the laws and regulations of the state, is a traditional public right.

The public trust lands of the state are those that are subject to the ebb and flow of the tide. Each state has a different interpretation of what activities the public has a right to pursue in those areas.

What Does Access Mean to You?

Not only do public access rights differ from state to state, but public expectations and perceptions regarding public access also vary. For some, public access means dining at a favorite restaurant next to a window overlooking the water. For a carload who have travelled from an inland city, public coastal access might mean a wide sandy beach safe for swimming, fully equipped with lifeguards, concessions, bathrooms, public telephones, and a video arcade.

The expectations of boaters and fishermen for public access are different still. One participant at a recent workshop concerning fishermen's public access needs commented, "Our livelihood depends on our being able to get our skiffs to the water to fish and shellfish." For boating, fishing, and shellfishing, public access means usable boat ramps and enough parking space for both cars and boat trailers. For still others, public access might mean a more passive recreational experience—the right to simply walk along the fringes of a salt marsh for nature photography or a breath of fresh air.

Conflict: Good Fences Make Angry Beachgoers

The controversy over public access boils down to the basic issue of private property rights vs. public access rights. Taxpaying citizens feel they have a basic fundamental right to freely experience the natural beauty of the coast; however, taxpaying property owners claim the basic fundamental right to protect their private property. A number of problems surface as a result of this conflict. Typically, these involve the public trying to get to the shore and the private landowner trying to protect his or her property and avoid liability.

Much of the friction igniting public access issues arises when the public attempts to access the coast via narrow pathways to the shore, typically referred to as right-of-ways. This type of coastal access is usually found in private residential neighborhoods, sandwiched between two homes or deeded through waterfront condominium developments. Because the right-of-ways are

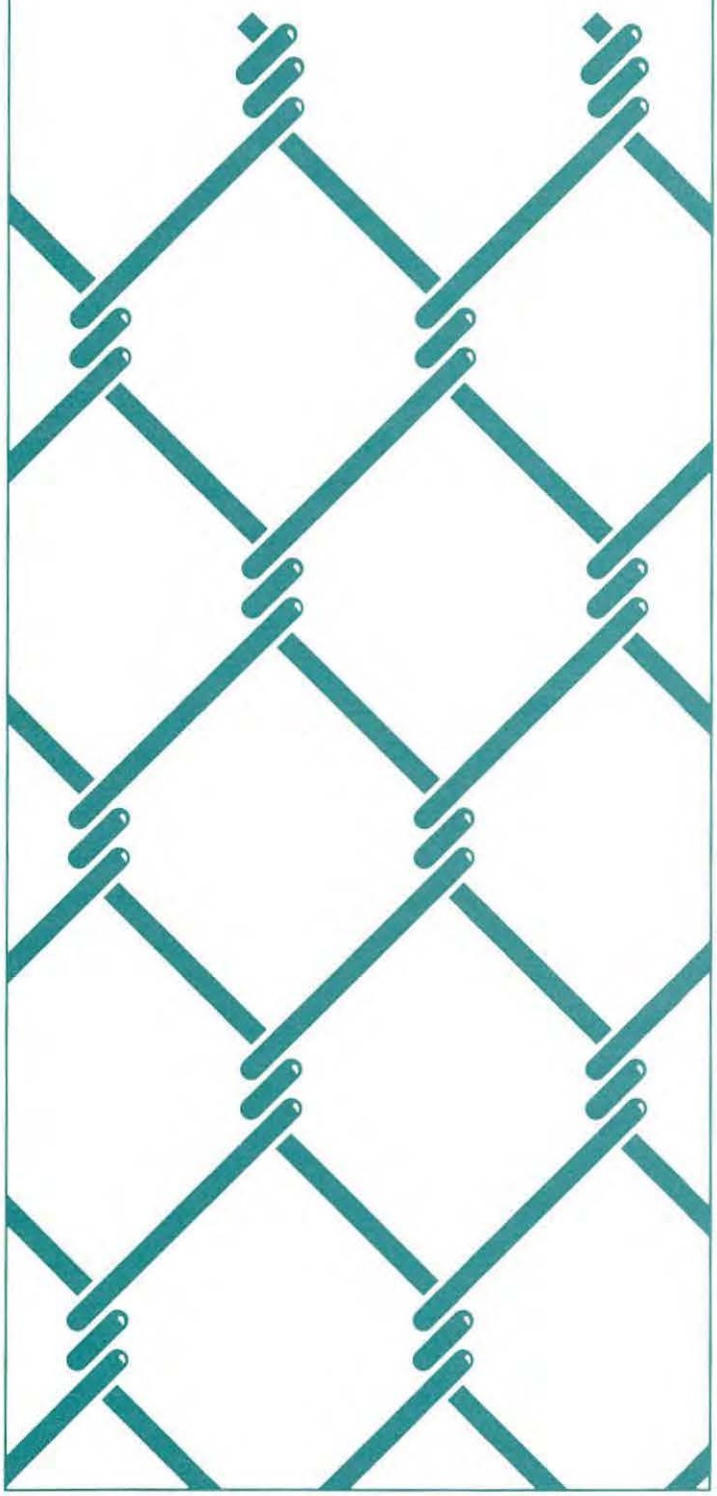
located in such secluded surroundings, the public can be easily intimidated by shorefront property owners' scare tactics aimed at maintaining the exclusivity of their neighborhoods.

The number-one complaint by beachgoers is the lack of parking at many coastal access sites. If parking is not available, beachgoers often assume the site is not open to the public. Private landowners sometimes post "No Parking" signs in an attempt to discourage the use of coastal access areas near or adjacent to their property. Their frequent complaint is that parked cars block driveways or even end up on their lawns.

Waterfront landowners often voice further concerns about abuse of the shoreline. Trash, plastics, and debris litter the coast, and sometimes abandoned boats, engine parts, and defective mooring tackle are strewn up and down the beach. Environmentally fragile habitats are damaged by people who carelessly tromp through dunes, wetlands, and other sensitive areas. Landowners fear that continued abuse of the shore might degrade the value of their property. Also, blaring radios, raucous late-night gatherings at the shore, and potential lawsuits over such things as a stubbed toe, tend to make landowners less than enthusiastic about public access across, or in close proximity to, their property.

To the beachgoer with a picnic basket, a yen for sand and surf, and responsible intentions, the public right-of-way is a cherished escape from the maddening crowds. Yet even as the demand is growing, these right-of-ways seem to be disappearing—or are they? Public access advocates claim many sites are camouflaged by nearby landowners, who employ gates, hedges, "No Trespassing" signs, and even Doberman pinschers to discourage the public. One agency tried posting signs to identify coastal access sites, but most of the signs mysteriously disappeared within a week. What use is the *de jure* right to public access when the shore *de facto* is barricaded?

Public access advocates claim many sites are camouflaged by nearby landowners. What use is the *de jure* right to public access when the shore *de facto* is barricaded?



Not all of Rhode Island's beaches are surrounded by huge parking lots and crowded with concession stands. *Above left*, access to Mohegan Bluffs on Block Island; *below left*, a narrow footpath leads to Green Hill Beach in South Kingstown. *Photos by Pam Pogue.*

Lawyers: Laughing All the Way to the Beach

The public's right to use the shore dates back to Roman times, when laws were created guaranteeing access to the tidal waters and the shore for navigation and fishing. This concept became known as the Public Trust Doctrine and was incorporated into English Common Law in the 13th century. The original American colonies adopted these public trust laws from England and included them in the early laws of the New World.

The trustees of the Public Trust Doctrine are the state legislatures, which often delegate their trust powers and duties to state commissions or agencies. Since the doctrine is implemented at the state level, what one can do at the shore and where it can be done varies from state to state. In Rhode Island, the 1986 Constitutional Convention defined public trust rights to include: fishing from the shore, leaving the shore to swim in the sea, gathering seaweed, and walking along the shore. In stark contrast, Maine has limited the Public Trust Doctrine to bare-bones traditional uses—fishing, fowling, and navigation—and explicitly excludes bathing, swimming, and other recreational shore activities. At the other extreme, New Yorkers have the right to use the area below the high water mark for myriad recreational uses.

In other Northeast states, Massachusetts holds that the Public Trust Doctrine includes

the right to seek or take fish, shellfish, fowl, and marine plants from a vessel or on foot, and the right to pass freely over tidelands for the purposes of fishing and fowling. Connecticut has passed legislation requiring new or expanding waterfront development to provide for public access, or to develop in a manner that will not interfere with the public's ability to use the shoreline.

Confusion about what rights are guaranteed by the Public Trust Doctrine, varying readings of the common law doctrine by the states, and inconsistent boundaries securing the public trust lands encourage the current legal turmoil over public access in many states. The primary beneficiaries of these public access legal battles are usually—the lawyers.

Seeking Out Common Ground

Every community's situation is unique, and public access planning must take place at the local level. State and local governments must address the issues and satisfy the public's demand to enjoy the shore, while alleviating the rightful concerns of shorefront landowners.

Although these are complex issues, many states have already begun to address some of the landowners' concerns through legislation. Florida has passed legislation granting tax breaks and liability coverage to landowners who permit the public to cross over their property to the shore. The Maine Legislature has significantly altered traditional, common-law rules to limit landowners' liability for members of the public who use their property for recreation.

Public access means different things to different people: *Top*, fishing in Narragansett Bay; *center*, boaters require special facilities; *bottom*, the world's simplest way to enjoy the water on a hot summer day. *Photos by Pam Pogue.*

To address the problem of late-night parties, California has instituted sunset curfews in all parks and coastal access areas. Assorted environmental organizations, youth groups, chambers of commerce, and local citizens' groups around the nation have "adopted" beach access sites, taking on the responsibility to clean up and maintain some of the smaller sites often overlooked by municipalities and state agencies.

In Rhode Island, URI's Coastal Resources Center (CRC) is working with the beachgoing public at the grass roots level. With funding from Rhode Island Sea Grant and the Rhode Island Coastal Resources Management Council (CRMC), CRC is producing a statewide listing of Rhode Island's public coastal access sites. The guide, to be published this summer, will include maps, site descriptions, and information on the facilities and environment at each location. Additionally, CRC, Rhode Island Sea Grant, and CRMC are planning a series of public workshops for summer 1991 to explore solutions to public access conflicts.

As state, federal, and local government budgets continue to shrink, it is critical to begin now to formulate long-range plans and develop innovative strategies to secure public access for the future. Experience so far has shown that a coordinated effort among private and municipal land trusts, environmental organizations, and land banks can successfully fund coastal land acquisitions.

None of the problems associated with public access are insurmountable. With a little give-and-take from private landowners and public access advocates, there can be room enough for everyone at the shore.

■ *Pam Pogue is a Marine Research Associate for URI's Coastal Resources Center.*

What Can I Do?

Concerned about public access to the shore in your state? Your involvement is important. Here is a brief report on current programs:

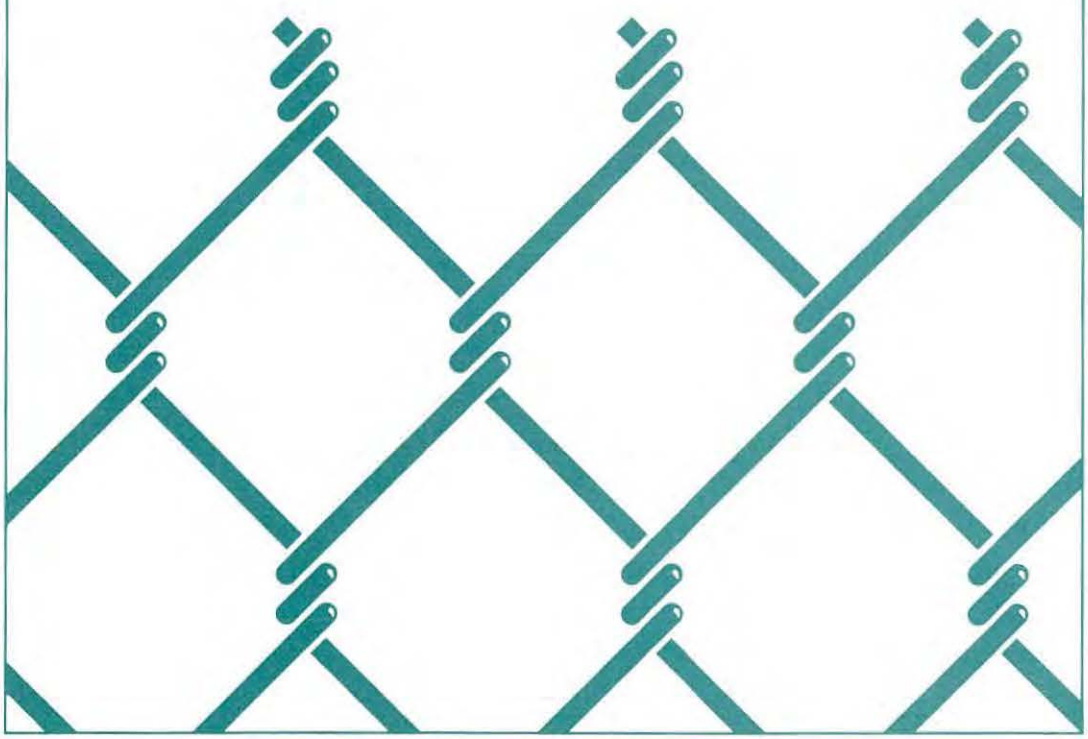
■ **Connecticut:** Connecticut Sea Grant recently sponsored a three-day workshop on the Public Trust Doctrine with the State Coastal Resources Management Division. The workshop drew some 250 state and municipal officials, lawyers, and community members. Proceedings from the workshop will be published, and a follow-up series is in the works. For more information call Heather Crawford at (203) 789-7865.

■ **New Hampshire:** In 1984 attorney Carolyn Baldwin of the Franklin Pierce Law Center wrote *Legal Aspects of Providing and Controlling Access to New Hampshire's Coastal Resources.* This report is available for $10 from the New Hampshire Sea Grant Communications Office, University of New Hampshire, Kingman Farm, Durham, NH 03824, or call (603) 749-1565.

■ **Rhode Island:** The University of Rhode Island's Coastal Resources Center, with joint suport from Rhode Island Sea Grant and the Rhode Island Coastal Resources Management Council, has written a statewide comprehensive coastal public access guide. The guide features more than 500 sites, ranging from right-of-ways to state and federal parks and wildlife refuges. The guide will be for sale in June from Rhode Island Sea Grant, University of Rhode Island Bay Campus, Narragansett, RI 02882-1197. Additionally, CRC, Rhode Island Sea Grant, and CRMC will be holding a regional workshop on public access and the Public Trust Doctrine sometime in June. For further information call Pam Pogue at (401) 792-2145.

■ **Maine:** The Marine Law Institute at the University of Maine Law School has produced two series of publications including booklets on public access, funded in part by the Maine Sea Grant Marine Advisory Service. All of the booklets are free and available from the Maine Sea Grant Office. Titles include *Coastal Right-of-Way Rediscovery Programs, Liability, Public Shoreline Access—the Moody Beach Case,* and *Protection Against Liability for Landowners Who Allow Access.* For further information on public access, call Alison Rieser at the Marine Law Institute at (207) 780-4474.

■ **New York** and **Massachusetts** Sea Grant programs report no active public access programs at press time. Concerned citizens may, however, contact their local office for further information.



GROWING FISH SALAD

An Experiment in Integrated Aquaculture

Take a pinch of resource conservation, a spoonful of sustainable agriculture, and a couple of tons of commercial fish feed. Mix them with a 4,000-year-old technology, simmer with solar energy, set them down in a greenhouse at the Massachusetts Southeast Regional Correctional Center in Bridgewater and you've cooked up an award-winning, integrated fish culture/hydroponic vegetable production system, behind bars.

Left: Visitor Manuel Puig examines appropriate technology in action.

Above: The aquaculture team calls this mixture of lettuce varieties a "solar salad bar."

Photos by Ron Zweig, EcoLogic.

The project combines agriculture without pesticides, aquaculture without pollution, heating without oil or gas, and wastewater treatment without sludge. It grows fish and vegetables simultaneously, makes money, puts food on the table, and trains prison inmates for jobs in the outside world.

The endeavor was initiated with funding from the MIT Sea Grant College Program and is part of a multifaceted, multimillion dollar agribusiness complex at the Department of Corrections, which includes a meat packing house, dairies, and conventional agricultural fields, greenhouses, and landscaping operations.

Ronald D. Zweig, president of EcoLogic of Falmouth, Mass., designed the system as an experimental prototype for a commercially viable backyard or small business (or institutional) venture. The prison inmates, now aquacultural pioneers, have learned to harness solar heat and light to grow fish and vegetables in low-cost, easily managed tanks.

Zweig is an expert in computer simulation of aquatic ecosystems, and has had extensive experience with aquaculture in developing countries. While his project bubbles away in Bridgewater, Zweig may be found in China, Vietnam, or Thailand, advising governments and developing new ways of looking at the ancient practice of fish culture—which was practiced in China before the advent of paper and was recorded alongside Egyptian hieroglyphics.

In 1990, with a weekly crop of about 300 heads of lettuce, plus a seasonal crop of up to 100 pounds of fish per tank, the aquaculture/hydroponics team sold their products to the culinary arts program at the prison, to prison staff, to a regional high school, and to a local health-food store.

Each aquaculture module is a 5-foot deep, 5-foot diameter, 675-gallon fiberglass tank. Fish swim in the lower portion and lettuce or other plants grow on top. A floating Styrofoam wheel, with channels radiating from an opening at its hub, supports the plants with their roots dangling into the fertile

by CAROLYN LEVI
MIT Sea Grant

fish-water. As the plants grow, inmates move them outward on the wheel, giving them more room and opening stations for new seedlings. The result is a gradient of greenery, with older plants at the rim and successively younger plants towards the hub. At capacity, each tank grows 100 heads of lettuce and produces 16 to 18 heads of lettuce per week. The favored lettuce varieties, thus far, are Buttercrunch and French Red Leaf.

The fish eat a commercial trout chow poured through the central opening in the Styrofoam. A donut-shaped cage keeps the fish from nibbling on plant roots, while an aerator oxygenates the water. The plant roots simultaneously improve water quality and derive their nutrition by taking up nitrogen-rich wastes of the fish; they also clarify the water by filtering out waste particles and collecting beneficial bacteria.

"It's internally self-reliant. We put food in and get fish and vegetables out," Zweig says. "In addition, there can be linkages of this system to outdoor ponds. We could culture fingerlings indoors in winter, and then grow them outdoors for a fall harvest."

The scientists and inmates found that lettuce was a good first crop because, although lettuce is low in protein, it does grow fast and, "lettuce, for what it is, is incredibly valuable, about 65 cents per pound wholesale," Zweig says. The inmates are experimenting with watercress and basil—also high market value crops, and Zweig is exploring raising flowers. The ideal plant for the system, Zweig says, is efficient at taking up nitrogen, grows quickly, and has a high protein content and good market value.

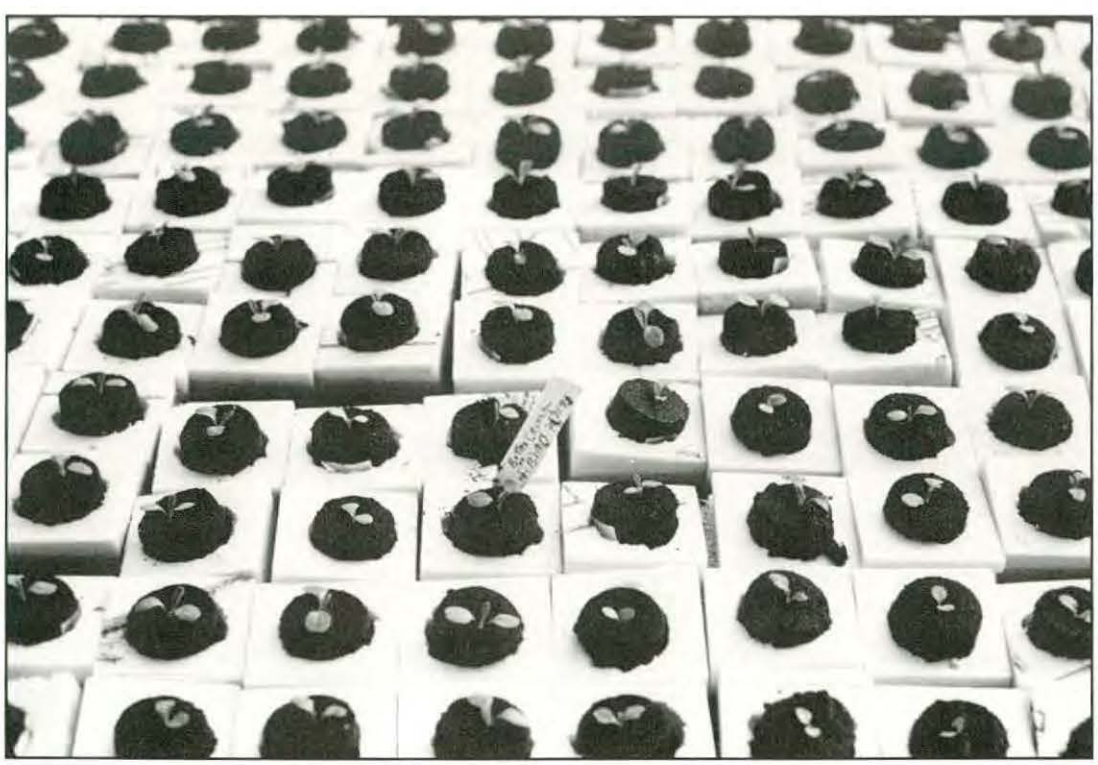
The team also has room to experiment with fish varieties. Having started with native bullhead catfish, an especially hardy fish, they are culturing a variety of other fish, as single species and in combination. These include striped bass; channel catfish; tilapia, tasty members of a group of widely farmed African and Asian fish; brown bullheads, which taste good and are in demand by the Harvard Biological Laboratories for vision research; Koi, a Japanese goldfish with a high retail price tag; guppies, which can live among the plant roots where they are safe from larger fish; and baitfish like fathead minnows, suckers, and the ever-popular golden shiner.

As with a home aquarium, the trickiest part of the system is the chemical balance. Inmates regularly test the water for pH, alkalinity, dissolved oxygen, phosphate, and nitrogen compounds. Richard Benton, an associate professor at the Massachusetts Maritime Academy in nearby Buzzards Bay, coordinates the monitoring of the tanks' chemical dynamics. Excess acidity is easily regulated with additions of calcium or magnesium carbonate, but keeping toxic concentrations of nitrogen compounds down is a different problem.

While fish pour out nitrogen, and plants take it up, the lead actors in the nitrogen saga are neither fish nor plants, but a couple of families of bacteria. Fish's nitrogenous wastes are ammonia. *Nitrosomonas* bacteria convert ammonia to nitrite, which is highly toxic. Another bacterial group, *Nitrobacter*, converts nitrite to nitrate, which is much less toxic and is a favorite of plant roots. If the bacterial populations take too long to become established, as often happens if the initial food ration is too high, or if *Nitrosomonas* grow well before *Nitrobacter*, the nitrogen balance goes awry.

The solution, Zweig suggests, is to start feeding the fish suboptimally—for instance, in a tank where tilapia and catfish will be grown together, the more hardy tilapia can be started alone and the catfish added only after bacterial populations have had time to stabilize the water quality. The feed rate can then be increased to its maximum limit, following cookbook-like instructions. Alternatively, bacteria-rich water from an established tank can be added to a new tank to give the bacteria a head start. Once the system is up and running, it becomes very stable.

In recognition of the ingenuity and value of the system, the Massachusetts Horticul-



The inmates are learning valuable skills that they may be able to transfer to careers, such as horticulture and aquarium management, after release.

tural Society presented the project with two major awards at the 1990 New England Flower Show—a gold medal for the best use of horticulture in therapy and a silver for best example of education.

After working out the first year's bugs with four units, the project has grown to 19 units in a renovated greenhouse at the prison. Staffing has varied from four inmates working 25 hours a week (two on water chemistry analysis, one to manage the hydroponic crop, and one on feeding and general maintenance) to the present arrangement of two inmates running the entire greenhouse on a full-time basis. Zweig holds regular training sessions at which the inmates study fish culture techniques, hydroponic plant cultivation, and integrated system management.

The inmates are learning valuable skills—nutrient requirements of plants, fish farming, water chemistry analysis, fish handling, record keeping, and some data analysis—which they may be able to transfer to careers, such as horticulture and aquarium management, after release. One inmate is already planning a commercial version of the aquaculture project with friends on the outside.

Since the combined fish and agriculture units are self-contained and have low capital costs, Zweig envisions the system as valuable for hobbyists or greenhouse owners. "And the economic viability is getting much stronger under rising energy costs."

The integrated system is attractive environmentally as well as economically. The lettuce never sees chemical pesticides—aphids that eat the lettuce are eaten in turn by ladybugs; the water is cleaned by the lettuce; and effluents are minimized or totally eliminated. Thus, the tanks are actually a wastewater treatment system, in contrast to standard aquaculture ventures like trout farms. "The problem with trout farms is they are basically feedlots," says Zweig. "They produce sewage, and the effluent can harm local ecosystems if not treated."

After a year's use the water is still healthy for the fish, although it begins to accumulate minerals. Zweig recommends draining and cleaning the tank yearly. In an agricultural setting, the drained water can be a fertilizer irrigation source.

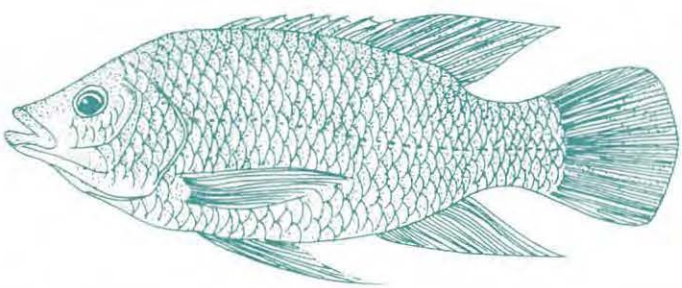
With that exception, Zweig says, "It is a totally contained system. Once set up, you just have to replace water lost to evaporation and transpiration."

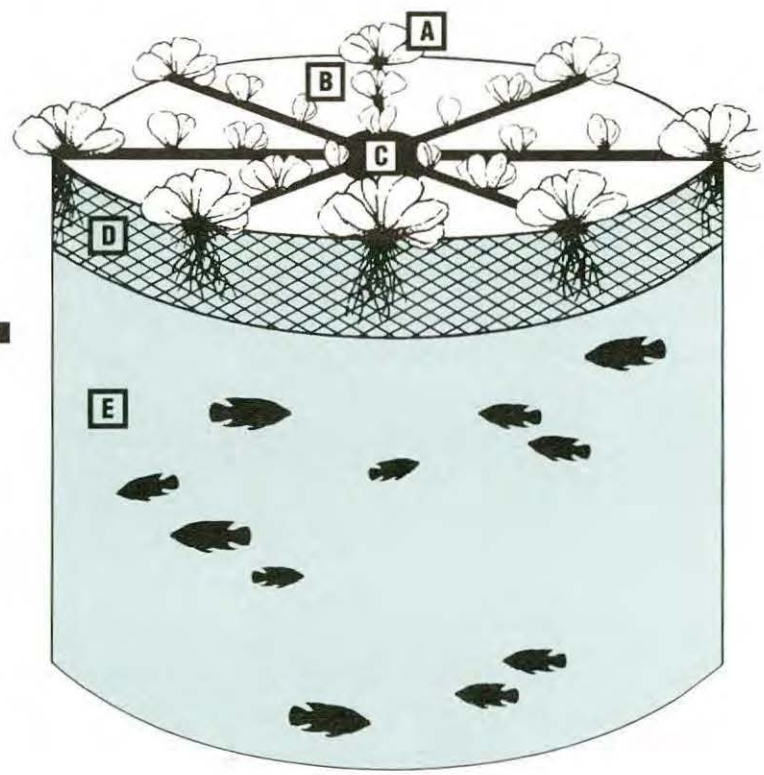
In addition, the system is designed to optimize the use of solar energy for heat as well as water purification. The transparent tanks collect and store solar heat during the day and slowly release it into the greenhouse at night. With the only other energy input a mechanical aerator that consumes about 12 watts per tank, "It's a matter of balancing economics with ecology," Zweig says.

To provide thorough analysis of the system, Zweig has developed a computer model with which managers can calculate what will happen to water quality parameters, and thus productivity, if they change growth conditions.

At the moment, the prison project has problems with staffing and financing, which make continuation precarious. But, as a pilot project, it has succeeded. The inmates now have something they can hand on to other institutions or individuals who want to invest in an energy-saving, sustainable, and intriguing area of food production.

■ *Carolyn Levi is an Editor for the MIT Sea Grant College Program.*





Far left: Buttercrunch lettuce seedlings get a head start before moving to the tanks. *Photo by Ron Zweig,* EcoLogic.

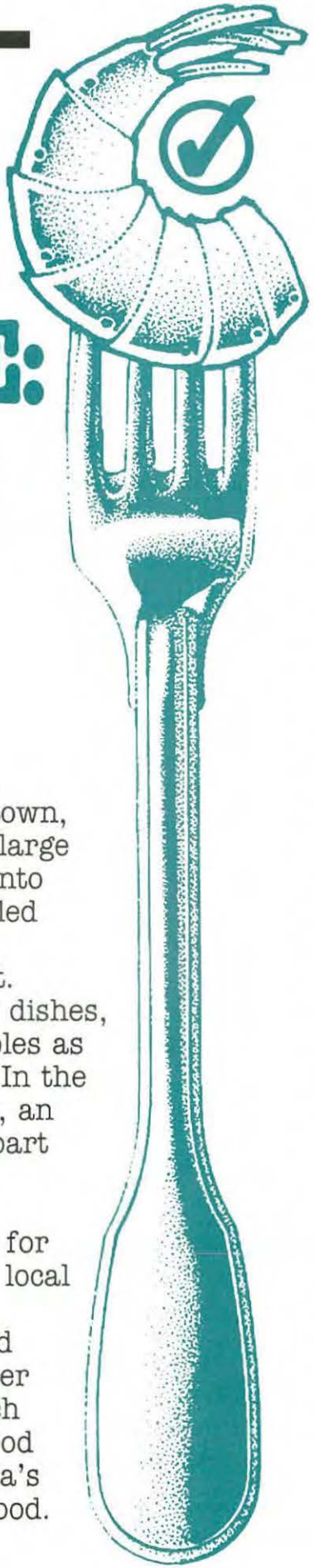
Left: In charge of pest management, this ladybug patrols a mature pepper plant. *Photo by Ron Zweig,* EcoLogic.

Above: Tilapia mossambica, a highly productive species grown in aquaculture ponds in the Philippines and Southeast Asia. This species is a close relative of the tilapia species now thriving in the Bridgewater greenhouse. *Illustration by Shoa-Wen Ling, from* Aquaculture in Southeast Asia, *with permission from the Washington Sea Grant College Program.*

Right: Tank diagram. *Illustration by Tekla McInerney, from a drawing by Ron Zweig.*

A Hydroponic vegetable on top of tank.
B Styrofoam flotation guides for plants.
C Central core opening for fish feeding.
D Mesh cage to prevent fish from eating roots.
E Fish-rearing area in tank.

SEAFOOD QUALITY ASSURANCE: STRATEGIES FOR THE 1990s

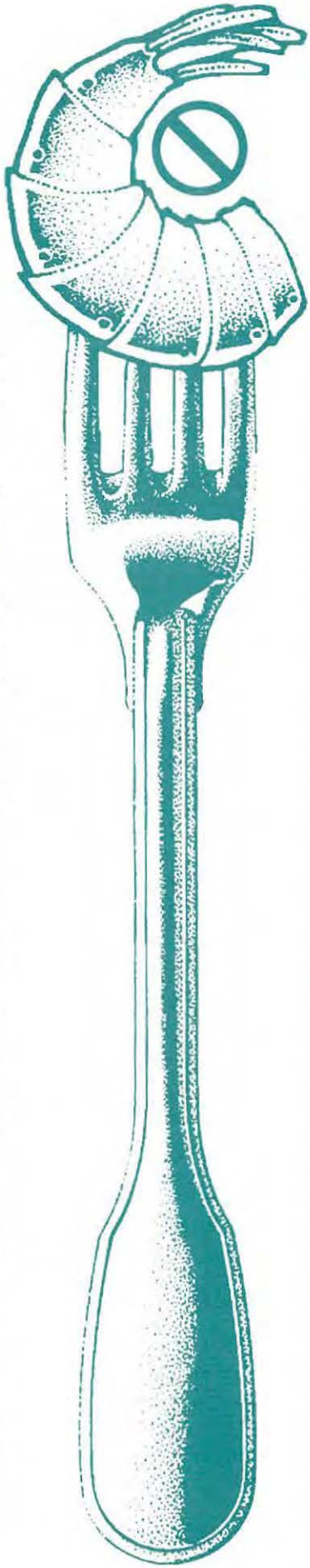


The 6 o'clock dinner crowd at the Smithtown, Long Island, Red Lobster had swelled so large that it threatened to force the standees into the rest rooms. Couples and families milled around outside the front door pondering whether it was worth the 90-minute wait. Inside, the restaurant staff yanked dirty dishes, silverware, and place settings off the tables as fast as the diners rose from their seats. In the meantime, on TVs throughout the region, an evening newscast was concluding a two-part series on seafood safety.

Within days of the broadcast the market for raw shellfish tumbled. For several days, local commercial fishermen watched demand decline as they wondered how they would make their next boat payment, or whether it was even worth the trouble to try. Such is the terribly strange plight of the seafood industry in America today, and the media's seeming love-hate relationship with seafood.

More than 98 million metric tons of finfish and shellfish were caught commercially worldwide in 1988, according to the latest figures from the United Nations Food and Agriculture Organization. In the United States, the National Marine Fisheries Service (NMFS) reports that in 1989 seafood consumption reached a record high of nearly 16 pounds of fish products for every man, woman, and child. American consumers spent an estimated $29 billion on seafood products in 1990. And while seafood is big business, it has also proved itself to be a healthful source of low-fat protein. There is even scientific evidence to suggest that omega-3 fatty acids found in seafood may reduce the risk of heart disease.

Despite the many benefits of consuming fish, public interest groups and other consumer advocates, along with members of the media, have expressed concern about seafood safety. These groups have, at times, taken issue with the lack of a mandatory national seafood inspection system. Others feel that these issues have received undue publicity. This view tends to be supported by a risk assessment performed in 1990 by the Food and Drug Administration (FDA) comparing seafood and poultry, which indicated that, overall, seafood is safer than poultry per serving. The assessment indicated that the risk of food-borne illness from seafood, discounting raw shellfish, is one in 5 million servings, while the risk from chicken is one illness in 25,000 servings. When the risks from eating raw shellfish



are included, the risk from seafood is one illness in 250,000 servings.

The current system for ensuring the wholesomeness of seafood in the United States falls under regulations specified by the Food, Drug, and Cosmetic Act, which is administered by the FDA. The FDA conducts inspections of fish and seafood plants to assure compliance with sanitation and processing regulations. The agency also monitors products to see that they conform to regulations concerning pesticides and other contaminants, as well as maintaining extensive surveillance of imported products at the port of entry. Because the United States imports about 50 percent of its seafood, the FDA is indirectly aided by countries like Canada, Japan, Norway, and Iceland, who themselves have mandatory national seafood inspection programs. Seafood is also subject to inspection by state and local health authorities.

The National Shellfish Sanitation program, which is a joint federal and state effort, oversees a monitoring program called the Interstate Shellfish Sanitation Conference, which is responsible for determining what waters are considered unfit for commercial shellfish harvesting. Shellfishing is one of the most heavily regulated of all food industries.

In addition to these programs, the Department of Commerce, through its National Marine Fisheries Service, provides many seafood processors, packers, and brokers, along with supermarkets and restaurant chains such as Red Lobster, with a voluntary seafood inspection program. Subscribers to the program pay a fee for inspections that evaluate raw materials and hygienic preparation of products, and certify the final quality and condition of the product. Once approved, the products are permitted to carry a federal inspection mark that says "Packed under Federal Inspection" or "U.S. Grade A," depending upon the type of inspection performed. Of course, just how good the food tastes is a matter between the customer and the chef.

While this system has been in place for some time, other national seafood inspection strategies are being explored, largely in response to the concerns of consumer groups and the media. The expectation is that Congress will make a decision about a mandatory system by 1992.

In the meantime, organizations throughout the country are not waiting for action by Washington, but are hard at work trying to find more-effective methods of monitoring or enhancing the quality of our seafood.

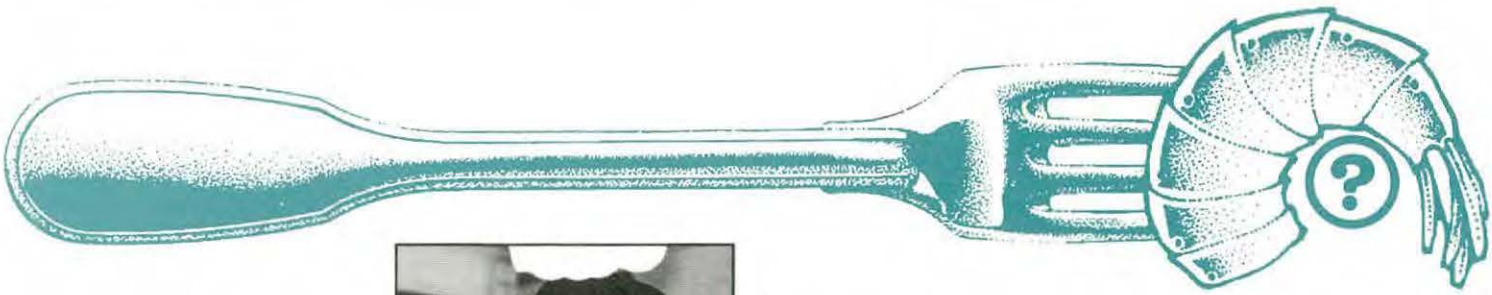
For example, the New England Fisheries Development Association, an industry trade group in Massachusetts, has developed a pilot program involving eight companies—processors of raw fish, mollusk and shellfish processors, distributors, and a food service/packaging operation. The system, titled Hazard Analysis at Critical Control Points (HACCP for short, pronounced "hassup"), allows companies to identify, monitor, and control the food production procedures important to their own individual operations. "In this pilot program we have eight separate HACCP plans. But if we had 100 operators in the program there would still need to be a specific plan for each business. That is the basis of the HACCP concept," explains George Nardi, the association's program director.

Working in cooperation with the FDA and NMFS, the association has established basic mandatory requirements that each business has to meet. The way they choose to meet these requirements is determined by each business individually, but they still must meet with the approval of the federal regulators. "It is not our intention to go into each business and tell the people involved what they should or should not do," says Nardi. "These people know their operations. What we want is for them to integrate this HACCP concept within their day-to-day operation."

Once all the parties agree on a specific approach, a site visit is arranged in which an NMFS inspector and an FDA investigator walk through the plant to make sure that all the procedures that have been agreed upon are being followed.

It is those procedures that make HACCP viable. "The HACCP concept first started out as a food safety program. The federal agencies, with the input of industry, have determined that it should apply also to food hygiene, which can be interpreted as plant sanitation, and the prevention of economic fraud consisting of improper labeling. So if a package says 5

by AVERY KLAUBER
New York Sea Grant



pounds of flounder on the label, there had better be 5 pounds of flounder in the box," Nardi explains.

Should something go wrong while fish is being processed, such as a skinning machine breaking down, efforts are made to fix the problem on the spot—in other words, the plan for that critical control point takes effect right away. "The plan tells plant personnel that the corrective action is to immediately repair the skinning machine, but until that is done, they skin the product by hand using the same sanitary precautions. A report is filled out by responsible plant personnel noting that a machine has broken down and the equipment manufacturer has been notified to send a repair person. Once this happens the plant person must sign the report acknowledging that these critical control procedures have been performed, providing accountability," Nardi says. Ultimately, all the seafood produced under this program will be allowed to display a seal on the package attesting to the integrity and wholesomeness of the products.

Further down the coast in New York State, another program designed to introduce HACCP-based quality assurance concepts is focusing on the small, independent seafood retailer and commercial fishing interests. Developed by the Marine Resources and Products Council (a 140-member industry trade group formed in 1989) with funding from the state's Urban Development Corporation, the Seafood Voluntary Quality Assurance Program was initiated in cooperation with New York Sea Grant and Cornell Cooperative Extension. Twenty retailers from New York City and Long Island, along with 20 commercial fishing vessels, are involved in the project.

Paul Houghton, owner of Miller Place Seafood on Long Island, has been keeping accurate records of his maintenance and sanitation procedures, which is an important part of the MRPC program. *Photo courtesy of the New England Fisheries Development Association, Inc.*

During the 15-week period of the pilot program, each retailer and commercial fishing vessel used an extensive set of sanitation and quality maintenance procedures, along with a logbook to keep track of display case temperatures, daily sanitation procedures covering all parts of the retail operation, and weekly sanitation procedures for facilities and equipment. The logbook also included checklists for reviewing handling and sanitation procedures biweekly. FDA-approved names of fish had to be used in store displays alongside any local identification as an aid to the consumer.

The fishing vessel guidelines included procedures for protecting, preserving, and handling the catch, in addition to the sanitation measures. The system was designed to help these businesses begin to evaluate their own operations and use monitoring and record-keeping procedures that would be needed to implement a HACCP program.

Before retailers were allowed to participate in the program, they first needed to pass an evaluation by a site team from Sea Grant and the Marine Resources and Products Council (MRPC). "It was not our intent to have this quality assurance program in a store that had problems," explains Roger Tollefsen, president of MRPC. "So after the initial inspection of each store was conducted, specific recommendations for improvement were made. What we tried to do was reinforce those things that were being done well."

According to Tollefsen, the concern of this segment of the seafood industry is developing better handling techniques, starting with the fishing vessels and the retailers, and ending with the consumer. "We can't make the product any better. We have no control over that. All we can do is maintain its quality," he says. "But we can go back and educate the first-line purchaser, the vessels, and the retail markets to essentially use seafood common sense." According to Ken Gall, a New York Sea Grant Extension specialist, "The program is focusing on handling concerns such as temperature, cleanliness, and sanitation. These are things the industry can control."

The key incentive for each retailer that participated in this pilot program was the rectangular blue and white MRPC Seafood Quality Assurance Program seal, which told customers that this retailer had made a commitment to do everything possible to maintain the quality and wholesomeness of the seafood sold.

While Tollefsen recognizes that the push for a national seafood inspection program is building, he firmly believes that this kind of voluntary system is the most effective method for protecting the public and enhancing the image of the industry. "For example, I could go into a store that was part of this program and check the retailer's records each day to make sure that they had been taking temperature readings twice daily," Tollefsen explains. "That was one of the important parts of the program—to establish that we could come back to a retailer and evaluate the standards." If retailers didn't follow the program faithfully, they could lose their MRPC membership, and lose the right to display the MRPC Quality Assurance seal.

"We tried to make a positive reason for following the procedures," Tollefsen notes. "Regulations in the past have been implemented from the negative point of view. Existing regulations often don't go back and reward you for doing a good job, they just put you out of business if you are not doing a good job. What we tried to do was set up a program that rewards retailers who do a good job—because the customers are aware of it and want to come to those stores. And that's the difference."

The program is currently being reviewed and modifications are planned. Although

The risk of food-borne illness from seafood, discounting raw shellfish, is one in 5 million servings, while the risk from chicken is one illness in 25,000 servings.

Tollefsen is hopeful that the program will be expanded in a few months, he says, "Even now, just the inclusion of the MRPC's logo on the packed fish coming off the vessels is a great thing because the name goes out there." And according to Tollefsen, the name recognition is crucial to the program's success. Including customers in the process by teaching them useful handling and cooking practices is also part of the program planning.

"Certainly customers have a responsibility to make sure that the seafood they buy is brought home promptly, is handled properly, and is kept well-refrigerated or frozen if it is not going to be cooked within a day or two," says Tollefsen. "And they must make sure that all seafood is thoroughly cooked. Because despite the best efforts of the industry, if consumers aren't aware of their role, then no system will be as effective as it could be."

In addition to specific programs that physically deal with the quality assurance of seafood, researchers are also looking for more comprehensive methods of monitoring water quality and its effect on seafood.

In a two-year study released in January 1990 by the National Academy of Sciences, researchers concluded that the safety of seafood could be better assured by reducing water pollution where the fish and shellfish are caught, rather than by putting more inspectors in processing plants.

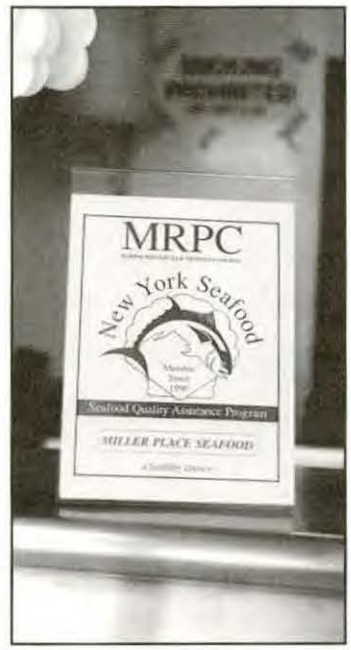
John Liston, professor emeritus at the University of Washington in Seattle and a specialist in food science and technology, was the study chairman. He said that an inspection system similar to the one used for meat and poultry would probably not improve the safety of seafood.

The study found that seafood quality depends on water quality—for which each state has primary responsibility. Federal guidelines to control pollution, microbiological contamination, and contamination from naturally occurring toxins (such as red tide) "should be extended and updated," the study said.

In this regard, researchers such as Judith McDowell Capuzzo, senior scientist in the biology department at the Woods Hole Oceanographic Institution, are involved with reviewing analytical methods for developing new standards in seafood safety. Capuzzo and her fellow researchers have been directly involved in reviewing the ways regulatory agencies measure chemical contaminants in fish and shellfish.

"As our information on the toxicological properties of chemical contaminants continues to improve, do our standards keep pace with current analytical methods or up-to-date toxicological information? We are seeking ways to better bridge the gap between more contemporary analytical methods, and the need for state agencies to monitor chemical contaminants in the environment," explains Capuzzo. "Many programs have been using approved analytical methods that do not consider our improved understanding of both analytical chemistry and toxicology."

Developing toxicity standards for seafood is a highly complex issue, involving many areas of research that are outside the scope of quality assurance programs. But according to Capuzzo, the only standard we have for closing down a fishery, in the case of a major oil spill for example, is based on "tainting." In other words, the fish taste or smell "funny." Capuzzo and others in the field hope that current research will help to develop improved toxicity standards.



To qualify to display the MRPC seal, each seafood retailer must follow a plan that outlines strict sanitation and quality maintenance procedures. *Photo courtesy of the New England Fisheries Development Association, Inc.*

Another important effort to assure the quality of seafood is the search for a low-cost, easy-to-use way to detect biotoxins and contaminants. "If you pick up some mackerel and look at it and smell it, you may be able to judge its quality, but you can't say if it is actually safe or if it contains a biotoxin like histamine," explains Bob Learson, laboratory director at the National Marine Fisheries Service in Gloucester, Mass. "One way to find out if naturally occurring toxins are present is to bring the fish back to the lab and have it tested. Now that's OK for one fish, but it would be extremely time-consuming and costly to do that for every boatload. But if you were to have a little dipstick procedure, a little probe that you could stick in each fish, then you could determine which ones are good and which ones aren't," Learson says.

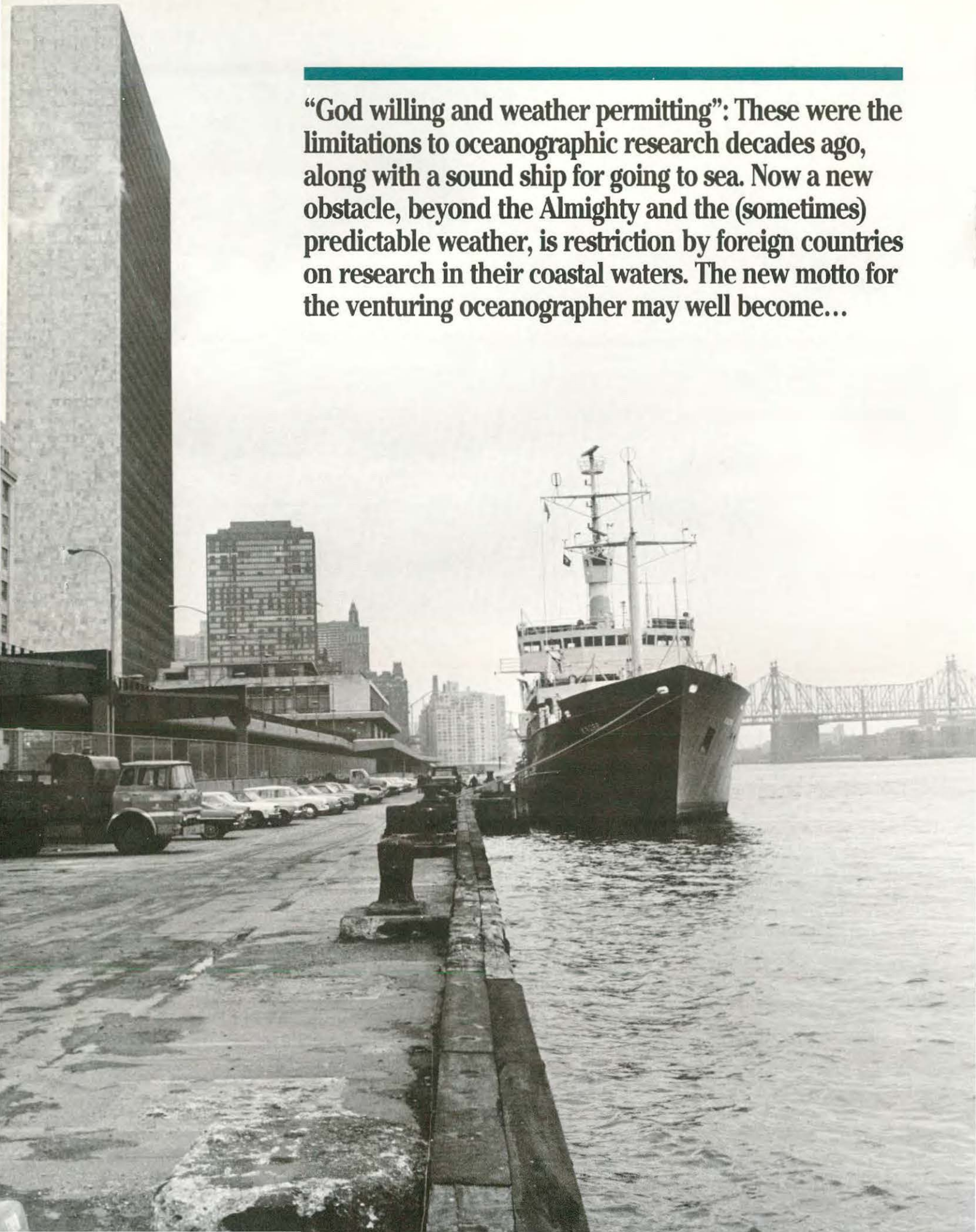
According to Learson, biological probes could be used in the context of a national quality assurance system operated through NMFS and the FDA in conjunction with state health departments. Field testing could take place almost any time throughout the chain of distribution, as the fish are coming off vessels, or as they come through processing plant doors. Tests could even be done in supermarkets and restaurants. "It will all depend on the ease of the system," Learson notes. "It's just like those home pregnancy tests; they have to be simple enough to be used successfully by nontechnical people."

But Learson also points out that while there is wide-ranging research on biological probes going on throughout the country by other NMFS labs, Sea Grant programs, and the FDA, the success of these devices will depend as much upon budget constraints and congressionally determined priorities as on scientific expertise.

As government and industry go through the process of developing and improving a set of meaningful seafood quality assurance standards and determining the costs of operating a mandatory (as opposed to an industry-led) national inspection program, the American public continues to look on with great expectation. A knife in one hand and a fork in the other, just hankering to pass the tartar sauce. Ready to continue loving its seafood.

■ *Avery Klauber is Communications Coordinator for New York Sea Grant.*

"God willing and weather permitting": These were the limitations to oceanographic research decades ago, along with a sound ship for going to sea. Now a new obstacle, beyond the Almighty and the (sometimes) predictable weather, is restriction by foreign countries on research in their coastal waters. The new motto for the venturing oceanographer may well become...



"Science Willing & Politics Permitting"

Oceanographic Research in an International Setting

The importance of studying the oceans is obvious to oceanographers and of increasing interest to the world's citizens. For centuries the oceans have been used for transportation of people, cargo, and messages, and as a constant source of food. Today, people are barraged by news stories on the ocean's role in climate change and global warming, fisheries depletion, offshore oil drilling and oil spills, plastics pollution, and offshore waste disposal. For the concerned citizen, understanding the oceans requires some basic scientific literacy. For the oceanographer, studying the oceans requires a new awareness of international relations, geopolitics, and the Law of the Sea as marine research ventures farther from home port and into a more global setting.

Doing marine research in the international arena means coping with increasing legal and political constraints. Research in foreign waters is now subject to tighter control by coastal countries, and the areas under control have grown enormously in the past few decades. Stringent regulations on marine research impose more formality and additional funding requirements on scientists. But along with these constraints come opportunities for improving international collaboration in marine science.

The International Marine Science Cooperation Program, funded by Sea Grant and based at the Woods Hole Oceanographic Institution (WHOI), is trying to ease the constraints and enhance the opportunities. One of its projects has been the publication of a guide to funding sources for marine scientists who wish to do international research. When a copy of the guide was received by Guillermina Cosulich at the library of Argentina's Fisheries Institute, she responded, "You cannot imagine how valuable this reference material is here, where science is so deteriorated and where our excellent professionals are every day searching for cooperation and new opportunities abroad." This program is one of many projects funded by Sea Grant meant to aid marine scientists who undertake international research.

Marine Science Research Meets the Law of the Sea

A slow trend toward expanded maritime claims began in 1945 with the U.S. Truman Proclamation, in which the U.S. claimed control of all seabed resources on or under its continental shelf (see Fig. 1). As technology expanded and marine resources became more economically attractive, extended maritime claims cropped up in order to control resource extraction. Most countries were concerned primarily with fisheries and offshore oil and gas. Jurisdiction over marine research was decades away.

The more recent trend of rising constraints on marine research began with the Law of the Sea negotiations, which took place from 1973 to 1982, with more than 150 countries participating. The negotiations yielded the most inclusive global treaty to date: the United Nations Convention on the Law

Left: Research vessel *Knorr*, of Woods Hole Oceanographic Institution, visited the United Nations during Law of the Sea negotiations. *Photo courtesy of WHOI*

By JUDITH FENWICK, Woods Hole Oceanographic Institution

of the Sea (known more informally as the Law of the Sea Treaty). For many centuries before this agreement, any country could claim the area extending seaward three miles off its coast as its territorial sea. Within this territorial sea, the country had complete sovereignty to defend, regulate, or exploit maritime resources and uses. Beyond this area lay the high seas, a vast unregulated area accessible to all, including scientists.

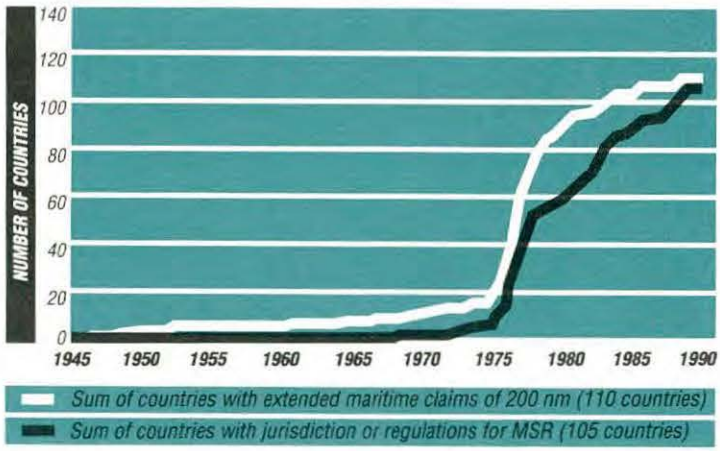
During the Law of the Sea negotiations, new standards evolved for maximizing a country's offshore claims. Territorial seas, where countries can claim complete sovereignty, were limited to 12 nautical miles, and the concept of an Exclusive Economic Zone (EEZ) was introduced (see Fig. 2). Within this new zone, a coastal country would possess sovereign rights to explore and exploit all the resources out to a distance of 200 nautical miles and could exercise jurisdiction over some other uses with economic impact, including scientific research. A country would not have complete sovereignty over or own the EEZ, but could control the use of the resources therein. Toward the conclusion of the negotiations, some countries selectively interpreted these new standards to justify "extended-claim mania." Extensive territorial seas, EEZs, and various types of fishing zones of up to 200 nautical miles were established and claimed under the Law of the Sea.

During these lengthy negotiations, other changes were under way in the world. In addition to improved technology for access to resources, nationalism was on the rise; former colonies became sovereign nations, particularly in the Caribbean, Africa, and the South Pacific. These new nations could quickly expand their sovereignty and improve their resource base with claims over vast offshore areas. The Pacific island nation of Kiribati, for example, has a land area of 291 square miles, yet its offshore Exclusive Economic Zone, which it claimed in 1983, puts an area of 770,000 square nautical miles under its jurisdiction, including control over the conduct of marine science research within the zone.

For many developing countries, offshore claims brought the pride and responsibilities of jurisdiction plus management of possibly valuable offshore areas, but not the technical know-how to assess resource potential. Some countries with limited oceanographic research capabilities were concerned about losing control over their marine resources if research by foreign scientists was unrestricted in their offshore areas. Figure 1 shows not only the rapid rise in extended offshore claims from 1975 onward, but also shows the parallel rise in national jurisdiction or regulations over marine research. This issue of regulating marine science research in offshore zones was debated during the Law of the Sea negotiations, and as a result, formal stipulations on the conduct of marine science were included in the treaty.

Figure 1

Extended Maritime Claims and Jurisdiction over Marine Scientific Research (MSR) 1947–1990. *Adapted from J. Fenwick and D. A. Ross,* International Profiles on Marine Science Research Jurisdiction and Boundaries: National Maritime Claims, MSR Jurisdiction, and U.S. Research Clearance Histories for 145 Coastal States *(in prep.).*



The coastal oceans, where research is under increasing control, are central to some of the most interesting and environmentally pivotal oceanographic studies: upwelling of ocean currents, exchanges of energy and chemicals that affect aquatic life, and human impact on ocean systems.

Doing Marine Science Research in the 21st Century

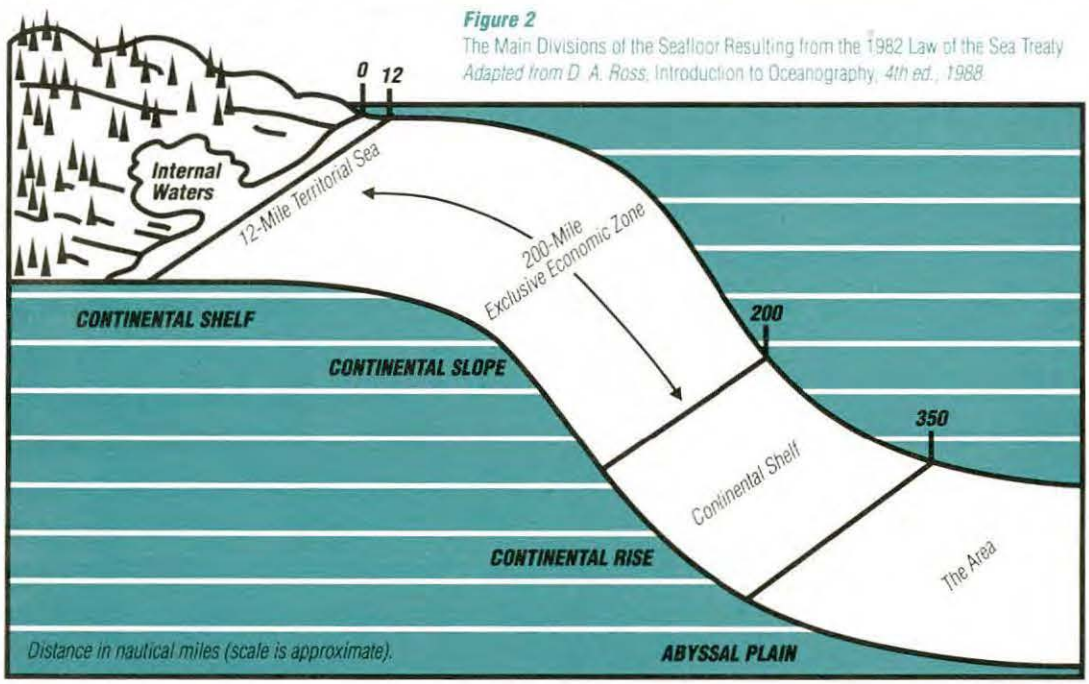
Robert Frost's line that "Good fences make good neighbors" may well be questioned by oceanographers. Almost one-third of the world's oceans are now politically enclosed by national maritime boundaries and most of these new maritime areas are controlled or restricted for their use in scientific research by foreign researchers. Up until the 1960s, oceangoing scientists were free to move in the environment they studied, unlike land-based colleagues who were often restricted by political boundaries. Currently, 110 coastal countries (out of a total of 145) have claimed maritime areas 200 nautical miles out from their shores. This ribbon of national claims runs along the world's coastlines, politically enclosing the globe's coastal oceans.

The coastal oceans, where research is under increasing control, are central to some of the most interesting and environmentally pivotal oceanographic studies: upwelling of ocean currents, exchanges of energy and chemicals that affect aquatic life, and human impact on ocean systems. The coastal oceans are also home to most of the living and nonliving resources found in the oceans. Thirty years ago, when large areas of the ocean were still unstudied, scientists denied access to a particular site could easily find another appropriate and accessible site. Current research tends to be either site-specific (e.g., hydrothermal vent studies) or requires many sites

Table 1
Research Clearance Requests by U.S. Oceanographers to Foreign Countries
Data from Office of Marine Science and Polar Affairs, Bureau of Oceans and International Environmental and Scientific Affairs, U.S. Dept. of State

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
NUMBER OF **CLEARANCE REQUESTS**	100	68	78	72	109	165	276	256	288	161	250
NUMBER OF **FOREIGN COUNTRIES**	34	19	24	25	30	49	58	57	76	47	50

Figure 2
The Main Divisions of the Seafloor Resulting from the 1982 Law of the Sea Treaty
Adapted from D. A. Ross, Introduction to Oceanography, 4th ed., 1988



across a vast area, as in large-scale international research programs investigating atmosphere-ocean interactions.

For U.S. marine scientists, foreign research access requires submitting research clearance requests and proposed cruise itineraries to the U.S. Department of State. Most foreign countries require four to six months advance notice, and scientists must patiently wait. Although the response to a research clearance request is usually positive, when it is not it results in cancellation, postponement, or alteration of the research. The request may be denied, there may be no response from the foreign country, or additional information or changes to the research agenda can be requested.

In an ideal world, the choice of location for research would be driven purely by the substance of the research. But geographic choices in recent years have been colored by several factors. First, diverse maritime claims require researchers to know the political boundaries the cruise will be crossing and what research regulations may apply. Second, the past record of particular countries that consistently deny access or create impediments to research makes scientists think twice about risking time and funding to work there. Third, the political instability of certain regions—hot spots—may make them unattractive as the site for oceanographic research.

As maritime zones have proliferated and increased in size, so has the volume of U.S. requests for clearance to conduct research in foreign waters (see Table 1). This rise in research requests does not necessarily reflect an increase in the volume of oceanographic research that is being conducted. It may simply mirror the increased political bureaucracy brought about by the diversity and size of maritime claims and the array of national regulations on marine scientific research.

At the close of 1990, 105 countries had formal jurisdiction or specific regulations concerning the conduct of marine scientific research in their extended maritime zones. The United States has some 3.1 million square nautical miles of maritime area including its EEZ (but no jurisdiction is claimed over scientific research beyond the 12-mile territorial sea); the Soviet Union's maritime area is approximately 1.3 million square nautical miles including jurisdiction over marine research; and Iraq's offshore area, with its attempted "annexation" of Kuwait, would have grown from less than 100 square nautical miles to 3,500 square nautical miles. Iraq claims a 12-nautical-mile territorial sea and full jurisdiction over research within this offshore area.

Opportunities for International Marine Science

The Law of the Sea Treaty also built in some opportunities for international marine science, mostly from the perspective of the coastal country whose waters might attract researchers from other countries. Data collected by the researchers, under the Law of the Sea, must be shared with the coastal country. This offers a good opportunity for countries without offshore research capabilities of their own to obtain important data. Some coastal countries, in legislating their jurisdiction over scientific research, may stipulate cruise participation by local observers when approving a research cruise request. This participation, for example by Senegalese observers aboard a U.S. research vessel, allows the

observers to examine new instrumentation, develop valuable scientific contacts, and learn new techniques for data analysis.

But the constraints that have been placed on marine research have not been evenly offset by the opportunities. The International Marine Science Cooperation Program at WHOI is trying to tip the balance. Since its inception in 1985, the International Program has attempted to demystify jurisdictional issues for marine scientists, administrators, and policymakers; to monitor and map the global patchwork of maritime claims; and to export U.S. marine science expertise to marine science communities in developing countries.

The broad objectives of the International Marine Science Cooperation Program are to increase and improve access for coastal countries to U.S. marine science expertise and education; to improve opportunities for collaborative research between U.S. and foreign scientists through information exchange and outreach; to increase opportunities for U.S. scientists to work in foreign waters; and to strengthen a global approach to ocean studies. In meeting these objectives, the International Program has been offering some direct solutions to researchers. Its continuing projects include:

- Establishing a Portuguese-U.S. Sea Grant cooperative marine science program for U.S. and Portuguese marine scientists. The program encourages information exchange on scientific research projects and publications, establishes cooperative research projects between the two countries, and provides scientific and technical assistance from U.S. institutions to Portuguese marine science institutions. In addition, the program assists in placement and exchange of students and staff with marine science interests between U.S. Sea Grant institutions and Portuguese institutions.

For marine scientists worldwide, the Law of the Sea regulations surrounding marine research must be translatable into scientific opportunities. Marine research must not be a pawn in any legal or political exercise between countries.

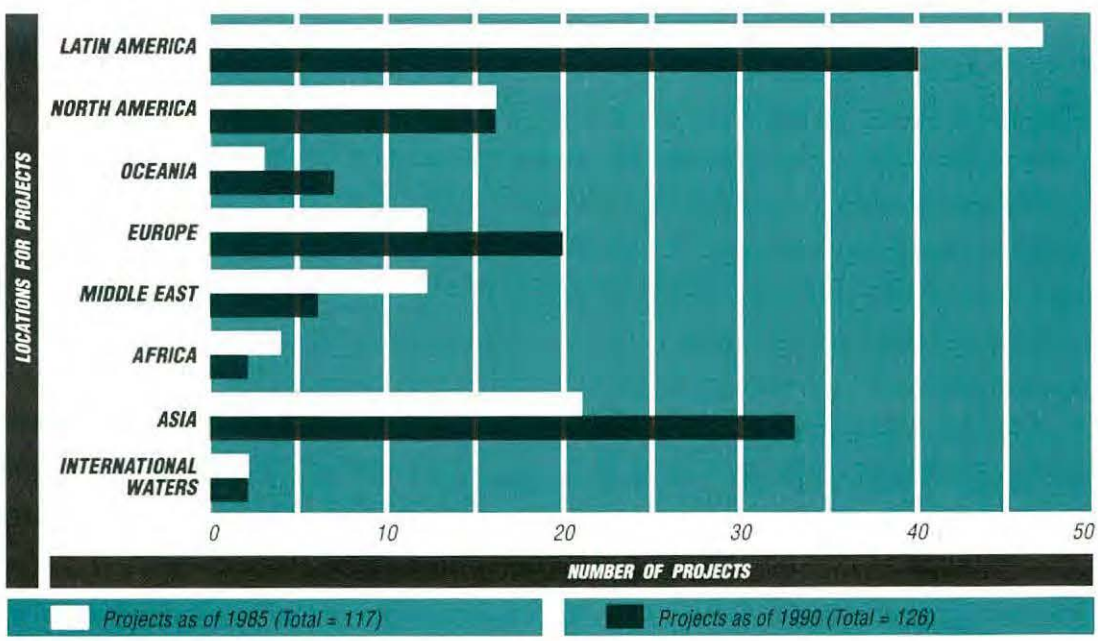
- Maintaining a database of more than 200 funding sources for scientists to undertake international marine science research. In 1990, the database was published by the WHOI Sea Grant Program as the *International Marine Science Funding Guide*, free on request and already distributed to 1,100 institutions outside the U.S. and 1,000 institutions and individuals within the U.S.
- Maintaining a database that profiles 145 coastal countries, their maritime boundaries and claims, jurisdiction over marine science research, and records of past U.S. research clearance requests. Appropriate portions of this database will be published in 1991 to assist marine science institutions, individual scientists, and administrators worldwide in planning research cruises and collaborative research programs.
- Preparing the second edition of a world map showing maritime boundaries and jurisdiction over marine scientific research. Some 1,500 copies of the 1986 edition of the map, which is out of print, were distributed free worldwide to marine science institutions, individuals, and agencies.
- Establishing the International Red Tide Information and Assistance Service, a database of 400 experts in the field of toxic algal blooms from which a directory of experts was published in 1990.
- Maintaining a database of international marine science projects at Sea Grant institutions. Data were collected from all Sea Grant programs via questionnaires in 1984 and 1989.
- Hosting foreign visitors and fulfilling literature searches and publication requests.

Cooperative programs in marine science, whether they are land-based or seagoing, fit into all sizes of research agendas: global, bilateral (between governments or institutions), or simply scientist to scientist. The continuing commitment of Sea Grant to international research is evident in Figure 3.

The need to promote cooperative marine research programs worldwide is underscored by the growth of global science programs and by the

Figure 3

International Projects Sponsored at Sea Grant Institutions as of 1985 and 1990. *Adapted from J. Fenwick and D. A. Ross,* International Marine Science Research Projects: Second Inventory of International Projects at Sea Grant Institutions—1990. *WHOI Technical Report (in press).*



growing interest in marine territory and resources by developing coastal countries. Examples of global programs involving marine scientists from many countries and various institutions include the World Ocean Circulation Experiment, which will use satellites to conduct a global survey of the physical properties of the ocean, and the Tropical Ocean Global Atmospheric Experiment, which will study the earth's equatorial regions and will contribute to prediction of climate patterns and occasional events such as El Niños that can disrupt climate.

For marine scientists worldwide, the Law of the Sea regulations surrounding marine research must be translatable into scientific opportunities. Marine research must not be a pawn in any legal or political exercise between countries. As global programs continue, the flow of international cooperative research will grow. As part of this growth and by providing access for developing countries to U.S. marine science expertise (through collaborative programs such as those supported by Sea Grant), more scientists from developing countries can be drawn into international collaborative programs. This process will help these countries assess and manage their own marine resources, and most important of all, build the educational bases from which successive generations of "global" marine scientists will come. If science is willing and politics permitting as we head into the 21st century, the Argentine fisheries librarian should be able to change the description of marine science in her country from deteriorating to flourishing.

■ *Judith Fenwick is a Research Associate at the Woods Hole Oceanographic Institution and Database Manager of the International Marine Science Cooperation Program.*

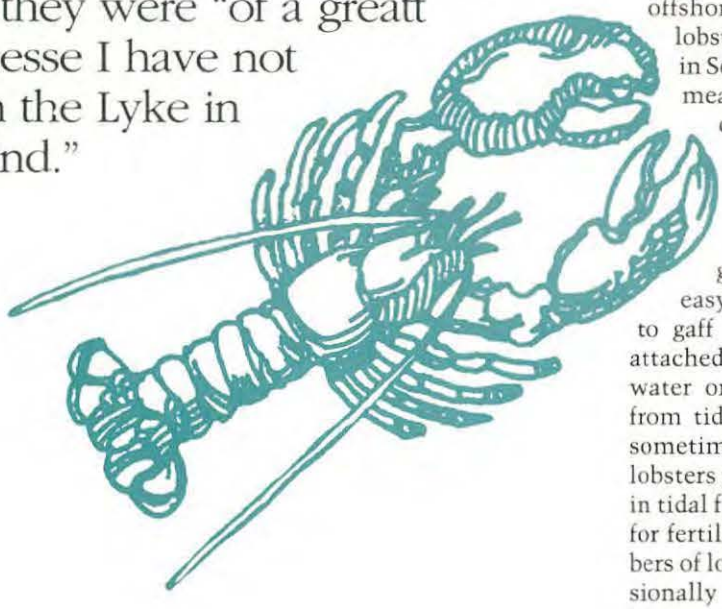
Sampler of International Projects at Northeast Sea Grant Institutions

Excerpted from J. Fenwick and D. A. Ross, *International Marine Science Research Projects: Second Inventory of International Projects at Sea Grant Institutions—1990*, WHOI Technical Report (in press).

Connecticut Sea Grant Program	Irish-American Applied Aquaculture Initiative	Ireland, N. Ireland
	Genetics of Morphology and Growth in *Laminaria* from the North Atlantic Ocean	Kenya
	Control of Reproduction and Growth Regulation in Crustacean Resources	Israel
Maine Sea Grant Program	Effects of Diarrhetic Shellfish Poison (DSP) on Shellfish	Sweden
	New Tectonic Studies of the Oak Bay Fault	Canada
	Viruses of Fish and Shellfish in Taiwan and Thailand	Taiwan, Thailand
MIT Sea Grant Program	A Novel Technology for the Manipulation of Fish Reproductive Cycles: Controlled Release of Gonadotropin-Releasing Hormones	Israel
	Autonomous Underwater Vehicles for Marine Research	Canada
	Fracture Characterization of Ice	Canada
New Hampshire Sea Grant Program	Marine Awareness Program Development	Brazil
	Water Mass Evolution and Circulation and Nutrient Environment in the Gulf of Maine	Canada
	The Arctic Ocean and the Law of the Sea	Canada, Norway, Iceland, USSR
New York Sea Grant Program	Mariculture of Economically Important Red Seaweeds from the Gulf of California, Baja California	Mexico
Rhode Island Sea Grant Program	Fisheries Stock Assessment Collaborative Support Research Program	Philippines
	Indonesian Fisheries Research and Development Project	Indonesia
	International Coastal Resources Management Project	Ecuador, Sri Lanka, Thailand
WHOI Sea Grant Program	Database of Maritime Boundary Claims and Marine Science Research Jurisdiction for 145 Coastal States	Worldwide
	Hurricane Impacts on Eastern Caribbean Coastal Ecosystems—A Special Focus Program, Rapid Response Phase	Caribbean
	Orinoco River Outflow—Effects on Coastal and Eastern Caribbean Waters: Nutrients and Primary Productivity	Caribbean

LOBSTERS A'PLENTY...

In 1607, near an island off the coast of Nova Scotia, crew members from the English ship *Mary & John* went lobster fishing. With their boat in only 3 feet of water, they leaned over the side and caught about 50 "great lopsters" in less than an hour. A chronicler of the voyage said there were so many lobsters you could load a ship with them, and they were "of a greatt bignesse I have not Seen the Lyke in Inglind."



by SUSAN WHITE, Maine Sea Grant

On board the *Mary & John* were settlers en route to the Kennebec region of Maine, where they would establish the Popham Colony. On shore were Native Americans who had been eating lobsters for thousands of years.

Back in colonial times, reports of 4-foot long and 45-pound lobsters were common. Although many think this is "just another fish story," it is probably true. When lobster boats began fishing offshore in the mid-20th century, lobstermen hauled up many of these colossal animals. Even today large lobsters are found offshore. Just last November, after a nor'easter stirred up offshore waters, a 20-pound lobster washed up on a beach in Scarborough, Maine, that measured 34 inches from claw to tail.

In Maine coastal and island communities, stories have been passed down through generations about how easy it was in the "old days" to gaff lobsters (with a hook attached to a pole) in shallow water or pluck them by hand from tidal pools. After storms, sometimes there were so many lobsters piled up on beaches and in tidal flats that they were used for fertilizer. Today, large numbers of lobsters still appear occasionally after a storm. In 1978, hurricane force winds and turbulent seas washed thousands of small lobsters onto Boston's South Shore beaches.

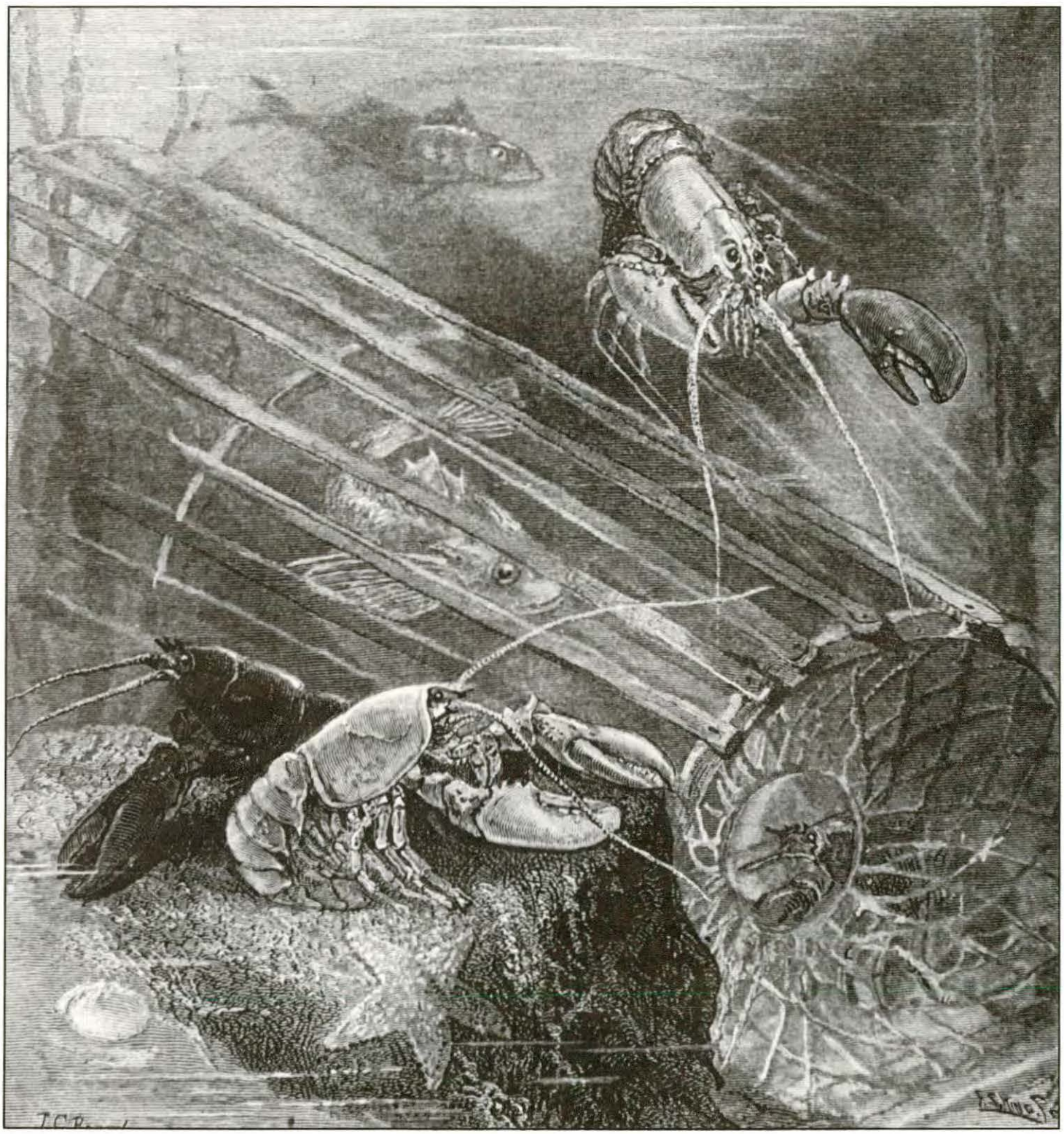
In the late 1800s, when lobster cannery operations were in their heyday, the catch declined. Throughout the 1960s and early 1970s, there were also periodic declines in the catch. However, even with these fluctuations, the catch has remained relatively stable over the years. For example, back in 1889 Maine lobstermen landed 24.5 million pounds of lobster—the largest catch on record. One hundred years later, in 1989, they landed 23.4 million pounds.

Although the catch has stayed about the same, many other aspects of lobstering have changed in the last century. Today, there are more than four times as many lobstermen and 20 times as many traps as in 1889. Modern traps are more effective, boats are faster, engines are more powerful, and hydraulic power has made hauling easier and more efficient. One might expect that fishermen would catch 20 times as many lobsters. However, this has not been the case. Beginning in the late 1960s, lobstermen fished more and more traps, and landed fewer and fewer lobsters. This trend, which continued until 1978, seemed to indicate that lobster stocks had been overfished.

Then, for no apparent reason, the trend began to reverse itself. Unlike many other world fisheries, in which stocks continue to decline, lobster stocks now appear to be holding their own and may be increasing. According to the Northeast Fisheries Center in Woods Hole, Mass., the U.S. lobster catch for the inshore fishery has risen steadily from 1978 to 1989, with an overall increase of 60 percent. The National Marine Fisheries Service reports that this increase can be attributed in part to an increase in the abundance of lobsters.

Right: Etching entitled "Lobster-Pot" taken from *Scribners Monthly*, June 1881.

BUT WHY?



WHY ALL THE BALLYHOO ABOUT LOBSTERS?

The lobster is the most economically important species in the Gulf of Maine, prompting many research projects aimed at ensuring a steady supply of this tasty crustacean. However, the lobster's importance goes way beyond its commercial value. It has also played a major role in the region's cultural history. In Maine, the lobster symbolizes the state more than any other animal, plant, or person—so much so that it appears on Mainers' license plates. Lobstermen and the lobstering lifestyle have given the state, as well as the New England region, much of its "independent" character.

Through the ages, people have been fascinated by lobsters. Maybe it's because they are prehistoric-looking creatures of the deep, which lends them an air of mystery. Or because they change color from a dull greenish-brown to a bright red when cooked. Whatever the reason, these "big bugs" continue to capture the imagination of storytellers, writers, and artists, as well as the attention of researchers and fisheries managers.

To understand lobsters and their population dynamics, researchers have been looking at this animal from all angles, and from top to bottom. Lewis Incze, oceanographer at the Bigelow Laboratory for Ocean Sciences in West Boothbay Harbor, Maine, has started at the top by studying lobster larvae that live in the water column. After larvae go through three planktonic (swimming) stages, they become postlarvae (PLs). These lobsters still can swim, but they soon are capable of settling on the bottom. When PLs successfully settle, they are called new "recruits."

Incze's study, funded primarily by Sea Grant, identified patterns of postlarval distribution and abundance and examined how these patterns related to suitable recruitment habitat. He also recorded factors such as winds and tides that could influence the distribution of PLs. Throughout the summers of 1989 and 1990, Incze towed surface-sampling nets in the Pemaquid-Boothbay Harbor region of Maine to collect postlarvae. By recording the daily average abundance of PLs per 1,000 square meters of ocean, Incze found that PLs started to appear in late July, their numbers peaked in early to mid-August, and declined to very low levels by early September. These numbers represent the population of potential recruits to the bottom.

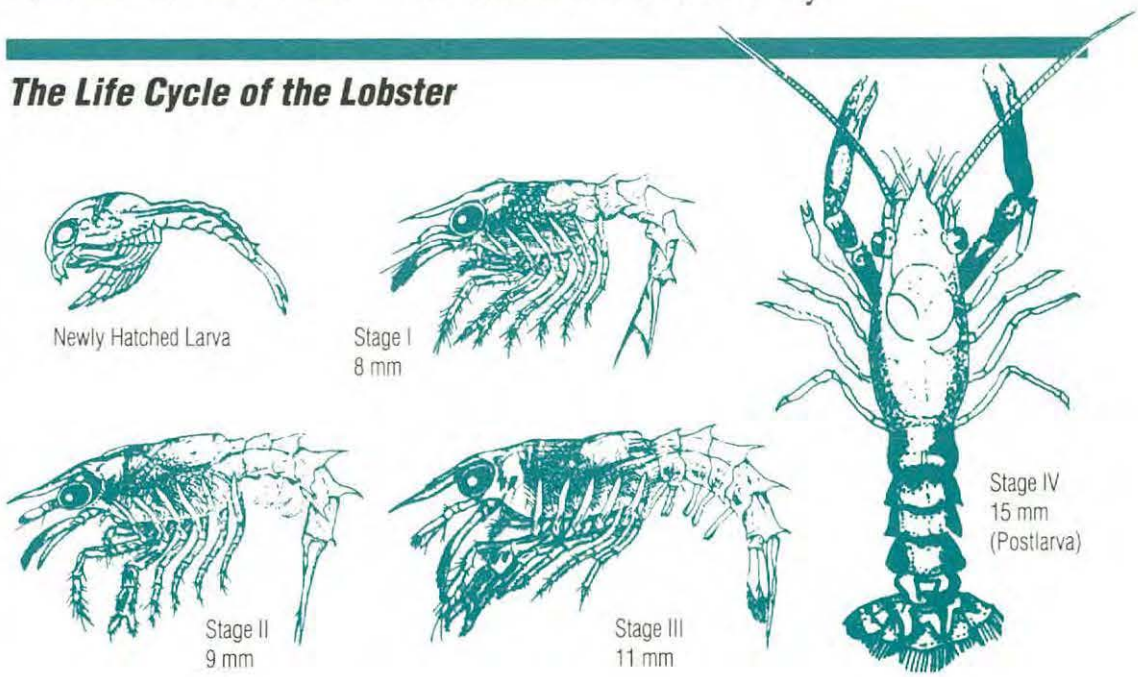
While Incze was looking at larval lobsters, Richard Wahle, graduate student in zoology at the University of Maine, was studying the ecology of early benthic phase (EBP) lobsters on the sea bottom. These are found in the spaces between small rocks or "cobbles" in certain areas. For his cooperative research project with Incze, Wahle focused on newly recruited EBP lobsters—those PLs that have recently settled to the bottom and are the smallest of the EBPs.

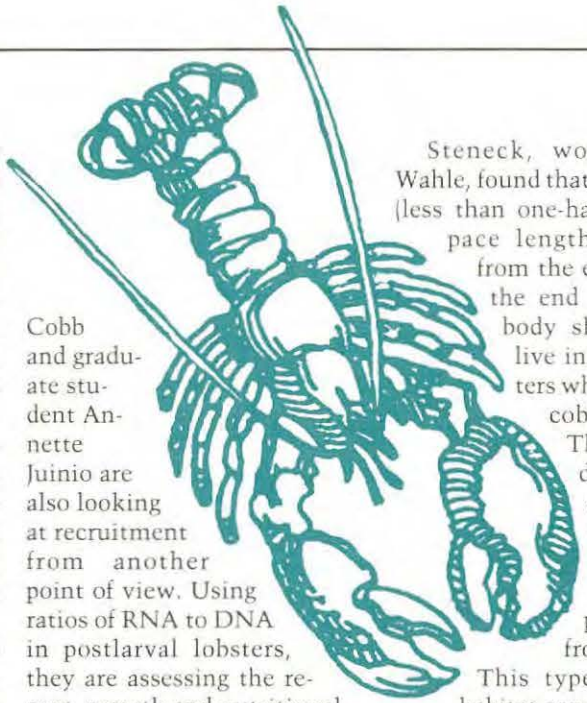
Using a suction sampler, Wahle counted new recruits in September after the PLs had

Above: According to local legend, big lobsters, like this one shown off by a proud Mainer in 1938, once were abundant along the coast. *Photo courtesy of the Maine State Archives, Augusta.*

After remaining relatively stable for so many years, the lobster catch has recently started to increase dramatically.

The Life Cycle of the Lobster





disappeared from the water column. Wahle and Incze found that the density of new recruits on the bottom was more than 100 times that of the average daily abundance of PLs recorded in the overlying water in August. Incze suggests that planktonic postlarvae may have selective behavior that enables them to find the most suitable recruitment habitats. Therefore, PLs that are dispersed over large areas of the ocean may become concentrated, resulting in the high density of new recruits in bottom cobble habitats.

When researchers compared data from 1989 and 1990, they found similar numbers and patterns of PL abundance, but new recruits averaged 60 percent lower in the second year. They are now examining possible causes for the differences in recruitment rates. Causes may include how rapidly PLs develop, how often they dive from the surface, how frequently they go all the way to the bottom, and how often their search of the bottom ends up in settlement.

Stanley Cobb, zoology professor at the University of Rhode Island, is also studying lobster larvae, particularly the swimming behavior of postlarval lobsters and how it may affect where they settle. With Sea Grant support, Cobb measured the swimming speed and endurance of PLs in the laboratory and in the field and found that in the field, PLs have swimming speeds of up to 20 centimeters per second. At this rate, they can swim 60 to 70 kilometers in a five-day period. Considering that PLs have a five-day reserve of food, Cobb suggests they can swim long distances if they swim in one direction.

Cobb determined that when PLs are south of Cape Cod, their swimming is directional and they swim northward toward shore. This suggests that offshore stocks may be the source of larval recruits for inshore populations.

Cobb and graduate student Annette Juinio are also looking at recruitment from another point of view. Using ratios of RNA to DNA in postlarval lobsters, they are assessing the recent growth and nutritional condition of PLs at different times of the year and at several locations. The nutritional condition of PLs could determine how many survive to recruit to the bottom. This research might help explain why recruitment varies and how lobster populations are regulated.

Robert Steneck, oceanography professor at the University of Maine, is interested in the ecology and behavior of lobsters after they have gone through their larval stages. Over the past several years, Steneck has been studying where lobsters live, why they live there, and how they act. He points out that, over the years, many researchers in the U.S. and Canada have contributed to this emerging picture.

Using a remotely-operated vehicle (ROV) and an underwater camera, Steneck has recorded behavior of lobsters in their natural habitat. Through Sea Grant–funded research, he observed that lobsters are very choosy and pick their homes according to their body size and what the bottom is like. Steneck discovered there is a close relationship between the number of shelter spaces in a given area and the number of lobsters living there. Also, the size of the spaces corresponds to the size of lobsters living there—an observation that confirms some earlier work by Cobb.

Steneck, working with Wahle, found that EBP lobsters (less than one-half-inch carapace length, measured from the eye socket to the end of the large body shell) mainly live in shallow waters where there is a cobble bottom. These lobsters depend on the small shelters created between the cobbles to protect them from predators. This type of bottom habitat seems to be limited and patchily distributed along the coast. Therefore, if larvae are abundant but there is not enough desirable habitat available, this could produce a bottleneck in the recruitment process.

Adolescent-phase lobsters (1.5-inch to 3.5-inch carapace length) live in areas with larger boulders, remain under cover during most of the day, and forage at night. (At 3.5 inches, an adolescent weighs about 1.5 pounds and is ready for market.) Steneck observed that adolescent lobsters appear to be highly competitive and aggressive, which could affect how many live in a specific area. Therefore, with this group, shelter space may be limited even if there are enough empty spaces of the right size.

When shelter spaces are too close together or face each other, lobsters compete, with dominant lobsters forcing subordinate individuals from their shelters. Steneck explains that when two larger lobsters are competing for space, both may begin in a dominant stance (standing on the tips of their legs), but eventually one will submit. When a lobster is in a submissive posture, it lies flat on its belly. This means it has lost the battle and will leave the area.

Adult lobsters of reproductive size (generally greater than 3.5-inch carapace length) appear to be somewhat less shelter-dependent than the other two sizes. Canadian researchers have found that these lobsters usually inhabit deeper water and can migrate long distances.

Studies of the growth process inevitably lead to the question of where lobsters go to find a mate and where the breeding takes place. Irving Kornfield, zoology professor at the University of Maine, used genetic markers or "tags" to find out whether offshore lobsters breed with inshore lobsters and thereby contribute to inshore production and larval recruitment.

Preliminary findings have shown that inshore lobsters in the Gulf of Maine are not genetically different from offshore lobsters. Therefore, Kornfield believes that inshore and offshore lobsters probably interbreed.

Estuaries differ from inshore, coastal marine waters in that they are semi-enclosed bodies of water in which fresh water from rivers and tributaries mixes with incoming tidal salt water from the ocean. To find out whether estuaries have lobster populations distinct from those in coastal waters and to what extent estuaries are used for breeding and nursery grounds, Win Watson and Hunt Howell, zoology professors at the University of New Hampshire, are studying lobster movements in Great Bay Estuary.

Over the past three years, Watson and Howell attached sonar transmitters to more than 10,000 lobsters to track their movements up and down the estuary and out into coastal waters. One of their most interesting observations is that large male lobsters tend to predominate in the upper estuary—with an 8-to-1 ratio of males to females. With Sea Grant funding, researchers plan to continue their studies to find out why this is true and what it means.

LOBSTER FACTS

■ How does a lobster smell?
The lobster "smells" or senses its food by using four small antennae located on the front of its head and tiny sensing hairs that cover its body.

■ Do lobsters have teeth?
The teeth of a lobster are in its stomach. The stomach is located close to the mouth, and the food is actually chewed in the stomach between three grinding surfaces, called the "gastric mill," that look like molar teeth.

■ Is lobster blood red?
Lobster blood is usually a gray or pale blue color, but it can sometimes be orange, green, or light pink.

■ What color are lobsters?
The American lobster is usually greenish brown when alive. However, lobsters also come in blue, yellow, red, and white. Except for the white ones, they all turn red when cooked.

■ How big is a lobster egg?
A lobster egg is the size of the head of a pin.

■ How many eggs does a female lobster have?
It depends on the size of a lobster. A 1-pound lobster usually has between 8,000 to 12,000 eggs. However, only about one-tenth of 1 percent of those eggs will develop and survive longer then six weeks.

■ How far do lobsters travel?
Researchers have discovered that large lobsters travel great distances. Lobsters tagged in Maine have been found as far away as Massachusetts and Rhode Island.

■ Where do lobsters go in winter?
Researchers believe that lobsters move offshore to deeper waters, which are warmer in the winter.

■ How long does it take for a lobster to grow to 1 pound in weight?
It takes four to seven years.

■ How old is an old lobster?
No one has yet found a way to determine the exact age of a lobster because it sheds its shell, or molts, periodically. However, researchers think that lobsters can live to be 100 years old.

■ How often do lobsters molt?
An adult male lobster will grow a new shell and shed its old one about once a year. Females molt once every two years, increasing an average of one-half inch and one-third pound with each molt. During its early growth stages, a lobster is believed to shed some 25 times over five to seven years. After a molt, a lobster's shell takes about eight weeks to harden.

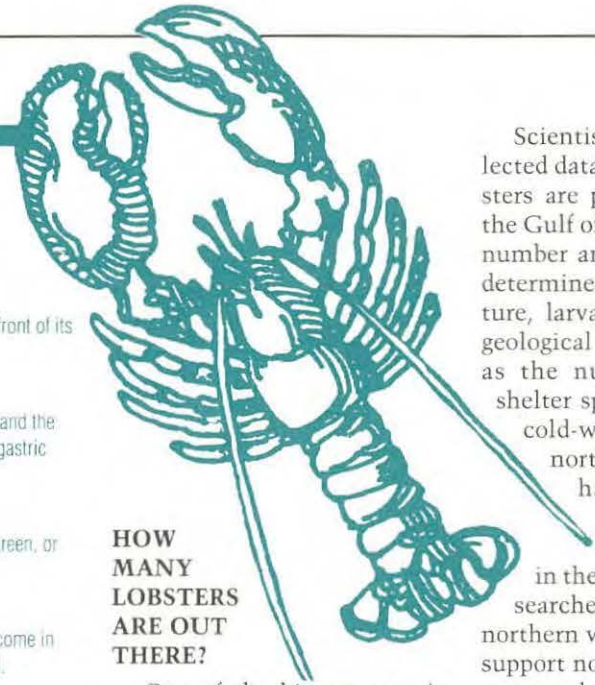
■ Are lobsters right-handed, left-handed, or both?
You can tell whether a lobster is right- or left-handed by which side the large crusher claw is on. Lobsters are usually right-handed—the crusher claw is on the right and the smaller pincer or ripper claw is on the left. It is very rare for a lobster to have two crusher claws.

■ What do lobsters eat?
Lobsters eat primarily *live* food, which includes crabs, clams, mussels, starfish, sea urchins, and sometimes even other lobsters.

■ What is a lobster pound? A lobster car?
Live lobsters are held (and fed) in saltwater storage areas called *pounds* until they are sold. Lobsters are penned in by fences or dams, which let the water in but keep the lobsters from swimming out. Lobstermen also store their catch in floating wooden containers called *live cars* while they wait for the prices to rise before selling the lobsters.

■ What part of a lobster's body is measured to determine if it is large enough to keep?
A gauge is placed between the eye socket and the end of the large body shell, called the *carapace*, to measure the lobster.

■ What are "shorts" or "snappers"?
They are undersized lobsters that a lobsterman throws back into the ocean so they can grow to legal size.



HOW MANY LOBSTERS ARE OUT THERE?

One of the biggest gaps in our understanding of lobsters is the number of animals living in the Gulf of Maine and where they are found. In the summer of 1989, Steneck and fellow researchers Incze, Wahle, and Dan Belknap, a geology professor at the University of Maine, inventoried lobster populations over a 10-day period from the 80-foot research vessel *Argo Maine*. For this Sea Grant–funded project, they explored five sites—three in Maine, one in New Hampshire, and one in Massachusetts. Researchers studied lobsters living in 10 to 40 feet of water within about five miles of shore.

Using a side-scan sonar instrument called a "fish," Belknap surveyed the bottom to determine the geological features. The fish produces a map, similar to an aerial photograph, of the ocean floor. The maps were used to choose five study sites, each having all four types of lobster habitat: cobbles, boulders, ledge, and sediment.

Incze and Cobb conducted plankton tows at each site, measuring the number of post-larvae in the water column. A team of divers headed by Steneck and Wahle dove to the ocean bottom to count and measure lobsters and their shelter spaces. The divers also used underwater video cameras to record lobster behavior and predators.

Scientists on the cruise collected data suggesting that lobsters are plentiful throughout the Gulf of Maine, and that the number and size of lobsters is determined by water temperature, larval development, and geological characteristics such as the number of available shelter spaces. Outer coastal, cold-water habitats in the northern Gulf generally had no small, EBP lobsters, although Incze found larvae in the overlying water. Researchers hypothesize that northern waters are too cold to support normal larval development and settling, and that PLs probably recruit to the bottom in areas with warmer water.

Steneck observed that lobsters also appear to lose their ability to live in high densities when they get larger. In locations where they were most abundant, they tended to be small. Where there were fewer lobsters, they were generally larger. Experiments conducted by Steneck indicate that the aggressive nature of larger lobsters may be responsible for this pattern. Finally, reproductive-phase lobsters were generally larger in the cold, northern regions than in the warmer, southern region of the Gulf near Nahant, Mass.

GIANT LOBSTERS STILL FOUND OFFSHORE

This past summer, Steneck teamed up with Richard Cooper, marine studies professor at the University of Connecticut, to extend his research into offshore, deepwater regions of the Gulf. Using the Navy's 137-foot nuclear-powered submarine *NR1*, Steneck and graduate student Paul Bologna examined the size, abundance, and distribution patterns of lobsters living in regions located between canyons on Georges Bank and the outer continental shelf.

At about 200 meters (656 feet) underwater, the captain of the submarine pointed out a blip on the sonar screen. According to

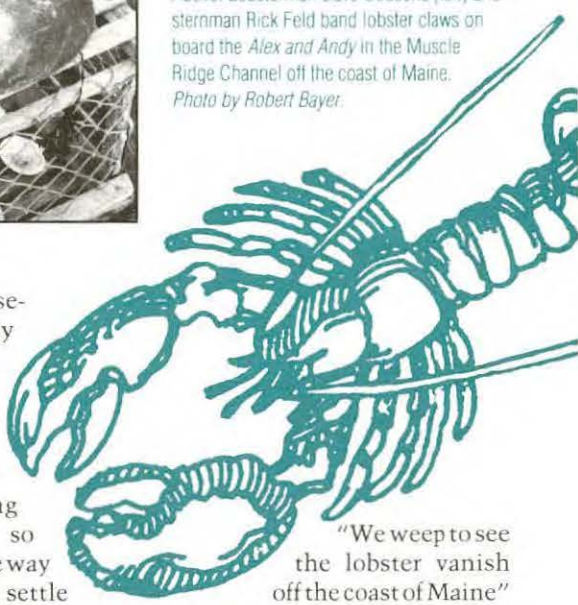
Steneck, "We went over to it, and it was a big 30-pound lobster lumbering along—so big the sub could pick it up 100 yards or so away." Using an electronic camera similar to those used on interplanetary satellites, the scientists measured the lobster. Its carapace length was more than 9 inches. The average lobster found on outer Georges Bank has a carapace length of about 7 inches and an estimated weight of over 15 pounds.

Steneck and Cooper's research, funded by NOAA's National Undersea Research Center at the University of Connecticut at Avery Point, is investigating where broodstock populations live. The distribution and abundance of sexually mature, reproductive lobsters is still largely unknown. This information is critical for management that often aims at protecting the broodstock. If certain habitats or regions are identified as critical for reproductive-phase lobsters, then steps can be taken to protect such areas.

In spite of the numerous lobster research projects throughout the years, there are still many questions that need to be answered. Managing the lobster resource is difficult without really understanding what limits or enhances it.

Left: Mario Iacopucci, a resident of Higgins Beach in Scarborough, Maine, found this large, 20-pound lobster washed up on the beach last November. *Photo by John Ewing,* Portland Press Herald.

Above: Lobsterman Dave Cousens (left) and sternman Rick Feld band lobster claws on board the *Alex and Andy* in the Muscle Ridge Channel off the coast of Maine. *Photo by Robert Bayer.*



LOBSTERS, LOBSTERS, EVERYWHERE

After remaining relatively stable for so many years, the lobster catch has recently started to increase dramatically. Cobb points out, "The combined lobster catch in the U.S. and Canada has increased by 50 percent over the last 10 years, from a little under 40,000 tons in the late 1970s to over 60,000 tons in the late 1980s. That is an enormous increase, and one that was totally unexpected by lobster scientists and managers who, in the mid-1970s, were predicting the imminent collapse of the fishery." Just last year, Maine lobstermen hauled in 28.1 million pounds of lobster—shattering the all-time record set in 1889.

Researchers are uncertain whether these recent changes indicate a long-term upward trend or short-term fluctuations in the catch. Scientists are as interested as fishermen and fisheries managers in trying to determine exactly what is going on. If the increase in harvests continues, scientists have several hypotheses to explain why this might be happening. One possibility is that the increase is a result of global warming.

According to Canadian researchers, the optimal water temperature for postlarval lobster settlement to the bottom is above 12° to 13°C (50° to 55°F). In some places along the coast, especially in Down East Maine, the water temperature has traditionally been too cold for settlement to take place. Since at least 1980, summer water temperatures have been warmer than usual. Consequently, there may be more PLs surviving on the bottom. Warmer water temperatures may also trigger the diving behavior of PLs, so that more go all the way to the bottom and settle there. If more PLs can successfully settle, and survive and grow to harvestable size, this could contribute significantly to the catch.

Other researchers have suggested that a reduction in lobster predators may have caused the surge in the lobster population. In the past, groundfish such as haddock, cod, and cusk preyed on lobsters throughout the Gulf of Maine. Now that some of these fish stocks have declined, predation may be dramatically reduced.

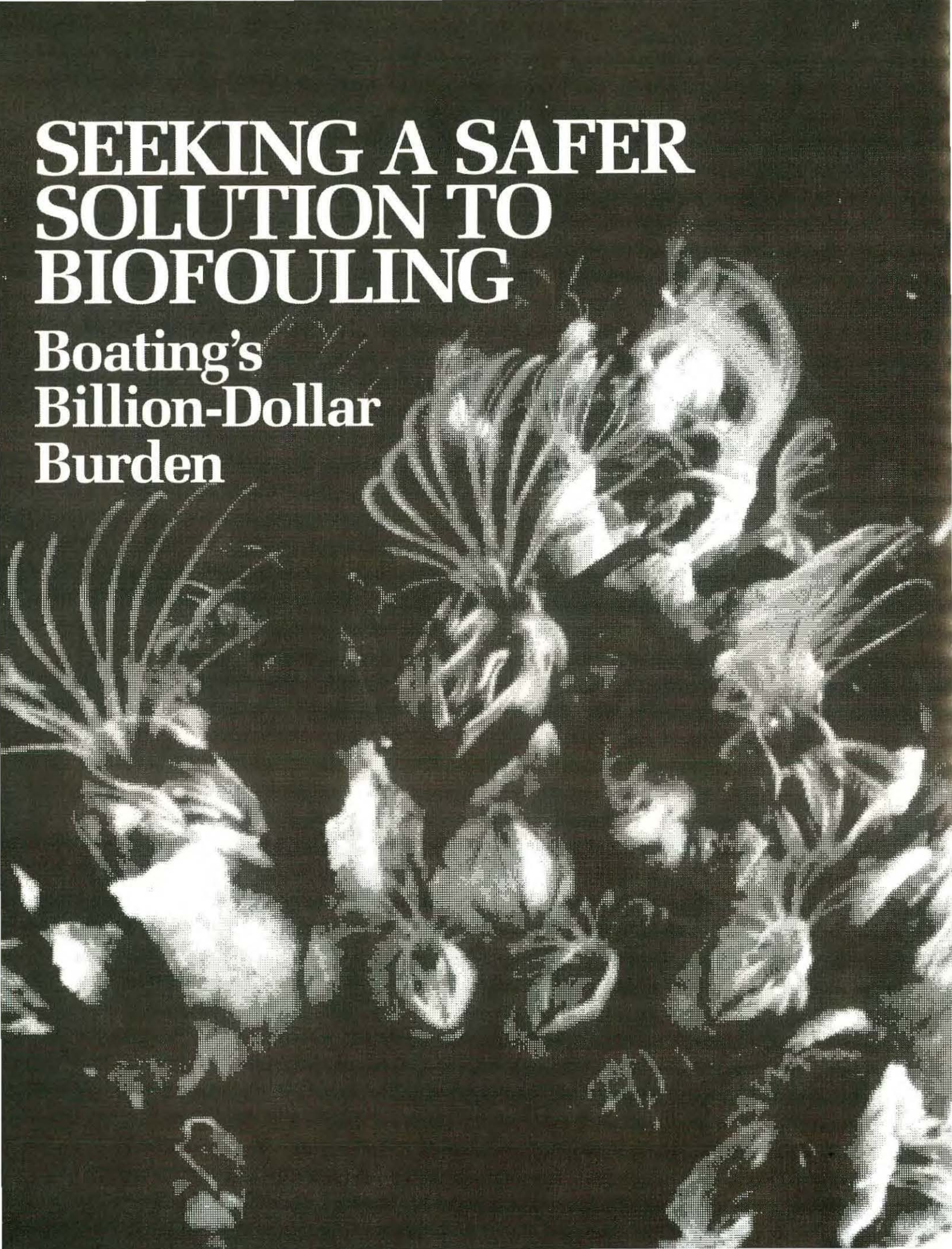
In his 1901 poem *Good-bye Lobster,* Holman Day wrote, "We weep to see the lobster vanish off the coast of Maine" and lamented the "passing of the hero of the dinner at the shore." Fortunately, Holman Day was wrong.

In the meantime, we may not be able to lean over our boats and catch 50 lobsters in an hour these days, but most people agree that lobsters are still a'plenty. Why lobsters are so abundant remains a big mystery, but researchers will continue to search for more clues to solve this complex puzzle.

■ *Susan White is a Communicator for Maine Sea Grant.*

SEEKING A SAFER SOLUTION TO BIOFOULING

Boating's Billion-Dollar Burden



Biofouling, the growth of barnacles, seaweeds, tubeworms, and other marine organisms on the hulls of oceangoing vessels, costs the international marine community billions of dollars a year. Most of this money goes for the extra fuel needed to overcome the increased drag on vessels. Some of it is spent for hull cleaning and repainting and for the upkeep on propulsion equipment. The rest is invested in the search for better biofouling inhibitors.

In addition to the huge financial burden biofouling represents, there is an environmental cost as well. The use of copper-based coatings to combat biofouling over the past century and tin-based coatings introduced over the past decade has resulted in the release of large quantities of both metals into the marine environment. And even relatively low levels of copper and very low levels of tin have been shown to inhibit the development of fish and invertebrate larvae.

"Tributyltin, one of the most popular of the biofouling inhibitors, worked like a charm," explains Gary Weisman, an associate professor of chemistry at the University of New Hampshire. "Unfortunately, it was toxic to much more than the target organisms." In fact, the tin-based inhibitor tributyltin (TBT) has been called the most toxic compound ever intentionally introduced into the marine environment. Currently, its use is restricted in 14 states and a number of European countries. However, the copper-based compounds that remain in common use as inhibitors today are also toxic and at the same time much less effective in controlling biofouling. The U.S. Navy reports that tin-based coatings can prevent significant fouling for five to seven years while ships with copper-based coatings can be fouled in a year.

"The Navy operates in a lot of different seas and ports and the biofouling problems are different in each and every one of them," explains Jerry Bohlander, a research engineer at the Navy's David Taylor Research Center in Annapolis, Md. "For example, barnacles are a major problem along the East Coast while tubeworms cause a lot of problems in Pearl Harbor, Hawaii. We have found that under certain conditions a ship with a mature biofilm (a layer of slime that forms on a wet surface due to microbial action) of 20 to 24 months growth can require some 8 percent more shaft horsepower to move as fast as a comparable ship with no biofilm. Our studies indicate that between 18 and 22 percent of the propulsive fuel used by the Navy goes to overcome the drag caused by biofilms and calcareous organisms, such as tubeworms and barnacles." Currently, the Navy is establishing biofouling test sites in Hawaii and Florida to study a greater range of antifouling strategies.

A great deal of research is being focused on the biofouling problem within the marine community, the paint industry, and the Navy. At UNH, a seven-person research team supported by Sea Grant and the Navy is involved in a multidisciplinary research project aimed at finding a solution that minimizes environmental impact. Weisman is leading the effort, together with Taylor Eighmy, a professor of civil engineering and director of the University's Environmental Research Group, and Donald Sundberg, an associate professor of chemical engineering and director of UNH's Polymer Research Group.

The primary focus of the UNH team is the development of controlled release technology for organic biofouling inhibitors. The scientists hope to learn how to mix selective, effective, biodegradable inhibitors of relatively low toxicity into marine coatings, and control their release at the slowest possible effective rate. Ships can then extend the time periods between being cleaned and recoated. Slow release rates also minimize environmental harm.

"We must find a solution to biofouling that doesn't involve putting more heavy metals into the environment," explains Sundberg. "Ideally, it will involve something organic that tells barnacles and algae that this isn't a place they want to live. No one compound or technology is going to do it. It's a huge project and the problem won't be solved quickly. Right now, we're trying to identify a few inhibitors and develop the technology to use them effectively." That accomplishment, he concludes, will mark the end of the beginning for the project.

Twice each year, the UNH team meets with other researchers who are working on the biofouling problem. These scientific meetings are convened by the Navy and have led to a multifaceted attack on biofouling. In addition to their col-

Left: Barnacles. *Adapted from a photo courtesy of Harold Wes Pratt.*

by STEVE ADAMS
New Hampshire Sea Grant

Left: Seeking new biofouling preventatives, UNH researchers are exploring polymer compounds. The compound would be mixed into marine coatings, applied to ship hulls, and released by the chemical reaction with seawater. Researchers Taylor Eighmy, Don Sundberg, and Gary Weisman (left to right) discuss a molecular model of such a compound. *Photo by Steve Adams.*

Right: Beaufort Sound in North Carolina attacks ship hulls with world-class biofouling. Here, Daniel Rittschof (left) and Joseph Bonaventura of the Duke University Marine Laboratory examine a test panel. The 5-inch coating of barnacles and hydroids grew in just three months. *Photo by Scott Taylor.*

Far right: Researchers Melanie Brown and Jim Arwa use an ultraviolet spectrophotometer to determine the release rate (in micrograms per square centimeter per day) of a coating that has been tested in the flow cell. *Photo by Steve Adams.*

laboration with scientists in the Office of Naval Research, the Office of Naval Technology, and various other Navy labs, the UNH team is working with researchers at four other institutions. Nancy Targett, associate professor of marine biology/biochemistry, and her coworkers at the University of Delaware's Graduate College of Marine Studies specialize in the identification and characterization of marine natural products, including antifoulants. Joseph Bonaventura, professor of cell biology and director of the Marine Biomedical Center at the Duke University Marine Lab in Beaufort, N.C., and his colleague Daniel Rittschof, assistant professor of zoology, have field facilities to test for a variety of fouling agents, including barnacles, bryozoans, and hydroids. At the University of Tennessee's Institute for Applied Microbiology, David White, professor of microbiology/ecology, offers expertise in testing for microbial inhibition. Robert Baier, associate professor of biomaterials and codirector of the University of Buffalo's Center for Biosurfaces, and his colleagues are involved in studies of surface chemistry and the physics of biofilms.

These semiannual meetings also involve naval officers, and sometimes the melding of scientific theory and naval reality is less than smooth. Sundberg recalls one officer who thought a meeting was wandering a little too far into the theoretical aspects of the problem. "'This is the problem!' he yelled, waving a 3-inch barnacle at us and bringing us back to the essence of the matter. In six months, the ship from which the barnacle had come had developed such a coating of them that the paint had to be taken off to get rid of the barnacles."

The UNH biofouling research project started in 1987 with support from the Office of Naval Research and the Hubbard Fund (a private endowment that provides funds for marine research at the University). Eighmy had been studying the formation of microbial biofilms in wastewater and water treatment systems. In these cases, biofilms serve as microbial reactors, providing benefits such as the transformation of organic carbon to carbon dioxide and water. If this carbon was not removed, it would cause an oxygen deficiency when the water returned to the environment. Because of this background and his concerns about the environmental damage done by heavy metals, Eighmy became interested in alternative means of inhibiting marine biofilm formation as part of the process of controlling biofouling. Realizing he needed the expertise of a chemist and a polymer scientist to attack the problem, he joined forces with Sundberg and James Morrison, a professor of chemistry. Early on, Morrison recruited Weisman to the project.

"Simplistically, there are two types of marine biofouling," Eighmy explains. "Soft fouling, or microfouling, consists of the formation of a biofilm, a development that in itself will increase hydrodynamic drag and decrease ship speed and efficiency. Hard fouling, or macrofouling, is the growth of barnacles and other large marine organisms on the hull. We're not sure if soft fouling must take place before hard fouling, but both types of fouling are problematic." He explains that a wide range of organisms contribute to the biofouling process. Bacteria such as *Pseudomonas*, *Vibrio*, and *Caulobacter*, and diatoms such as *Amphora* and *Navicula* cause soft fouling. Hard fouling is the work of bryozoans such as *Bugula*, barnacles such as *Balanus*, bivalves such as *Mytilus*, and hydroids such as *Clava*.

Sea Grant joined with the Navy in sponsoring the research in 1988 and UNH researchers started focusing their efforts on two methods of controlling the release of inhibitors. One is based on microcapsules and the other is a self-polishing concept.

With the microcapsule method the inhibitors are encapsulated in spherical capsules, each perhaps 10 microns in diameter, or about one-fifth the diameter of a human hair. These capsules would be applied to a hull as a component of a marine paint. "The capsules would work in the same manner as cold capsules do in the body," according to Sundberg. "They would release the inhibitor over time. The big difference is that while cold capsules are designed to work for 24 hours, the Navy

wants a controlled release that will last for several years."

Sundberg and his colleagues in the Polymer Research Group, research associate Robert Cimini and senior chemistry major Scott McCallum, are concentrating on the microcapsule approach. They must develop a capsule that allows the inhibitor to escape at a slow and steady rate and a binder (the paint or other medium in which the capsules will be applied) through which the inhibitor will pass quickly and easily. However, first they must find a few effective inhibitors.

"Lately, we've been working with a few model inhibitors that were identified as such by other research groups in laboratory testing," Cimini explains. "These include benzoic acid and dinitrophenol. We've also been working with extracts from gorgonian coral, which has a natural resistance to biofouling. While these substances may not pan out, they are closely related to other potential inhibitors. So the research we do on them today will help guide our future studies."

With the self-polishing method, the inhibitors are chemically bound to the "backbone" of a polymer molecule. The polymer molecules would be a component of a marine coating applied to the hull and be released by their chemical reaction with seawater. As the coating wore away, a new layer of inhibitor would constantly be available on the surface. Again, the challenge is to achieve a controlled and optimum release rate that will continue for several years. With the collaboration of polymer specialists, Weisman and graduate student Melanie Brown are taking the lead in this effort.

As the research progresses and suitable candidate coatings are prepared, they are applied to epoxy slides and tested in a flow cell. These candidate coatings are assorted inhibitor-polymer combinations in various concentrations. The flow cell, designed and built by Cimini and operated by McCallum, is a closed system in which artificial seawater is pumped through a number of loops. Each slide is submerged in the moving water and the resulting test roughly approximates the movement of a ship's hull. Made in the lab, the seawater is used to approximate the actual environment to which the films will be exposed in the field. After a period of days, each slide is removed from the flow cell and tested to determine the release rate of the inhibitor. The slide is then returned to the flow cell and the cycle is repeated until the release rate falls below acceptable levels. The researchers use ultraviolet spectroscopy and other analytical methods to measure the release rate of the inhibitors.

James Arwa, a research associate in the Environmental Research Group, tests the slides to determine if any soft biofouling has taken place. If he discovers that a film has formed, he examines it to determine the health of the organisms in the biofilm. The possibilities range from finding a film of organisms that are dying, to finding the organisms eating the inhibitor for breakfast and multiplying rapidly. To determine if a particular coating is effective against hard fouling, the researchers send coated epoxy rods to the team at Duke. The rods are tested in the lab against barnacle larvae and field tested in the Atlantic Ocean.

The UNH researchers know that they are reconnoitering the edges of a scientific labyrinth and that there will be many wrong turns taken and blind alleys explored before they are done. However, they think the problem is solvable and that a multidisciplinary, multi-institutional approach is the only one feasible.

"We have a well-defined goal and a huge problem," says Weisman, "but by working together we can solve it. There won't be any magic bullets, no single solution. I think we'll find that different combinations of inhibitors and delivery systems will have to be developed for the different fouling agents and for different bodies of water."

"It's a very complex problem," adds Sundberg, "but there is a real need to solve it. It will take time and money and expertise and cooperation. The answers we find today will help us formulate the questions we ask tomorrow."

■ *Steve Adams is Communications Coordinator for New Hampshire Sea Grant.*

COASTAL HABITAT RESTORATION

CAN THE DAMAGE BE UNDONE?

Above: Milford, Conn., White Sands Beach area: Development along the shoreline complicates restoration efforts. The wooden structure in the beach is a channelized creek that feeds a salt marsh behind these homes. To restore the marsh without flooding adjacent properties, a self-regulating tide gate was installed. *Photo by Heather M. Crawford.*

by HEATHER CRAWFORD and PEG VAN PATTEN, Connecticut Sea Grant

More than 50 percent of our nation's coastal wetlands have disappeared. These wetlands provide nursery areas for commercially important fish and shellfish species as well as habitat for many other plant and animal species. Few of the remaining wetlands are undamaged. Other important coastal habitats, such as dunes, estuaries, rivers, eel grass beds, coral reefs, and kelp beds have been decimated. This alarming situation has developed largely through the profound impact of human activities. Yet mankind can also alter ecosystems in ways that restore coastal habitats to a state approximating the original. As an ancient Chinese proverb says, "What has been spoiled through man's fault can be made good again through man's work."

Protected coastlines where rivers meet the sea create conditions for the formation of tidal flats and marshes through the accumulation of sediment and organic material. These areas also provide quiet harbors, an important component in the development of a society dependent on water-based transport. Early settlers, drawn to these safe harbor areas, considered the marshes to be at best a nuisance, and at worst a place of pestilence and madness; estuaries and rivers were used as garbage disposals for every sort of waste.

Beginning with the industrial revolution, massive quantities of toxic chemicals and metals were dumped into the waters. The use of petroleum products and their worldwide transport led to disastrous oil spills. And as coastal populations grew, many wetland areas were drained, filled, ditched, dammed, paved, polluted, and otherwise destroyed. Large parts of the cities of Boston, New Haven, and New York are built on areas that once were salt marsh or tidal flats. The Northeast now has the most densely populated coastal zone in the United States.

The national loss of wetland acreage today is equivalent to 16 times the area of the city of Boston every year. Census figures project an additional 10 percent increase in coastal population by the year 2010, when 60 percent of the nation's total population will live in the coastal zone. The potential for increased human impact on coastal habitats is clear. Global climate change and accelerated sea level rise may add to the forces tearing away at our remaining tidal wetlands.

Scientists and the public are increasingly aware of the roles coastal areas play as wildlife habitat and spawning grounds; as well as their value in pollution filtration, flood water storage, education, and recreation. Many endangered and threatened species of plants and animals depend on wetland habitat for their survival. As wetland ecologist William A. Niering of Connecticut College points out, "The future for many rare plant and animal species may be bleak unless we act quickly to slow the pace of habitat destruction." Federal, state, and public organizations are mobilizing their efforts to reduce habitat loss, and the first years of the 1990s are already witnessing an unprecedented level of government emphasis on habitat restoration, a high degree of interagency cooperation, and scientific emphasis on restoration ecology. Habitat restoration is an idea whose time has come.

Restore, Create, or Mitigate?

Several terms important to restoration ecology are often confused. *Restoration* refers to an attempt to return a damaged habitat to its original, pre-disturbance condition. *Creation*, on the other hand, is an attempt to construct a new habi-

Many endangered and threatened species of plants and animals depend on wetland habitat for their survival.

tat where it did not previously exist—a risky venture at best.

"Tidal wetland *creation* projects are generally doomed to failure from the start because the creation site is a high-energy one that is incapable of sustaining a wetland over a long period of time," says Ron Rozsa, a senior environmental analyst for the Connecticut Department of Environmental Protection's Coastal Resources Management Division (CRMD). "The single most important factor overlooked is the requirement for a sheltered environment free from wave action." In contrast, *restoration* projects have a higher success rate because the conditions necessary for the habitat once existed at the site, and may be revitalized if the cause of the degradation is correctly identified and removed.

Mitigation, another common term, is actually used in two ways. On the one hand, mitigation describes efforts to minimize damage from human activities. One example is providing adequate tidal flushing when marshes are divided by roads or railways. On the other hand, mitigation is the practice of compensating for intentional damage to a critical habitat (usually a wetland filled in in the interests of highway construction or development) by creating "equivalent" area elsewhere. Experts agree that creation and compensatory mitigation attempts usually are doomed to fail, and restoration has far more potential for success.

"We have given away all the habitat we can afford to, and need to make up for what has been lost—not make excuses for new destruction, which is the effective result of a mitigation policy," said Roger McManus, president of the Center for Marine Conservation. Of course, the old saying, "An ounce of prevention is worth a pound of cure," is a good motto for coastal and marine habitats. It's always easier to prevent a problem than to try to clean up after one.

Above. A site review team examines vegetation that has recolonized a filled and gravelled parking lot. *Photo by Heather M. Crawford.*

Above right. Open marsh water management techniques of reservoir pools and ditches provide the dual benefits of increasing saltwater flow to restore original vegetation and providing mosquito predator habitat to help control mosquito populations without pesticides. *Photo by Heather M. Crawford.*

"Somebody Ought to Do Something!"

With the loss of critical habitat areas reaching the level of a national crisis at a time when development pressures on coastal areas are also intensifying, the public is looking to government for a solution. When the National Oceanic and Atmospheric Administration (NOAA) sponsored the symposium, "Restoring the Nation's Marine Environment" in Washington, D.C., in September 1990, more than 400 scientists, lawyers, economists, and policymakers attended to learn more about the status of restoration ecology and the direction federal habitat protection and restoration policies would be taking in the future.

NOAA's new Coastal Ocean Program has three objectives: determination of coastal and estuarine habitats that support marine resources, mapping resource areas for the analysis of present values and historical losses, and synthesis of the resulting information for use in resource management policy decisions. The Environmental Protection Agency's National Estuaries Program is examining many kinds of habitat restoration through its action plan demonstration projects. These projects are models for experimental restoration techniques such as the use of restored wetlands as stormwater filters to improve coastal water quality. The U.S. Fish and Wildlife Service (USFWS) has developed a successful program with private owners of wetlands. USFWS restores the wetlands to their natural condition at no cost to the owner if the owner agrees to maintain the area in the restored condition for no less than 10 years. Between 1987 and 1988, 1,700 such agreements led to the restoration of more than 35,000 acres of wetlands.

Still another federal agency joining the restoration battle is the Army Corps of Engineers. The Corps is in charge of the permitting process for altering wetlands under Section 404 of the Clean Water Act and has recently elevated wildlife habitat to an equal footing with navigation and flood control in its analysis of civil projects. The Corps has also signed an agreement with NOAA to develop a nationwide program for fisheries habitat restoration and creation that can draw on the expertise of both agencies.

Federal agencies are starting to take advantage of some older legislation in support of their new emphasis on habitat restoration. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly referred to as the Superfund Act, was enacted in 1980 with the twin goals of eliminating the threats of uncontrolled hazardous waste sites and removing hazardous substance threats to public health and the environment in a cost-effective manner. The act established a system for identifying, analyzing, and prioritizing hazardous waste sites, established federal authority to clean up such sites when the responsible party cannot be found or will not take any required actions, created a trust fund to pay for the cleanup of such sites (the Superfund), and made those persons responsible for the release of the hazardous substances liable for cleanup and restitution costs.

The National Resources Damage Assessment Program, created through the CERCLA legislation, is the key part of the act. This program allows federal agencies to assess levels of environmental injury and economic impact at a Superfund site, then assess fines and use the collected money to restore the damaged area.

"There's no such thing as a free lunch, and CERCLA is now

tos and the readily identifiable marsh plant layer that has been preserved under the dredge spoils. Approximately 20 acres of the site have been recontoured as of December 1990, and in some areas there are already healthy stands of marsh grass. This project illustrates how cooperation between state, local, and federal agencies can lead to more extensive and creative restoration efforts than any one agency would consider tackling alone.

"We have given away all the habitat we can afford to, and need to make up for what has been lost—not make excuses for new destruction, which is the effective result of a mitigation policy."

—Roger McManus, president of the Center for Marine Conservation

sending out overdue bills for a lot of old habitat destruction 'lunches,'" according to Dan Esty, special assistant to the Administrator, Environmental Protection Agency. NOAA, through the National Marine Fisheries Service, acts as the trustee for living marine resources, and USFWS acts as the trustee for migratory birds, anadromous fish (saltwater fish that spend part of their life cycle in freshwater streams), and endangered species. These agencies work closely with EPA to evaluate Superfund sites. NOAA is currently assessing some 250 Superfund sites out of more than 500 coastal hazardous waste sites identified through this program, including New Bedford Harbor in Massachusetts.

Given the complexity of ecosystems, assessing the amount of environmental damage at a Superfund site is always difficult. Calculating the economic impact of such damage is also not an easy task. While it's relatively easy to come up with a dollar value for some coastal resources—for example, the loss to commercial fisheries—intangible values are harder to quantify. During the damage assessment of the *Exxon Valdez* oil spill in Alaska, the economic impact of the death of a puffin was valued at $8. Can we really assign an economic value to the loss of an egret, or the bird-watching and beachcombing that our grandchildren won't be able to do?

States are also increasing their emphasis on coastal restoration. In Connecticut, the cooperative efforts of the CRMD and the Mosquito Control Section of the Department of Health Services have led to the restoration of significant areas of salt marsh through the Open Marsh Water Management Program. An important restoration project now under way as part of this program also involves the cooperation of the USFWS and the Town of Groton Health Department. This project, in Mumford Cove, Groton, involves the restoration of a 35-acre salt marsh that was used as a dumping ground for dredge spoils. The sediment, in some places 3 feet thick, is being bulldozed off the marsh area and the land is being recontoured based on old aerial photos and the readily identifiable marsh plant layer that has been preserved under the dredge spoils. Approximately 20 acres of the site have been recontoured as of December 1990, and in some areas there are already healthy stands of marsh grass. This project illustrates how cooperation between state, local, and federal agencies can lead to more extensive and creative restoration efforts than any one agency would consider tackling alone.

On a smaller scale, towns and local environmental groups all over New England are restoring fishways, shellfish beds, and salt marshes; and monitoring important environmental parameters such as water quality. Within the Connecticut Department of Environmental Protection, the Wildlife Bureau has programs for the restoration of waterfowl and osprey habitat, the Fisheries Bureau has programs to restore fish habitat including spawning areas, and the Coves and Embayments Program, part of CRMD, provides financial assistance to municipalities interested in estuarine habitats. Tim Visel and Nancy Balcom, educators with the Connecticut Sea Grant Marine Advisory Program, have provided educational programs and technical assistance to several Connecticut towns attempting to restore their natural oyster beds and re-establish historical alewife runs.

Last Spring, the Connecticut state legislature passed a major bonding package to fund a pilot project for restoring the state's coves. Many coves have been separated from Long Island Sound for decades by railroad or road causeways, resulting in increased sedimentation and damage to the ecosystem. The pilot project, in Quiambaug Cove, Stonington, will look for ways to restore the ecological health and biological diversity of the cove. Scientific and historical data collected and analyzed by the Connecticut Sea Grant Marine Advisory Program was critical in the choice of this cove for the pilot effort. If the project proves successful, other coves with similar problems in Connecticut and along the Atlantic shoreline will benefit.

"If It's Green, Is It a Marsh?"

Determining the success of a restoration effort can be difficult. Coastal habitats and estuaries do not exist in isolation, but are part of specific hydrologic regimes and ecosystems whose boundaries extend far beyond the area targeted for restoration. As ecosystems, these areas perform vital functions other than providing habitat, including biomass production, nutrient accumulation, pollution filtration, shoreline stabilization, and flood control. For example, marsh grasses (*Spartina alterniflora* and *S. patens* in the Northeast) are the base of the marsh food web, but are even more important to the food webs of adjacent waters, where the dead grasses contribute organic material in the form of detritus.

To determine the success of a restoration project, the ecosystem of a restored area must be compared with a nearby natural area, to determine whether the two areas are functioning in the same manner—that is, if the two areas are "functionally equivalent." Such comparisons are difficult in the Northeast, where it is almost impossible to find coastal areas that have not been altered by human activity. In such cases, there is no choice but to use the most minimally impacted areas as references.

Just because an area turns green doesn't mean it is fulfilling its desired role, says Joy

Zedler, a research scientist with the Pacific Estuarine Research Lab. Zedler attempted to restore a marsh in California, a state which has lost 91 percent of its tidal marshes. The project's goal was to restore habitat for the clapper rail, an endangered marsh bird. These birds require tall marsh grasses for their nests. While the restoration effort did grow *Spartina* grass, its size was stunted compared to grasses in a natural marsh. Clapper rails, finding the short grass inadequate for nest-building, were not attracted to the site. Zedler considered her project a failure because no clapper rails settled in the area; however, nearly 100 percent of the fish species originally present returned to the adjacent estuary. Had the goal been to restore fish habitat, the project would have been deemed successful. When the entire ecosystem was considered, Zedler estimates that the restoration had a 57 percent functional equivalency.

The Ecosystem Approach

The use of an ecosystem-wide, as opposed to species-specific, perspective in habitat restoration is growing. An ecosystem approach is a better gauge of success because appropriate habitat must be available for all of the life stages of the desired species, as well as for other species with which they must interact, for the restoration to be deemed successful. For some species this can be quite complicated, as with anadromous fish such as striped bass, alewives, and salmon, that spend part of their lives in freshwater streams and the remainder of their time in the open ocean. In Washington and Oregon, where salmon restoration efforts have been under way for some time through hatchery programs and stream restoration, emphasis is now being placed on restoration of juvenile salmon feeding habitat in estuaries. This change in emphasis is based on the idea that since saturation of the ecosystem with hatchery-raised fingerlings is not increasing the adult population, the lack of habitat for juvenile fish may be creating a population bottleneck, limiting the number of fish that successfully reach adulthood. Since other species indirectly benefit from even species-specific restoration efforts, broadening the perspective of the effort to an ecosystem level helps maximize the benefits without significantly changing the costs.

Right: Paul Capotosto of the Mosquito Control Section of the Connecticut Department of Health Services examines a marsh restored through sill ditching, which provides for saltwater inflow and mosquito predator habitat without large reservoir pools. *Photo by Heather M. Crawford.*

One difficulty of restoration at the ecosystem level is that scientists have not yet unraveled all the complex interactions between different portions of an ecosystem. Without this understanding, different types of damage to the ecosystem may be missed that, uncorrected, would cause the failure of a restoration effort. Conditions need to be right not only for the "key" species, but for everything down to the microbial communities responsible for biogeochemical processes such as nitrogen cycling, if a restoration effort is to be truly successful.

Monitoring Restoration Efforts

Another important aspect of habitat restoration that is often overlooked is the post-restoration monitoring effort. Such monitoring is critical in determining the long-term success of a restoration effort. Connecticut Sea Grant's *Coastal Resources Restoration Handbook* stresses the importance of monitoring over an adequate time frame. Monitoring needs to occur over a long time scale because a project may appear successful in the first year and fail shortly thereafter. Although nature is resilient, the time scale for recovery of some damaged ecosystems is generally longer than anticipated. For example, when the oil tanker *Torrey Canyon* ran aground in 1967 causing the world's ninth-largest oil spill, the coasts of Great Britain and France were ravaged. The French and English used different cleanup methods to restore their coasts. Twenty years of monitoring show that shores cleaned mechanically recovered in five years; those treated with light doses of chemical dispersants recovered in 10 years; but due to the toxicity of early chemical dispersants, areas scoured with every possible chemical (tourist beaches) took more than 15 years to recover.

The Time Is Now

With levels of both government and citizen awareness and commitment at an all-time high, habitat restoration may become a key environmental effort in the 1990s. Some people feel that we have more pressing concerns than the environment right now—crisis in the Persian Gulf, Soviet upheaval, the downturn in the economy of the Northeast. Even in these troubled times, however, it should be pointed out the enormous contribution a healthy environment makes to the economy of a region or nation. For example, current cost estimates for the cleanup of Long Island Sound are about $7 billion over a 20-year period. A 1990 study by Marilyn Altobello, associate professor of agriculture and resource economics at the University of Connecticut, found that the annual economic contribution of Long Island Sound to the economy is between $5 and $10 billion. This value would only be increased by improving the water quality, allowing harvest of shellfish from areas now closed, enhancing fisheries, and reducing beach closings.

Historical examples abound of the detriment to civilization that can occur when attention has turned away from environmental concerns. When the Persian army invaded Syria in the seventh century, followed by invading nomads, traditional practices for soil and water conservation were forgotten. Once-thriving cities were buried under 3 to 6 feet of soil eroded from the hillsides. In the Sahel region of Africa, the traditional migratory lifestyle conserved productive grasslands for thousands of years. But in recent times, the change to permanent settlements and overgrazing by domesticated animals has stripped the land to barren desert and brought about recurring famine. Michael Deland, Chair of the National Council on Environmental Quality, sums up the importance of both environmental concern and habitat restoration in his comment, "Healthier habitats lead to healthier balance sheets; a clean environment helps our economy."

■ *Heather Crawford is an Educator, and Peg Van Patten is Communications Coordinator, for Connecticut Sea Grant.*

MARINE **PUBLICATIONS**

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Coastal Land Use Issues and Alternatives in the Northeast
N.K. Bender, K. Gardner, C. Arnold, and H. Crawford

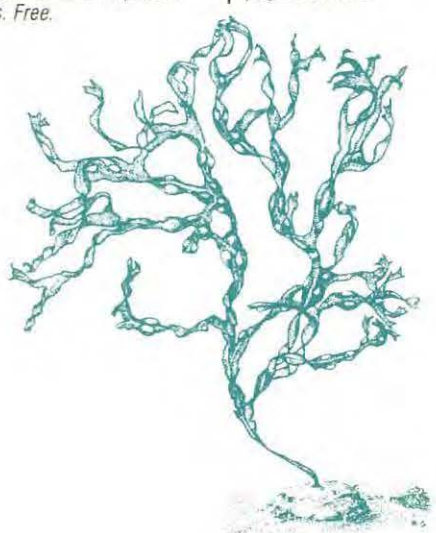
Reprinted from *Coastal Land Use Issues in the Northeastern United States*, Newark, Del.: University of Delaware and Northeast Regional Center for Rural Development, Northeast Land Use Series, Leaflet No. 5. Development pressures from a surge in coastal population during the past two decades have resulted in major alterations in coastal land use patterns. The increased demand for coastal lands and urban waterfront sites in the Northeast has led to land use conflicts that will impact generations to come. This leaflet examines the protection and enhancement of water-dependent uses, waterfront revitalization, public access to the shoreline, small harbor management, coastal pollution, habitat restoration, public trust, global warming trends, and coastal land and resource management techniques. *8 pages. Free.*

Plants and Animals of Long Island Sound
Lisa Wahle

Often called the "Urban Sea," Long Island Sound is a large and complex estuary. It stretches from densely populated New York City on the western end to the eastern tip of Long Island. The Sound is used for a variety of purposes by the 14.6 million people who live in its watershed, and sometimes the human users compete with the animals and plants in its waters and along the shores. This popular guide with its many detailed line drawings introduces the curious reader to the beauty and diversity of the creatures with whom we share the Sound. *33 pages. CT-SG-90-11. Free.*

Economically Important Marine Plants of the Atlantic
C. Yarish, C.A. Penniman, and P. Van Patten (eds.)

This proceedings volume from a Connecticut Sea Grant symposium in 1988 includes results of recent phycological research in biotechnology and discusses the future of seaweed aquaculture and utilization. Also included are chapters on kelp and Irish moss cultivation. Illustrated. *158 pages. $12.50.*



MAINE

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Hindcast Estimates of Extreme Wave Conditions in the Gulf of Maine
Vijay Panchang, Bryan R. Pearce, and K.K. Puri

Reprinted from *Applied Ocean Research* 12(1):43-49 (1990). The Gulf of Maine is lacking in wave data for use in engineering and research. In this report, extreme wave statistics for the Gulf have been computed by numerical hindcasting.

The researchers conclude that as a first-order estimate, any major engineering effort in the Gulf of Maine will have to reckon with a 1 percent chance of encountering wave heights up to 13 meters. These results agree extremely well with estimates based on shipboard observations. *7 pages. R-MSG-90-7. Free.*

Protection Against Liability for Landowners Who Allow Public Access
Marine Law Institute, University of Maine School of Law

Many coastal landowners are willing to allow their neighbors or the public to use part of their land for recreational or harvesting activities. However, they sometimes hesitate to give permission because they are concerned that they could be sued if someone were injured. This report, one of a series of *Citizens' Guides to Ocean and Coastal Law*, explains the Maine law that greatly limits the liability of private landowners and suggests methods for further reducing risk. *6 pages. E-MSG-90-6. Free.*

Egg Production of V-Notched American Lobsters *(Homarus americanus)* Along Coastal Maine
Peter C. Daniel, Robert C. Bayer, and Cheryl Waltz

Current Maine law allows fishermen to place a V-shaped notch in the right uropod of ovigerous lobsters before returning them to the sea. The landing of a lobster in Maine with a mutilated or notched right uropod with or without eggs is illegal. The marking and protection of ovigerous lobsters has been in practice in Maine since 1917.

Twenty-nine percent of trapped nonvigerous females and 69 percent of trapped ovigerous lobsters were found to be V-notched, during a three-year survey of trap hauls conducted from 1982 to 1984 by the Maine Lobstermen's Association. The size-frequency distribution of V-notched lobsters is biased toward larger females relative to unmarked females. Calculated numbers of annual eggs per V-notched lobsters were about nine times greater than for unmarked lobsters as a result of their larger size, hence a greater proportion of sexually mature lobsters with higher fecundity.

These preliminary results indicate the need to include V-notched lobsters in Maine fishery surveys and assessments, and to investigate the possibility of V-notching as a management tool for the Gulf of Maine fishery region. *6 pages. R-MSG-89-2. Free.*

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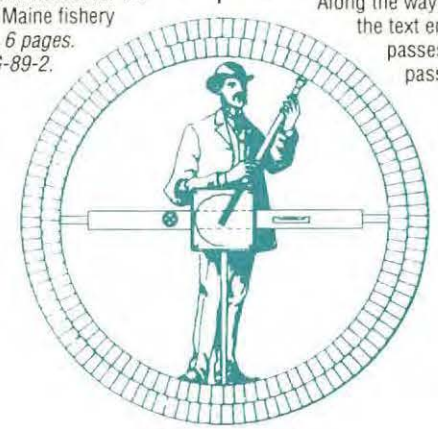
Dirty Water/Clean Water: An Annotated Chronology of Events Surrounding the Degradation and Cleanup of Boston Harbor
Eric Jay Dolin

Boston Harbor is one of the most polluted harbors in the United States. It is also one of the most studied, subject to the most litigation, and recently, the most politically embarrassing.

Despite the attention poured into Boston Harbor, researchers, the public, and the press often overlook the scope and history of the issues involved. Lacking a single authoritative source documenting the trials and tribulations of pollution in the harbor, investigators may be unaware of pertinent information.

Dirty Water/Clean Water meets this need by listing and annotating the historic events, documents, and legislation affecting Boston Harbor. The chronology begins in 1630 with early attempts at regulating sewage disposal, and ends in 1999 when the last of the court-ordered deadlines for cleanup are to be fulfilled. Along the way, the text encompasses the passage of



MIT Publications continued

the Clean Water Act, the court cases that forced the Commonwealth to begin a cleanup, the increasing body of reports from scientific and environmental organizations decrying the polluted state of the harbor, and finally, the first steps of the cleanup.

Each entry is fully annotated and many significant passages are excerpted. Accompanying the entries are two bibliographies, one arranged chronologically and one alphabetically. A listing of general articles and of libraries with Boston Harbor–related documents further expands the utility of this publication. *144 pages. MITSG 90-21. $14.95.*

The Health of the Ocean, or, Boston Harbor is not the Sargasso Sea
John A. Knauss

In this monograph based on the 18th annual MIT Sea Grant Lecture, John A. Knauss, administrator of the National Oceanic and Atmospheric Administration, contrasts the impact of pollution on coastal areas and small, enclosed oceans with the impact on planet-spanning oceans such as the open Pacific. Knauss argues that anthropogenic influences are diluted by the vast amount of water. However, although a natural flow of debris and erosional products from land into the oceans has proceeded for millions of years, human activity has suddenly changed the natural balance.

Knauss argues that our understanding of the ocean is insufficient to confidently distinguish between natural and anthropogenic effects. To study these effects he suggests that we should establish discrete zones, called Large Marine Ecosystems, and closely monitor them over time. *10 pages. MITSG 90-24. Free.*

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Research Vessels of the Northeast
B. McAvoy and S. Adams

This directory contains extensive information on 21 coastal research vessels, all of which are available for hire and operate along all or portions of the Atlantic coast between Maine and New York. The directory is designed to help researchers find the right boat for their particular research project. Photos of the boats are included. *UNHMP-AR-SG-91-1. $5.*

Marine Distress Communications Form

This 6-inch-square "Mayday" sticker lists the 14 steps involved in making a Coast Guard–approved radio distress call. It is designed to be mounted next to the radio in the wheelhouse of vessels. *Free. One per vessel, please.*

The Shot-Sensor Method of Measuring Currents in Shallow Estuarine Waters
F. Anderson

Reprinted from *Estuaries* 13(3):250-257;1990. This paper covers the design and construction of a low-cost current meter suitable for use in shal-low waters. The device releases stainless steel shot into a flowing water mass. The shot is dispersed by the current and deposited in settling traps. Mean current speed and direction can be calculated from the patterns of dispersal and the percentages of shot in the traps. It is easily deployed and simple to use, adaptable for student use, and can be left unattended and exposed in an intertidal environment. *UNHMP-JR-SG-90-11. $1.*

UNH/UM Sea Grant Project Directory 1991-1992

This booklet contains concise descriptions of the Sea Grant projects under way in Maine and New Hampshire. It also lists the researchers involved in these projects as well as Sea Grant staff, the program's Marine Advisory Program Cooperators, and members of the Policy Advisory Committee. *Free.*

UNH Sea Grant Marine Education Programs

This brochure presents the big picture on marine education programs available through UNH Sea Grant Extension. It includes brief descriptions of all programs as well as a chart that shows when they are offered, what the most appropriate audiences are, and whether there is a separate brochure available on a particular program. *Free.*

Anadromous Fish of the Northeast

This five-color, 22-by-19-inch poster is designed to teach about anadromous fish. It includes specific information on and drawings of five species and basic information on anadromous fish in general, and it is an eye-catcher. *$5, paper; $10, laminated.*

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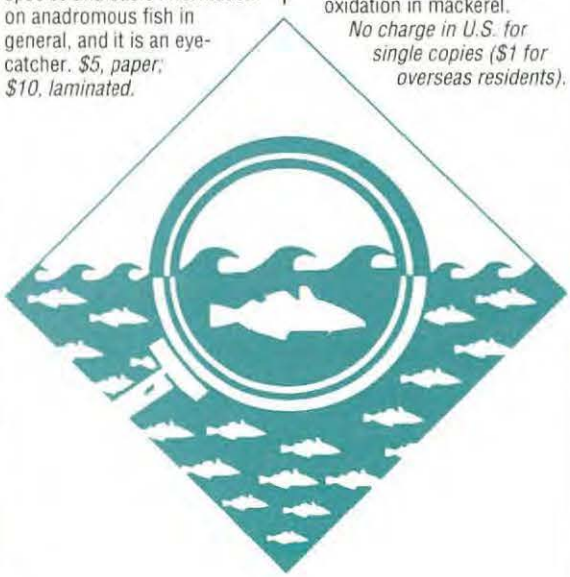
Effects of Vacuum Packaging, Glazing, and Erythorbic Acid on the Shelf Life of Frozen White Hake and Mackerel
E.E.M. Santos and J.M. Regenstein

Reprinted from *Journal of Food Science* 55(1):64-70;1990. The maintenance of quality and the extension of shelf life of frozen fish by packaging systems is one route to marketing success, and the choice of appropriate packaging materials and methods can be a critical marketing factor. This study was designed to evaluate the effect of different packaging systems, glazing, and antioxidants on shelf-life extension of two underutilized species: mackerel (a fatty fish) and white hake (a nonfatty fish). The results highlight the different handling needs of the two. Air (oxygen) prolonged the shelf life of hake but lessened that of mackerel. Erythorbic acid accelerated the rate of texture deterioration in hake but inhibited the rate of lipid oxidation in mackerel. *No charge in U.S. for single copies ($1 for overseas residents).*



The Underwater Catalog: A Guide to Methods in Underwater Research
J. Coyer and J. Witman

How can instructors in underwater research courses maximize valuable field time, without compromising their students' understanding of techniques? This 72-page catalog, developed by the Shoals Marine Laboratory and published in cooperation with the New York Sea Grant Program, presents various methods learned over the years through the grapevine linking marine labs throughout North America. For the first time, this information has been collected, written down, and presented in a convenient format. *Single copies available for $6. Call (516) 632-6905 for information on multiple copies.*

Determination of Mono- and Non-Ortho Coplanar PCBs in Fish
C.-S. Hong and B. Bush

Reprinted from *Chemosphere* 21(1-2):173-181;1990. This paper outlines a method that uses sulfuric acid cleanup, carbon chromatography, and high-resolution gas chromatography to identify mono- and non-ortho coplanar PCB residues in fish samples at parts-per-trillion levels. Since these PCBs are environmental contaminants that pose a threat to humans and wildlife, this simple, sensitive, and rapid analytical method for isolating these substances is extremely useful. *No charge in U.S. for single copies ($1 for overseas residents).*

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Rhode Island Sea Grant
The University of Rhode Island Bay Campus
Narragansett, RI 02882-1197

Identification and Assessment of Technical Information Requirements for Developing Coastal Erosion Management Strategies
J. Tanski and H.J. Bokuniewicz (eds.)

An Overview and Assessment of the Coastal Processes Data Base for the South Shore of Long Island
J. Tanski, H.J. Bokuniewicz, and C.E. Schubert (eds.)

A Preliminary Assessment of Erosion Management Strategies for the South Shore of Long Island, New York
J. Tanski and H.J. Bokuniewicz (eds.)

Government officials and others who need to identify, assess, and select appropriate erosion management strategies for a particular area will find useful information in these proceedings from a series of three workshops held in 1989. Experts in both coastal processes and engineering examined erosion problems encountered along Long Island's south shore and considered practical ways of dealing with these problems from a technical perspective.

The first workshop focused on identifying the generic information needed to develop a sound coastal erosion management program for Long Island's south shore; the second identified the technical data presently available for this area; and the final workshop attempted to use the data to discriminate among various erosion-control strategies for different reaches of the coast. *Technical Information Requirements (Special Report 103), 28 pages, $2.50; Coastal Processes Data Base (Special Report 104), 81 pages, $3; Erosion Management Strategies (Special Report 105), 34 pages, $2.50.*

Plastics Are Forever Poster
LaVie McDonald

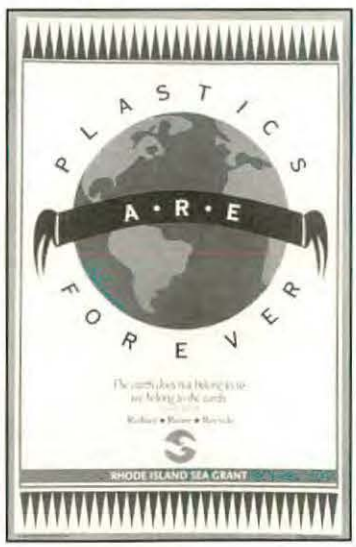
Plastics last indefinitely in the environment. This 11-by-17-inch poster reminds us to conserve resources and protect the planet. Printed on recycled paper. *RIU-G-90-015. P1190. First copy free, additional copies 50¢ each.*

***The New* Tides and Tidal Currents of Narragansett Bay**
Malcolm Spaulding, Craig Swanson, and Chris Turner

Updated for the '90s, this popular book—aimed at the recreational user—is available once more. The book includes tables giving the time and range of tides at Newport, R.I., from 1990 to 1999; as well as charts showing the hourly speed and direction of tidal currents in Narragansett Bay. The charts are based on computed values at approximately 600 locations in the Bay. *40 pages. RIU-M-90-001. P1177. $5.*

How to Find Marine Information in Public and School Libraries
Mary Grady

Students writing term papers or doing science projects on marine topics may not realize that relevant information is available in local libraries. This brief but thorough brochure explains how to get around in the library, select a topic, search the card catalog, and more. *8 pages. RIU-H-91-003. P1205. Free.*



Proceedings of the Fisheries Conservation Engineering Workshop
Joseph T. DeAlteris and Mary Grady (eds.)

Nine papers presented at the 1990 workshop in Narragansett are gathered here. Topics covered include the impact of ghost gillnets, effects of various net designs on catch selectivity, data analysis techniques, and fish behavior. *71 pages. RIU-W-90-002. P1202. $5.*

Atlantic Fishing Vessel Safety Manual
Kathleen Castro and Joseph DeAlteris (eds.)

This safety manual, modeled on a popular North Pacific guide, provides a definitive sourcebook for fishermen in the Atlantic region. Reviewed by the Coast Guard, as well as a committee of fishermen and others from Maine to Virginia, the manual deals with safety equipment, procedures, and personnel issues. *320 pages. RIU-H-91-001. P1199. $30.*

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Sea Grant's Role in Marine Education
Robert D. Wildman and David A. Ross

Reprinted from *Oceanus* 33(3):39-45. In this article, Robert Wildman, the director of NOAA's National Sea Grant College Program, teams with WHOI Sea Grant Program Coordinator David Ross to summarize Sea Grant's involvement in marine education in the 21st century. The authors examine the problem of declining student enrollment in the marine science fields, compounded by rapid technological changes in those fields. The article then outlines the current educational activities of the Sea Grant College network that attempt to reverse this trend. *7 pages. No charge for single copies while supplies last.*

Tidal Velocity Asymmetries and Bedload Transport in Shallow Embayments
Virginia A. Fry and David G. Aubrey

Reprinted from *Estuarine, Coastal and Shelf Science* 30:453-473. To understand sediment transport in estuaries and bays, the various processes that cause transport must be determined. This report discusses how tidal circulation can lead to a net transport of sediment if the tidal velocity is asymmetric about a zero mean; the rate of sediment transport will have a nonlinear relationship to the velocity. The paper shows how to estimate from the vertical tide if there is a potential for net transport of sediment in a flood or ebb direction due to tidal asymmetrics. *20 pages. No charge for single copies while supplies last.*

Toxic Algal Blooms: An International Directory of Experts in Toxic and Harmful Algal Blooms and Their Effects on Fisheries and Public Health
Alan W. White

Toxic and harmful algal bloom events are increasing in frequency, intensity, and geographic distribution around the world. They now constitute a global problem for fisheries, mariculture, and public health. Developing countries, lacking the scientific and managerial expertise to deal with the resulting fisheries and public health emergencies, are especially vulnerable to these occurrences. International coordination and cooperation on toxic phytoplankton blooms and their effects is needed. This international directory lists scientists, fisheries managers, public health officials, and physicians experienced in dealing with toxic and harmful algal bloom episodes and their impact on fisheries and public health. The directory is intended to improve international information assistance for red tide emergencies, particularly in developing countries. *215 pages. WHOI-D-90-001. No charge for single copies while very limited supplies last.*

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