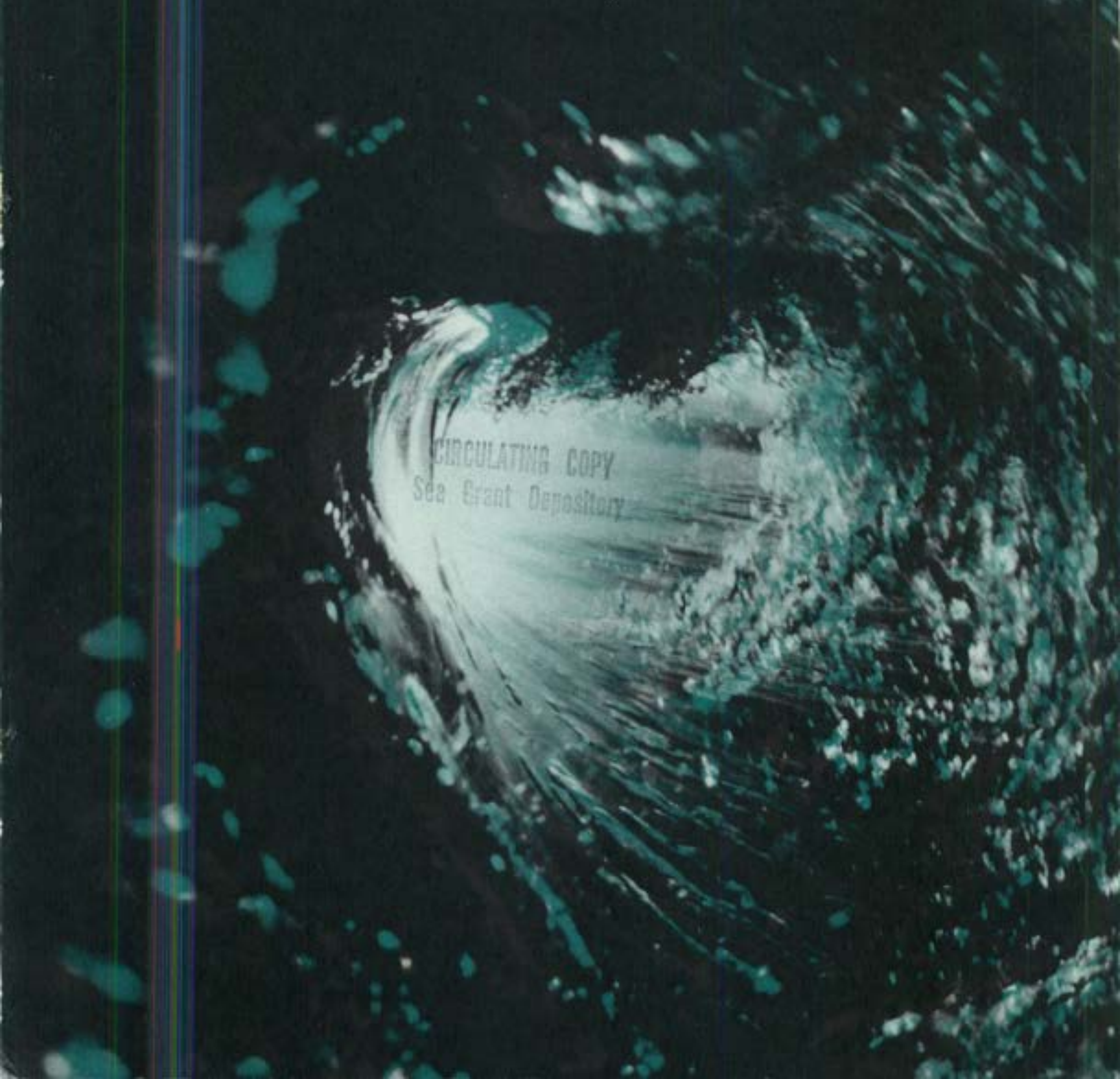
MIT Sea Grant: Ten Years of Ocean Development



MIT Sea Grant: Ten Years of Ocean Development

A Report on the
Massachusetts Institute of Technology
Sea Grant College Program

1970-1980

Report Number: 80-15
Index Number: 80-015-ZAY

October 1980

Cover Photograph © Oceanic Society

Letter from the Director

Congress established the National Sea Grant Program in 1966 to foster the wise and balanced use of marine and coastal resources. MIT's Sea Grant Program is one of 29. Each is university based and committed to serving national and local constituencies in the marine community through research, education and advisory services.

Sea Grant's research is principally applied, focusing on specific problems, limited in duration, and often multidisciplinary. Student participation in projects is not only educational for them, but brings to the research a freshness and an inquisitive enthusiasm. Sea Grant public education fosters in people of all ages an awareness of water and its impact on their lives. Advisory services connect the university base of Sea Grant to those citizens in the marine community who need the information and can apply research results to existing opportunities and problems.

The past ten years, in which MIT has operated a formal program as part of a national network, have seen many changes, evolving opportunities and myriad accomplishments. With major support and encouragement from the National Office of Sea Grant and matching support and participation from MIT, state and local governments, marine industries, and citizen's groups, MIT Sea Grant has been helping to make ocean resource utilization more efficient, coastal waters cleaner, offshore exploration safer and more economical, and onshore development conform more closely to natural processes. The program's contributions were rewarded in December of 1976 when MIT was made a Sea Grant College—the first private school to be so designated—an honor bestowed by the U.S. Department of Commerce through the National Oceanic and Atmospheric Administration.

The Program's first two directors, Alfred A.H. Keil, Ford Professor of Engineering Emeritus, and Ira Dyer, Head of the Department of Ocean Engineering, guided the Program from 1970 through 1975. In the early years, many projects originated in Ocean Engineering, an important Institute source of marine research. Currently many departments and centers are involved in Sea Grant sponsored research and education activities, including faculty and students from the Departments of Civil Engineering, Mechanical Engineering, Electrical Engineering and Computer Sciences, Chemical Engineering, Nutrition and Food Sciences, Biology, and from the Sloan School of Management and the Nuclear Reactor Laboratory.

In this report, we are taking an abbreviated look at Sea Grant's ten program years at the Institute. A sampling of projects illustrates how all segments of the community can cooperate to solve marine-related problems and take advantage of industrial opportunities. At the report's end, a summary of publications, projects, participants, and expenditures looks specifically at the 1979-1980 program year.

Dean A. Horn
Director

Coastal Zone

The beauties of the coastal zone have drawn more than fifty percent of the country's populations to a narrow strand of land directly bordering the sea. Some results have been good: more jobs and services; more people experiencing the pleasures of the ocean environment. On the other hand, rapid development has not given some communities time to choose how to best use the shorefront, with the unfortunate result of overcrowding, marshland destruction, and reduced public access.

At present there is growing interest in planning growth and in using advances in computational technology to forecast the effect of development and various land-use schemes. MIT's students and faculty, working with Sea Grant's advisory services, have helped in the past decade to solve specific community problems and to provide models that have applications worldwide.

Managing Boston Harbor's Future

In May of 1980, residents and visitors lining the waterfront glimpsed the past when the Tall Ships sailed into Boston's large and picturesque harbor. Once one of the most important ports in the country, today's harbor presents a different face. Physically and politically it is divided; an outer harbor stretches from the tip of Revere to the tip of Hull, and an inner harbor is the densely populated Boston metropolitan waterfront area.

Most of the changes and new activities are occurring in the inner harbor where old warehouses have become restaurants, shops, galleries and residences; once bustling wharves have gone out of use and many are deteriorating; some of the more traditional economic opportunities the harbor had offered are gone, replaced by some new ones; and recreational areas, except for the waterfront park, are rarely to be found. In the rest of the harbor there is some fragmented development and recreational space, but no overall plan guides growth and reconstruction of the entire waterfront resource.

In an attempt to understand and lay the foundations for improving the harbor's future, an interdisciplinary group at MIT led by Judith T. Kildow recently commenced a management project. The overall objective is to design alternative management schemes that will improve the political and economic system and better handle the environmental, public access and economic development issues.

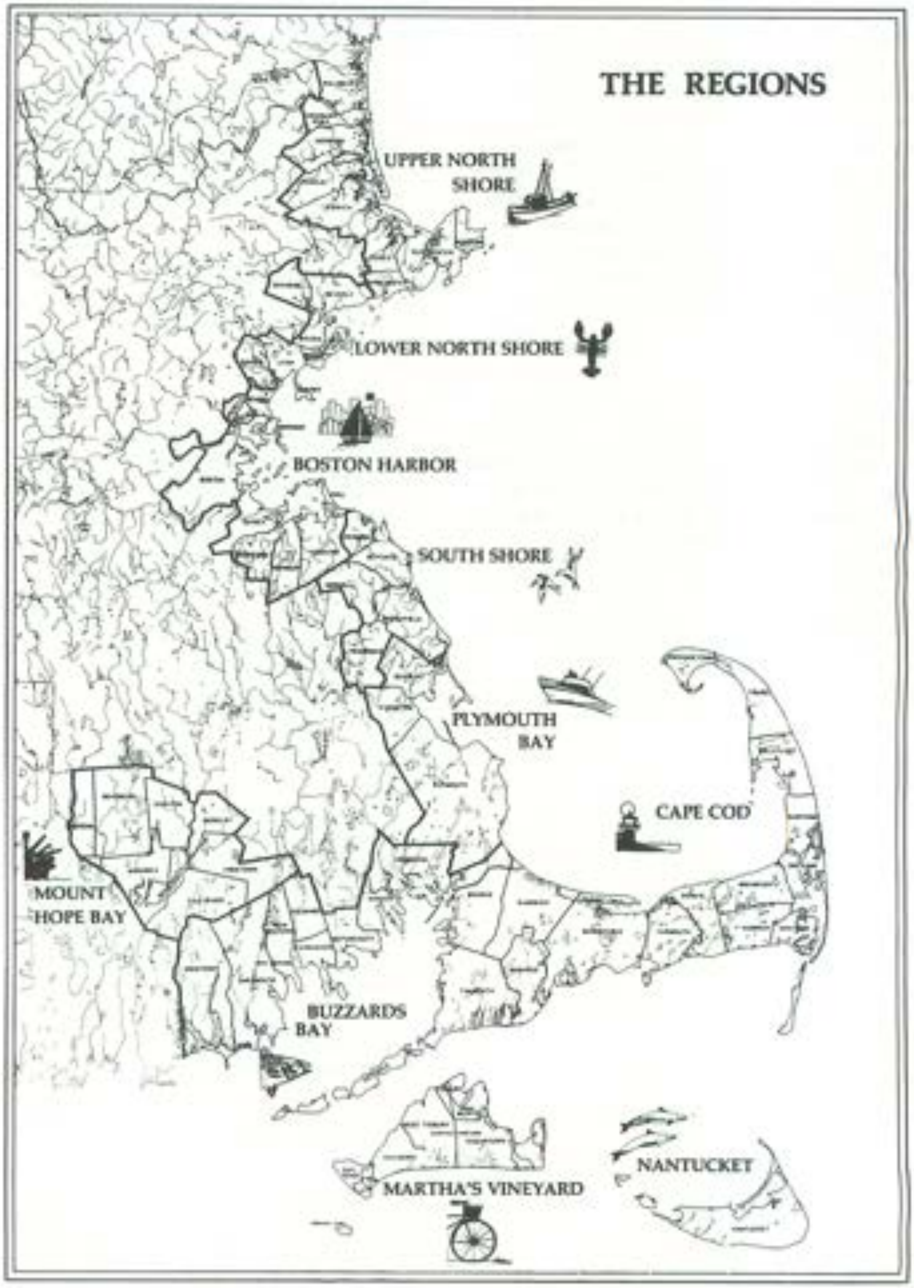
A multitude of governmental and non-governmental groups have decision-making responsibility for harbor activities, resulting in an ill-defined system of responsibilities and public accountability. Through a set of case studies, interviews and other vehicles, this group will suggest where public intervention might be justifiable and where current market forces and/or existing governmental structures seem to be ineffective.

Aided by students, the project team has compiled an atlas on current harbor uses to understand better trends in harbor use and disuse. From this atlas they hope to evolve a more detailed map indicating public access points to the water's edge, annotating the quality and type of access.

The project team, which includes Professor Kildow, Gary Hack, Associate Professor of Urban Studies and Environmental Design, Richard De Neufville, Professor of Civil Engineering, Lee Warren, Lecturer in the MIT Writing Program, and Richard Tabors, MIT Energy Laboratory and Lecturer, Department of Urban Studies and Planning, will be working closely with a Harbor Commission established by the Massachusetts legislature. The completed Sea Grant project will offer the Commission alternative harbor management ideas and strategies for planning the harbor's future.

Other support for this project has come from the Massachusetts Office of Coastal Zone Management, the Massachusetts Port Authority, Boston Shipping Association, Inc., the New England River Basin Commission, the Boston Seaman's Aid Society and the Massachusetts state legislature.

Principal Investigator
Judith T. Kildow
Associate Professor
Department of Ocean Engineering


THE REGIONS
UPPER NORTH SHORE
LOWER NORTH SHORE
BOSTON HARBOR
SOUTH SHORE
PLYMOUTH BAY
CAPE COD
MOUNT HOPE BAY
BUZZARDS BAY
NANTUCKET
MARTHA'S VINEYARD

Algal Pollution In Nahant Bay

Every year many sandy beaches in Nahant Bay are strewn with decaying filamentous brown algae which drive away bathers with foul smelling fumes. In 1976 Sea Grant learned of the problem when an extension Sea Grant advisory agent was approached by the Metropolitan District Commission (MDC) and Congressman Michael Harrington to help find causes of the algal blooms and try to eliminate the noxious effects.

The Sea Grant Program asked Professor Alician V. Quinlan, well known for modeling complex environmental problems, to organize a research team with expertise in marine environmental studies. Participants from MIT, Northeastern University, the University of Massachusetts, Harvard University, Trinity College (Connecticut), the Marine Biological Association of the United Kingdom Laboratory, and the University of Liverpool began to work on this problem in July 1978, sponsored jointly by the MDC Division of Environmental Quality and Sea Grant.

To formulate an ecosystem approach, they listed the many unanswered questions:

Which water quality variables (temperature, salinity, dissolved oxygen, phosphate, ammonia, nitrite, nitrate, trace metals) might cause or intensify the bloom?

What special factors cause the algae to become so foul? What nutrient sources feed the algae? Do these come from sewage treatment plants or sewer outfalls? How much biomass is produced in the Bay? What species predominates? How do they differ from others?

How are the predators that live off each algal species different or similar? To what effect?

What trajectories do the predominant algae follow?

Finally, how do all the answers tie together?

Two students used a sextant and Loran C to locate fifteen sampling stations in the Bay and along the beach. During the first two years of the project, the research team gathered field samples for chemical, biological and physical analyses in the laboratory. These samples combined with other research methods have provided some insights into the problem. Results of dye, drift-card and drogue studies surprised the researchers by indicating the large-scale circulation of the Bay moved in a counter-clockwise direction, and not clockwise as they had believed before their studies began. At this time, it also appears that wind plays the dominant role in setting up currents which concentrate the bloom algae in shoal waters and drive masses of algae onto the beaches.

The researchers' conclusions will be translated into a recommendation for environmental modification management and control that will stem the growth and decay of the algae, leaving the beaches in Nahant Bay a source of pleasure and recreation for the community.

Some of the adjoining maps and diagrams show the research methods and report some preliminary conclusions.

Principal Investigator
Alician V. Quinlan
Assistant Professor
Department of Mechanical Engineering
Henry L. Doherty Professor In Ocean Utilization 1978-1980

Modeling Physical Processes In Massachusetts Bay

In the early seventies when MIT joined the Sea Grant network, the United States had already begun to realize the profound effects of environmental misuse. Legal requirements as well as increased civic and corporate concern mandated methods for forecasting the influence that industrial effluents, power plant cooling waters, offshore dredging and other man-made modifications would have on marine ecosystems. Massachusetts Bay had long been a dumping ground for about a hundred communities and three million people in the eastern Massachusetts region. For the MIT Sea Grant Program between 1971 and 1977 it became a "living laboratory" to develop and test numerical models that would help alleviate pollution in embayments throughout this country and abroad.

The late Professor Arthur T. Ippen and Professor Erik L. Mollo-Christensen directed a group of scientists from the Ralph M. Parsons Laboratory and from the Department of Meteorology to simulate the complicated physical processes that disperse and circulate pollutants. Four resulting finite element models have aided marine communities from New Hampshire to Florida to the Straits of Magellan in Chile.

Jerome J. Connor, Professor of Civil Engineering, helped to create the final versions of the models, Cafe 1 and 2 and Disper 1 and 2. Cafe predicts the circulation patterns of tide- and wind-driven coastal waters, while Disper predicts dispersion. Both can determine currents, velocities and related particle dispersal patterns in one layer or in two layers to account for the salinity and temperature stratification that occurs in many bodies of water, including Massachusetts Bay, during

the early spring and fall months. Verification of the Cafe model involved gathering and analyzing data from drogue studies in computer-predicted dispersion patterns of thermal plumes from the Pilgrim Nuclear Power Plant.

To introduce these environmental tools to industry and to government agencies, the Marine Industry Advisory Service held a Collegium meeting, "Computer Models for Environmental Engineering and Research in Near Coastal Environments," in 1976.

Principal Investigators
Arthur T. Ippen (deceased)
Professor
Department of Civil Engineering

Erik L. Mollo-Christensen
Professor
Department of Meteorology

Jerome J. Connor, Jr.
Professor
Department of Civil Engineering

Coastal Erosion: A Matter Of Control

A summer stroller on a long, white strand of shore sees the beach as peaceful, serene, unchanging. An aerial view of the sands marching beneath the sea's surface reveals the deception.

The movement of sand by the combined forces of winds, wave, tides and currents is one of the most serious problems of managing coastal use and development. In the past, oblivious to nature, people established buildings and recreational areas close to the shore. Many structures are now threatened by erosion or have already been swept away by severe winter storms. Jetties and groins erected for protection have saved some structures but have robbed coastal neighbors of sand that should have been delivered by longshore currents.

Researchers since the early 1800s have been trying to understand the properties of waves and their effect on the ocean bottom and the shoreline. The first successes came when German scientists based a numerical model on an assumption that waves move in a symmetrical train over an infinite ocean. With today's advances in computational capabilities, scientists and engineers no longer need to make such simple and misleading assumptions. Still, the variables of predicting the action of waves and their affect on the movement of sand are numerous, and intensive coastal research is new.

Professor Ole S. Madsen has been working with Sea Grant since 1976 to develop numerical models capable of quantifying the rate of longshore sediment transport, and the resulting coastal erosion and deposition. The aim is to make predictive tools available to government regulatory agencies, environmental consultants, and the building industries so they can locate industrial and power facilities that will neither harm the overall coastal environment nor be threatened by it.

In a Sea Grant report, Professor Madsen introduced two predictive models created with input from specially designed instruments that measure current speeds and wave heights at the shore, both in and outside of the surf zone. An array of the instruments used in field experiments to gather information tested various assumptions and hypotheses of laboratory studies.

Principal Investigator
Ole S. Madsen
Associate Professor
Department of Civil Engineering
Henry L. Doherty Professor in Ocean Utilization 1977-1979

Heed those shellfish bans

WOODS AND SHORE
By MONTY MONTGOMERY

The current spate of shellfish closings along the New England coastline north of Cape Ann appears to mark a new era. This is the fifth consecutive summer when part of the coast has been closed to the taking of clams, mussels and related animals.

However, there is no problem with any of the finned fish, or with lobsters or crabs.

In the limited areas of the ban, the only dangerous things to eat are the molluscs — both the bivalves, clams and mussels, and the univalves, including periwinkles and moon snails. Almost anyone will eat clams, a few people have learned the joys of mussels, and only the sophisticates eat periwinkles or moon snails.

The disease is caused by a microscopic single-celled plankton, and only affects filter-feeding animals like the clams, or their predators, including the moon snail. The periwinkles are algae eaters and apparently pick up the plankton in the process of scraping a living off the coastal rocks.

Paralytic shellfish poisoning is no joke, although persons can be supported with auxiliary breathing help until the worst symptons pass ... the biggest problem is when the attack is misunderstood. The most serious cases last year involved some people who had eaten periwinkles and didn't think that they had eaten "shellfish."

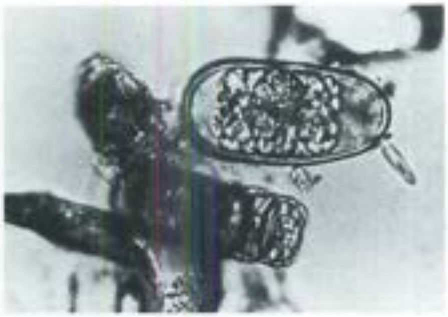
Shellfish closings should be taken seriously, and persons used to digging shellfish from polluted areas and getting away with it should be much more cautious when there are paralytic shellfish poisoning closings in their area. One may escape both the shellfish warden and ordinary diseases, but shellfish poisoning is too serious to fool with.

One may safely eat fish or lobsters from "red tide" waters. The toxin that causes paralytic poisoning has to be concentrated by the filter-feeding clams and mussels. Shellfish move hundreds of gallons of water through their systems and across their filtering mechanisms — a clam is nothing but concentrated and metabolized minutia — and when the "red tide" plankton is in the water, the clams quickly become a concentrate of poison.

While sensible people are safe, extreme levels of toxicity can cause problems for wildlife. A number of birds, including adult black ducks, feed heavily on mussels (the hottest concentrators of paralytic toxin) right through the summer months.

Gunners and ornithologists alike once thought that black ducks only ate mussels during the bitter winter months, but a rash of shellfish poisonings in and around the Parker River Wildlife Refuge in Newburyport four summers ago proved that adult birds, having learned to eat mussels during the previous winter, continued to feed on them all summer.

Boston Globe, June 4, 1978



Controlling Red Tide's Poisonous Blooms

If you work or play near the coast, you have probably heard of the poisonous "red tide" which appears from time to time in New England waters from Maine to Cape Cod (and elsewhere in the world). Red tide is a concentration of one-celled algae which contain small amounts of a powerful toxin. These algae are eated by shellfish, which in turn may be eaten by humans. If a person dines on mollusks, such as soft-shelled clams, mussels, or quahogs, which have stored enough of the toxic substance, paralytic shellfish poisoning (PSP) may result.

In 1975 Francois M. M. Morel began to study New England's red tides. He and graduate student Donald M. Anderson first hypothesized that water chemistry played a critical role in encouraging the blooms of the red tide organism, *Gonyaulax tamarensis*. Laboratory experiments indicated that copper has a toxic effect on the dinoflagellate. In marine waters where an influx of organic substances bind up, or chelate, the copper, *Gonyaulax* is left unthreatened and in a favorable environment to bloom.

During the summer of 1978, Sea Grant's Communications Office and the Massachusetts Marine Liaison Office held a workshop for Professor Morel and Dr. Anderson to present their findings to those people who most needed red tide information: shellfish wardens and state officials responsible for monitoring shellfish beds for toxic red tide blooms.

The researchers described those chemical and biological mechanisms which they felt caused the timing and geographic spreading of the blooms. They suggested that outbreaks on Cape Cod, which occurred first in 1972, had probably been linked to a dormant over-wintering cyst stage in the organism's life cycle and to the trace metal chemistry of coastal waters.

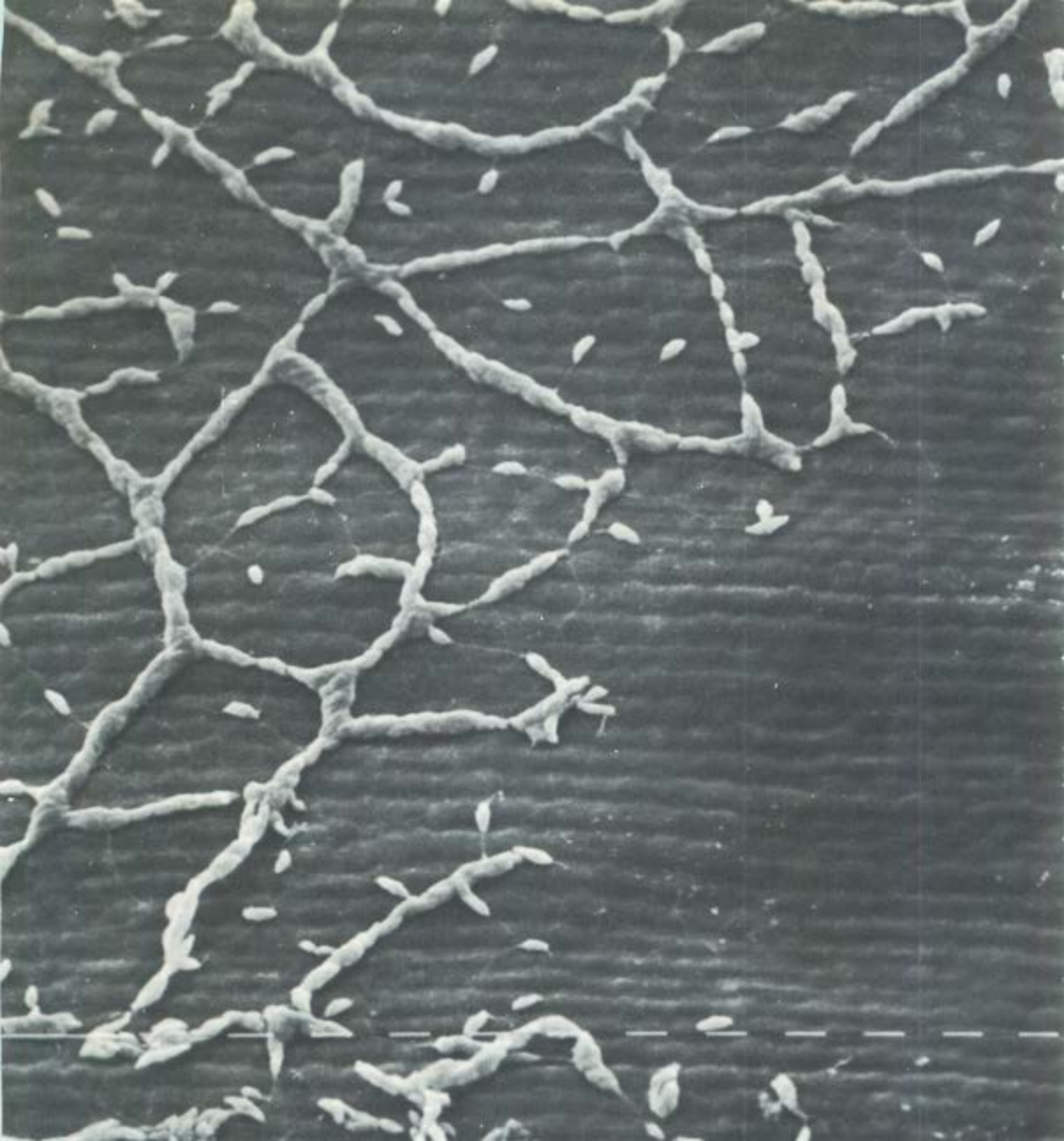
Laboratory and field studies had demonstrated that *Gonyaulax* cysts had accumulated in those estuarine sediments where blooms had occurred. When the temperature of the waters began to rise in spring, these dormant cysts revived into a motile, photosynthetic stage. According to the researchers, the decrease of temperatures in the fall had the same effect. They speculated resting cysts serve as seed populations for annually recurring blooms in New England ponds. Transported by tidal currents, the algae in cyst form can move to new locations along the coast. Human activities such as dredging or dumping or shellfish bed seeding are also suspected as vehicles for spreading red tide.

The meeting initiated a "mapping" project with the state's Cat Cove Marine laboratory. For over a year, the lab's biologists worked with Sea Grant to document the presence of dormant cysts in northern Massachusetts's coastal waters. This information is being used to monitor shellfish areas and to observe further how and where the cysts are moved.

Now an Assistant Scientist at the Woods Hole Oceanographic Institution, Dr. Anderson is an associate investigator on a Sea Grant project begun in 1979 under the leadership of Sallie W. Chisholm. Their studies are a complement of laboratory and field analysis. They are measuring *in situ* growth of *G. tamarensis* and *G. excavata* throughout a bloom period. In the lab, by examining the vertical migration capacities of the organisms, the scientists hope to gain insights into bloom growth and density. They have isolated and cultured several species of phytoplankton other than *G. tamarensis* from geographical locations with a history of red tides, to compare photosynthetic characteristics. Physiological analysis will hopefully move scientists a step further toward the development of methods for predicting and ultimately controlling red tides.

Principal Investigators
Francois M. M. Morel
Associate Professor
Department of Civil Engineering
Henry L. Doherty Professor in Ocean Utilization 1975-1978

Sallie W. Chisholm
Associate Professor
Department of Civil Engineering
Henry L. Doherty Professor in Ocean Utilization 1980-1982



Scanning electron microscope photograph of a Labyrinthula colony growing on a leaf of eelgrass. *Zostera marina*

Eelgrass Declines: An Unanswered Question

Fields of eelgrass, an open water plant of immense ecological importance, line both the Atlantic and Pacific coasts. At different stages in the plant's life cycle it nourishes, protects, and shelters fish, shellfish and birds, helps prevent erosion, and fertilizes the coastal ecosystem. Many organisms graze or grow on it, some creatures eat its leaves or seeds directly, while others digest the nutrients as it decays. Still others prey on neighbors living in the eelgrass community.

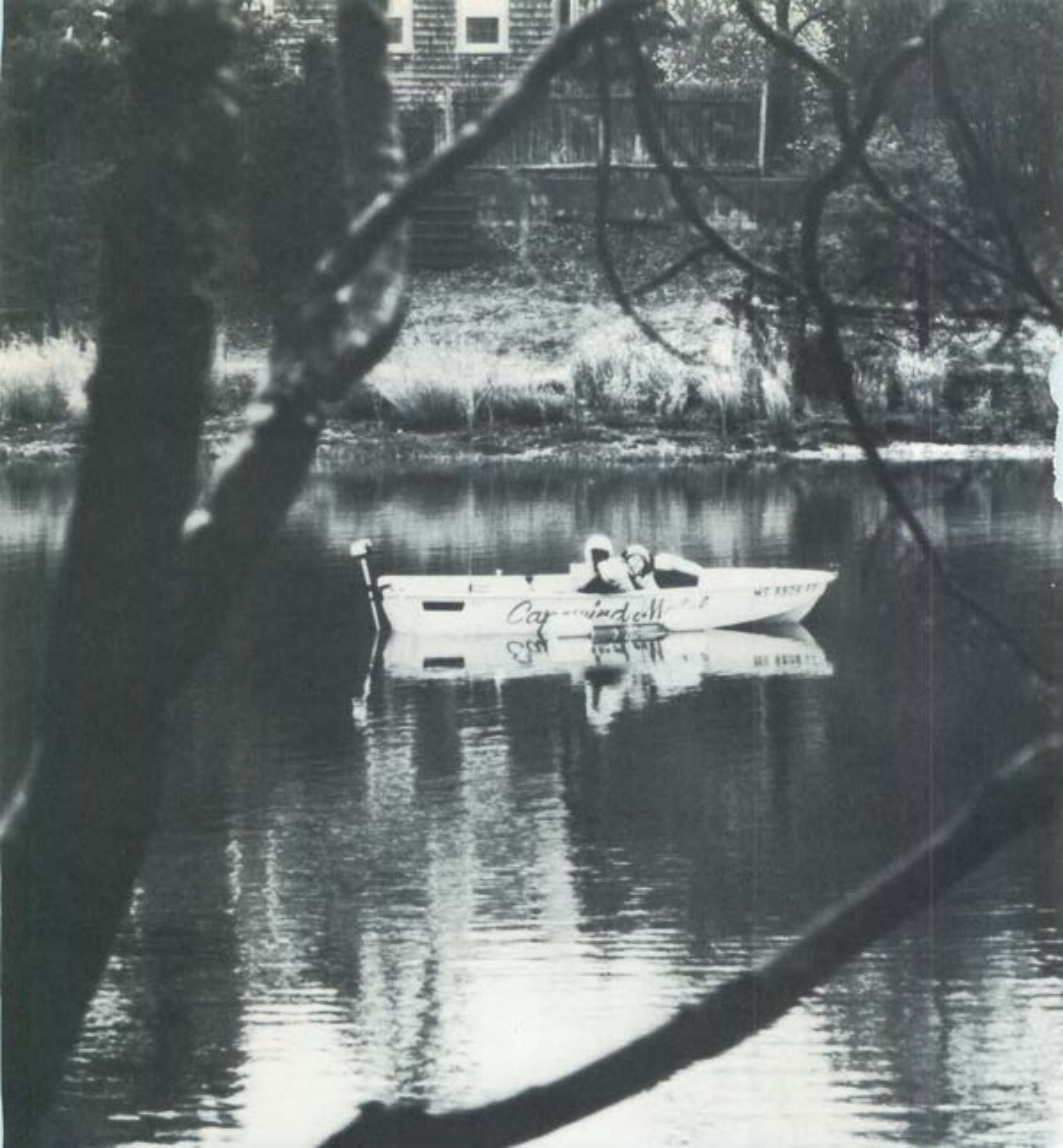
Occasionally a serious plague attacks the eelgrass fields, causing the plants to brown and wither over thousands of estuarine acres. The loss of this key source of plant detritus and of the microscopic organisms on the bottom of the food chain causes a devastating domino effect throughout populations of fish, shellfish and birds. In short, the whole marine food chain is disrupted.

In the 1930s, researchers in Maryland and Europe blamed an international eelgrass plague on *Labyrinthula*, a parasitic protozoan which lives on eelgrass, *Zostera marina*. Since the plant is a vital part of the coastal ecosystem, Professor Eugene Bell and research associates are trying to learn whether *Labyrinthula* really is the cause. They are also devising a reliable, systematic way of studying a difficult environmental problem. Sound laboratory assays will be exceedingly useful in the future for looking at the plant and the materials that grow on it.

To date, the researchers have found no definitive evidence that *Labyrinthula* is responsible for the eelgrass declines, but they have learned what characteristics of the colonial protozoan permit it to move on the plant. They believe this information could help clarify how (or if) it causes plant disease. From their experiments, the group found that *Labyrinthula* not only grazed on other microscopic eelgrass inhabitants, but probably utilizes the leaf components directly by releasing little packets of enzymes. However, this process may occur only on those parts of the leaf which are already dead. Nobody knows yet whether this release can break down healthy plant tissues, or whether the enzymes work only on weakened plants. Perhaps special environmental conditions must also be present at the same time to cause disease.

Environmental science is relatively new and difficult. According to Professor Bell, it involves considerable guesswork—or intelligent forays—into a complex problem. The more that can be brought into the laboratory for precise analysis the better.

Principal Investigator
Eugene Bell
Professor
Department of Biology



Modeling Seawater Intrusion

Recently, management of freshwater resources has been prominently in the headlines. Toxic contamination dramatically threatens the water we and the whole ecological chain need for survival and nourishment, but faulty septic tanks and excessive sewage disposal also deplete available water supplies. For coastal communities seawater is an additional enemy.

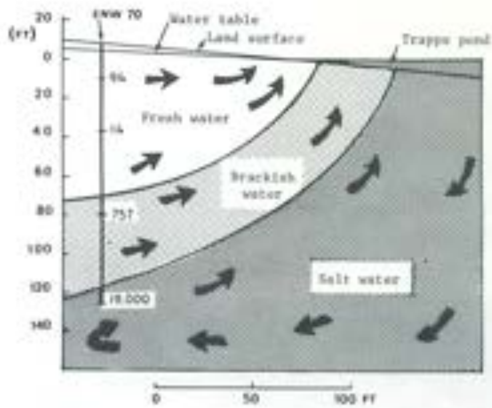
Coastal aquifers are bounded by salt water. Drawing out too much fresh water upsets a boundary equilibrium and salt water moves upward and landward. Once this happens and freshwater supplies are contaminated by salt, it can take years to cleanse and restore the aquifer.

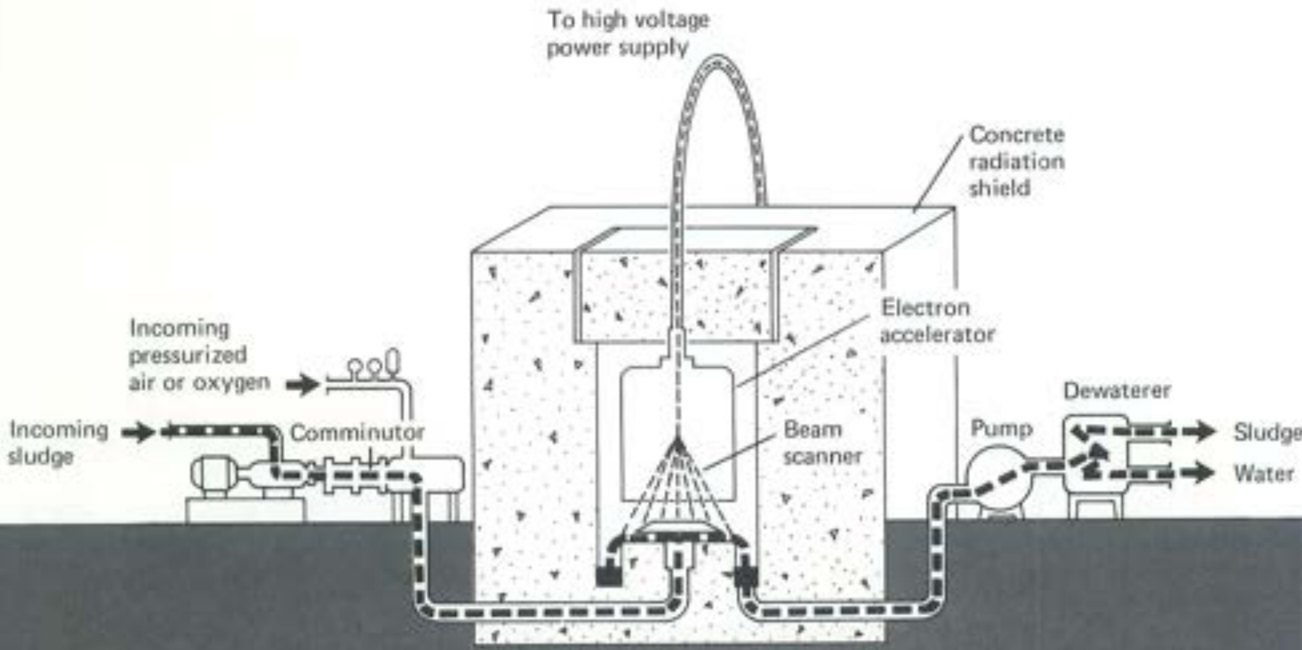
The residents of Martha's Vineyard have worried that the Island's continuous growth and enormous population fluctuations from summer tourism endanger their water supplies through saltwater intrusion. Aquifers on Cape Cod under similar conditions have been damaged. In California and Florida and on Long Island, rapid, concentrated growth has reduced local water supplies and required expensive piping systems to bring fresh water from faraway sources.

With Sea Grant support, Professor John L. Wilson and an MIT doctoral candidate have created a seawater intrusion model (SWIM) which has predictive capabilities for analyzing various levels of demand on coastal water supplies. SWIM's special attention to unusual island and peninsular aquifer configurations makes it a unique intrusion model. The data used in SWIM includes geology, groundwater flow patterns, well locations, precipitation records, and monthly pumping records.

Working closely with the Martha's Vineyard Commission, the Sea Grant researchers are refining the model to look at development proposals and estimate their effects on the Island's freshwater supplies—both quantitatively and qualitatively. A user's manual is being prepared for the model to make it simply and inexpensively applicable to any coastal area. Sea Grant's projects are initiated in response to a national need, but marine problems, like the ocean itself, have no boundaries and all efforts are made to share the Program's research results with other countries. Professor Wilson has already applied SWIM to saltwater intrusion problems in Israel and Egypt.

Principal Investigator
John L. Wilson, III
Associate Professor
Department of Civil Engineering




To high voltage power supply
Concrete radiation shield
Electron accelerator
Incoming pressurized air or oxygen
Incoming sludge
Comminutor
Beam scanner
Dewaterer
Pump
Sludge
Water

Wastes to Resources

Today, waste disposal is one of the nation's most serious problems. Our way of living produces more refuse than we can throw away. Communities are running out of dumping sites; and perhaps more problematic, toxic industrial wastes can endanger the public health.

It is possible that the oceans offer a reasonable, safe alternative for waste disposal—if the effects can be predicted and damage to the environment mitigated. It is also possible that some wastes, rather than being thrown away, can be transformed into useful raw materials through the development of new technologies.

Fertilizing the Oceans With Urban Wastes

By summer 1981 barges loaded with pasteurized sewage sludge from the MDC's Deer Island Treatment Plant may be chugging to an ocean site in Massachusetts Bay. They plan to repeat the trip every week for twelve months, with scientists and engineers following to study the effects of the waste's nutrients on the productivity of the marine environment.

An outgrowth of past waste treatment research, initiated in 1973 with Sea Grant support, this new study is aimed at producing an innovative and cost-effective waste disposal alternative for coastal cities. The problem is serious. In 1972, the Water Pollution Control Act mandated that communities treat their wastewaters to remove solid materials. The byproduct of that treatment is sludge, by definition a mass of pollution because it is simply the residue sifted and screened from heavily contaminated commercial and residential wastewaters. At this time the national output of sludge is estimated at 10 million tons per year. And Boston alone produces 50,000 tons at its Deer Island treatment facility.

Dr. John G. Trump is the leader of both the past and the current studies. In the first phase he and associates proved the technical and economic feasibility of employing high energy electron irradiation to inactivate disease-causing microorganisms, making the sludge reusable for aquaculture and agricultural fertilization. Now scientists want to know if the treated sludge, free of harmful viruses, bacteria, protozoa and worms, can be effectively used to fertilize the oceans. Sea Grant, MIT, the New England Aquarium, the Woods Hole Oceanographic Institution, and the High Voltage Engineering Corporation have asked for support from the Department of Environmental Affairs for this project. They hope to prove that sludge, carefully disposed of and dispersed in the oceans, will create the same nourishing results as the natural upwelling of nutrients. The end result may be an ever-renewing food supply from areas of the oceans that are now biologically unproductive, with waste used to create a resource.

Principal Investigator
John G. Trump
Professor Emeritus
Director
High Voltage Laboratory


GREAT LAKES DREDGE & DOCK
DELMUR C LYNN

Trace Element Uptake In the Marine Food Chain

Professor John G. Trump's modern technology shows promise for advancing an ancient Chinese method of farming known as polyculture. Different species cohabitate in this efficient system, each occupying its own ecological niche and consuming different foods. The system begins with algae (which could be nourished by electron irradiated sewage sludge). The algae then feed a colony of resident oysters. After digesting the plankton, the oysters secrete nutrients coveted by a ubiquitous sea lettuce and bottom dwelling worms. Popular seafood such as abalone enjoy the flourishing sea lettuce, and in a separate but nearby tank the plump worms serve as dinner for flounder.

These mariculture systems could help produce a stable, abundant supply of protein. Today's aquatic farmers, however, have a problem unknown by their Chinese predecessors. The wastes which nurture the algae contain accumulations of trace elements, such as copper, lead, cadmium, and zinc, which could possibly be harmful if concentrated within the food chain of the aquaculture system, and then passed along to humans.

Dr. Morteza Janghorbani and Dr. Guy C. McLeod are measuring the uptake of the trace elements and their accumulation in the tissues of various marine organisms from phytoplankton to juvenile fish which have been raised on different mixtures of sewage effluent and sea water. Dr. McLeod is also determining the optimal mixtures of the wastes and seawater for producing a prolific effluent-fed aquaculture system. Projects like this may advance large-scale aquatic farming and increase available protein around the world.

Principal Investigators
Morteza Janghorbani
Senior Radiochemist
Nuclear Reactor Laboratory

Guy C. McLeod
Director of Research
New England Aquarium

Recycling Dredge Spoils

Waterways such as Boston Harbor and the Cape Cod Channel are corridors for ships carrying raw materials and manufactured goods to and from New England. To keep these passages open, dredges remove the sand and silt deposited by tides and waves. In the past, these materials have become landfill or were deposited in coastal waters not used for marine transport. Controversy has surrounded dredging, because the materials contain toxic levels of metals and minerals. Now, the whole concept of recycling promises to partially resolve the conflict between environmentalists and the dredging and shipping industries.

Professor Michael Modell has undertaken a conceptual study on the feasibility of extracting heavy metals and organic materials using water brought to near critical temperatures and high pressures as a solvent. He and student research associates believe that this new process may adequately remove trace materials which could then be sold to pay for the recovery process and part of the dredging costs. The organic content of the dredge spoils from many urban harbors is high enough to be recycled as a fuel. Cadmium, copper, nitrites, lead, zinc and magnesium are valuable as raw materials, especially as the supplies of metals diminish and their costs escalate. An analysis of bottom samples in New Bedford Harbor, an important fishing port, showed heavy concentrations of copper, chromium and zinc. Thirty-five hundred metric tons of these elements are estimated to rest on the harbor bottom at a current market value of $5,000,000.

Characteristic of much Sea Grant research, this particular project is a conceptual study beyond the research and financial resources of several groups who can use the information. If the research succeeds, with a relatively small investment by the federal government and MIT, then it helps more than just the immediate users in the dredging and shipping industries. All of us benefit from a cleaner marine environment and having necessary materials reclaimed and recycled. If the study disproves the feasibility of the concept, there is still a gain. Students will have gleaned knowledge of a marine problem and experience in working side by side with an MIT faculty member on a research challenge with both environmental and economic implications.

Principal Investigator
Michael Modell
Associate Professor
Department of Chemical Engineering

Shellfish Wastes Transformed Into Valuable Raw Materials

A malodorus heap of lobster and crab shells discarded after the meat has been removed looks anything but useful, but appearances can be deceiving. Shellfish wastes are being transformed into a range of raw materials with some exciting applications.

Crustacean exoskeletons contain chitin, a natural polysaccharide related to cellulose. Chitin and its most common derivative, chitosan, lend themselves to extensive modification, and for this reason have attracted scientific intrest since the 1880s. Research intensified in the early 1970s after the Environmental Protection Agency banned the chitin-rich shellfish carcasses from being dumped into coastal waters. Slow to degrade, the shells were serving as unwanted ocean landfill.

By 1976, worldwide interest and research activity prompted the MIT Sea Grant Program and the Massachusetts Science and Technology Foundation to hold the First International Chitin/Chitosan Conference in Boston. Researchers from 14 countries examined 52 papers on the diverse and extraordinary properties of the polysaccharides. They discussed the uses of chitin and chitosan:

as an additive in paper making to improve the wet and dry strength of newsprint, paper towels, grocery bags, disposable baby diapers, and non-woven fabrics;

as a coagulant to treat water supplies, domestic sewage and industrial wastewater;

as a filter to extract heavy metals and radionuclides from dilute fresh and salt water solutions;

as a wound healing accelerator in sutures;

as an artificial skin in burn treatment;

in fiber modification to improve the dyability of artificial fabrics;

in the manufacture of transparent films for food packaging and photographic supplies;

as a matrix in food manufacturing to invest fabricated foods with texture and juiciness.

Despite this long and impressive list, chitin and chitosan's potential has been largely unrealized because of processing difficulties.

In Sea Grant sponsored research that spanned 1974 through 1980, Professor Benjamin L. Averbach advanced chitosan processing employing x-ray diffraction and small angle x-ray scattering. Using these techniques he was able to detail the characteristics of chitin and chitosan and to specify the manipulation of variables in making certain kinds of chitosan films.

Once the initial studies were done, Professor Averbach collaborated with a shellfish processor in Virginia to study the economic and technical feasibility of establishing a chitosan plant in the Mid-Atlantic states. The processor, the Hunt Crab Meal Company, established a "bench top" facility to supply MIT researchers with chitin and chitosan, while students and faculty extended their experiments to make films that would be effective in water pollution control. Chitosan attracts many chemical substances, such as DDT, PCBs and heavy metals. Many of these toxic materials could be removed by submersing the films in or near public and industrial waste outfall. Professor Averbach's films, strong and impervious to water, show great promise, and plans are underway to build a plant in Virginia to transform a troublesome seafood waste into a versatile raw material.

In the Department of Nutrition and Food Science, Professor ChoKyun Rha is investigating how to form a chitosan food matrix for replicating a variety of foods—fruits, vegetables, breads, cheeses, and fish. Chitosan is biodegradable, non-toxic, and bonds readily, all attributes that make it ideal for food engineering. It can be manipulated to be elastic or rigid to give food texture. Because it ruptures easily, it could supply juiciness.

Professor Rha and student associates have created globules, the structural unit to be used for the food matrices. In laboratory studies, the researchers have analyzed the deformation and rupture characteristics of these units. Ersatz caviar they have made may seem a frivolous example of chitosan's potential, but it illustrates the substance's talent for creating an illusion. Beyond duplicating luxury foods—which show economic promise—there is another and perhaps more serious objective.

Protein shortages plague people around the world, including the United States, and a chitosan matrix could increase the amount of available protein. Disused parts of commonly caught fish, such as muscle tissue, could be chopped, powdered or pureed, then bonded by chitosan to other ingredients to duplicate known and appealing foods. Unfamiliar fish species which are currently shunned could be treated in the same way. A chitosan matrix also has possibilities for helping to produce food products for people with allergies to certain ingredients such as gluten in bread. With a chitosan matrix it would be possible to eliminate ingredients like gluten.

Principal Investigators

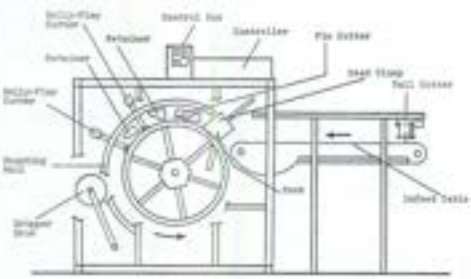
Benjamin L. Averbach
Professor
Department of Materials Science and Engineering

ChoKyun Rha
Associate Professor
Department of Nutrition and Food Science

Fisheries Technology

Expanding foreign markets, an increase in U.S. fish consumption, and passage of 200-mile limit legislation have all promoted a stronger, more profitable fishing industry in this country. As the profit opportunities have grown, fishermen and seafood processors have sought more sophisticated tools.

Sea Grant's university base has been one source of assistance for this small, growing, and important group of citizens. At the Institute, faculty and student strengths in engineering and technology development have been applied to making vessel gear safer and more economical. And improvements in processing equipment promise to help market abundant underutilized fish at home and abroad.



Skinning the Dogfish Shark Mechanically

Some of the most profitable fish in New England's waters are harder to find and catch these days. Quotas established through the Fisheries Management and Conservation Act are helping to re-establish some stocks which have been "fished out." In the meantime, fishermen are looking for alternative fisheries. The dogfish shark offers one potential option during the summer months when it is extraordinarily abundant in New England waters; in one season alone it has been reported that 27,000,000 were caught.

Ironically, most dogfish are thrown overboard, unwanted and detested, for the shark has until now actually imposed an economic burden on New England fishermen. Extremely voracious, they either drive off or devour vast amounts of mackerel, cod, haddock, and flounder, the traditional fish upon which the industry depends. Their appetite and habit of tearing and snarling nets cost fishermen millions of dollars every year.

These predators are not widely harvested and sold for a profit because there is no mechanical method for skinning and processing them. A sizeable market does exist in Europe where the shark is used for fish and chips and in popular seafood stews. Its belly flap, when smoked, is an expensive delicacy with an appeal similar to smoked salmon. In the past, machines have been unable to remove the shark's rough skin to produce the smooth product achieved by hand skinning. Unfortunately, U.S. wages make hand skinning unprofitable and have discouraged development of a large dogfish fishery.

In 1976 with Sea Grant support, Professor ChoKyun Rha studied the tensile strength and surface characteristics of the shark's skin, while Professor David Gordon Wilson analyzed the limitations of existing fishery technology and the efficiency of hand-skinning operations. These early investigations were followed by two graduate student projects which have produced a machine to process the shark in the round, removing the tail, dorsal fins, bellyflap and back skin. The remaining section requires only a manual head cut and separation of the back meat to complete the processing. MIT has filed a patent application for this innovative technology.

In March 1980 the Massachusetts Marine Liaison Service and research co-sponsor, the National Marine Fisheries Service, introduced the machine to the fishing industry at a laboratory demonstration. The response was excellent and it is expected that by the end of the year licensing arrangements will be made with a machine manufacturer. The net benefits of this research will mean new opportunities and greater profits for an important U.S. marine industry.

Principal Investigators

David Gordon Wilson
Professor
Department of Mechanical Engineering

ChoKyun Rha
Associate Professor
Department of Nutrition and Food Science

Fuel Efficient Trawl Doors

Trawling is the method used by New England's fishermen to harvest profitable bottom dwelling fish such as cod, flounder and haddock. The design of the gear has been passed down through generations and many of the current techniques and hardware are inefficient.

In a trawling operation, the boat pulls a funnel-shaped net which herds seabed fish into it. Floats and weights keep the net open vertically, while the outward angle of the two trawl doors maintains horizontal spreading. A wider opening catches more fish. Traditional flat doors made of steel-banded wood are fairly effective at spreading the net's mouth, but they operate at such extreme angles of attack they result in substantial drag and high fuel consumption.

Sea Grant's steel trawl doors have been designed like a hydrofoil to give hydrodynamic lift and a lower angle of attack as they move through the water. Door drag has been reduced about 70 percent so that fishermen could benefit by maintaining an efficient speed to cut fuel costs, or by employing a larger net to catch more fish for the same fuel expenditure.

The door is marketed through one of New England's best known trawl door manufacturers, Wharf Forging and Welding Corporation. Ron Giovanni, president of the company, participated in the research project by contributing labor and long years of practical experience in the fishing business.

Principal Investigators
J. Kim Vandiver
Associate Professor
Department of Ocean Engineering

Arthur B. Clifton
MIT Sea Grant College Program

Improving the Trawl Door Hook-up System

Hooking up a trawl door after the nets are pulled in is dangerous. The doors present a heavy, flat surface which can easily crush an arm or hand. Unless a trawler is equipped with extra net hauling equipment, the doors must be secured at the rail and uncoupled from the main tow cable before the net with the catch is hauled aboard. A crew member operating a winch controls the operation. Carelessness on his part or an extreme roll or surge can cause the break to slip and the doors to flail. Setting the nets reverses the operation and poses the same dangerous problem.

The improved Sea Grant design has automated part of the hook-up procedure to eliminate the need for manually securing the door. In the operation, a hanger pivots on extensions of the main bollard-pulling shaft. When lowered, the hanger rests on a cable until the coupler passes under, then the winch is slackened and the coupler pulls back into a "u"-shaped slot. At this point the door is fastened to the boat and a crew member can safely uncouple the net lines from the door. Tests aboard the VINCIE-N have indicated that the simplified hook-up system leads to a much safer operation.

Principal Investigators
Stephen P. Loutrel
Assistant Professor
Department of Ocean Engineering

Arthur B. Clifton
MIT Sea Grant College Program

Professor Loutrel testing new hook-up block aboard the VINCIE-N

Engineering a Safer Hook-up Block

When the MIT Sea Grant Program's advisory services approached the region's fishing industry late in 1972 and offered to undertake projects that would improve fishery operations, it was recommended that MIT design a safer, more efficient hook-up block.

MIT Professor Stephen P. Loutrel and student associates met with James Boord, at that time Captain of the CORSAIR CANYON, to discuss block design concepts. Captain Joseph Novello of the VINCIE-N offered his boat as a study site for the research team. The MIT engineers first observed trawling procedures and the hook-up block's role in setting and retrieving gear. In 1974 they completed the first prototype which Novello tested in the late summer. Some modifications were recommended and made. From that day, Novello claims he hasn't sailed without it, so dramatically does it improve safety conditions for his crew and the speed with which they are able to handle the nets.

During this past year, Marine Liaison fisheries engineer Clifford Goudey, an MIT graduate, redesigned the hook-up block for the U.S. Coast Guard, with a 3,000 pound working load, for use in their new single point hoisting methods on life boats. Goudey has applied for a patent, anticipating other uses that would benefit maritime workers. The Coast Guard has installed the block aboard the Cutter ALERT and deployment throughout the fleet is anticipated.

Principal Investigator
Stephen P. Loutrel
Assistant Professor
Department of Ocean Engineering

Offshore Resources

For centuries people around the world have turned to the ocean for food; more recently they have looked seaward for energy and mineral resources. Once inaccessible because of technology limitations, the deep seas are already producing oil and gas. By 2000, deep ocean mining operations will recover valuable manganese nodules.

Technology and analytical techniques are needed by government and industry to survey the seabeds and recover resources. As exploration moves away from land into a harsher, more unforgiving environment, engineers require accurate information on ocean forces, sediments, and platform performance to design safe structures that can be built and maintained economically. Sea Grant's offshore research has intensified in the past several years as the national need for ocean resources has grown.

In Situ Tests To Predict Soil Strength

At present offshore structure designers must use uncertain data obtained through expensive and time-consuming core drilling procedures. For several years, Professors Mohsen M. Baligh and Charles C. Ladd have been evolving new techniques and analytical methods to determine soil properties directly at offshore sites. As participants in a major geological exploration program, they have tested their instrumentation and methodology *in situ* off the coast of Venezuela with promising results. They used a Dutch cone, made by Fugro, to measure penetration resistance, and a modified piezometer probe to determine pore water pressures. A current research objective is to combine the two devices into one instrument.

Data from the Dutch cone can identify soil types, estimate undrained shear strength of clays, strength and compressibility of sands, and predict the point and shaft resistance of foundation piles. Continuous measurements are made as the cone is pushed into the soil at a fixed speed. These measurements can detect the presence of thin layers in the soil, which might affect stability and drainage, and can distinguish between soil types.

The piezometer identifies soil types and evaluates soil stratification by measuring the pressures which develop as the cone penetrates steadily into the ground. Studies of rising pore pressures during penetration and decay as penetration stops are particularly suitable for judging soil permeability and detecting thin layers in an otherwise homogeneous stratum. The reliable and accurate data provided by these *in situ* tests will greatly improve the predictive value of soil mechanic models.

Support for the project has been shared by Sea Grant, the Venezuelan Petroleum Technological Institute and Fugro Consulting Engineers.

Principal Investigators
Mohsen M. Baligh
Associate Professor
Department of Civil Engineering

Charles C. Ladd
Professor
Department of Civil Engineering

Systematic Modeling of Uncertainties

Professor Gregory B. Baecher is incorporating data from soil analysis into a model for coherently treating geotechnical uncertainties in designing and monitoring offshore structures. He is analyzing the risks of building offshore platforms under various conditions—given the uncertainty of environmental loadings, sediment properties, and foundation behavior. Also considered is uncertainty introduced by the geotechnical models themselves due to factors such as inadequate theoretical understanding, approximations in boundary and initial conditions, and structural relations.

The civil engineering researchers will use probability analysis and statistical techniques to study aggregate risks and to predict sequences and consequences of potential geotechnical failures. This kind of risk analysis will help government officials in setting environmental standards and will aid engineers who must now compensate for uncertainty by over-designing offshore platforms.

Principal Investigator
Gregory B. Baecher
Assistant Professor
Department of Civil Engineering

Foundation Displacement of Gravity Platforms

Dr. W. Allen Marr and Professor T. William Lambe are leading a research group to investigate the effects of cyclic loading on the foundations of gravity platforms. These massive structures rest directly on the sea bottom. While they are heavy enough in proportion to the waves to remain stable, the continuous, cyclic stresses cause changes, especially deformations, in the foundation soil.

In this Sea Grant project, the civil engineering researchers are trying to develop techniques for predicting the deformations so that design criteria will be set to minimize or tolerate their magnitude. The team began with models of soil behavior that predicted stress for a particular wave load at different points in the foundation. Then they moved to the laboratory to duplicate the existing stresses on an element of soil from the sea bottom, and applied changes in stress which a wave would exert. They cycled those stresses—just as a wave would in the field—and extrapolated to a general set of conditions for stressing. The resulting mathematical model will allow them to predict the effect of waves of different heights on the cyclic and permanent deformation of the structure.

They had an opportunity to test the finite element model in field tests on Rotterdam flood defense plans and were pleased that the results showed their approach to be sound and based on a rational set of principles. When the researchers finish their Sea Grant sponsored work on the model, they will begin to study types of offshore structures other than gravity platforms. Their efforts will be supported by the Venezuelan government. This opportunity will help to extend their Sea Grant research with the aid of the people who want and need the results. By applying their theory and model to real structures in South American waters, they will determine how accurate the model is and where the shortcomings are. The incremental additions and improvements to offshore technology will lead to greater cost efficiencies for the offshore industry and more protection to coastal waters around the world where oil is being recovered.

Principal Investigators
W. Allen Marr
Research Associate
Department of Civil Engineering

T. William Lambe
Edward K. Turner Professor
of Civil Engineering
Department of Civil Engineering

Frequency Analysis For Offshore Structures

Despite the best efforts to apply modern technology and sophisticated modeling to the design of offshore structures, these massive buildings will be subjected to severe stresses from ocean waves, shifting sediments, high winds and strong currents. Under these tremendous continuous strains, the structures are likely to weaken and require repair. It is important to identify defects before they become serious enough to cause human or environmental casualties or force costly closings of large, productive oil and gas rigs.

For several years, civil engineers have measured the natural frequencies of buildings with sensitive devices known as accelerometers to locate possible structural damage following an earthquake. A detected shift in the vibration response between successive measurements indicates a change in the structure. Such a change implies failure in either the structure itself or its supporting bottom conditions. Professor J. Kim Vandiver has extended this technique to ocean platforms and established standards against which vibration measurements can be compared to determine if structural changes have taken place.

The approach does not require detailed features of the final design and eliminates the gross approximations and cumbersome computations of existing techniques. An engineer using it needs to know only the structure's estimated natural frequency, the wave conditions typical to the structure site, and the gross geometric layout of the structure.

Following a Collegium meeting focused on his work, Professor Vandiver received support from the U.S. Geological Survey Branch of Marine Oil and Gas Operations to continue a related project. In this work he is investigating technology that would allow engineers to suppress the vibration response of a structure and resulting cyclical stresses by careful configuration and placement of oil and water storage tanks on the platform deck. Another Collegium meeting to present the results of this research was held in October of 1980 in conjunction with MIT Sea Grant's tenth anniversary celebration.

Principal Investigator
J. Kim Vandiver
Associate Professor
Department of Ocean Engineering

Robot Sonar Platform

Unmanned vehicles are becoming increasingly important as a mode of travel for the instrumentation that supplies data about the ocean environment. Through Sea Grant, a Collegium member, the Navy's Explosive Ordnance Disposal Facility, has supported the development of a small untethered vehicle which is basically a sonar platform. The design objectives have called for a small, easily transportable, untethered computer-controlled submersible which could operate in salt water and fresh water. Instrumentation includes communications for command and control while underway, and collision avoidance, bottom following, pinger and side scan sonar.

Initiated as a Sea Grant student project several years ago in the Ocean Engineering Summer Laboratory, MIT graduate and undergraduate students continue to make a significant contribution to the robot's development. The researchers have kept the weight down so that the submersible would be mobile, requiring just a few people to handle and launch it. It weighs about 120 pounds in air and is 8 feet long and 13 inches in diameter. Designed to submerge to 300 feet, it has an initial range of 10 miles. Lead-acid gel cells allow three to four hours of operating time at three knots. In the future a lithium battery will be used for longer missions.

The vehicle is pre-programmed to give the operator the option of changing programs remotely. Professor A. Douglas Carmichael, who heads the project, expects to have a series of programs in the system that allow the operator to insert changes, such as depth and course direction. Robot II, as it is called to differentiate it from a predecessor, will be able to make limited decisions to help avoid collisions.

Principal Investigators
A. Douglas Carmichael
Professor
Department of Ocean Engineering

David G. Jansson
Associate Professor
Department of Aeronautics and Astronautics

Telemanipulators for Deep-sea Tasks

Sea Grant researchers at MIT are not only working on robots that carry instrumentation to look at the ocean environment, but they are creating mechanical devices that will work in the deep seas.

As ocean exploration moves seaward, the economic costs of deep-sea diving grow exponentially. Oil and gas companies drilling in waters 1,000 feet deep could pay as much as $200,000 a day for a major dive. For scientists surveying or inventorying the seafloor this expenditure would be prohibitive. Perhaps more important, operations in the North Sea have shown that deep dives exact a high human toll.

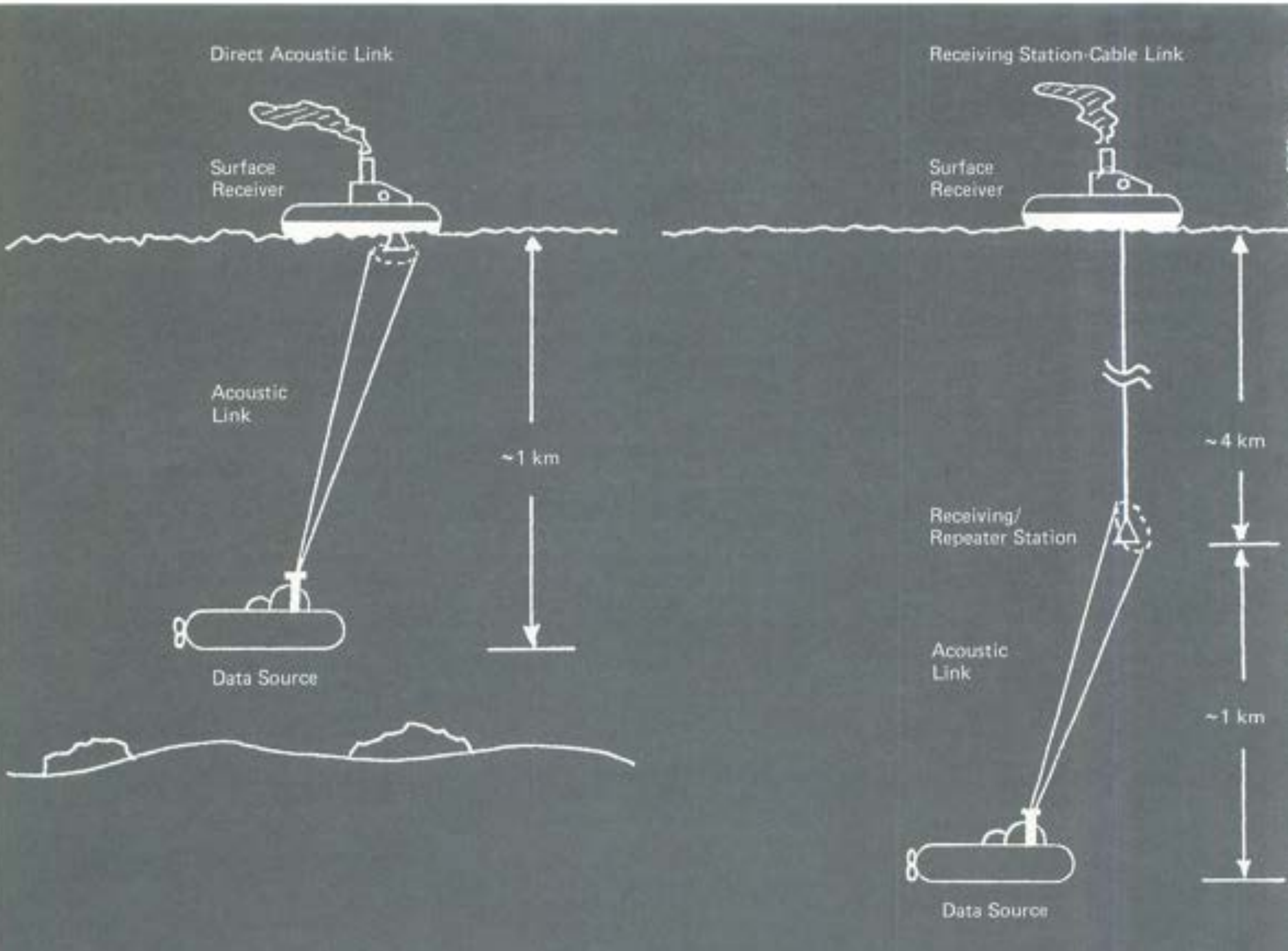
Professor Thomas B. Sheridan has long been interested in combining the talents of humans and machines to extend the capabilities of both. Beginning in 1976, he and two graduate students began a project to create a communications system using computers and master-slave controls. The entire system is known as "supervisory control." In it a human operator directs a subordinate telemanipulator designed with joints to give it freedom of movement, and sensors to help it make some decisions. The human operator, located on board a ship or platform, plans the actions and directions of the mechanical device, teaches it how to do the job, then monitors its performance on a television screen. The operator intervenes if the device seems to have trouble maneuvering or accomplishing its assigned task.

In a Sea Grant report published in July 1979, graduate student Thurston L. Brooks describes the computer program and the master/slave controls that teach the manipulator basic tasks for undersea platform maintenance. The MIT engineer developed a language and control philosophy, dubbed SUPERMAN, which takes into account spatial relationships between the manipulator and its tasks as well as the slow and low resolution television communications now achievable in the ocean environment.

From July 1980 through June 1983, Professor Sheridan and associates aim toward decreasing master-slave direction and increasing computer instruction and control. Using a newly renovated laboratory manipulator, they hope to overcome relative motion between the vehicle and its task—a problem encountered by human divers and the telemanipulators alike because current forces constantly push along free swimming objects. A diver tightening a valve or scrubbing a platform leg simply holds on with one hand. It's more complicated for a robot. The researchers plan to keep the manipulator steady by use of sensor and computer arms that make constant adjustments for changes in position. Similar compensation will be possible if a manipulator reaches for a valve but misses; the computer could simply say, try again but move to the left.

Work is underway to determine the best tradeoffs between the man/machine co-workers to automate what can be understood and predicted and to assign to human beings what is not predictable nor understood, a common circumstance in the ocean environment.

Principal Investigator
Thomas B. Sheridan
Professor
Department of Mechanical Engineering


Direct Acoustic Link
Surface Receiver
Acoustic Link
~1 km
Data Source
Receiving Station-Cable Link
Surface Receiver
~4 km
Receiving/ Repeater Station
Acoustic Link
~1 km
Data Source

Acoustical Telemetry for Untethered Vehicles

One of the greatest hindrances faced by ocean scientists who are employing unmanned vehicles for study and data recovery is the tether that links the instrumentation to a surface vessel or working platform. Not only do the tethers tangle easily on platform legs or underwater debris, but they create tremendous drag, which restricts the independence and movement of the underwater vehicles. Advances in microprocessing, underwater transmission equipment and communications theory promise to free remotely operated underwater vehicles from an encumbering umbilical cord.

In a Sea Grant project that began in 1978, Professor Arthur B. Baggeroer has led the task of applying communications theory to the encoding of digital data through frequency shift keying of acoustic signals. A microprocessor converts four bits of data into a code comprised of eight-tone chords. The chords are then transmitted directly through the ocean on a frequency band centered at 50 kHz. Each message is accompanied by two other signals. One is 60 kHz tone and acts as a reference to help the receiver account for a Doppler shift (the change in pitch of a sound resulting from relative motion between the source and the receiver); the other signal sent on 30 kHz keeps the messages separate.

This new system of telemetry must overcome the severe reverberative problems characteristic of the ocean environment, especially in shallow waters where the signals echo. Shift keying into different frequencies overcomes the reverberation. By sending each eight-tone message on a different frequency, each channel has time to free itself of echo before being reused.

The Sea Grant researchers are using a directional data transmission system borrowed from sonar and radar technology to steer the message along a path. A four by eight element array consists of small transmitters, each with a prescribed signal time delay that points the encoded chords in a direction controlled by an operator on the surface.

When the messages reach the receiver they are split into three separate signals—the eight-tone chords, a Doppler signal and a synchronizing signal; each eight-bit data segment is reconstructed from the frequency spectrum; and the original four-bit message is derived from an error-correcting algorithm.

Professor Baggeroer and his research team from MIT and Woods Hole Oceanographic Institution hope to transmit 4 kilobits that can be manipulated to accommodate the variables of individual remotely operated vehicle (ROV) assignments, such as task complexity, error tolerance, distance from the data source to the decoding receiver, acoustic channel characteristics, and ocean conditions.

Principal Investigators

Arthur B. Baggeroer
Associate Professor
Department of Ocean Engineering
Department of Electrical Engineering and Computer Science

Jeffrey H. Shapiro
Associate Professor
Department of Electrical Engineering and Computer Science

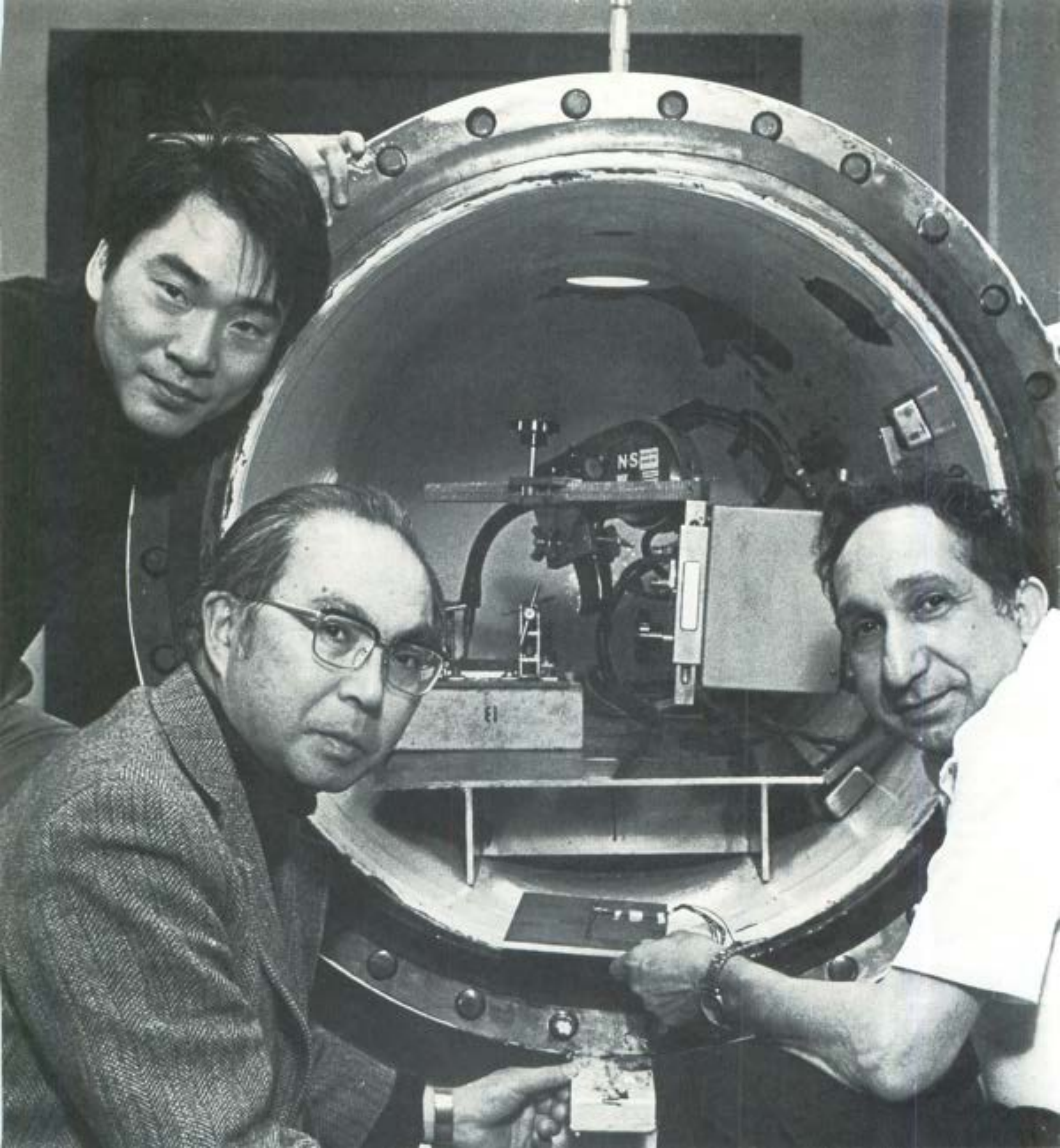
Donald E. Koelsch
Senior Research Associate
Woods Hole Oceanographic Institution

Deep-sea Welding

Professor Koichi Masubuchi has generated basic information about deep-sea welding and cutting techniques that can be employed to make repairs more efficiently and economically on both marine structures and cargo ships. In 1974, he published the first comprehensive study on the fundamentals of underwater welding in a Sea Grant report; in 1977 he patented a device for stud welding; and in 1979 he patented a submerged arc welding process which works well in marine conditions.

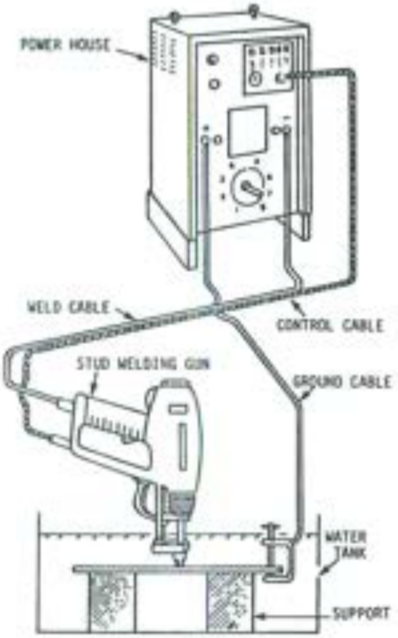
Underwater welding has generally resulted in brittle, unreliable welds because of the rapid cooling effect of seawater, and hydrogen ions freed by the underwater arc. In using the new technique, a flux-filled, water-tight plastic enclosure is laid over the joint to be welded. The electrode is inserted through the plastic, and the welding takes place in a flux-filled environment. Brittleness is prevented because the weld cools before the water displaces the flux.

The welding technique and welding tools were extensively tested in a six-foot pressure tank which could be activated by an operator standing on the outside and viewing the welding process through a window on the wall of the tank. In the laboratory the researchers were able to simulate underwater conditions up to pressures of 700 feet (300 psi) without a costly investment in equipment.


NS

Now Professor Masubuchi has turned his attention to the development of a cassette system capable of performing a stud weld by pushbutton control. By turning to 20th century "instamatic" technology, the researchers foresee a tool that could be used by an untrained diver or by a robot vehicle. It will also have uses offshore and for ship salvaging and repair work. The device will be safer than existing welding methods because no sparks and few fumes are released to cause a fire or explosion.

Principal Investigator
Koichi Masubuchi
Professor
Department of Ocean Engineering



Mining Manganese Nodules

In the past decade, deep-ocean mining has attracted the intense interest of the marine community for two reasons. One, the search for manganese nodules promises to be profitable; and the extracted metals could help to reduce U.S. dependence on foreign imports. 1975 figures show that the United States imported 9 percent of its primary cobalt, 71 percent of its primary nickel, and 15 percent of its primary copper. In twenty years it is expected that the country will be totally dependent on imports of the first two metals and a large fraction of copper.

Professor J. D. Nyhart collaborated with one of the major consortia interested in developing a new deep-sea industry to create a model that would permit easy exploration of various financial and operational alternatives as they affect the economics of mining manganese nodules. Sea Grant supported the initial compilation of the model, which has become a primary information source for negotiating financial arrangements in the Third United Nations Law of the Sea Conference. Those talks have progressed more slowly than expected, but deep-sea mining holds the potential of being a trillion dollar business— with many countries holding rights to the seabed, but only a few possessing the technology to mine it.

Both the Law of the Sea negotiators and the U.S. government seek to create a stable economic and political climate in which national and multinational companies can remove the valuable resources with the assurance that their massive investments will be protected. At the same time everyone wants to find a way to share the benefits of a commonly held resource.

One of Sea Grant's initial goals in sponsoring research is to find matching support, like that supplied by the mining consortia, so that users of the research become immediately involved. If the research moves into a second or third phase, the Program sometimes continues its support or helps the principal investigator to find another appropriate industry or government sponsor. An update and refinement of the deep-sea mining model is now being supported by the National Oceanic and Atmospheric Department's Division of Marine Minerals through Sea Grant.

Principal Investigator
J. D. Nyhart
Professor
Department of Ocean Engineering
Alfred P. Sloan School of Management

Oil and the Environment

For as long as oil is needed as a primary energy source, the attendant problems of oil spill pollution will continue. Oceans are the highways for carrying petroleum from field to refinery to consumer. And increasingly, new oil sources will be tapped in offshore areas. The threat of accident from a human error is ever present, despite the best efforts of industry and government.

MIT Sea Grant's research has sought to reduce potentially negative impacts of offshore development on other marine industries by helping to improve oil containment technologies and provide information that can be used to devise strategies for sharing ocean spaces.

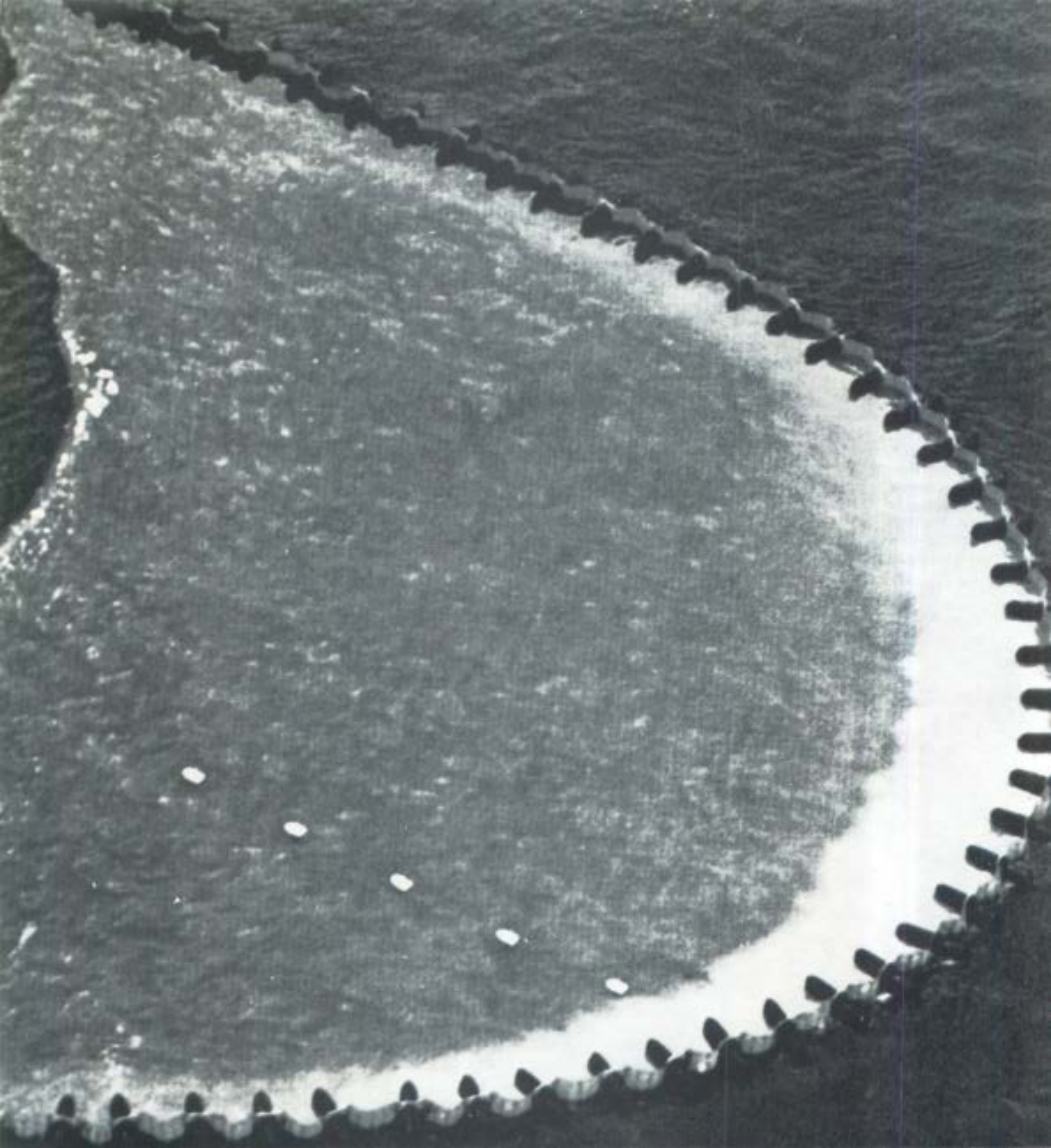
Oil on Georges Bank
Offshore Effects on the Coastal Zone

When the Secretary of Interior in June 1971 announced a schedule for leasing petroleum tracts on Georges Bank, a number of New England groups strenuously objected. State and local government, regional authorities, conservationists, environmentalists, private citizens and the entire fishing industry noted a lack of factual, credible information that would help them assess either economic benefits or the environmental risks of drilling for oil on one of the world's richest fishing grounds, near a coastal area economically dependent on a thriving tourist industry.

In December 1971 Sea Grant Director Alfred A. H. Keil organized a conference of state and industry representatives to solicit advice on the research needs of the Massachusetts and New England communities. Two attendees of that meeting, the New England River Basin's Commission (NERBC) and the New England Regional Commission (NERCOM) suggested that Sea Grant study the Georges Bank controversy to determine what impact oil production would have on regional income, on the quality of New England's environment, and on other marine industries. The two organizations agreed to share support of this critical undertaking with Sea Grant, the Doherty Foundation, and MIT. An interdisciplinary study team was formed, led by Professor John W. Devanney, III and Instructor J. B. Lassiter. Six student research assistants participated in helping the entire faculty team which included Professors M. A. Adelman (Department of Economics), J. A. Fay (Department of Mechanical Engineering), the late E. R. Gilliland (Department of Chemical Engineering), D. P. Hoult (Department of Mechanical Engineering) and S. F. Moore (Department of Civil Engineering).

The researchers used computers to model production schedules, the number of producing wells, and the frequency of petroleum shipments in New England's waters. Variables for the model were a series of hypothetical estimates of the amount of oil and gas under Georges Bank from zero to a major find. Creating a comprehensive model allowed the team to ask "what if." Their purpose was not to offer advice or make judgments, but to devise a trustworthy planning tool—free of bias and proprietary interests.

When the project was completed in March 1973, the research group published their results in an MIT Sea Grant report, *The Georges Bank Petroleum Study*. Sea Grant organized a one-day symposium of 300 people from environmental groups, government and industry. Professor Devanney presented the project results to the Massachusetts Special Legislature Commission on Marine Resources and Boundaries. In Washington, the White House Council on Environmental Quality asked the project team to conduct a similar major environmental study of offshore oil developments on the entire Atlantic Continental Shelf and the Gulf of Alaska. These results were published in 1975 in MIT Sea Grant report, *The OCS Petroleum Pie* and MIT Sea Grant report, *Primary Physical Impacts of Offshore Petroleum Development: Report to Council on Environmental Quality*.



Aerial photograph of an oil containment boom being towed by two vessels

The Georges Bank study team recommended further research in oil spill containment and clean-up. They concluded that although estimated petroleum spills would have little effect on the offshore Georges Bank ecosystem or its fisheries, coastal ecologies could be threatened by onshore refinery activities and increased tanker traffic.

A model they developed to predict the spread of an oil spill on Georges Bank is used today by the U.S. Coast Guard. Its most dramatic application occurred in December of 1976 when the ARGO MERCHANT went aground on Nantucket Shoals spilling 7.7 million gallons of fuel oil.

Principal Investigator
John W. Devanney, III
Associate Professor
Department of Ocean Engineering

Oil Spill Modeling, a Review

The need to develop regulations that balance risk and benefits has become more pressing as ocean development moves forward. Offshore areas offer potential energy supplies essential to the operation of our technological society. These same waters also nurture seafood, a valuable source of protein.

Regulations now being formulated with the cooperative efforts of government and industry are accounting for the world's needs for food and fuel. To do so confidently, a number of important questions need to be answered: What impact will oil have on off- and near-shore fisheries; what effect would a major oil spill have? How and where would spills in different offshore areas spread? How can strategies be devised for containing slicks?

Computer models are helping scientists and engineers answer these difficult questions. In 1977, under Sea Grant sponsorship, a team of researchers from MIT's Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics reviewed the state-of-the-art of oil slick modeling for predicting the spread of instantaneous surface spills. The purpose was to prepare a yardstick for measuring existing modeling efforts and to evaluate the current demand for new research. Their conclusions, documented in a Sea Grant report, are now considered a critical reference for scientists, engineers and legislators.

Principal Investigator
Keith D. Stolzenbach
Associate Professor
Department of Civil Engineering

Oil Slick Control Offshore

Oil coming ashore anywhere, whether from a refining accident, a tanker collision, or an offshore drilling mishap, often results in considerable loss. Closed beaches impose economic hardships on tourist and recreational industries. And damaged marine life—even if it recovers completely—can critically affect the productivity of nearshore ecosystems.

Technology for nearshore spills has advanced greatly in the past ten years, but IXTOC I, the accident in the Gulf of Mexico, revealed serious shortcomings in offshore clean-up operations. At MIT Professor Jerome H. Milgram has warned for some time that more research is needed to devise more effective control technology for offshore oil spills. Beginning in 1975, Sea Grant sponsored several projects under the leadership of Professor Milgram.

He first constructed a laboratory flume in which to study effects of waves and currents on contained oil. The narrow channel, 30 feet long with perfectly aligned sides, allowed Professor Milgram and Robert Van Houten (now an MIT Assistant Professor in Ocean Engineering) to observe the unstable boundary between oil and the moving water that pulls oil bubbles beneath containment barriers. Because the channel was designed to minimize turbulence, it allowed accurate measurement of the effect of spilled oil in simulated seawater currents.

While working on Sea Grant oil spill research, Professor Milgram was also involved in a Coast Guard study of oil dispersion into the sea. When the ARGO MERCHANT went aground, he went aboard the stranded vessel with Dr. Edward Kern of the MIT Lincoln Laboratory to observe the spill and its interaction with breaking waves. He subsequently wrote a Sea Grant report, *Being Prepared for Future ARGO MERCHANTS*, which outlined his observations and recommendations for preventing calamitous spills from damaging the coastline in the future. The ocean engineering researcher was asked to participate in efforts to cap the IXTOC I blowout. This has led to support from the U.S. Geological Survey for research on the hydrodynamics of oil-gas-water plumes from subsea blowouts and on methods for collecting oil in these plumes.

Principal Investigator
Jerome H. Milgram
Professor
Department of Ocean Engineering

Developing Effective Clean-up Strategies

According to U.S. Department of Transportation figures, in 1977 alone over 11,000,000 gallons of oil were accidentally spilled by vessels into the nation's waters, with tankers responsible for 9,800,000 gallons. Despite the seriousness of this ongoing problem, no analytical study exists for estimating the economic and environmental costs to marine industries and to society.

At the present time, the Coast Guard is designing an optimal oil spill clean-up system for large accidents involving quantities of over 100,000 gallons. But of at least equal concern are the pernicious smaller spills that occur more frequently, close to the vulnerable coastal environment. This sort of problem is multidimensional, involving regulations, technology, economics, and systems analysis—just the type of challenge Congress mandated Sea Grant to accept.

In July 1979, motivated by a MIDAS meeting and jointly supported by Sea Grant and industry, Professor J. D. Nyhart, a lawyer who teaches ocean regulatory law, and Professor Harilaos N. Psaraftis, operations research expert, assembled a research task force to develop two analytical clean-up models for small and medium spills. Rounded out by several ocean engineering consultants, the team has enlisted an advisory committee from government and industry. They have received financial support from the Coast Guard, the U.S. Navy and the Spill Control Association of America, a group of companies involved in cleaning up oil on private contract or in conjunction with the Coast Guard.

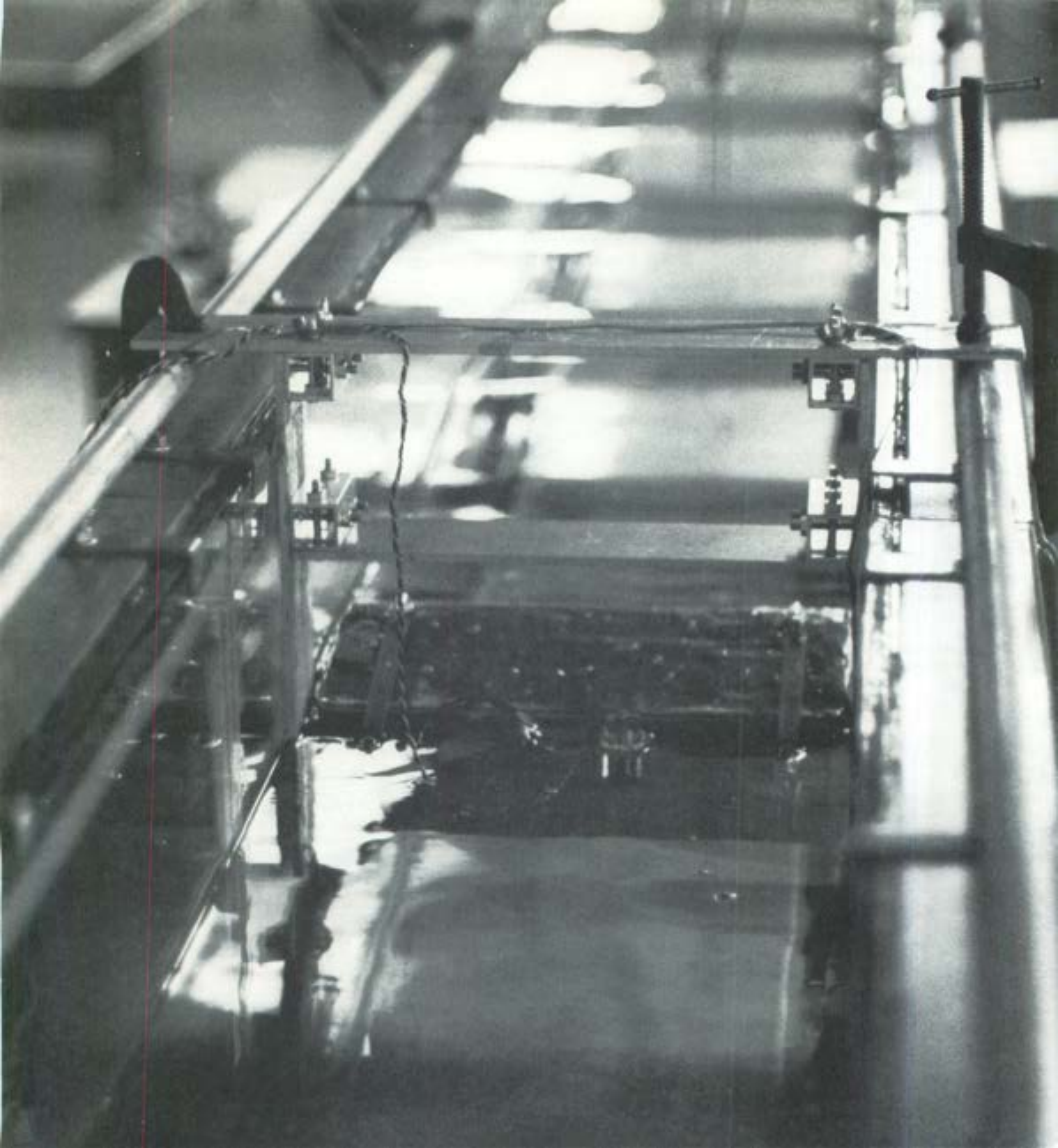
Through June 1981, the team will collect extensive data and construct two computer models. One will help to analyze the costs to industry and to society of cleaning up oil spills; and it will enable the researchers to compare environmental damage costs—with the price of systematically cleaning up all (or most) of the oil spilled in nearshore accidents.

The second model will help devise strategies for designing optimal clean-up systems, recommending good locations for emergency facilities, designating the equipment needed, and recommending tactical decisions for oil spills of varying sizes and locations.

In tandem with the development of the models, the researchers and their advisory committee will analyze the constraints that current or proposed regulation and legislation could have on optimal oil spill clean-up.

Principal Investigators
J. D. Nyhart
Professor
Department of Ocean Engineering
Alfred P. Sloan School of Management

Harilaos N. Psaraftis
Assistant Professor
Department of Ocean Engineering
Henry L. Doherty Professor in Ocean Utilization 1979-1981



Technology for Ocean Uses

At the Institute, Sea Grant has joined with faculty and student researchers to advance technologies for opening up the ocean's vast potential. The waters themselves — tides and waves — promise new energy sources; the seabed, once unreachable, can be probed and photographed; and traditional uses such as transportation and recreation are being made more efficient and safer.

In ten years the range of problems attacked by MIT Sea Grant has been broad and exciting. The projects reported in this section are a sampling of those undertakings, illustrating past accomplishments and future challenges that remain in ocean development.

Energy From the Oceans

Almost everyone agrees that sources of energy other than oil and gas will be needed in the decades ahead. At present no one energy source appears to provide an easy or feasible answer, but scientists in industry and universities have only recently undertaken intensive alternative energy research. As technologies develop, it may be possible to produce a whole system of energy sources using the sun, land and marine biomass, winds, ocean temperature differentials, and tides and waves.

At MIT, Sea Grant investigated the efficiency and practicability of employing a teardrop-shaped cylinder as a potential small power source for at-sea use. Named after its British inventor, the Salter Cam rotates on a central axis, rocking back and forth with the waves and absorbing energy. Uncertain about its behavior under random wave conditions, Professor C. C. Mei conducted a theoretical hydrodynamic computer analysis that proved the efficiency of the concept. Professor A. Douglas Carmichael used MIT's wave and towing tanks to assess how the cam would perform with waves approaching it from various directions and experimented with mooring forces and efficiencies.

The results showed that the device indeed absorbs and converts wave energy very well. The waves are capable of transmitting impressive amounts of power, with an average of 60 kw per meter in some environments but about 8 kw in a low energy location like New England. However, Professor Carmichael's economic studies found that the costs of conversion to electricity, electrical transmission to shore, mooring, and total capital investment made the cam uncompetitive for the present.

At a 1979 Collegium meeting, the investigators conferring with a number of people from industry concluded that the research had been most useful in narrowing wave energy research to other systems for the time being. It is as much a mandate for Sea Grant to find out what will fail as to discover what can work. Energy and ocean research are both on a frontier where no progress is possible without risk. University research, with government support, can boldly take some of those risks. Further theoretical studies are now being pursued by Professor Mei and Professor J. N. Newmen of the Department of Ocean Engineering.

Principal Investigators

A. Douglas Carmichael
Professor
Department of Ocean Engineering

Chiang C. Mei
Professor
Department of Civil Engineering

Thermal Tests Detect Fiberglass Flaws

Over the last twenty years, fiberglass composites have been used more and more frequently by the boating industry, replacing such traditional materials as wood, steel and aluminum. Fiberglass offers the advantage of high strength and stiffness in a lightweight compound. Although it is less expensive and requires less maintenance that these traditional materials, it is inherently nonhomogenous and slight variations in the fabrication, curing, and heating procedures may create flaws that weaken the fiberglass without any visual effect.

Existing techniques for determining structural flaws such as the x-ray scan used by the aircraft industry are prohibitively expensive, and so scientists and boat manufacturers have been searching for cheaper methods of inspection.

Currently, Professor James H. Williams, Jr. is working with both graduate and undergraduate students in MIT's Mechanical Engineering Composite Materials and Nondestructive Evaluation Laboratory to develop an inexpensive, easily utilized thermal testing technique that can identify fiberglass flaws in watercraft. The researchers are correlating how various types of imperfections affect the structural integrity of different types of fiberglass through thermal testing. The method is based on the detection of surface temperature differences that result when a flaw alters a structure's normal heat flow pattern.

Professor Williams is investigating the use of cholesteric liquid crystals applied to a test surface as a thermally sensitive coating. Temperature differences above a flaw show up as a vivid color region that can be observed directly as a "hot spot."

He is adapting this process to a kit with simple tables and graphs. Companies could purchase a complex version with a continuous line of spraying and heating elements for inspecting crafts before they are sold. Insurance companies might use the technique as an alternative to present-day inspection techniques to determine hull standards. And ultimately, individual boat owners will be able to use the Sea Grant technique to monitor the condition of boats at the end of each season to check for any weaknesses or hull damage.

Principal Investigator
James H. Williams, Jr.
Associate Professor
Department of Mechanical Engineering

Ship Wave Resistance

A basic problem in naval architecture has been to predict and minimize wave resistance in ship hull design. As long ago as 1976, fundamental experimental and theoretical research was initiated to find solutions. In his Sea Grant project, Professor Francis Noblesse has been evaluating a theory which he recently devised.

His attention and the interest of others in reducing wave resistance have increased in the past ten years because escalating fuel bills have created an acute need for diminishing the drag of ships. At the same time, advances in computer technology have made it possible to contemplate the development and implementation of complex mathematical theories.

Principal Investigator
Francis Noblesse
Assistant Professor
Department of Ocean Engineering
Henry L. Doherty Professor in Ocean Utilization 1979-1981

The Doherty Professorships

In 1973, the Henry L. and Grace Doherty Charitable Foundation established the Henry L. Doherty Professorships in Ocean Utilization to encourage non-tenured MIT faculty to focus on contemporary problems in the marine field. The chairs help to attract and support outstanding young teachers and researchers with interdisciplinary backgrounds as they begin work in the emerging marine field.

During their two-year appointments Doherty Professors remain affiliated with their respective academic departments, but conduct their research under the aegis of the MIT Sea Grant Program. The Doherty Professors during the past year have been Professors Francis Noblesse, Alician V. Quinlan, and Harilaos Psaraftis.

MIT Sea Grant Research 1970-1980

Duration of Project	Project	Principal Investigators
1970-1971	**National Ocean Policy**	N.J. Padelford
1970-1972	**Ocean Transportation**	E.G. Frankel
1970-1972	**Future of Atlantic Ports**	E.G. Frankel
1970-1972	**Estuary Modeling**	A.T. Ippen
1971	**Oil Oxidation by Marine Bacteria**	P.W. Robbins
1971-1972	**Environmental Impact of a Supertanker Port in the Machias Bay Area**	S.F. Moore
1971-1974	**Ocean-Borne Commerce and the Future Interoceanic Canal**	N.J. Padelford
1971-1974	**The Sea Environment in Massachusetts Bay and Adjacent Waters**	A.T. Ippen E.L. Mollo-Christensen
1974-1976	**The Sea Environment in Massachusetts Bay and Adjacent Waters**	J.J. Connor, Jr.
1976-1977	**The Sea Environment in Massachusetts Bay and Adjacent Waters**	J.J. Connor, Jr. B.R. Pearce
1971-1974	**Fundamental Research on Underwater Welding and Cutting**	K. Masubuchi
1974-1976	**Development of New and Improved Techniques for Underwater Welding and Cutting**	K. Masubuchi
1976-1980	**Development of Joining and Cutting Techniques for Deep Sea Applications**	K. Masubuchi
1980-1982	**Development of Fully Automated and Integrated ("Instamatic") Welding Systems for Marine Applications**	K. Masubuchi
1971-1975	**Utilization of Squid for Processed Food Products**	S.A. Goldblith
1972-1973	**Offshore Petroleum and New England**	J.W. Devanney, III
1972-1973	**Assay of the Marine Resources of Massachusetts Bay**	J.B. Lassiter
1972-1973	**Mariculture Project Development**	W.W. Seifert
1972-1973	**Planning the Development of Automatic Means of Classifying Plankton**	L.S. Sutro
1972-1974	**Port Design and Analysis Methodology**	E.G. Frankel
1972-1974	**Non-Technical Problems of Marine Waste-Food Recycling Systems**	I. Dyer J. Huguenin
1972-1975	**Fracture Toughness of Reinforced Plastic Hull Materials**	F.J. McGarry
1973-1974	**Analysis of Offshore Mineral Leasing and Royalty Policies**	J.B. Lassiter
1973-1975	**Sludge and Wastewater Treatment with High Energy Electrons**	J.G. Trump
1973-1975	**An Improved Hook-Up Block for Side Trawling**	S.P. Loutrel
1973-1975	**Using Cooperatives to Aid the New England Fishing Industry**	H.S. Marcus
1973-1976	**Evaluation of Potential of Heated Finishing Plant for Oysters**	W.W. Seifert J.W. Zahradnik

Duration of Project	Project	Principal Investigators
1973-1975	**Structure of Chitosan**	B.L. Averbach
1975-1976	**The Properties and Applications of Chitosan**	B.L. Averbach
1976-1980	**Chemical and Structural Characterization of Chitin and Chitin Derivatives for Industrial Application**	B.L. Averbach
1979-1982	**Synthesis of Chitosan Structure Matrix for Food**	C.K. Rha
1973-1976	**Multipurpose Offshore Platform Design**	C. Chryssostomidis
1974-1975	**Conceptual Study of International Marine Technology Transfer**	J.T. Kildow
1974-1975	**Resolution of the Oil Spill Transport Controversy**	J.W. Devanney, III
1974-1975	**Practitioner's Guide to the Law of the Sea Conference**	J.D. Nyhart R.R. Baxter J.T. Kildow L.B. Sohn
1974-1975	**Survey of Ocean Engineering**	J.W. Devanney, III
1974-1975	**Management of Fishery Resources Under the 200-Mile Limit**	J.W. Devanney, III
1974-1977	**Content, Composition and Fate of Physiologically Important Lipid Components in Raw and Processed Shell- and Finfish**	S.A. Goldblith E.R. Pariser
1975-1977	**Review and Evaluation of Oil Spill Trajectory Models for Use in Risk Assessment Associated with Proposed Deep Water Ports**	J.J. Connor, Jr. B.R. Pearce K.D. Stolzenbach
1975-1976	**Oil Spillage Impact Study on World War II Tanker Sinkings**	E. Kern
1975-1976	**Perspectives for Building Public-Private Cooperation in the Coastal Zone**	J.T. Kildow
1975-1976	**Spectrofluorometric Remote Sensing of the Red Tide Algae**	S. Ezekiel G. White
1975-1976	**Survey of Methods of Determining Wave Forces of Offshore Structures**	J.H. Milgram
1975-1976	**Industrial Application of Chitin and Chitin Derivatives**	N.A. Ashford
1975-1977	**Regulation of Offshore Technology Under Extended Jurisdiction**	J.D. Nyhart
1975-1977	**Numerical Theory of Wave Effects on Offshore Structures**	C.C. Mei
1975-1977	**An Improved Trawl Door Hook-Up System**	S.P. Loutrel A.B. Clifton
1975-1977	**An Analysis of the Foreign Trade Impacts of the Sea Grant Program**	J.H. Hollomon
1975-1977	**A Biochemical Model for Coastal Waters with an Application to Red Tide Outbreaks**	F.M.M. Morel
1977-1979	**The Role of Trace Metals on New England Red Tides**	F.M.M. Morel
1979-1982	**Analysis of Growth Strategies of the New England Red Tide Organism: *Gonyaulax tamarensis***	S.W. Chisholm

Duration of Project	Project	Principal Investigators
1975-1978	**Oil Slick Control in Offshore Environments**	J.H. Milgram
1976-1977	**The Application of the Robot Submersible to Side Scan Sonar Operation**	A.D. Carmichael
1976-1977	**Georges Bank Fishery Study**	J.W. Devanney, III
1976-1978	**An Improved Trawl Board for the New England Fishing Fleet**	J.K. Vandiver A.B. Clifton
1976-1978	**The Hydrodynamic and Engineering Evaluation of an Ocean Wave Energy System**	A.D. Carmichael C.C. Mei
1976-1978	**Longshore Sediment Transport**	O.S. Madsen
1976-1978	**Computer Documentation Dissemination**	J.J. Connor, Jr.
1976-1978	**Development of a Guide to Information Sources in the Field of Offshore Engineering**	M. Chryssostomidis
1976-1978	**Dynamic Analysis of Offshore Structures**	J.K. Vandiver
1976-1978	**Exploration and Evaluation of Engineering Properties of Marine Soils for Foundation Design of Offshore Structures**	M.M. Baligh C.C. Ladd
1978-1981	***In Situ* Evaluation of Geotechnical Properties of Marine Sediment**	M.M. Baligh C.C. Ladd
1976-1978	**Development of Processes for Skinning the Spiny Dogfish Shark**	C.K. Rha D.G. Wilson
1978-1980	**Development of Processes for Skinning the Spiny Dogfish Shark**	D.G. Wilson
1976-1979	**Enhancement of the Stability of Common Polymeric Materials Against Undersea Degradation**	R.G. Donnelly R.E. Cohen
1976-1980	**Application of Teleoperators to Undersea Tasks**	T.B. Sheridan
1980-1983	**Remote Control Techniques for Unmanned Underwater Work Vehicles**	T.B. Sheridan
1976-1981	**Study of a Cost Model of Deep Ocean Mining**	J.D. Nyhart
1976-1981	**An Analysis of Offshore Brine Disposal Techniques**	K.D. Stolzenbach
1977-1978	**Laser Inertial Rotation Sensor for a Portable Navigation System**	S. Ezekiel
1977-1978	**Wave Spectra Monitoring Direction Buoy**	R.J. Van Houten
1977-1979	**Surf Zone Hydrodynamics: A Field Investigation**	O.S. Madsen
1977-1979	**The Effects of Oil Composition and Physical Properties and of the Ambient Water on Oil Slick Dispersion**	R.G. Donnelly
1977-1979	**Offshore Geotechnical Risk Analysis**	G.B. Baecher
1979-1982	**Analysis of Geophysical Information in Offshore Geotechnical Exploration**	G.B. Baecher
1977-1981	**Seawater Intrusion in Offshore Islands**	J.W. Wilson, III

Duration of Project	Project	Principal Investigators
1978-1979	**The Dynamic Behavior of a Tethered Current Meter**	M. Triantafyllou
1978-1979	**Measurements of Heavy Metals in Seawater Containing Surface Active Agents**	D.N. Hume
1978-1979	**Massachusetts Bay Circulation Studies**	J.J. Connor, Jr.
1978-1979	**Physiological Measures of Mental Workload**	E. Cravalho J. Tole
1978-1979	**Theory for Mass Transport due to Water Waves Beneath Wind**	J.H. Milgram
1978-1980	**Robot Vehicles for Search and Survey Applications**	A.D. Carmichael
1978-1979	**Underwater Communication System for Untethered Vehicles and Sensors**	A.B. Baggeroer
1979-1981	**Underwater Communication System for Untethered Vehicles and Sensors**	A.B. Baggeroer J.H. Shapiro D.E. Koelsch
1978-1980	**Quality Control of Fiberglass Boat Hulls Using Thermal Testing and Liquid Crystals**	J.H. Williams, Jr.
1980-1982	**Development of a Liquid Crystals Kit for the Structural Integrity Assessment of Fiberglass Watercraft**	J.H. Williams, Jr.
1978-1981	**Wave Attenuation by Bottom Friction**	O.S. Madsen
1978-1981	**Ecodynamic Analysis of Algal Blooms Fouling Nahant Bay Beaches**	A.V. Quinlan
1978-1981	**Wave Attenuation by Bottom Friction**	O.S. Madsen
1978-1981	**Ecodynamic Analysis of Algal Blooms Fouling Nahant Bay Beaches**	A.V. Quinlan
1978-1981	**Motility and Metabolism of a Marine Microorganism in Relation to its Substrate *Zostera marina***	E. Bell
1978-1981	**Trace Element Uptake in the Maine Food Chain**	M. Janghorbani G.C. McLeod
1978-1981	**Implementation of a New Method for Evaluating the Wave Resistance of a Ship**	F. Noblesse
1979-1980	**Method to Predict Foundation Displacement of an Offshore Facility**	W.A. Marr W.T. Lambe
1979-1980	**The Role of Heavy Metals and Other Cathodic Depolarizers on the Corrosion of Aluminum in Sea Water**	R. Latanison J. Mavor
1979-1981	**Boston Harbor Management Project**	J.T. Kildow
1979-1981	**Oil Spill Clean-Up and Liability Models**	J.D. Nyhart H. Psaraftis
1979-1982	**Decontamination of Dredge Spoils by Extraction with Water under Near Critical Conditions**	M. Modell

Duration of Project	Project	Principal Investigators
1979-1982	**Tidal Induced Transport in Salt Marsh Ecosystem**	H.F. Hemond K.D. Stolzenbach J. Teal
1980-1982	**Isolation of Bioactive Compounds from Shark**	R.S. Langer J. Glowacki
1980-1982	**Small Scale Tidal Power in Eastern New England**	J.A. Fay
1980-1983	**Design Against Collision for Offshore Structures**	J.G. de Oliveira

	National Research Projects	
1978-1979	**Development of a Simple Engineering Model for the Nearshore Velocity Field**	O.S. Madsen
1978-1980	**Review Theory of Tracer Dispersion and Advection in Fluids and Evaluate Present Tracer Use in Sediment Transport Studies**	O.S. Madsen
1980-1983	**The Nature of Pitting of Aluminum in Seawater**	R.M. Latanison

Advisory Services

The concept of advisory services is one of sharing information and of stimulating communications between the university base of Sea Grant and people working in business, industry and government or living in coastal areas. The relevance of the Program's research to the community's needs is dependent on a continuing, lively interaction among these groups.

A study prepared by MIT's Sloan School of Management in 1977 pointed out that early community and industry involvement in Sea Grant's research helps to ensure the broad and timely applications of the results. A partnership between faculty and students with the people who will use the results tailors the research to real problems and attracts valuable information and financial support for a research team. Sea Grant's advisory services play an important role in developing and promoting these partnerships.

Each Sea Grant Program throughout the entire network has designed advisory services differently to reflect the host institution's strengths, traditional constituencies, and evolving local interests and problems. MIT's services mirror the Institute's preeminence in technology sharing. The Massachusetts Marine Liaison Service provides a critical connection to constituents in New England and the Commonwealth; the MIT/Marine Industry Advisory Service has developed a strong working partnership with U.S. government agencies and industries here and abroad; the Communications Information Services are the Program's publishers and provide ready access to information generated through the Sea Grant network, MIT and in allied marine-related organizations who are working toward the wiser utilization of ocean and coastal resources.

MIT/Marine Industry Collegium

The MIT/Marine Industry Advisory Service created the Collegium in 1975 to provide a forum for government, academia and industry to discuss the use and economic potential of evolving marine technologies. A complement of the Institute's Industrial Liaison Program—which has a long-standing partnership with U.S. and foreign businesses—Sea Grant's Collegium emulates its dictionary definition of "an association of peers banded together for some common good."

Workshops presented four times a year promote cross-fertilization of ideas among attending members and MIT faculty and students. Each half-day or day-long workshop includes a presentation by university researchers centered around an active research project. Advance drafts of Opportunity Briefs outline the project's objectives and potential and help Collegium members select meetings of use and interest. At the workshops, dialogue between the academics and members shifts from lectures to lively debates to sedate one-on-one conversations.

Industry engineers and scientists can share perceptions with government members, suggesting where federal monies can best aid the development and management of ocean resources. University faculties and students can make valuable industry contacts and gain access to industry perspectives that further or help redefine their research.

Since its founding, the Collegium has helped to guide the direction of MIT's research program as the needs of these Sea Grant constituents become evident. A glance at an opportunity brief list reveals great interest in the enonomic, political, social and engineering aspects of offshore development. It also shows a range of concerns from coastal zone management to "ocean power" as an energy source.

Principal Investigator
Norman Doelling
Manager
MIT Sea Grant College Program


HELP US
SAVE
CHAPIN BEACH
EROSION Control PROJECTS
SCRAP TIRE REEF
To Reduce WAVE Erosion
PLANTING BEACH & MARSH GRASS
TO REDUCE WIND EROSION
SAND BAG SILLS
To Catch Drifting Sand and Build Up Frontal Beach
Please Keep Off Tire Reef for Safety Reasons. Do Not walk on any Grass or slide down the dunes. This beautiful area is yours to enjoy. HELP US SAVE IT... Dennis Conservation Commission.

Massachusetts Marine Liaison Service

Many businesses, like those that comprise the fishing industry, are small and entrepreneurial. Because of their size, they are often unable to invest in the kind of research and development that would spur growth and greater profitability. One of Sea Grant's responsibilities is to ensure that these small companies can call upon the talents within the nation's university system.

At MIT, the Massachusetts Marine Liaison Service (MMLS) keeps track of local needs and tries to leverage support by coordinating research expertise at the Institute with the experience and knowledge of the marine community. Improved trawling gear and food processing technology are the products of close cooperation between the fishing industry and MIT faculty and students. Fishermen tested a new trawl door, a trawl door hook-up system, and a hook-up block throughout the prototype and final design phases. A dogfish skinning machine resulted from the joint support of Sea Grant, the National Marine Fisheries Service and the careful, ongoing evaluation from people who are the ultimate users of the technology.

Increasingly as coastal communities have expanded, shorefront erosion has become a problem. Public beaches are disappearing and shoreline homes are threatened. Town governments, homeowners, tourist businesses have called upon Sea Grant through a joint project, the Extension Sea Grant Advisory Program (ESGAP), which is guided by MMLS and the University of Massachusetts Cooperative Extension Service. On Nauset Beach, extension agents worked with residents to replant a dune area with new stands of protective beach grass. During 1977-1979, ESGAP installed sand-filled plastic bags in several locations as an experimental protection device. The technique, though successful in other states, proved inadequate for the high energy Massachusetts coastline.

An extension coastal engineer has met with hundreds of local citizens to discuss and evaluate efficient and economical protection techniques. Working with a group of MIT students and the Nantucket Conservation Commission the Sea Grant advisory service staff devised a long-range planning tool to assess the stability of Nantucket's shorefront properties. Accumulated data of erosion and deposition trends over one hundred and twenty five years can be used by banks, homeowners, developers to select new building sites or protect existing homes.

MMLS manager Arthur Clifton and Massachusetts Maritime Academy faculty member David Kan have organized an educational program for fishermen. The courses held during winter and early spring months help fishermen keep abreast of new technology and regulations and strengthen some necessary and basic skills such as piloting, net mending, equipment maintenance, and business management.

This advisory service project's resources go beyond the state. Workshops and conferences organized with other Sea Grant Programs draw upon the research strengths of many schools and capitalize on an entire network of information sources.

Principal Investigator
Arthur B. Clifton
Manager
MIT Sea Grant College Program

Research Vessel EDGERTON

The christening of MIT's research vessel on 26 August 1977 launched a working platform and classroom that had been five years in the making. In 1972, Professor E. L. Mollo-Christensen and the late Professor A. T. Ippen had organized an *ad hoc* committee of faculty and staff to find a vessel equal to the demands of the Institute's expanding commitment to marine research.

With the approval of the Provost and the help of Dr. Alfred A. H. Keil, then Director of the Sea Grant Program, the committee attained, through the Office of the Oceanographer of the Navy, the charter of a surplus government ship. On 28 August a charter agreement, permitting MIT conversion rights, turned over to the Institute the ex-Army T-Boat, T-424.

After three years of work in which a stern oceanographic A-frame, knuckleboom crane, winches, a new electronics suite, an auxiliary diesel generator and improved work and living space were added, T-424 officially became R/V EDGERTON. Named after one of MIT's most renowned scientists and popular teachers, the vessel has been extensively used for marine research by scientists and engineers from MIT, other academic institutions and industry to advance our understanding and uses of resources in the coastal zone and on the continental shelf.

Communications/Information Services

Information dissemination and communication are at the heart of a public service research program like Sea Grant. If the research is to be useful and serve the public good, the results must be available, in a form that can be used, and easy to retrieve. Communications/Information helps to transfer research through a publications series that includes technical and advisory reports.

The series is publicized through abstracts, publication directories, news releases and special articles that appear in the public press or special interest magazines and journals. Mailing lists of abstract subscribers, the media, and special industry and government leaders aid the staff in reaching diverse and interested audiences.

All reports are also available through the Marine Resources Information Center for a fee that defrays the production and handling costs. The Center, a small reference facility, also keeps archival copies for public use, at no charge.

An information specialist manages the Center, exchanging news of completed and on-going research with other programs and with marine-related organizations throughout New England. Reference books, pamphlets, magazines and newsletters on subjects that include fisheries, coastal zone management, environmental issues, law-of-the-sea, oil pollution, offshore development and onshore impacts are available for room use to anyone who visits the Sea Grant offices.

Answers to phone and letter inquiries help the marine community locate publications that may not be in our collection, names of specialists working in a particular field, or a government agency responsible for managing some aspect of marine development.

Until recently, the public's understanding of all aspects of water—its properties and the resources it nourishes—has been limited. The general press has just started to concentrate on exploring the potential of the oceans and coasts—such as mineral resource development and waterfront redevelopment—and the problems, such as freshwater shortages, recreational impacts and nearshore pollution. Factsheets, proceedings, and advisory bulletins prepared by Communications/Information make relevant information available directly to the public or to journalists who incorporate it into broadly disseminated news and magazine articles.

Communications/Information, like other members of Sea Grant staff, promotes greater discussion of issues and the cooperation between university researchers and the people in the marine community who need and will use the results.

Principal Investigator
Elizabeth T. Harding
Manager
MIT Sea Grant College Program

Education

The original mandate in the Sea Grant Act of 1966 called for the integration of an educational component into every program. At MIT this was in concert with the Institute's own philosophy that future scientists and engineers are best trained through research experience and through exposure to real problems in industry, government and the community. Funding for each Sea Grant research project includes support for students, usually at a graduate level. But undergraduates, too, are critical constituents to attract and train for ocean-related careers.

In the renewal of the 1976 Sea Grant Act, Congress widened the educational commitments of individual programs and increased formal responsibilities to include pre-college students. The goals and objectives in the act read:

"To build and maintain broad, high-quality curricula for education and training of qualified professionals and technicians to meet requirements for the development and management of the nation's marine resources; continuing education opportunities for practicing professionals, technicians, and decision-makers engaged in marine-related activities; educational exchange programs; *public education at all levels* to increase public awareness and understanding of the realm of marine affairs and enjoyment of the sea; and other stimulating and innovative educational actities to further the general goals of Sea Grant . . .

To increase public awareness and understanding of the economic, social, and aesthetic values of the marine environment . . .

To improve the quality of citizen participation in decision-making processes relative to marine resource issues and to enhance enjoyment of the sea."

Ocean Project Engineering Laboratory

The Ocean Engineering Summer Laboratory began in the 1971-1972 program year as a joint undertaking between MIT's Department of Ocean Engineering and the Maine Maritime Academy. By actually dealing with the sea environment, undergraduate students have received "hands-on" learning experiences that have been stimulating, instructive, and often joyously exciting.

In the summer of 1972, students conducted an oceanographic and biological survey of Holbrook Cove, Maine. They also successfully concluded an underwater search for the remains of a Revolutionary War privateer sunk in 1779, the DEFENCE. Cannon, shot, scuppers, and a grandstone were among the artifacts recovered. The following year, they continued archaeological surveys and salvage of the DEFENCE and mapped its remains. To conduct their search and survey mission they designed and used special instrumentation from a constant depth tracking float to a radio range finder for ship-to-ship operations.

In 1974 the undergraduates designed and launched an underwater robot, a 250-pound free-swimming submersible that they would program the following year to carry out various underwater tasks. The vehicle, originally christened ALBERT-ROSS, now carries the more mundane designation of Robot I. Robot II, a sophisticated, sonar extension of student work, is now being funded as a research project under the direction of A. Douglas Carmichael.

In 1977 and 1978 the engineering challenges met by MIT's student researchers included the design and construction of a small buoy-mounted electric generator powered by winds and tidal currents, and a device for measuring the efficiency of the Maine Maritime Academy's floating breakwater.

The Ocean Engineering Laboratory continues as a Sea Grant project, but the seagoing component is held now in the winter during MIT's Independent Activities Period. The schooner WESTWARD serves as a base of operations for performance measurements, and soil loading characteristics. Students continue to enjoy and profit from ocean-related studies that allow them to use their ingenuity and extend their classroom knowledge to real problems.

Principal Investigators

D. E. Cummings
Assistant Professor
Department of Ocean Engineering

A. Douglas Carmichael
Professor
Department of Ocean Engineering

Keatinge Keays
Administrative Officer
Department of Ocean Engineering

Ira Dyer
Head
Department of Ocean Engineering


PO
BM 19
Armory
Cranberry
Bogs
Jr High
Sch
Hyannis
Inner
Harbor
Hyannis
Park
Grove
Cem
Snows Cr
OCEAN
Harbor
Bluff
Veterans
Memorial
Park
LEWIS BAY
Fiddle Head
Rock
Kalmus
Park
Beach
Dunbar
Pt
HARBOR

Student Planners
For Coastal Communities

In the Department of Civil Engineering, a very successful education project has given students an opportunity to gain first-hand experience in the field and to provide assistance to a New England community. Since 1971, each spring a group of upperclass and graduate students from MIT, Harvard University, and Wellesley College have analyzed a "real world" coastal zone management problem and devised a systems-based solution. Dr. William W. Seifert has led the classes through a number of complex studies that have required technical, managerial, economic and socio-political disciplines. The students have met with community groups and local officials to garner an understanding of city problems, aspirations, and resources.

In Gloucester, after investigating the city's fishing and manufacturing industries, retail trade, tourism, transportation, and government, the multidisciplinary team recommended options for alleviating economic stagnation while managing some of the negative effects of growth and development.

During 1975-1976 and 1976-1977, Dr. Seifert organized the class assignments to help the City of Lynn. Lynn, once a thriving coastal city with a bustling waterfront, has suffered from severe urban decay, loss of population, and dwindling economic opportunities during the past several years. A student solution, presented to the town officials, recommended the redevelopment of the waterfront area for recreational and retail uses as a way of benefiting the community economically and aesthetically.

Most recently, Hyannis on Cape Cod has been the focus of the students' talents and efforts. Shopping centers ringing the traditional downtown business district have sapped its economic and social vitality. At the same time nearby waterfront areas have gone unused. By linking the downtown to one of the town's greatest assets, its harbor, the students recommended a way of infusing new life into Hyannis. In the official presentation to the community in the spring of 1979, the students also suggested that it was essential for the town's policymakers and its citizens to improve communications. They noted that past plans, developed by outside consultants, had not been implemented because of misunderstandings and the absence of a well-understood time schedule.

At the end of each Interdisciplinary Systems Design Subject, the students have compiled a report and published it through Sea Grant. Beyond the benefits of field and analytical experience for these young "planners," their research results have provided generic case studies for others to follow in evaluating the common problems of many coastal urban communities.

Principal Investigator
William W. Seifert
Senior Lecturer
Department of Civil Engineering

Into the Ocean World

After two years of careful planning, an interdisciplinary course, "Into the Ocean World," was introduced to undergraduates from over twelve Boston area colleges and universities in the spring of 1980. The course, which integrates many facets of marine studies, has its roots in the winter of 1977, when Sea Grant invited area faculty members from all disciplines to explore the feasibility of an interdisciplinary, intercollegiate marine program.

The city houses a great many academic institutions, with an array of courses and talented faculty members. A consortium committee came together to ask: Could these resources be coordinated for the mutual benefit of all? Was it possible to create an exciting, unique educational opportunity? The students who took "Into the Ocean World," the Consortium's pilot project, answered these questions with an enthusiastic "aye."

Students and faculty both agreed that the course was rewarding, exciting and demanding. The students were challenged by the many disciplines that touch the sea, from the marine sciences to history, the arts, politics and economics. Boston's cultural, social and economic development, so dependent on access to the sea, illustrated the profound effects that the ocean had on the life of the city and the nation. The insights gained by the students will hopefully help them appreciate the role of water in shaping societies and nourishing all life and will lead them to make careful, thoughtful decisions on water management and uses as professionals and private citizens.

Principal Investigator
E. R. Pariser
Associate Director for Education
Coordination and Training
MIT Sea Grant College Program


Lesson I Experiment I

Pre-University Marine Studies

A child's day begins and usually ends with a "water experience." The morning starts with splashing water on one's face, brushing teeth and watching someone make orange juice or coffee. By evening, just one last glass of water, perhaps delivered to a bedside, brings peace and universal comfort. In between, puddles are splashed, rainbows are spied, paints are mixed, mudpies are made, dirty clothes are washed, foods are boiled. Water appears to be, and is, ubiquitous in not only a child's life, but in all the planet's life as well.

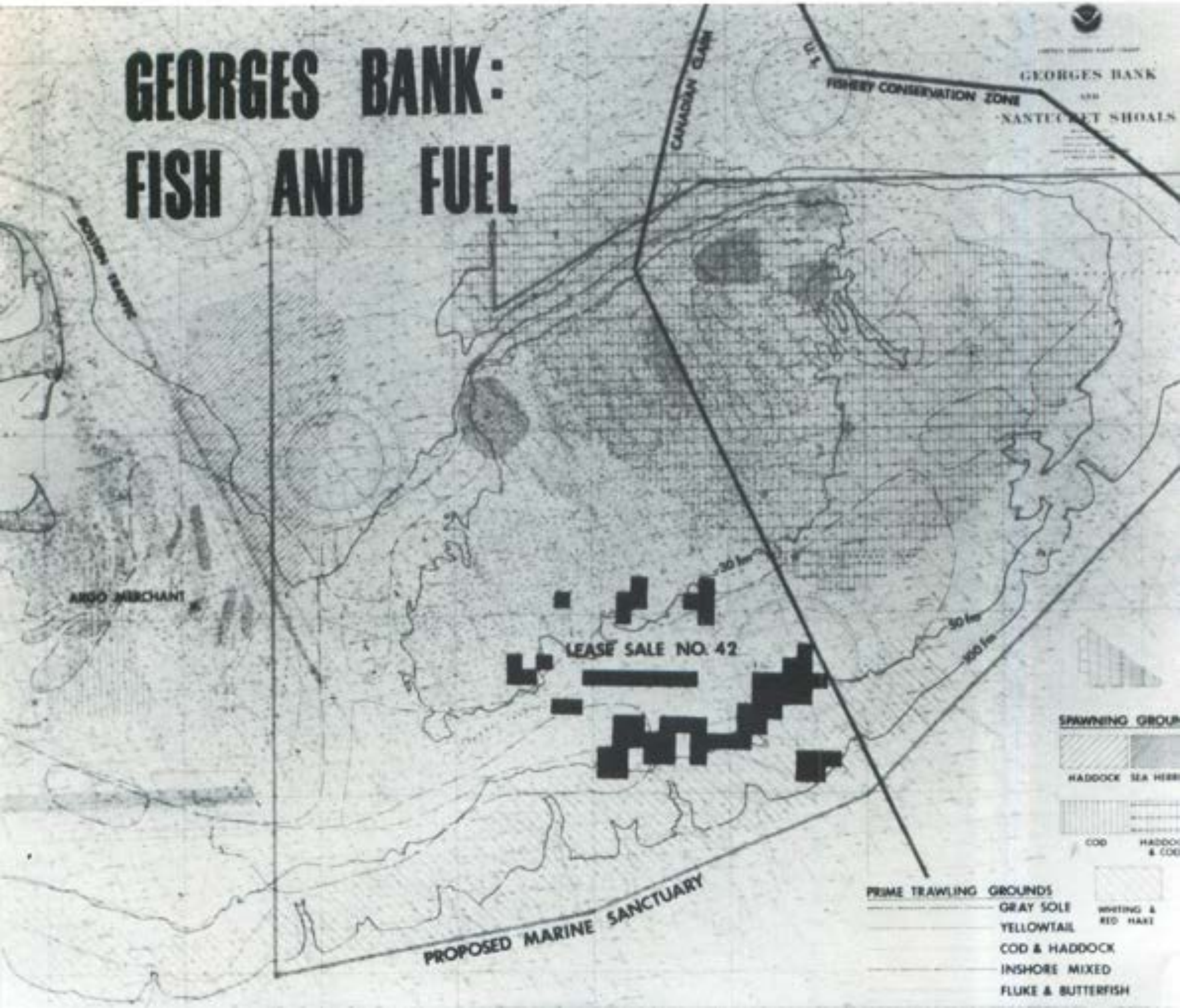
Because of water's commonality and utmost importance it is being used to develop teaching materials for children in kindergarten through the twelfth grade. As a substance to experiment with—to measure, dissolve, mix, make bubbles—it is completely familiar and non-threatening. For a teacher it is a versatile device for illustrating basic principles and phenomena: mixtures, suspensions, density, surface tension, calories and many more.

MIT Sea Grant's education staff is employing water and its properties to create teaching materials that begin by having the student concentrate upon the simplest of everyday experiences: dissolving salt in an aqueous liquid. This introduces simple laboratory equipment, requires adherence to instruction, and encourages observation and documentation. As the child becomes more experienced, the materials become more sophisticated and complex, focusing on advanced mathematics and physics *and* on the essentialness of water. Ultimately, the lessons weave a tapestry that reveals water's effects on daily life, history, industry, economics, music, art, and literature.

It is an ambitious task, but one that has been taken on with the aid of MIT faculty and teachers in the New Bedford, Massachusetts school system. As the materials are developed, tested and refined, they are being introduced to teachers throughout Massachusetts in special workshops. When completed, Sea Grant will publish the series for educators around the country—in coastal communities where water's conspicuous presence is often taken for granted, and in Mid-West plains where scarcity makes it a precious, though little understood, substance.

Principal Investigator
E.R. Pariser
Associate Director for Education Coordination and Training
MIT Sea Grant Program

GEORGES BANK: FISH AND FUEL



The Ninth Annual Sea Grant Lecture

One of the major events on the Institute's calendar each Fall is the annual Sea Grant Lecture, initiated in 1972 to stimulate discussion of critical marine issues. The format for each lecture remains essentially the same: a position paper delivered by an expert, followed by discussion and debate between the lecturer and a panel representing opposing views. The topics themselves are quite different, a reflection of the complex and interdisciplinary demands of ocean development. Deep-ocean mining, oil pollution from tanker traffic, world energy and the oceans, the Panama Canal treaties and barriers to women and minorities in the marine field have all been explored through the lecture's forum.

This year's topic, *Georges Bank: Fish and Fuel*, addresses a controversy that has been ongoing since 1971, when the fertile fishing ground off Georges Bank was declared a new "frontier" for oil and gas exploration.

The Bank, covering twenty thousand square miles of ocean floor, is fed and nourished by a unique current system that has helped make it rich biologically. In 1976, Congress passed the Fisheries Management and Conservation Act to limit foreign fishing in U.S. waters and strengthen a primary U.S. marine industry. Some have argued that to drill for oil on Georges Bank would endanger the environment and threaten the fisheries. Others, including the Department of Interior, which is responsible for leasing offshore properties, have maintained that with sufficient safeguards, this area off New England's coast could double its national value as an ocean resource, providing both fish *and* fuel.

Drilling operations are scheduled to begin in early 1981. There remains, however, some disagreement on how to share the ocean space between oil and fishing interests and how to adequately protect the marine environment from drilling-related pollution. Sea Grant's tenth anniversary celebration seemed an appropriate and timely opportunity to publicly examine some of these questions and find solutions that would ensure that the Bank, a truly unique marine resource, is developed methodically and beneficially for the good of all.

Proceedings published to report on the lecture, the debate and audience participation will be available to the public. This publication will be added to the list of Sea Grant reports on Georges Bank, fisheries issues, and offshore drilling concerns.

Institutional Program Summary Fiscal Year 1980

This summary matches the project breakdown in the MIT Sea Grant College Program proposal for 1979-1980/81.

Program Management		
Sea Grant Program Management	Mr. D.A. Horn	Continued project
Project Development Opportunities	Mr. Horn	Continued project
Education and Training		
Education and Training: Development, Operation and Management	Mr. E.R. Pariser	Continued project
Interdisciplinary Systems Design Subject	Dr. W.W. Seifert	Continued project; report published
Ocean Engineering Project Laboratory	Dr. I. Dyer	Continued project; report to be published
Public Education and Training Short Courses	Professor J.M. Austin	Continued project
Development of an Integrated Course on Offshore Structures	Professor O. Buyukozturk	Continued and completed project; report to be published
Annual Sea Grant Lectureship	Dr. A.A.H. Keil	Continued project; report published
Development of Teaching Material for Pre-University Marine Education	Mr. Pariser	Continued project
Development of an Intercollegiate Interdisciplinary Course in Marine Studies	Mr. Pariser	Continued project
Ocean Engineering Curricula	Dr. Dyer	Continued project; New Curricula developed
Advisory Services		
Massachusetts Marine Liaison Service	Mr. A.B. Clifton	Continued project
MIT/CES Marine Extension Service	Mr. Clifton Dr. J. Noyes	Continued project
Massachusetts Marine Fisheries Education and Training Program	Mr. Clifton Dr. D. Kan	New project
Marine Industry Advisory Service	Mr. N. Doelling	Continued project
Research in Ocean Engineering, University Sources and Resources	Mr. Doelling	Continued project; reports published
Marine Communications/Information Service	Ms. E.T. Harding	Continued project; reports published
Computer Documentation Dissemination	Professor J.J. Connor	Continued project

Technology Development for Ocean Uses		
Development of Joining and Cutting Techniques for Deep Sea Applications	Professor K. Masubuchi	Continued and completed project; report to be published
Quality Control of Fiberglass Boat Hulls Using Thermal Testing and Liquid Crystals	Professor J.H. Williams, Jr.	Continued and completed project; report to be published
Implementation of a New Method for Evaluating the Wave Resistance of a Ship	Professor F. Noblesse	Continued project; report published
Study of a Cost Model of Deep Ocean Mining	Professor J.D. Nyhart	Continued project; report to be published
Oil Spill Clean-Up and Liability Model	Professor Nyhart Professor H. Psaraftis	New project
Decontamination of Dredge Spoils by Extraction with Water under Near Critical Conditions	Professor M. Modell	New project
The Role of Copper and Minor Constituents of Seawater in Corrosion Mechanisms of Aluminum	Professor R. Latanison Professor J. Mavor	New and completed project; report to be published
Physiological Measures of Mental Workload	Professor J. Tole Professor E. Cravalho	New and completed project; report to be published
Effects of Oscillating Air Stresses in Induced Drift	Professor J.H. Milgram	New and completed project
The Dynamic Behavior of a Tethered Current Meter	Professor M. Triantafyllou	New and completed project; report to be published
Unmanned Underwater Work Vehicles		
Application of Teleoperators to Undersea Tasks	Professor T.B. Sheridan	Continued and completed project; report published
Underwater Communication System for Untethered Vehicles and Sensors	Professor A.B. Baggeroer Professor J.H. Shapiro Dr. D.E. Koelsch	Continued project
Robot Vehicles for Search and Survey Applications	Professor A.D. Carmichael	Continued project
Offshore Facilities		
In Situ Evaluation of Geotechnical Properties of Marine Sediment	Professor M.M. Baligh Professor C.C. Ladd	Continued project; reports published
Method to Predict Foundation Displacement of an Offshore Facility	Professor W.A. Marr Professor T.W. Lambe	New and completed project; report to be published
Analysis of Geophysical Information in Offshore Geotechnical Exploration	Professor G.B. Baecher	Deferred for FY80

Coastal Processes, Physical		
Seawater Intrusion in Offshore Islands	Professor J.L. Wilson	Continued project; report published
Tidal Induced Transport in Salt Marsh Ecosystems	Professor H.E. Hemond Professor K.D. Stolzenbach Dr. J. Teal	New project
Wave Attenuation by Bottom Friction	Professor O.S. Madsen	Deferred for FY80
Coastal Ecology		
Ecodynamic Analysis of Algal Blooms Fouling Nahant Bay Beaches	Professor A.V. Quinlan	Continued project
Motility and Metabolism of a Marine Microorganism in Relation to its Substrate *Zostera marina*	Professor E. Bell	Continued project
Analysis of Growth Strategies of the New England Red Tide Organism: *Gonyaulax tamarensis*	Professor S. Chisholm Dr. D. Anderson	New project
Living Resource Development		
Chemical and Structural Characterization of Chitin and Chitin Derivatives for Industrial Application	Professor B.L. Averbach	Continued and completed project; report to be published
Synthesis of Chitosan Structure Matrix for Food	Professor C.K. Rha	New project
Coastal Zone Development		
Boston Harbor Management Study	Professor J.T. Kildow	New project
National Projects		
Development of a Simple Engineering Model for the Nearshore Velocity Field	Professor Madsen	Continued project
Review Theory of Tracer Dispersion and Advection in Fluids and Evaluate Present Tracer Use in Sediment Transport Studies	Professor Madsen	New project

Summary of Expenditures by Activity

		NOAA Grant Funds	University Matching Funds
Program Management	Program Administration	$ 64,800	$ 156,827
	Program Development	76,700	1,660
Marine Education and Training	College Level	124,300	213,931
	Vocational Marine Technician Training	46,000	92,056
	Other Education	54,300	71,592
Marine Resource Development	Pathology of Marine Organisms	145,000	225,394
	Marine Extracts—Chitin	40,700	16,604
	Marine Economics	55,000	—
Marine Technology Research and Development	Ocean Engineering	145,600	41,685
	Sea Floor Engineering	124,000	120,680
	Materials and Structures	—	33,000
	Vehicles, Vessels and Platforms	97,200	57,673
	Dredging	45,000	6,639
	Seafood Science and Technology	25,600	13,619
Marine Environmental Research	Ecosystem Research	82,100	49,738
	Pollution—Oil Spills	100,000	42,447
	Environmental Models—Physical Processes	92,100	28,840
	Coastal Zone Management—Social Sciences	42,500	45,942
Advisory Services	Extension Programs	193,600	128,081
	Other Advisory Services	154,300	19,060
	Total	$ 1,708,800	$ 1,385,468

This summary is only approximate. In accordance with Federal grant requirements, the official financial report will be submitted by the MIT Comptroller to the Office of Sea Grant.

Publications

The Coastal Zone		
Anderson, D.M.	Effects of Temperature Condition on Development and Germination of *Gonyaulax tamarensis* Hypnozygotes	Journal of Phycology 16 (1980)
Cassella, S.	Impact of Wetlands Legislation on Development in a Rural and Urban Waterfront Community	M.C.P. Thesis Department of Urban Studies and Planning Massachusetts Institute of Technology
Zeien, Jennifer	Ocean Systems Management. Key Variables in the Decision-Making of a Port for Expansion: The Port of Boston, a Case Study	S.M. Thesis Department of Ocean Engineering Massachusetts Institute of Technology
Kildow, Judith T.	Interim Report on Boston Harbor Management Study	Internal report
Kildow, Judith T.	The Urban Waterfront: A Current Coastal Zone Management Dilemma	Oceanus, Vol. 23, No. 4, Winter 1980
Kildow, Judith T.	Boston Harbor Management Project: A Case of Integrating Research into the Political Decision-Making Process	Coastal Society Meeting San Diego, California, October 1980
Hovis, J.S.	Ecodynamic Analysis of the Growth of *Ectocarpus siliculosus* in Batch Culture, in Relation to Algal Blooms Fouling Nahant Bay Beaches	S.M. Thesis Department of Mechanical Engineering Massachusetts Institute of Technology
Teno, B.A.	Development of Apparatus for *In Situ* Growth of the Alga *Pilayella littoralis*	S.B. Thesis Department of Mechanical Engineering Massachusetts Institute of Technology
Hoyt, J.K.	The Applications of Aerial Photogrammetry to Biomass Estimation of the *Pilayella* Drift Community in Nahant Bay	S.B. Thesis Department of Mechanical Engineering Massachusetts Institute of Technology
Lewis, T.	Analysis of Trace Metals in the Waters of Nahant Bay, its Beaches and the Bloom Alga	S.M. Thesis Department of Chemistry Northeastern University
Heureux, A.H.	An Analysis of the Hydrodynamic Circulation in Nahant Bay	S.M. Thesis Department of Mechanical Engineering Massachusetts Institute of Technology
Wilce, R.T., C.W. Schneider, K. van den Bosch and A.V. Quinlan	Free-Living *Pilayella littoralis* (L.) Kjellm. in Nahant Bay, Massachusetts: Morphology, Occurence and Associated Species	Proceedings of the International Phycological Society Meeting, Glasgow, Scotland, August 1980
Wilson, John L., III and A.G. Sa da Costa	Groundwater Hydrology of Martha's Vineyard Island	Conference on Geotechnology, Boston, 1980

Oil and the Environment		
Milgram, J.J. and Robert J. Van Houten	Mechanics of a Restrained Layer of Floating Oil Above a Water Current	MITSG 80-4J Massachusetts Institute of Technology Cambridge, Massachusetts; reprinted from Journal of Hydronautics, Vol. 12, No. 3, July 1978
Offshore Development		
Levadoux, Jacques-Noel and Mohsen M. Baligh	Pore Pressures During Cone Penetration in Clays	MITSG 80-12 Massachusetts Institute of Technology Cambridge, Massachusetts
Baligh, Mohsen M. and Jacques-Noel Levadoux	Pore Pressure Dissipation after Cone Penetration	MITSG 80-13 Massachusetts Institute of Technology Cambridge, Massachusetts
Vandiver, J. Kim	Prediction of the Damping-Controlled Response of Offshore Structures to Random Wave Excitation	MITSG 80-9J Massachusetts Institute of Technology Cambridge, Massachusetts; reprinted from The Society of Petroleum Engineers Journal, February 1980
Unmanned, Underwater Work Vehicles		
Ansorge, A.C.	Design, Construction and Development of Sonars for a Robot Submarine	S.M. Thesis Department of Ocean Engineering Massachusetts Institute of Technology
Carnevale, J.S.	Electronics Systems Development and Integration for a Second Generation Robot Submarine	S.M. and O.E. Thesis Department of Ocean Engineering Massachusetts Institute of Technology
White, J.W.	Mechanical Systems Development and Integration for a Second Generation Robot Submarine	S.M. and O.E. Thesis Department of Ocean Engineering Massachusetts Institute of Technology
Sofyanos, Thomas N. and Thomas B. Sheridan	An Assessment of Undersea Teleoperators	MITSG 80-11 Massachusetts Institute of Technology Cambridge, Massachusetts
Odhara, Tetsuichi	Experiments in Supervisory Control of a Computerized Vehicle for Inspecting Curved Surfaces	Man Machine Systems Laboratory Report Massachusetts Institute of Technology Cambridge, Massachusetts

Technology for Ocean Uses		
Koch, Pierre	Comparison of Four Simple Wave Resistance Formulas	O.E. Thesis Department of Ocean Engineering, Massachusetts Institute of Technology
Koch, Pierre and F. Noblesse	A Note on the Waterline Integral and the Thin-Ship Approximation	Proceedings of the Workshop on Wave Resistance Computations, David Taylor Naval Ship R&D Center, Bethesda, Maryland, 1979
Chen, D.Y. and F. Noblesse	A Numerical Investigation of a Low-Froude-Number Slender-Ship Wave Resistance Formula	Continued Workshop on Wave Resistance Computations, Japan, 1980
S.S. Lee and J.H. Williams, Jr.	Thermal Nondestructive Testing of Fiberglass Laminates Containing Simulated Flaws Orthogonal to the Surface Using Liquid Crystals	
Williams, J.H., Jr., S.H. Mansouri and S.S. Lee	One-Dimensional Analysis of Termal Non-Destructive Detection of Delamination and Inclusion Flaws	British Journal of Non-Destructive Testing, May 1980
Williams, J.H., Jr., S.H. Mansouri and S.S. Lee	Thermal Nondestructive Testing of Fiberglass Laminates Using Liquid Crystals	British Journal of Non-Destructive Testing
Gonzales, T.A.	Nondestructive Evaluation of Fiberglass Using Cholesteric Liquid Crystals: Review of Techniques and Industrial Applications	S.B. Thesis Department of Mechanical Engineering Massachusetts Institute of Technology
Fisheries Technology		
Hoff, William B., III and David Gordon Wilson	The Design, Construction and Development of a Prototype Machine for Skinning Spiny Dogfish Shark	MITSG 80-14 Massachusetts Institute of Technology Cambridge, Massachusetts

Education		
Connor, J.J., Jr. and S. Shyam Sunder	Wave Theories, Wave Statistics and Hydrodynamic Loads	Department of Civil Engineering Massachusetts Institute of Technology Cambridge, Massachusetts
Vanmarcke, Erik and Demosthenes Angelides	Risk Analysis and Probabilistic Modeling for Offshore Structures	Department of Civil Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts
Sunder, S.S., J.J. Connor, Jr. and D. Angelides	User Manual for POSEIDON. A Program for Evaluating the Frequency Domain Response of Offshore Steel Jacket Platforms	Department of Civil Engineering MIT-CE-R79-15, 1979
Sunder, S.S., D. Angelides and J.J. Connor, Jr.	A Stochastic Model for the Simulation of a Non-Stationary Sea	BOSS '79, Second International Conference on Behavior of Offshore Structures, Paper 9, 1979
Branson, J.R. J.W. Mayo, M.P. Rowe, L. Sallada, and R.M. White	Understanding the Oceans: Motivating Today's Youth to Work for Tomorrow. Eighth Annual Sea Grant Lecture	MITSG 80-1 Massachusetts Institute of Technology Cambridge, Massachusetts
Advisory Services		
	A Report on the Massachusetts Institute of Technology Sea Grant College Program: 1 July 1978-l July 1979	MITSG 80-2 Massachusetts Institute of Technology Cambridge, Massachusetts
	Directory of MIT Sea Grant College Program Publications 1978-1979	MITSG 80-3 Massachusetts Institute of Technology Cambridge, Massachusetts
Steen-Elton, B.	Marine-Related Research at MIT 1980	MITSG 80-10 Massachusetts Institute of Technology Cambridge, Massachusetts
MIT/Marine Industry Collegium	Opportunity Brief #18: Some Federally Sponsored Research Programs for Unmanned Vehicles	MITSG 80-5 Massachusetts Institute of Technology Cambridge, Massachusetts
MIT/Marine Industry Collegium	Opportunity Brief #19: New Underwater Communication System	MITSG 80-6 Massachusetts Institute of Technology Cambridge, Massachusetts
MIT/Marine Industry Collegium	Opportunity Brief #20: Protection of Materials in the Marine Environment	MITSG 80-7 Massachusetts Institute of Technology Cambridge, Massachusetts
MIT/Marine Industry Collegium	Nondestructive Evaluation of Fiber Composites	MITSG 80-8 Massachusetts Institute of Technology Cambridge, Massachusetts

Matching Fund Support: Participants and Contributors

The Boston Shipping Association, Inc.
Managers of Boston Port and Seamen's Aid Society
Commonwealth of Massachusetts—
Metropolitan District Commission
Commonwealth of Massachusetts—
State Office of Environmental Affairs, Coastal Zone Management
Commonwealth of Massachusetts—
State Office of Environmental Affairs, Coast Energy Impact Program
Henry L. and Grace Doherty Charitable Foundation Inc.
Hunt Crab Meal Company
Intevep Project
JBF Scientific Corporation
Kawasaki Heavy Industries
Massachusetts Institute of Technology
MIT State-Industry Advisory Council
Massachusetts Maritime Academy
Massachusetts Port Authority
Marine Industry Advisory Services Collegium Members
Martha's Vineyard Commission
Multi-Sponsor Industrial Support
New Bedford School System
New England Aquarium
New England Marine Studies Consortium
New England River Basin Commission
Sea Grant Lecture Endowment Funds
Spill Control Association of America
Texaco
Town of Barnstable
University of Massachusetts
Whitaker Health Science Fund

MIT/Marine Industry Collegium Membership

Akzona, Incorporated
Alfa-Laval AB
American Cyanamid Company
Ametek
Aquatic International Corporation
Arthur D. Little, Inc.
Atlantic Richfield Company
Avco Corporation
Beatrice Foods Company
Bechtel National, Inc.
Becton, Dickinson and Company
Bell Telephone Laboratories, Inc.
BOC Limited
The Boeing Company
Bolt Beranek and Newman
Boston Edison Company
Campbell Soup Company
Caterpillar Tractor Company
Celanese Corporation
Central Research Laboratories
Cities Service Company
Combustion Engineering, Inc.
Compass Publications
Conoco Incorporated
The Continental Group, Inc.
Dames & Moore
The Dow Chemical Company (Dow Chemical U.S.A.)
E.I. du Pont de Nemours & Company, Inc.
E G & G, Incorporated
Environmental Devices Corporation
Environmental Research and Technology
Exxon Corporation
Ferranti, Ltd.
Fiat, S.p.A.
The Foxboro Company
General Dynamics Corporation
General Electric Company—Aerospace Group
General Electric Company—Industrial and Marine Steam Turbine Division
General Instrument Corporation
Getty Oil Company
The Goodyear Tire and Rubber Company
Gould, Inc.
W.R. Grace and Company
Grumman Corporation
Gulf Research & Development Company
Halliburton Company, Inc.
Honeywell Inc.
Hudson's Bay Oil and Gas Company, Ltd.
Hydro Products, Inc.
IHC Holland
IKU, Continental Shelf Institute
Imperial Chemical Industries Limited
International Proteins Corporation
International Underwater Contractors, Inc.
InterOcean Systems, Inc.
Interstate Electronics Corporation
JBF Scientific Corporation
Kennecott Copper Corporation
Liberty Mutual Insurance Company
Litton Industries Inc.
Lockheed Aircraft Corporation
Lord Corporation
Maclaren Marex
Massachusetts Port Authority (MASSPORT)
Massachusetts Technology Development Corporation
McClelland Engineers, Inc.
J. Ray McDermott and Company, Incorporated
McDonnell Douglas Corporation
Mitsui & Company, Ltd.
Mobil Oil Corporation
Montedison S.p.A.
New England Ocean Services
New England Power Service Company
Newport News Shipbuilding
Newport Shipyard, Incorporated
Occidental Research
Oceaneering International
Offshore
Omnithruster Incorporated
Raytheon Company
R C A
R.J. Reynolds Industries, Inc.
Rockwell International Corporation
Samson Ocean Systems, Inc.
Sanders Associates, Inc.
Schlumberger Limited
Shell Oil Company
Solus Ocean Systems, Incorporated
Sperry Rand Corporation
Standard Oil Company of California
Standard Oil Company (Indiana)
Stone & Webster Engineering Corp.
Sun Shipbuilding & Dry Dock Company
Tecnomare S.p.A.
Tennessee Gas Pipeline (TENNECO)
Texaco, Inc.
TRW Incorporated
Unilever Limited
Union Carbide Corporation
Union Oil Company of California
United Gas Pipe Line Company
U.S. Coast Guard
U.S. Geological Survey
U.S. Maritime Administration
U.S. National Oceanographic and Atmospheric Administration
U.S. Naval Ocean Systems Center
U.S. Naval Sea Systems Command
U.S. Naval Surface Weapons Center
United Technologies Corporation
Westinghouse Electric Corporation
Williams, Inc.
Woodward-Clyde Consultants

Administration and Staff

Director
Mr. Dean A. Horn
Senior Lecturer
MIT Department of Ocean Engineering

Director of Sea Grant Research
Dr. Jerome J. Connor, Jr.
Professor
MIT Department of Civil Engineering

Associate Director for Education Coordination and Training
Mr. E.R. Pariser
Senior Research Scientist
MIT Department of Nutrition and Food Science
Education Assistant
Mr. Jay R. Kaufman

Manager of the Marine Industry Advisory Service
Mr. Norman Doelling
Assistant Manager
Mr. John B. Bidwell
Editor
Ms. Debbie Levey

Manager of the Massachusetts Marine Liaison Service
Mr. Arthur B. Clifton
Coastal Engineer, Extension Sea Grant Advisory Program Specialist
Mr. Andrew L. Gutman
Fishery Engineer, Extension Sea Grant Advisory Program Specialist
Mr. Clifford A. Goudey

Manager of the Marine Communications/Information Service
Ms. Elizabeth T. Harding
Information Specialist
Ms. Barbara Steen-Elton
Editor
Ms. Bronwyn L. Davies

Administrative Officer
Mr. Lawrence W. McKinnon

Chairman, Sea Grant Policy Committee
Chairman Sea Grant Faculty Council
Dr. Alfred A.H. Keil
MIT Ford Professor of Engineering Emeritus

Chariman, Sea Grant State-Industry Advisory Council
Mr. Edward Brainard II
President
Environmental Devices Corporation