MIT Sea Grant

Contents

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

1 July 1978 to
30 June 1979

Report Number
MITSG 80-2

Index Number 80-002-Zay

31 December 1979

Letter from the Director

During this past year, MIT celebrated its ninth anniversary as part of Sea Grant, a national program established by Congress to aid the United States in developing its marine and coastal resources.

Throughout history, the seas have been important for defense, for transporting goods and raw materials, for supplying food, and for providing inspiration and relaxation to people of all ages. In this nation, coastal areas were the first to be settled, and their attractiveness as desirable places to live, work and play continues today unabated. The result has been concentrated residential and industrial development along the coasts.

With so many of our citizens living within easy reach of the oceans and Great Lakes, many resources have been terribly strained. Competition for resources, sometimes heated and acrimonious, is common. Decision-making that protects the environment while meeting society's needs is complex. Resolution of many conflicts is particularly difficult because competing groups have such widely different perceptions, governed by proprietary interests and subjective judgments. Until recently, a paucity of concrete and quantitative data to support arguments has exascerbated divisions between concerned groups living in the coastal zone.

When Congress established Sea Grant in the mid sixties, it saw the nation's universities as a source of information and research results that could be useful to: industries vying for rights to the same territory; environmentalists and businesses arguing over the effects of development and growth on marine ecologies; coastal citizens maintaining access to the shoreline and coastal resources. Congress also saw Sea Grant's potential in providing research and development assistance to companies and industries that are important contributors to a vital, prosperous marine-related economy.

By congressional design, every Sea Grant Program has three interdependent elements:

research to provide the answers to questions and solutions to problems;

advisory services to transfer technology from university laboratories to citizen constituents, and to keep the researchers abreast of community problems and needs;

education to train professionals for work in marine occupations and to help the public make informed judgments on ocean and coastal issues.

During MIT's nine years of association with Sea Grant, the Institute Program has contributed research and education that stems from long interest and great expertise in ocean engineering, technology development, and resource management. Water quality analysis, economic and environmental studies of Georges Bank, fishing gear development, oil spill cleanup technology are but a few of the research areas in which the faculty and the students of the Institute have applied their talents. In 1976 MIT's efforts were rewarded when the university 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. This award, made in recognition of outstanding research, education, and advisory services, means that MIT is eligible for Sea Grant's highest level of program funding.

This annual report covers our Program's activities for the period from July 1, 1978 through June 30, 1979 and describes the work that was accomplished with a grant of $1,476,400 from the federal government, and with matching support of $1,087,887 from industries, private organizations, local governments, the State of Massachusetts, and MIT.

This matching support is a requirement of Sea Grant. Each Program must raise *at least* one third of its total budget to encourage collaboration between university researchers and the various publics using the research results. Congress, in establishing this requirement, felt that the partnership would ensure Program flexibility and responsiveness to problems. This foresight is one very important reason why the National Sea Grant Program has continued to grow and succeed over the past thirteen years and why our own MIT activities have enabled the Institute to make new and significant contributions in the marine field.

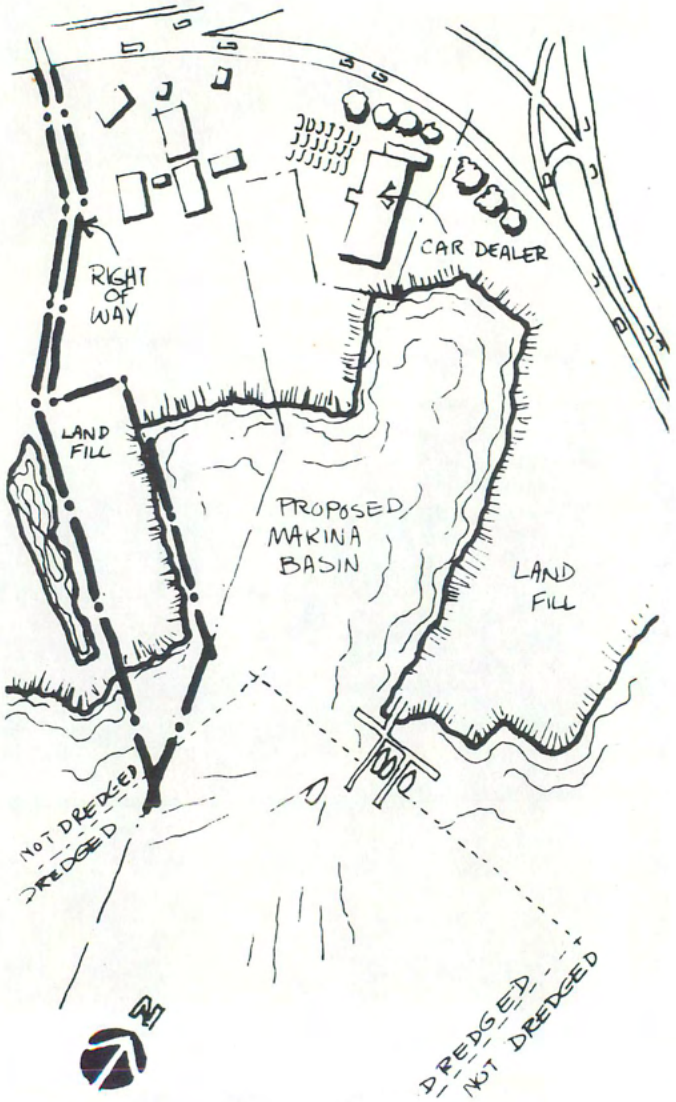
Dean A. Horn
Director

Research

The Coastal Zone

More than half the people in the United States live in areas that border the oceans and Great Lakes. The concentration has infused many communities with economic and cultural vitality, but in some instances it has also led to the destruction of valuable natural resources. Estuaries, spawning grounds for fish sought by commercial and recreational fishermen, have been filled for development or poisoned by wastes. Public access to waterfront facilities has been greatly reduced. Beaches have eroded away because of badly sited coastal construction and groundwater supplies seriously threatened by over use.

Growth itself need not be tagged the villain. The potential problem lies in unplanned growth where critical relationships between social and environmental systems are not considered. Having witnessed the destruction of valuable resources, many coastal citizens are currently participating in community activities that allow them to forecast the effects of development so that resources are reasonably used—without being used up. At MIT and in other Sea Grant universities around the country, researchers are creating planning tools and generating environmental information which can aid coastal residents in guiding community growth.



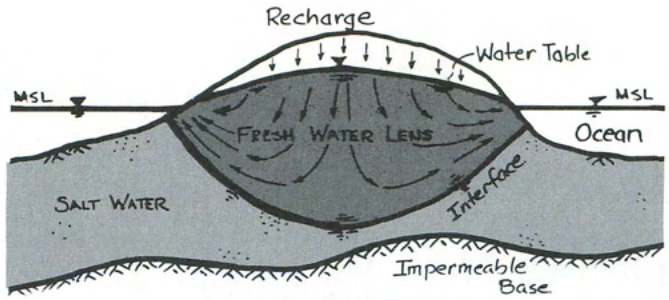
Modeling Saltwater Intrusion

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

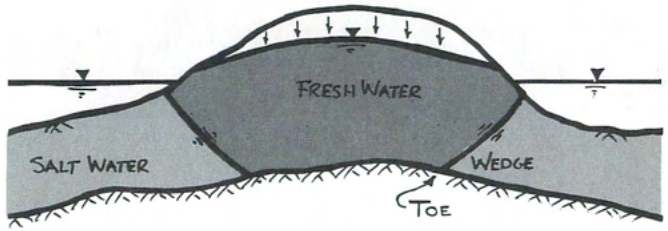
As island and peninsular communities become more heavily populated, they may find freshwater wells contaminated by encroaching sea water. Fresh and salt water share underground spaces, separated by a hydrological process in which the lighter fresh water flows seaward over a denser saltwater layer. Excessive pumping of the fresh water upsets the equilibrium between the two, and the salt water moves inland, contaminating drinking water supplies and freshwater ponds.

With the advent of high speed digital computers, scientists and engineers are now able to describe numerically the groundwater flow and can predict what rates of pumping will cause saltwater intrusion. In his Sea Grant project, Professor Wilson and a student research assistant have created a model that will allow coastal planners to study the effects of various development projects and policies on the overall freshwater supplies of a community.

In a coming year, the researchers will apply and refine the model on Martha's Vineyard, where they have worked closely with the U.S. Geological Survey and the Martha's Vineyard Commission. In the final stage of the project, they will prepare a user's manual that will be distributed by Sea Grant in the United States and abroad.



FRESH WATER LENS



SALT WATER WEDGE WITH "TOE"
"A MOVING BOUNDARY"

Precipitation recharges freshwater aquifiers, like the two shown in the cross sections, and keeps salt water from moving inland to contaminate community water supplies.

The one hundred government agencies that have jurisdiction over the land bordering Boston Harbor need an overall management scheme to coordinate development and growth of this coastal resource.

Principal Investigator:
Professor Judith Kildow
Department of Ocean Engineering

Boston Harbor is representative of many urban waterfronts in the nation. Renovation of dilapidated facilities has begun, but there is little or no coordination that insures the final results will actually improve environmental conditions, public access, and long-term economic vitality of the shoreline resource. Professor Kildow has assembled a research team supported by Sea Grant and several Massachusetts public agencies and private associations, which beginning in the fall of 1979 will devise a working philosophy to govern the growth and uses of Boston's urban waterfront. Compilation of an atlas, that identifies and describes overall harbor uses, private and public interests, and the agencies with jurisdiction over the area, will be a first step in formulating a management scheme. This document will be used to decide how public and private interests can be mutually served. The final management recommendations will aid not only the Massachusetts community, but will serve as a model for other cities seeking to make more effective use of the resources offered by their harbors.

Understanding Surf Zone Hydrodynamics

Principal Investigator:
Professor Ole S. Madsen
Department of Civil Engineering;
Henry L. Doherty Professor in Ocean Utilization

The shoreline changes constantly. Some of the reshaping is a result of natural forces uninterrupted by human activity. In other instances, groins, dredged channels, filled land, and large coastal structures play a critical role in affecting the erosion and accretion of the coast.

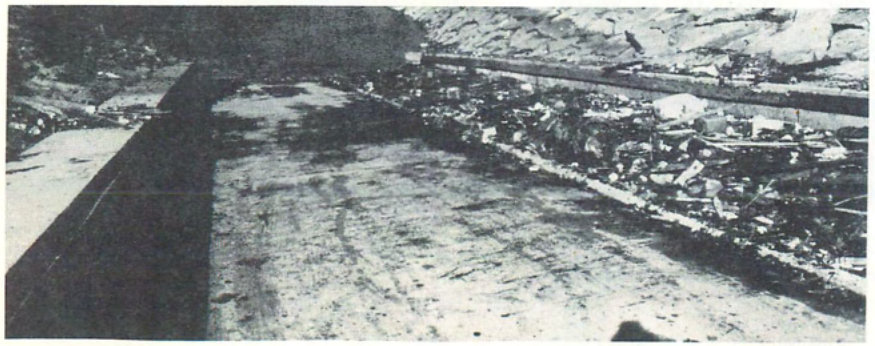
Professor Madsen's research in measuring and predicting surf zone dynamics is needed by engineers and planners to predict natural changes in the shoreline and to assess the environmental impact of construction that could alter existing patterns of sediment transport. In two related projects, he has developed a theory and instrumentation to measure and model dynamics of the surf zone. He and associates have also created a theoretical model to describe longshore currents and associated sediment transport. A prototype digital wave gauge and electromagnetic current meter have been tested with good results. The equipment measures currents that run parallel to the shore and determines how wave heights are reduced by ocean bottom friction. The hydrodynamic models and wave forecasting techniques will produce quantitative, order of magnitude information that can be used to manage and utilize the coastline in a rational manner.

Marine Pollution

Experts believe that continuing abuse of marine and aquatic resources will contribute to critical shortages in the near future.

Wastes are the inevitable byproducts of living. They are the remnants of the activities that feed, house, and refresh us. We cannot entirely prevent them, but by ignoring their potential effect on the world around us, we have paid a high price in air, water, and land pollution. Technological advances, which have contributed to a higher standard of living for many countries around the world, have also created new kinds and excessive amounts of wastes. And to date, we have not kept pace with finding ways to dispose of these substances.

At one time, waterways seemed a logical place for disposal, but it was soon found that currents and tides only moved materials to another place, into another person's backyard. Government regulations at state and federal levels have restricted the uses of rivers and coastal waters for dumping, but this has only partially solved the problem. What can be done with the wastes? How can they be reintroduced into the ecosystem without disrupting effects? Is it possible to recycle some of the wastes into new sources of raw materials? Past and current Sea Grant research is aimed at answering these questions and developing disposal technology that can be used to reduce marine pollution.



Analyzing Offshore Wastewater Disposal

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

Professor Stolzenbach has participated in the Stategic Petroleum Reserve Program, a national project to store large quantities of oil in caverns created in underground salt deposits on the coast of Louisiana. One of the byproducts of excavating the storage areas has been brine, a natural, heavily saline substance. Before disposing of the brine in the nearby Gulf of Mexico, the government conducted extensive tests to be certain the disposal would not disrupt the productive ecological systems in the Gulf.

The MIT researcher contributed theoretical analyses and laboratory modeling of five sites originally selected for disposal. In addition, the results of his studies were used to design jet diffusion systems—a technology that disperses effluents and prevents harmful concentration from forming when dense wastes, such as the brine, are introduced into a marine ecosystem. Professor Stolzenbach's research, which was sponsored by the National Oceanic and Atmospheric Administration through Sea Grant, will have future applications in monitoring the ocean disposal of dredge spoils, sewage sludge, and deep-sea mining effluents.

Measuring Trace Metals in Seawater

Principal Investigator:
Professor David N. Hume
Department of Chemistry

Unusually high levels of trace metals can accumulate in wastewaters and can upset delicate ecological systems or contaminate freshwater supplies. Monitoring the components of effluents is a step toward lessening the potential for health and environmental problems.

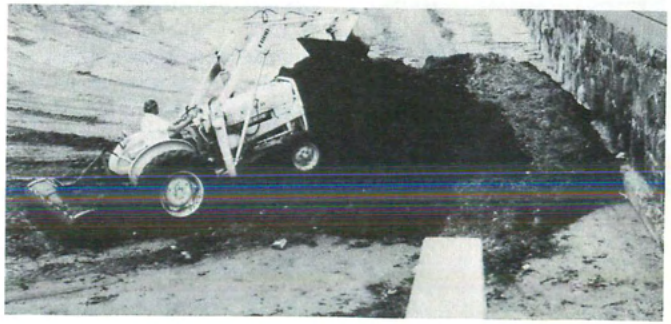
A relatively easy and inexpensive way of measuring concentrations of heavy metals in pure seawater is an electrochemical technique called anodic stripping voltammetry. However, this technique is limited because surface-active materials commonly found in seawater may interfere with the data, while otherwise showing no evidence of their presence. Professor Hume's research was undertaken to determine the interfering effects of representative surface-active agents, to identify factors governing the interference, and to devise means of preventing it. In laboratory studies of water containing cadmium, lead and copper, ultraviolet irradiation proved to be the most effective way of reducing the interference. Future research could eliminate a major problem in the monitoring of potentially dangerous trace metal concentrations in seawater.

Analyses of Algal Beach Fouling

Principal Investigator:
Professor Alician V. Quinlan
Department of Mechanical Engineering;
Henry L. Doherty Professor in Ocean Utilization

Each year, the sandy recreational beaches around Massachusetts' Nahant Bay become fouled with algal blooms (genus: *Pilayella littoralis* and *Ecotocarpus*) that spoil the appearance of the beaches and create foul odors as far as a quarter-mile inland. The temporary remedy has been to send work crews in to rake up the algal mats for hauling and burying in sanitary landfill areas. The repetitive clean-up effort has been frustrating and expensive to the community.

To find a longer term solution, Professor Quinlan has established a multidisciplinary field and laboratory program with researchers from universities in the Boston area, with support from Sea Grant and the Metropolitan District Commission. Information gathered at fifteen field sampling stations, from circulation dye studies, and from previously gathered public health and water pollution data will be used to create models that allow the researchers to look closely at the many variables that could be nurturing the blooms. Simultaneous studies of the bloom ecology and algal growth characteristics will be incorporated into the model and used to recommend corrective measures that will alleviate or, it is hoped, end a long-standing environmental problem.

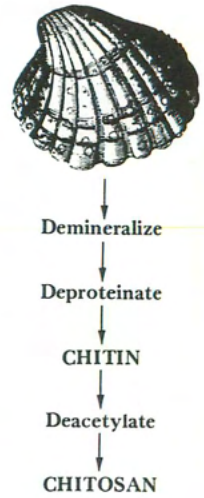


Chitin: Pollutant to Antipollutant

Principal Investigator:
Professor Benjamin L. Averbach
Department of Materials Science and Engineering

Chitin and its derivative chitosan have attracted considerable research and industrial interest in the past several years. First, chitin is an extremely versatile natural substance, similar to cellulose, that has many possible uses in medicine, papermaking, adhesives, pharmaceuticals, food processing, and water decontamination. At the same time, sources are readily available in shellfish wastes, which currently present processors with a disposal problem. The shells of crabs, lobsters, mussels, and clams cannot be dumped into coastal waters according to EPA regulations.

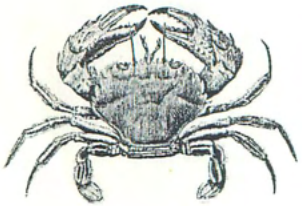
The first step in Professor Averbach's research was to develop techniques for controlling the processing of chitin and chitosan into raw materials that were consistently high in quality. At present he is experimenting with a chitosan film that has the ability to adsorb complex chemicals and heavy metals from industrial wastes and polluted waterways. Refinements in the manufacture of the film will make it more resistant to degradation in the marine environment and extend its promise as an economical, efficient antipollutant. The benefits of transforming wastes into raw materials not only alleviate serious disposal problems, but also offer new sources of revenues for the shellfish processing industry.



Shellfish wastes can be transformed into valuable raw materials by carefully controlling the removal of minerals, proteins, and acetyls.

Professor Quinlan and her research team are attempting to eliminate algal pollution in Nahant Bay.

Food from the Seas



Thalamita natator

In recent years, the U.S. fishing industry has shown great economic promise for the nation. Passage of legislation extending jurisdictional control over coastal waters from 12 to 200 miles, thus limiting foreign access to highly productive fishing grounds, has opened up new opportunities to American fishermen. Simultaneously, U.S. consumers have started to include fish as a major element in their diets.

To promote the development of the industry and to generate more low fat, high protein foods for consumers here and abroad, MIT Sea Grant has undertaken a number of exciting research challenges. These have included modeling studies for managing valuable yellowtail flounder stocks, design projects for making trawling safer and more efficient, and marketing analyses for promoting interest in squid. At present, information is being generated to encourage growth in the aquaculture industry and to solve "red tide" problems that have adversely affected mollusk harvesting in coastal waters. The Program is also currently working closely with industry to process the spiny dogfish shark, a fish with marketing potential that has been unrealized in the past.

The United States is gearing up to compete with technologically sophisticated foreign fishing industries. In 1978 1.7 billion dollars worth of fish were landed in U.S. waters, up ten percent in quantity and twenty three percent in value from 1977.

Technology Skins the Dogfish Shark

Principal Investigator:
Professor David G. Wilson
Department of
Mechanical Engineering

Europeans have long considered the tender, white meat of the spiny dogfish shark *Squalus acanthias* a delicacy, but like many other "nontraditional fish" it has been shunned in the United States. However, fish in general is enjoying an upsurge in popularity in this country, and this includes an interest in the underutilized dogfish shark. New England fishermen and food processors asked Sea Grant to assist in supplying both domestic and foreign markets with shark meat by developing technology to skin the dogfish.

Despite its abundance in New England waters during the summer months, processing the shark at a cost acceptable to consumers has been impossible. Its extremely tough skin has dictated time-consuming, expensive manual labor, a marketing deterrent.

Working with representatives of the industry and the National Marine Fisheries Service, Professor Wilson and research associates have developed a machine that will automatically skin the dogfish in the round, a requirement of foreign markets. Refinements in the machine allow it to handle fish of different sizes without manual adjustment. The machine, which is a totally new concept in fishery technology, also guts the fish and removes a sought-after flap from the fish's belly—which when smoked is eaten in other countries as an expensive gourmet food.

In the final stage of the project, the researchers will be making those small changes that will ensure satisfactory high performance of this world's first prototype machine for skinning the spiny dogfish shark. Plans to turn the technology over to industry will be realized in early 1980.

Aquaculture Fertilization by Sewage Sludge

Principal Investigators:
Dr. Morteza Janghorbani
Senior Radiochemist
MIT Nuclear Reactor Laboratory;
Dr. Guy McLeod
Director of Research
New England Aquarium

Sewage released into the ocean produces a buildup of nutrients that could be used to fertilize algae in aquaculture systems. Heavy concentrations of nitrogen and phosphorous that can cause eutrophication at sewage disposal sites offer a rich diet to shellfish and other marine foods. Research has shown that effluent nutrients introduced into controlled seaweed-aquaculture systems produce high yields, but scientists still need to be certain that the effects of other elements present in the sewage are not harmful to the public health.

Drs. Janghorbani and McLeod are studying the uptake and accumulation of trace elements through the food chain, beginning with phytoplankton and continuing through scallops and juvenile fish. The outcome of these studies will have significant implications for an emerging industry and will establish baseline data for estimating the severity of trace element accumulation in the marine food chain under field conditions.

Controlling Red Tides

Principal Investigator:
Professor Francois M.M. Morel
Department of Civil Engineering

Toxic algal blooms, commonly known as "red tides," have occurred along the coasts of the United States and Canada for many years, but Massachusetts was not affected until 1972. At that time, all the shellfish beds in the state were closed to avert outbreaks of paralytic shellfish poisoning, an illness caused when humans eat mollusks that have ingested and concentrated red tide toxins. The economic losses to the industry were estimated at around one million dollars, a crippling blow, but officials had to heed their responsibility to protect the public health. Since that time, research results have made it possible to monitor shellfish beds more discretely so that only those suspected of being affected are closed.

Professor Morel and research associates have contributed significantly to furthering our knowledge of the environmental factors that seem to cause toxic blooms of *Gonyaulax tamarensis*, New England's red tide alga. They have identified, isolated, and are mapping the presence of dormant cysts as the seed population that restarts and transports the potentially toxic algae each year.

Blooms from the cysts are triggered in the spring by an upward shift in temperature, according to Sea Grant research results. Outbreaks in the fall, it is believed, are caused by downward temperature shifts. Working closely with shellfish wardens and local fishermen, Sea Grant researchers will continue to accumulate and analyze data to determine what other environmental factors—such as favorable trace element chemistry—or what botanical characteristics of *G. tamarensis* permit it to outgrow other non-toxic phytoplankton.

Protecting Eelgrass from Microorganism Attacks

Principal Investigator:
Professor Eugene Bell
Department of Biology

Eelgrass, *Zostera marina*, is at the base of the food chain for many species of fish and it is also the only marine grain that is harvested. As such, it is a coastal resource of considerable significance. There are a number of well-documented instances of marked decline in eelgrass stands and one suspected culprit has been a slime mold, *Labyrinthula*. Professor Bell is studying how these mold cells move, what determines their direction of movement, and their capacity to decompose eelgrass. The laboratory development and analysis of an eelgrass microecosystem could provide a useful tool for coastal resource management in protecting eelgrass meadows from attack by microorganisms. Research data shows that *Labyrinthula* may not be the destructive factor it is now thought to be and scientists may have to search for another cause of eelgrass fluctuations.

Zostera marina

Offshore Resource Development

Offshore platforms will be recovering almost forty percent of the world's oil supplies by the year 2000.

Americans use oil as their primary fuel source, and have only recently realized the economic danger of this dependence. Alternative energy sources are under development, but the United States will require substantial quantities of petroleum for many years to come. To make the best use of the resource, the country will be forced to conserve and recover reserves that have been too difficult and expensive to reach previously.

The deep oceans have such reserves, but new technologies are needed to explore for and extract them. Currently, progress is being made in offshore construction and maintenance under hostile conditions. In the North Sea, massive structures have been built and to date are performing well under some of the worst wave and weather conditions in the world. But exploration is moving continuously seaward, into greater and greater depths where it will be extremely dangerous or impossible for human divers to work. Instead, they will be replaced by submersibles and robots which can bring back data on ocean bottom conditions, or assemble and repair deep-sea platforms.

At the request of offshore industries and federal regulatory agencies MIT Sea Grant has become increasingly involved in offshore oil technology development, technology which will also be put to use in manganese nodule mining, basic oceanographic exploration, as well as search and survey work. In addition, several attendant issues of deep-sea work are receiving the Program's attention—issues such as regulation of offshore activities in international waters and oil spill cleanup.

Deep-sea Welding

Principal Investigator:
Professor Koichi Masubuchi
Department of
Ocean Engineering

Professor Masubuchi's research continues to generate basic information about deep-sea welding and cutting techniques that can be used to make repairs more efficiently and economically on marine structures and on 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 this past year he received a patent on a submerged arc welding process. These accomplishments, with many others, have made him a world renowned expert in this field.

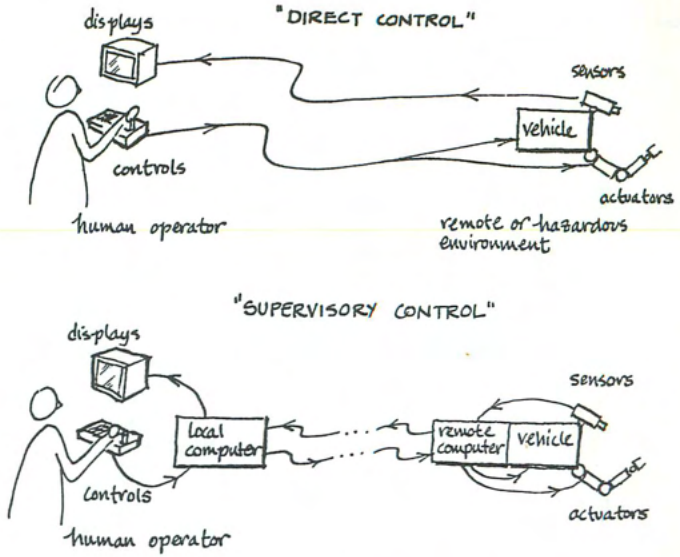
At present Professor Masubuchi's research team is simulating ocean pressures at 700 foot depths using a laboratory tank to see what effects intense deep-sea pressures have on welds created with the new technologies. Simultaneous studies are being conducted to characterize offshore construction and repair tasks as a step toward the further development of cutting and joining tools. Aiming for simplicity and economy, he expects the tools will be easy to manufacture and to use, a cost benefit for offshore industries.

Mechanized Workers for Deep-sea Tasks

Principal Investigator:
Professor Thomas B. Sheridan
Department of
Mechanical Engineering

Divers are unable to work routinely and safely in offshore depths beyond 650 feet. This presents a construction and maintenance problem for the oil and gas industries as production moves seaward. To supply manpower for deep-sea work, researchers are developing remotely controlled equipment called "teleoperators." Under human control and supervision, these mechanized devices will be able to perform tasks of manipulation—such as tightening and loosening bolts, or of sensing—such as finding broken welds and discovering pipeline leaks.

Professor Sheridan's work is designed to advance the state of the art of teleoperation and to provide a framework for matching present undersea tasks and available tools. Effective control of mechanized workers depends on how quickly and precisely the human operator, located on the sea's surface, can communicate with the device working hundreds, and perhaps thousands, of feet underwater. Using a laboratory teleoperator, adapted from aerospace technology, the researcher and student assistants are experimenting with methods by which the human operator can instruct and receive feedback directly, or can transfer control to a computer. Ultimately these unmanned, underwater devices will be used to conduct foundation studies and environmental surveys and to construct, inspect and repair offshore platforms.



Under supervisory control the human operator directs a mechanical subordinate by planning its actions, teaching it how to do each job, monitoring its performance, intervening when it gets in trouble, and trusting it to operate without continuous assistance.

Communications Systems for Untethered Submersibles

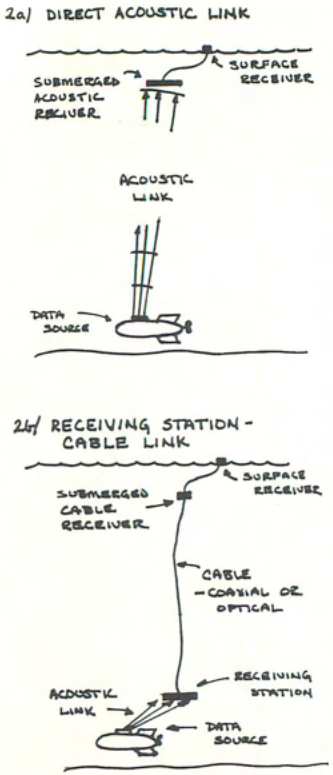


Figure 2a shows how an untethered robot would communicate with its base station via an acoustic link over short distances, while Figure 2b illustrates how fiber optical or coaxial cables could provide transmitting linkage for distant, deeper ocean work.

Principal Investigator:
Professor Arthur B. Baggeroer
Department of Ocean Engineering and Department of Electrical Engineering and Computer Science

Underwater vehicles and sensors are often severely limited by their use of a tethering cable for sending information to a user at the surface. The tether restricts the operation of these underwater vehicles and requires cable-handling equipment that is both cumbersome and expensive. Professor Baggeroer is developing a communications system that uses acoustic transmission links and fiber optics instead of a cable. Taking advantage of recent advances in modern communication theory and microprocessor technology, he is seeking ways to overcome the communications data rate limitations imposed by the ocean environment. Successful development of these techniques will mean that messages and information can be transmitted between robots and their control stations quickly and precisely. The absence of a tether, freeing the work vehicle from drag and the danger of entanglement, will mean greater flexibility for the inspection of offshore platforms, for deep-sea recovery of sunken objects, and for conducting oceanographic and geophysical studies.

Robot II: An Untethered Submersible

Principal Investigator:
Professor A. Douglas Carmichael
Department of Ocean Engineering

Five years ago undergraduates in the Ocean Engineering Laboratory designed, constructed, and tested an undersea robot as an education project. Currently their research and engineering are being applied to build a more advanced search and survey vehicle that will be untethered and computer controlled. Robot II will be small, about 18 feet long, and lightweight, about 250 pounds, so that it can be handled and launched by a few people. Essentially the vehicle will be a sonar platform carrying an array of equipment that includes sonar for command and control, collision avoidance, bottom following, as well as a pinger and, most important, a side-scan sonar. Like Professor Thomas Sheridan's teleoperator, Robot II will help reduce the high costs and risks in using human divers and will be useful in basic oceanographic exploration and research.

The researcher also suggests uses in looking for lost objects in the ocean or for measuring icebergs. A small fleet unleashed by an oceanographic vessel could simultaneously collect data over a large section of inshore waters. They could study thermal effluents of power plants, detect pollutants, and provide survey capabilities over a considerable area with minimal logistic support.

Robot II is still being built and has not yet been tested. Sponsored through Sea Grant by the Naval Explosion Ordnance Disposal Facility, it is meant to be state of the art, without presenting great technical risk.

Analyzing Marine Sediments for Foundation Design

Principal Investigators:
Professors Mohsen M. Baligh and Charles C. Ladd
Department of Civil Engineering

Questions about soil stability, compressibility, and how much loading marine sediment will support must be resolved before offshore structures are designed. Professors Baligh and Ladd are evolving new measuring techniques and analytical methods to determine soil properties directly at offshore sites.

In cooperation with an international geotechnical consulting firm and the Venezuelan Petroleum Technological Institute, they have investigated the use of two devices that combine simplicity, consistency, and economy. One, the Dutch cone, helps to identify soil types, estimate the undrained shear strength of clays, and strength and compressibility characteristics of sands. The other, a piezometer, identifies soil types and evaluates soil stratification. Following *in situ* tests off Venezuela's coast in June of 1979, the researchers have been calibrating the data, using past lab analysis of clays from three U.S. onshore sites. The researchers hope to combine two devices into one instrument to replace costly and time-consuming core drilling procedures now being used to study subsea soils.

Risk Analysis of Offshore Construction

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

In the design of offshore structures that rest on the ocean floor, uncertainties about the properties of foundation soils create risks. These economic, environmental, and safety risks must be compensated for by costly over-design. To develop methods for assessing and quantifying these risks, Professor Baecher has analyzed ocean floor samples and classified uncertainties in geotechnical prediction. Statistical analyses of these uncertainties is a first step toward devising optimal strategies to reduce overall risks, and may provide an initial framework to weigh risk reduction against the costs of changes in design, construction, and operations of offshore facilities.

A Cost Model of Deep Seabed Mining

Principal Investigator:
Professor J.D. Nyhart
Sloan School of
Management
and Department of
Ocean Engineering

The problems associated with exploring the new ocean frontier are not solely ones of technology. Politics, economics, national and international claims of ownership all play a part in dividing up the resources recoverable from waters beyond 200-mile jurisdictional boundaries.

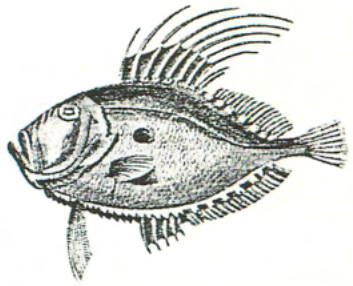
Over the past year, Professor Nyhart and a team of researchers have been refining and expanding a cost model of deep seabed mining. The model permits easy exploration of various financial and operational alternatives as they particularly affect the economics of mining manganese nodules, a rich source of many valuable metals. The model has become a primary information source for negotiating financial arrangements in the Third United Nations Law of the Sea Conference. Additionally, it is being used by Congress to examine policy options for domestic ocean mining legislation. Currently congressional committees are exploring the effects of taxation legislation on investments and tax revenues related to manganese nodule mining. In each of these instances, the U.S. government is trying to create a stable economic and political climate in which national and multinational companies can recover much needed valuable mineral resources. Support for this research has come through Sea Grant from NOAA's Division of Marine Minerals.

Oil Slick Dispersion

Principal Investigator:
Professor Richard G. Donnelly
Department of
Chemical Engineering

In arguments over many offshore development plans, fears of oil spills and their effect on living resources are a critical part of the controversy. Carefully sited, well-built and closely monitored working platforms reduce the danger of blowouts and operational spills. But some accidents will inevitably occur, and the danger of tanker collisions and groundings makes the development of oil spill clean-up technology an economic and environmental necessity.

To devise better strategies and equipment, scientists and engineers are trying to understand better oil's characteristics and behavior in water. Professor Donnelly has studied how the dispersion of oil slicks is influenced by chemical and physical properties of the oil, and by the action of waves on the slick. Using a specially developed wave tank and synthetic oils, the experiments provide basic information for understanding the behavior of slicks on the open sea.



Zeus faber

Technology for Ocean Uses

The uses of the oceans are so varied that through the year Sea Grant has joined with many departments at the Institute to contribute solutions to a range of problems. In some instances, we have focused on categories of research, such as offshore technology and living resource development. At other times, we have taken on a single problem, unrelated to other Program research. One such project last year involved an economic and engineering appraisal of ocean waves as an energy source. In this Program year, three projects have been undertaken to aid different segments of the marine community—designers and builders of immense tankers and cargo ships, pleasure boat manufacturers and users, and producers of marine electrical systems. Each one of these projects allows us to draw upon the varied and extensive engineering capabilities at the Institute, and each is creating new technologies for improving the way the country can take advantage of ocean resources.

Polymers for Insulating Underwater Cables

Principal Investigators:
Professors Richard G. Donnelly
and Robert E. Cohen
Department of Chemical Engineering

The severely limited applicability of metallic and natural materials in the marine environment points to a need for new materials for undersea operations. Common polymers seem well suited to a variety of marine uses because they cost little and resist degradation. Professors Cohen and Donnelly have completed a three-year study in which they examined the stability of several polymers; investigated the effects of mechanical stresses on these materials; and explored techniques for increasing resistance in a corrosive ocean environment.

In their research they have devised and tested several novel surface treatments that retard corrosion of several kinds of polymers. Baseline studies will aid in producing better materials for insulating underwater electrical cables used in aids for navigation and message transmission across the oceans.

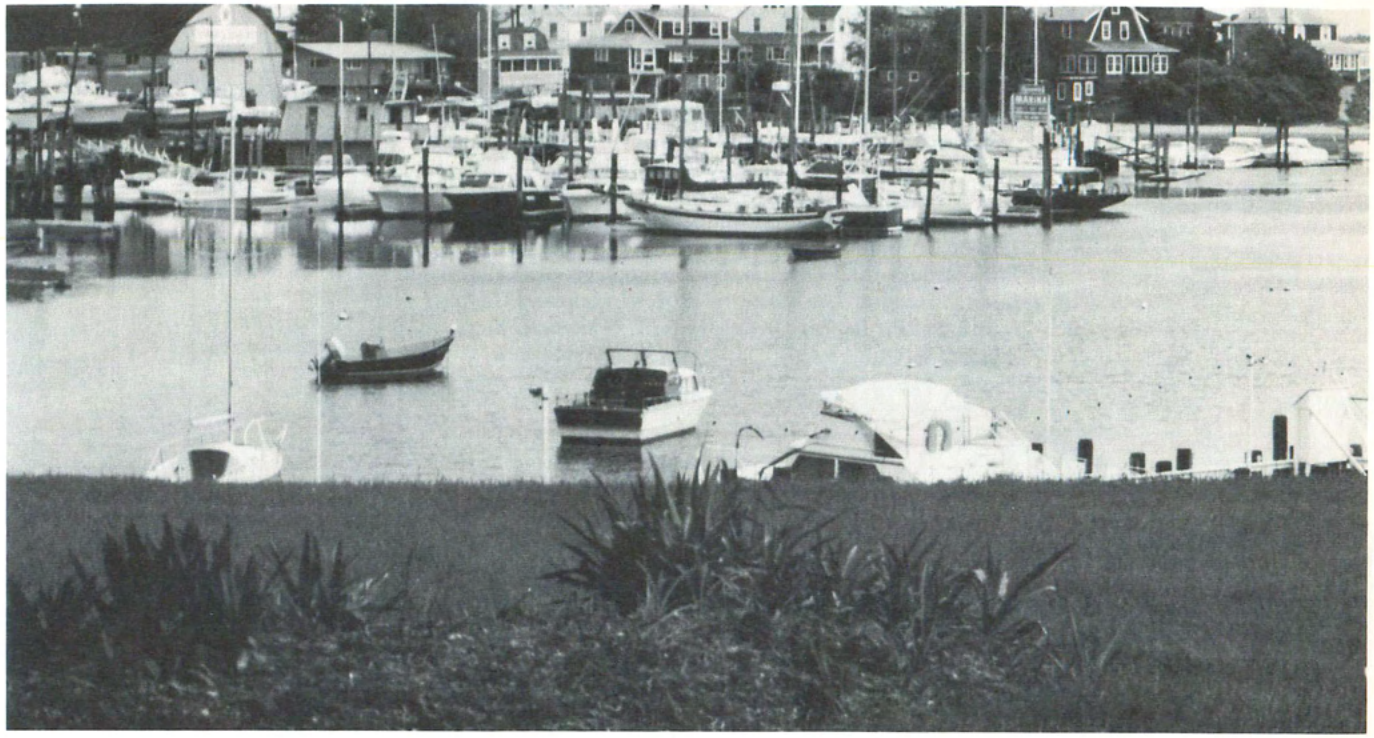
Minimizing Ship Wave Resistance

Principal Investigator:
Professor Francis Noblesse
Department of Ocean Engineering;
Henry L. Doherty Professor in Ocean Utilization

Despite intensive research over the past century, engineers and naval architects have been unable to develop design formulae for reducing the wave resistance of ships. Slight variations in the hull configuration create changes in wave resistance that affect speed and fuel consumption. Professor Noblesse has now developed a nearly exact theory that will overcome this long-standing problem. He is applying his analytical technique to two idealized hulls—a wedge-like bow, and a parabolic strut—and to arbitrary ship hull forms. In the past year he has been solving basic computational problems with the goal of providing a predictive tool for minimizing ship drag due to wave action. The result will help to increase the speed of cargo ships or will allow maritime industries to reduce escalating fuel bills.

Assessing the Structural Integrity of Fiberglass Hulls

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

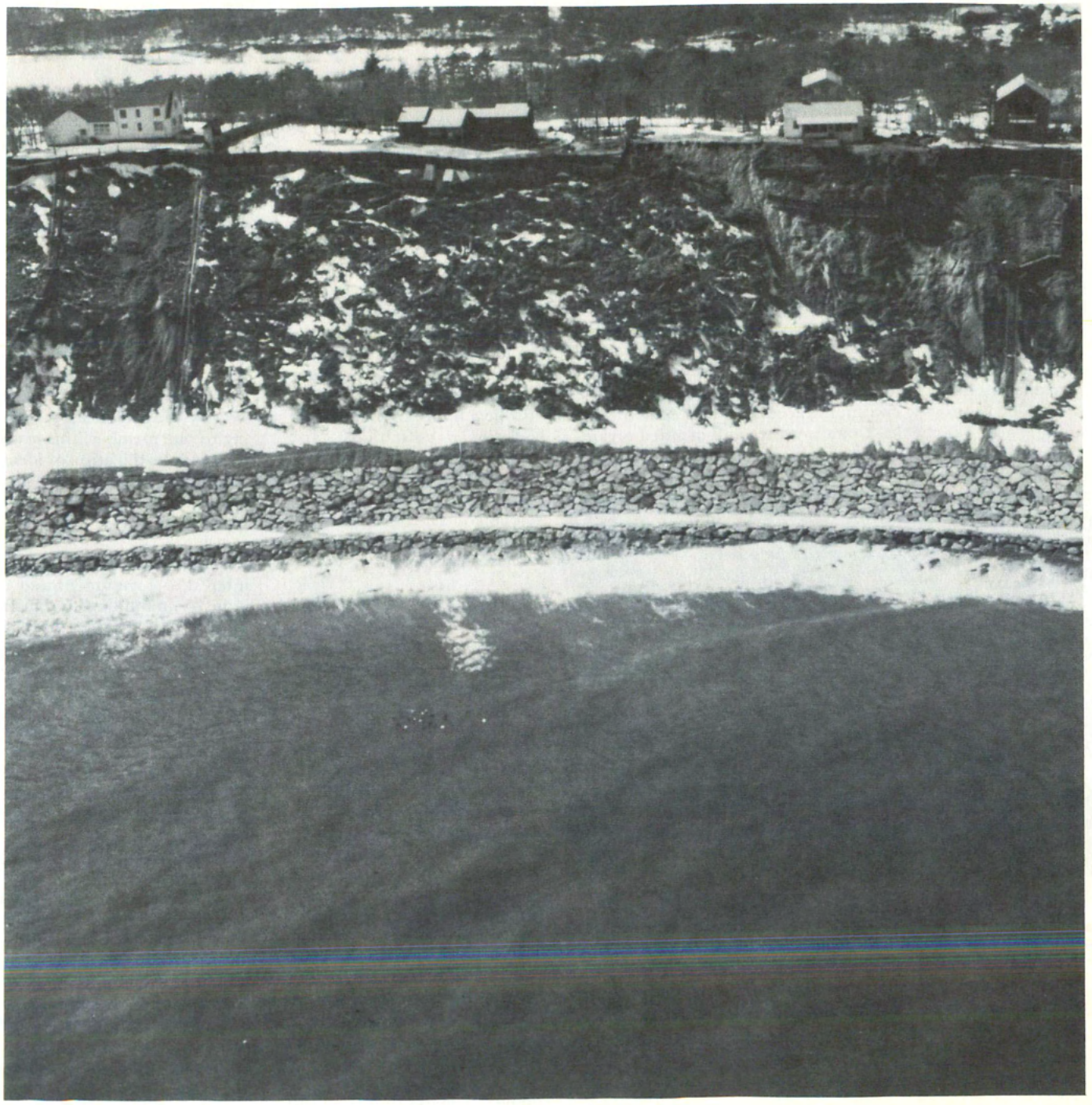


Manufacturers of fiberglass boats have no simple and effective way to test the structural integrity of fiberglass hulls. The seriousness of this lack has been emphasized in recent years by a number of documented accidents and fatalities related to hull defects in fiberglass craft. Professor Williams is exploring a novel technique of nondestructive testing based on the use of inexpensive liquid crystals that change color with varying exposures to heat. When these thermal testing techniques are more fully developed, they will provide simple procedures for detecting such defects as delaminations, uncured resins, and small cracks. Boat manufacturers will have a cost-effective method for establishing quality controls; government agencies and insurance companies will be able to establish safety standards; and marine surveyors and boat owners can inspect used boats for damage and wear.

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 Ole S. Madsen, Francis Noblesse, and Alician V. Quinlan.



Advisory Services

Transferring Technology to the Public

Sea Grant's advisory staff is the public service arm that transfers research results to population centers and industries in the coastal zone.

The whole concept of advisory services is one of sharing information and of stimulating communication between the university base of Sea Grant and people working in industry and government and living in coastal areas. The relevance of the Program's research is dependent on this continuing dialogue.

At MIT, the Massachusetts Marine Liaison Service provides an important link to the citizens of the Commonwealth; the Marine Industry Advisory Service has developed a strong partnership with national industries; and the Communications/ Information Service works with both the Sea Grant staff and the public to provide continuing access to information generated throughout the Sea Grant network and in allied organizations working toward wiser marine resources utilization.

MIT's Marine Industry Advisory Service: MIDAS

Principal Investigator:
Mr. Norman A. Doelling
MIT Sea Grant Program

In 1975, MIT Sea Grant initiated MIDAS and its principal element, the Marine Industry Collegium, to create an active link between the Program and representatives from academia, industry, and government. The idea behind the Collegium follows one of its dictionary definitions: "an association of peers banded together for some common good." In this case, the common good is the utilization and mangement of U.S. marine resources.

Through this Sea Grant organization of more than 90 member groups, participants are able to meet four times a year to discuss significant business opportunities emerging from marine research at MIT and other universities. Each meeting is organized as a workshop and focuses on an Opportunity Brief, written by a member of the Sea Grant Collegium staff. The Briefs outline and document the potential of one research project or an interrelated group of projects. Considerations of the technical, economic, and marketing aspects are mixed with the environmental and regulatory factors influencing potential profitability. Subjects in the past have ranged widely, reflecting the diversity of member groups that include oil companies, ocean engineering firms, utilities, construction companies, consulting and research laboratories and four federal government agencies.

Each of the workshops begins with a presentation by one or more research experts, with a follow-up analysis and discussion by the attendees. According to one member, this leads to "cross-fertilization of ideas." Another says, "The meetings have opened my eyes to new technology."

Last year's topics reflect the interest of government and industry in building and maintaining offshore structures, a concern that also shows up in a listing of Sea Grant's ongoing research projects. A 1978 October workshop brought almost 80 Collegium members to the Sea Grant conference room to discuss Professor Thomas Sheridan's teleoperator experiments. A Collegium poll had identified the need for sophisticated, versatile underwater vehicles. In just a few years, the number of commercial, unmanned vehicles capable of seeing or working in the deep seas has gone from zero to 146, and that number is growing steadily. Since the cost of each averages over $500,000, this new market represents millions of dollars of business per year.

The March 1979 session, "Towards Improved Techniques for Predicting Soil Strength in Offshore Environments," and the May 1979 workshop held in conjunction with the MIT Industrial Liaison Program, "Risks and Costs for Ocean Structures," attracted business and government representatives involved in planning, designing, operating and maintaining the huge offshore structures being built off U.S. coasts. Attendees discussed the research of five scientific teams from MIT's Department of Civil Engineering. Each meeting involved new technology and analytical techniques for making the structures more stable, easier to maintain, and less expensive to build.

In addition to looking toward the oceans for energy from gas and oil, the Collegium has also explored methods for using ocean forces to generate power. In January 1979, "Wave Power Systems" examined some of the engineering problems associated with certain kinds of wave power devices and analyzed the promises and drawbacks of each concept.

The drafts of the Briefs, following each workshop presentation, are edited to incorporate Collegium members' suggestions and are issued as Sea Grant reports by the Communications/Information Service for broad dissemination.

The Collegium was a new concept for Sea Grant in 1975 when MIT started its project. Now after four years of success, the idea is spreading to other universities in the Sea Grant network. Mr. Doelling and the Office of Sea Grant in Washington are exploring how to expand and diversify the industry base at other schools to put more research results directly to work and to keep Sea Grant current with the needs of marine businesses throughout the country.

The success of the Collegium pointed the way to information sharing through a newsletter on current ocean engineering research around the country. Within nine months after its first issue appeared in spring 1979, the quarterly *Research in Ocean Engineering: University Sources and Resources* amassed over 2000 subscribers worldwide. Each issue of the four-page newsletter discusses several research projects in progress around the country. Topics are not restricted to work funded by the newsletter's sponsors, Sea Grant and the NOAA Office of Ocean Engineering.

As the premier issue states, "By focusing on ongoing work, we hope to stimulate an exchange of ideas while the project is still underway. Ideally this increased communication would provide researchers with input from outside sources, and would help others by outlining new techniques or results long before the conventional (journal) publication date. Increased technology transfer would be another reasonable expectation."

Names, addresses and phone numbers of the principal investigators are published at the end of each article to facilitate communications between researchers and readers. Articles have touched on such diverse topics as unmanned submersibles at MIT and UNH, oil spill sensors at URI, studies in ship capsizing at Berkeley, diving apparatus at Wisconsin, mathematical models of antifouling paint at Louisiana State, and wind/wave forces on offshore structures at Texas A&M.

About half the subscribers work for industries, while the others seem almost evenly divided between academic and government posts. Judging by the hundreds of responses to surveys, readers particularly approve of the newsletter's focus on work in progress and the ease of reaching the researchers for more details. Dozens of inquiries and contracts have already occurred between subscribers and investigators.

Massachusetts Marine Liaison Service

A new semi-automatic trawl door hook-up system being tested aboard the Vincie-N.

Principal Investigator:
Mr. Arthur B. Clifton
MIT Sea Grant Program

Of the states bordering the oceans and Great Lakes, Massachusetts has one of the longest coastlines. Its 1220 miles of shoreline wind along recreational beaches, into estuaries, and through harbors of small seaside towns and urban centers. Historically, the state has one of the most heavily populated coastal areas, long dominated by marine industries such as fishing, tourism, and shipping.

Many of the businesses, like those that comprise the fishing industry, are small, entrepreneurial, and family-owned operations. Because of their size, they are infrequently able to invest in research and development, yet this kind of expenditure is often vital for growth and profitability. By congressional design, Sea Grant offers research support through the nation's university system. At MIT, it is through the Sea Grant Massachusetts Marine Liaison (MML) that the Institute is able to give specialized support to local industries.

During the past several years opportunities for the fishing business have opened up, but new operating methods are needed. MML has cooperated with the industry on a number of projects to develop technologies promising greater economic and safety benefits.

In collaboration with the captain and crew of the 68-foot Gloucester trawler the *Vincie-N*, MIT engineers designed and tested a new hook-up block for controlling the net handling cables more efficiently and safely. The captain, Joe Novello, recently told Sea Grant that after five years of continual use, "We would not sail without the block." MML is currently working to install the block on other boats and hopes to see a reduction in insurance premiums for vessels that add the new technology.

Another piece of trawling gear, a semi-automatic trawl door hook-up system, was engineered by graduate student Clifford A. Goudey. Now MML's fishery engineer, Mr. Goudey has written a report that describes how fishermen can make and install the system which operates faster and, like the hook-up block, promises safety advantages.

Americans have missed marketing opportunities abroad, inhibited by existing technology that makes processing certain fish species uneconomical. This is true of the dogfish shark for which a machine is now being designed through the support of MIT Sea Grant and the National Marine Fisheries Service. MML is playing a critical role in seeing that this skinning machine is effectively transferred to a manufacturing company which will make it available for fish processors in all U.S. areas where the dogfish shark can be found.

Besides straight engineering assistance, there are other ways that MIT Sea Grant through MML can serve the citizens of Massachusetts. Educators, consumers, homeowners, local conservation groups need information to make decisions that direct the management of the state's coastal resources. To create a mechanism for reaching these groups with useful information, MIT established the Extension Sea Grant Advisory Program (ESGAP) as a joint effort with the University of Massachusetts. Directed by MML's manager, Mr. Clifton, and Dr. John Noyes of UMass., marine extension agents use publications, lectures, and workshops to transfer research results from MIT and the rest of the Sea Grant network to the communities. Meetings have been held to aid teachers in directing students toward marine careers. Publications prepared by ESGAP and the Communications/Information Services are being used to reestablish marshlands on residential property, to analyze low cost erosion control techniques, and to foster understanding that will help to control red tides.

Erosion problems along the Massachusetts coast are acute, as they are in many other parts of the country. Sea Grant's coastal engineer, Andrew L. Gutman, has met with representatives of local governments and homeowners to help people understand how the coastal processes affect the coastline. He has also discussed with them how to choose shoreline protection techniques that will work under different sets of conditions. A series of lectures he delivered on these topics was so suc-

Communications/ Information Services

cessful that he was asked to record the information and to prepare a slide-tape show that could be borrowed and shown throughout Massachusetts and around the country.

In another erosion-related activity, the coastal engineer directed the preparation of an historical survey of Nantucket's coastline. MIT students collected erosion and accretion data covering 125 years and prepared base maps and tables that can be used to pinpoint individual sites, determine what changes have taken place in the past, and estimate what changes might occur to the property in the future. With this information, developers, realtors and homeowners can avoid those building sites which the accumulated data show will be seriously threatened by future erosion. The same information can be used to determine the effects of shoreline protection on the Nantucket shoreline.

MML and ESGAP are an outreach element of Sea Grant, disseminating information from the universities to the community. They are also "eyes and ears" for the Program, identifying for MIT and the national Sea Grant network the current concerns and needs of Massachusetts citizens.

Principal Investigator:
Ms. Elizabeth T. Harding
MIT Sea Grant Program

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. To achieve these objectives, the Communications/Information Service at MIT works with the rest of the Sea Grant staff.

Every Sea Grant project must be documented in a report when the research has been completed. The manuscript, which is prepared by the scientists and engineers, is ushered through production into publication by the communications manager, an editor, and an editorial assistant. When completed, the reports are publicized through abstracts, publication directories, news releases, and special stories that appear in the public press or special interest magazines and journals. Mailing lists of abstract subscribers, of the media, and of special industry and government leaders aid the staff in reaching diverse and interested audiences.

The reports are available through the Marine Resource 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 ongoing 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, offshore development and onshore impacts are available for room use to anyone who visits the Sea Grant offices.

Like other members of Sea Grant's advisory services, Communications/Information promotes greater discussion and cooperation between university researchers and people in the marine community who need and will use the results. In a study prepared by MIT's Sloan School of Management several years ago, it was shown that early community involvement in Sea Grant's activities helps to ensure broad and successful application of the results. In 1979, a new bulletin, the *Quarterly Report*, was initiated to alert Sea Grant's constituents to new projects and to encourage participation during initial and intermediary stages. Brief articles describe objectives, methods, and suggested applications of the research. Education projects that can benefit students of all ages are also included.

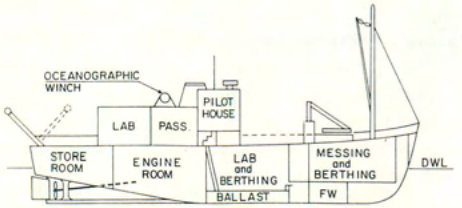
Providing information for the general public is another aspect of Sea Grant's communications efforts. Factsheets, lecture and conference proceedings, advisory reports, brochures, annual reports, displays and slide-tape shows all contribute to increasing the community's awareness of marine issues and of the potential for using the oceans to serve many of society's needs. To learn more about Sea Grant or to get on our mailing lists, contact the Communications/ Information office.

This publication was one of thirty-one scheduled for production by the Communications/ Information staff in the 1979 MIT Sea Grant Report Series.

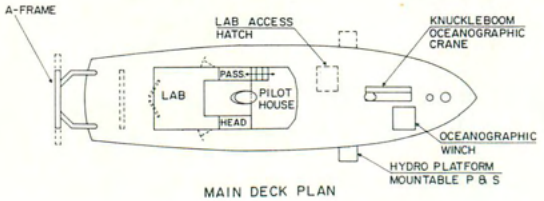
Research Vessel Edgerton

Scientists working in the seas today are crossing the frontiers of knowledge. And sophisticated research vessels, like the Woods Hole Oceanographic Institution's *Alvin*, are aiding them in exploring the ocean floor at depths of 16,000 feet. But smaller research vessels, that are economical and flexible, are also needed to help us better understand the shallower waters in the coastal zone and on the continental shelves.

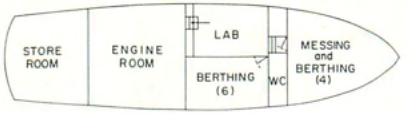
At MIT, the *R/V Edgerton*, a 65-foot, 90-ton ship, provides such a working platform for scientists and engineers. Managed by the Sea Grant Program, the *Edgerton*, since its christening in 1976, has taken hundreds of researchers to sea for a variety of oceanographic and engineering studies. The vessel is diesel powered with AC/DC redundancy for scientific instrumentation and ship's service. An A-frame aft and a telescoping crane forward are served by a free-fall, fast retrieval oceanographic winch located topside. Deck workspace and a lab will accommodate a research team of ten. Sea Grant's Massachusetts Marine Liaison Office manages the operation and charter of the vessel which is available to scientists and engineers from MIT, other universities, and industry.



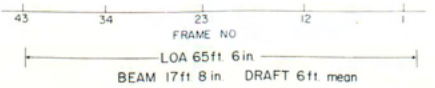
INBOARD PROFILE



MAIN DECK PLAN



HOLD PLAN



Education

Developing Human Resources

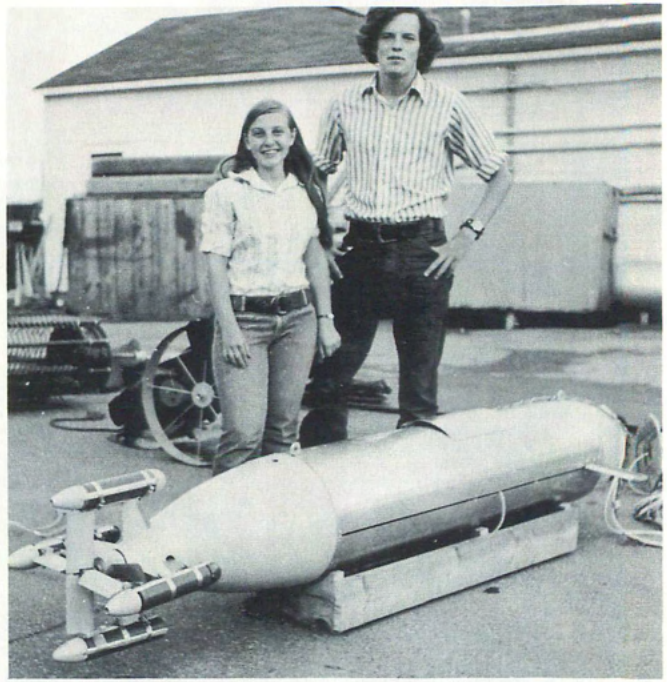
Preceding page: students are gathering water quality data aboard the R/V Edgerton.

Students in an Ocean Engineering laboratory course designed and built an untethered submersible that has led to the development of Robot II described on page 14.

The original Sea Grant College Act made it a national objective to educate and train scientists and other specialists for work in the marine field. When the Sea Grant Program began at MIT, it funded many educational projects in ocean engineering and established multidisciplinary studies that are ongoing today. The national objective blended perfectly with MIT's own philosophy of immersing students in research as undergraduates, giving them experience in solving scientific and engineering problems under the guidance of faculty.

During Sea Grant's nine years at the Institute, the Program's educational objectives have continuously expanded, reflecting a growing national interest in marine resource management. Today, a range of projects aim toward not only MIT students, but also those attending other universities in the Boston area. For professionals out of school and working in the marine field, courses have been designed for information dissemination on new technology and management methods. The public's need for information is tended by the educational component of Sea Grant, often in collaboration with advisory services. Our newest constituency is comprised of students in grade and high school.

Together, the projects described in the following section point to a key tenet of Sea Grant: decisions made with knowledge and real understanding help to produce a world in which people live in less conflict with each other and with their environment.



Ocean Engineering Studies

Principal Investigator:
Dr. Ira Dyer
Department of
Ocean Engineering

MIT's ocean engineering curriculum is carefully designed to provide a solid educational background for professional careers in marine industries, research, or teaching. To remain effective, the curriculum must continually be subject to evaluation and change. Only in this way can it reflect new knowledge and advancing technologies and at the same time remain responsive to current and projected needs in the education of competent professionals.

In addition to ongoing curriculum development, Sea Grant supports laboratory and field projects that allow students to gain first-hand experience in ocean engineering. These projects engage students in activities that may involve marine research or the design, construction, installation, and testing of systems and devices for use in the ocean. Working directly with faculty members, students have an opportunity to transfer science and engineering from the classroom to actual applications in the laboratory or at sea.

Interdisciplinary Systems Design

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

Each year since the Sea Grant Program was started at MIT in 1970, Professor Seifert has conducted an interdisciplinary course in systems design. The course has engaged students from MIT, Harvard and Wellesley in a coordinated investigation of a complex "real-world" planning problem of current concern to a New England coastal community. The topic typically chosen encompasses technical, managerial, economic, leagal, and socio-political disciplines. Not only do students have the opportunity to apply classroom knowledge to an actual situation, but the course illustrates how conflicting considerations must be integrated into the solution of broad, complex problems.

Undergraduates in the Interdisciplinary Design Course produced a planning study and a report recommending how underutilized land in Lynn Harbor could be converted into a community resource.

The 1977-1978 course concentrated on analyzing development options that would revitalize an unused, deteriorated harbor area in Lynn, Massachusetts. During the 1978-1979 academic year, the students worked closely with a community planning group in the Cape Cod town of Hyannis. They studied alternatives for linking the traditional business district with the harbor to promote economic revitalization of a downtown area and to achieve greater integration of commercial, industrial and recreational uses of the waterfront area.

Both projects, like the courses that have preceded them, have resulted in Sea Grant reports that have immediate uses to the Massachusetts communities and can also be employed by other towns or by educators as generic studies in how to approach different aspects of coastal zone planning.

Integrated Course on Offshore Structures

Principal Investigator:
Professor Oral Buyukozturk
Department of
Civil Engineering

Professor Buyukozturk is integrating graduate-level subjects dealing with civil engineering aspects of the design and construction of offshore structures. The major goal of this effort is to produce a coordinated set of materials that can serve as the basis for a textbook and, over the longer term, lead to improved competence and efficiency in the design and construction of offshore facilities.

For students at MIT, this course, which was presented first in the spring of 1977 and again in 1978, provides the opportunity to study offshore design and construction in a systematic and coordinated manner. The eventual completion of a textbook in this field will extend similar opportunities to students at other universities.

Marine Studies Consortium

Principal Investigator:
Mr. E.R. Pariser
MIT Sea Grant Program

An exciting new course will be available to Boston area undergraduates in the spring of 1980. The course, "Into the Ocean World," is a marine studies course introducing the many disciplines that touch on the sea—the marine sciences, maritime history, marine politics and economics, marine art and literature. Team taught by experts in the sciences, social sciences, humanities and arts, the course is designed to highlight the sea's complexity and the far-reaching consequences of our interactions with it. The course objective is to help students learn to interrelate the many perspectives required to understand the marine environment and to make decisions about the oceans.

The course is the result of a two-year planning effort and is being sponsored by the Inter-institutional Marine Studies Consortium, an organization of Boston-area institutions with faculty members interested in all areas of marine study.

Public Education and Training Courses

Principal Investigator:
Professor J.M. Austin
Department of Meteorology

During the summer of 1978, the MIT Sea Grant Program participated in the MIT Special Summer Program, presenting six marine-related short courses: Transportation Systems Management and Analysis; Air Transportation; Port Planning and Development; Urban Transportation; Freight Transportation; Forecasting Transportation Demand. Each year these one- and two-week sessions attract professionals from the United States and abroad. A series of coordinated topics are designed for engineers and scientists from industry, government, and education. The intent is to provide practicing professionals with concise and detailed information on the latest techniques, developments, and technical progress in a specific marine-related field of interest. By spending concentrated time meeting with each other and with MIT's scientists and engineers, marine professionals keep abreast of new and evolving technologies in their fields.

At the Bottom Trawl workshop, fishermen learn to design, make, and mend nets—one of the most important tools aboard any fishing vessel.

Teaching Materials for Pre-University Marine Education

Principal Investigator:
Mr. E.R. Pariser
MIT Sea Grant Program

Water is such a familiar part of our existence that its essentialness to human life and its value as a resource may be easily overlooked. Creating a heightened awareness, understanding, and appreciation of "the world of water" is the goal of marine educational materials being developed by the project. Some of these materials have been tested and evaluated in an innovative summer program, the "Sea Lab" in New Bedford, Massachusetts. For students at elementary through high school levels, "Sea Lab" offers a unique learning experience acquainting them with the properties that make water precious and useful, and also providing knowledge and tools for studying the relationship of water to their world. Present plans call for incorporating some of these materials into the regular New Bedford school curriculum and later into other Massachusetts schools. This project is oriented not only toward education in coastal communities, but in the heartland of America as well, with the long-term goal of creating citizens who can creatively use, enjoy, and protect our aquatic resources, salt and fresh water alike.

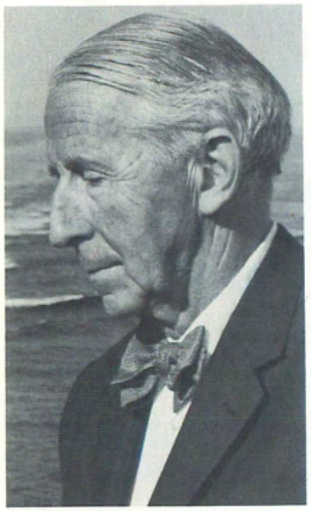
Educational Opportunities for Fishermen

Principal Investigators:
Mr. Arthur B. Clifton
MIT Sea Grant Program;
Dr. David L. Kan
Massachusetts Maritime Academy

Today's fishermen, taking advantage of new educational opportunities, are returning to school to strengthen existing skills and to study new technology. At the Massachusetts Maritime Academy (MMA), short courses and lectures are available to New England professionals during the winter and early spring months, when fishing activity is slowest. The educational program, which has received the support of MIT Sea Grant, the State of Massachusetts, and MMA, offers classes in piloting, aids to navigation, equipment maintenance, safety, and business management.

These courses, begun as electives for MMA students to motivate them to enter careers in U.S. fisheries, were adapted and expanded to include working professionals as the needs and interests of the industry became clear. The one- and two-day sessions are "hands on" laboratory classes taught by the team teaching method. One teacher, an MMA faculty member, concentrates on the theoretical aspects of the subject; the other, an experienced professional fisherman, supplies first-hand skill and experience in applying the course lessons to day-to-day operational problems and conditions.

An evening lecture series complements the workshops by exploring and discussing the policy and regulatory issues that confront the fishing industry. The topics have included: "The Future of the New England Fisheries Under the 200-Mile Limit," "Fishing Quota, Regulation, and the 200-Mile Limit," and "The Offshore Lobster Industry."



Erling D. Naess delivered the Seventh Annual Sea Grant Lecture to an audience of over 200 in MIT's Kresge Auditorium.

Principal Investigator:
Dr. Alfred A.H. Keil
Ford Professor of
Engineering Emeritus

Each year, MIT Sea Grant sponsors a lecture and debate on a topic of concern and interest to the marine public. In October of 1978, we asked Erling D. Naess, Chairman of the International Association of Independent Tanker Owners, to discuss "Oil Pollution of the Oceans: A Tanker Owner's Perspective." Mr. Naess urged maritime nations to agree on uniform ship standards if they hope to eliminate oil pollution of oceans by tankers. After outlining industry's recent efforts to solve this serious problem he warned, "Although the tanker industry is diligent about policing itself through restraints developed by the International Chamber of Shipping, with 40 or 50 nations involved, it is a hopeless task to develop a police mechanism on a voluntary basis." He added that the governments of each of these nations must negotiate: "International action is imperative." Responding to Mr. Naess were William M. Benkert, Rear Admiral in the U.S. Coast Guard; James A. Cole, Jr., General Manager of the Marine Department of Texaco, Incorporated; Jerome H. Milgram, Professor of Naval Architecture, Department of Ocean Engineering at MIT; and Evelyn F. Murphy, Secretary of Environmental Affairs, Commonwealth of Massachusetts. The panelists discussed and debated some of the reasons that tankers contribute to the world's serious oil pollution problem: flags-of-convenience ship registry, inadequate personnel training, irresponsible operational practices by individual vessel owners. And they suggested various methods for alleviating pollution caused by tankers: better national legislation and policing, greater research support to study tanker difficulties, navigational aids and traffic vessel services, and better personnel training.

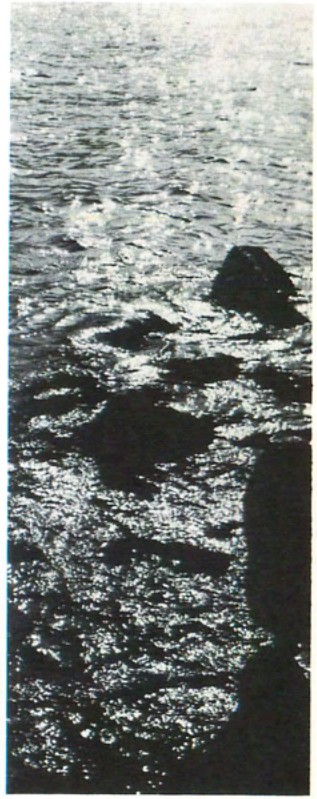
Institutional Program Summary Fiscal Year 1979

This Summary matches the project breakdown in the MIT Sea Grant College Program proposal for 1978-1979.

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
	TV Series: "World of Water"	Mr. Pariser	Continued project
	Interdisciplinary Systems Design Subject	Dr. W.W. Seifert	Continued project; report to be published
	Ocean Engineering Project Laboratory	Dr. I. Dyer	Continued project
	Ocean Engineering Curricula	Dr. Dyer	Continued project
	Development of a Commercial Fisheries Training Program	Dr. Dyer	Continued project
	Public Education and Training Short Courses	Professor J.M. Austin	Continued project
	Development of an Integrated Course on Offshore Structures	Professor O. Buyukozturk	Continued project
	Annual Sea Grant Lectureship	Dr. 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	New project

Advisory Services	Massachusetts Marine Liaison Service	Mr. A.B. Clifton	Continued project
	MITSG/CES Marine Extension Service	Mr. Clifton Dr. J.H. Noyes	Continued project
	Marine Industry Advisory Service	Mr. N.A. Doelling	Continued project; reports published
	Marine Communications/ Information Service	Ms. E.T. Harding	Continued project
	Computer Program Dissemination	Professor J. Connor	Continued project
	University Research in Ocean Engineering, Sources and Resources	Mr. Doelling	New project; reports to be published
Technology Development for Ocean Uses	Development of Joining and Cutting Techniques for Deep Sea Applications	Professor K. Masubuchi	Continued project
	Enhancement of the Stability of Common Polymeric Materials Against Undersea Degradation	Professors R.G. Donnelly and R.E. Cohen	Continued and and completed project; report to be published
	Quality Control of Fiberglass Boat Hulls Using Thermal Testing and Liquid Crystals	Professor J.H. Williams, Jr.	New project
	Implementation of a New Method for Evaluating the Wave Resistance of a Ship	Professor F. Noblesse	New project
	Measurements of Heavy Metals in Seawater Containing Surface Active Agents	Professor D.N. Hume	New and completed project; internal report
	Study of a Cost Model of Deep Seabed Mining	Professor J.D. Nyhart	Continued project; report to be published

	The Effect of Oil Composition and Physical Properties and the Ambient Water on Oil Slick Dispersion	Professor Donnelly	Continued and completed project; report to be published
Unmanned Underwater Work Vehicles	Application of Teleoperators to Undersea Tasks	Professor T.B. Sheridan	Continued project; report published
	Underwater Communication System for Untethered Vehicles and Sensors	Professor A.B. Baggeroer	New project
	Robot Vehicles for Search and Survey Applications	Professor A.D. Carmichael	New project
Offshore Facilities	Offshore Geotechnical Risk Analysis	Professor G.B. Baecher	Continued and completed project; report to be published
	In-Situ Evaluation of Geotechnical Properties of Marine Sediment	Professors M.M. Baligh and C.C. Ladd	New project
Coastal Processes, Physical	Analysis of Offshore Brine Disposal Techniques	Professor K.D. Stolzenbach	Continued project; report to be published
	Surf Zone Hydrodynamics: A Field Investigation	Professor O.S. Madsen	Continued and completed project; report to be published
	Seawater Intrusion in Offshore Islands	Professor J.L. Wilson	Continued project; report published
	Wave Attenuation by Bottom Friction	Professor Madsen	New project



Coastal Ecology	The Role of Trace Metals on New England Red Tides	Professor F.M.M. Morel	Continued and completed project; report to be published
	Ecodynamic Analysis of Algal Blooms Fouling Nahant Bay Beaches	Professors A. Quinlan and J. Connor	New project
	Motility and Metabolism of a Marine Microorganism in Relation to its Substrate Zostera Marina	Professor E. Bell	New project
	Trace Element Uptake in Marine Food Chain	Dr. M. Janghorbani and Dr. G. McLeod	New project
Living Resource Development	Feasibility Study on the Utilization of Shellfish Wastes as Reinforcing Fillers for Plastics	Professor N.K. Sung	New and completed project; internal report
	Chemical and Structural Characterization of Chitin and Chitin Derivatives for Industrial Applications	Professor B.L. Averbach	Continued project
	Development of a Process for Skinning the Spiny Dogfish Shark	Professors D.G. Wilson and C. Rha	Continued project; report to be published
National Projects	Forcing Function Nearshore Velocity	Professor Madsen	New project

Summary of Expenditures by Activity

		NOAA Grant Funds	University Matching Funds
Program Management	Program Administration	$ 95,400	$ 150,165
	Program Development	36,200	63,689
Marine Education and Training	College Level	55,700	97,070
	Other Education	133,900	92,890
Marine Resource Development	Marine Extracts—Other	45,900	21,876
	Pathology of Marine Organisms	114,900	152,479
Marine Technology Research and Development	Ocean Engineering	174,200	126,892
	Sea Floor Engineering	60,000	19,997
	Materials and Structures	30,900	6,170
	Vehicles, Vessels and Platforms	78,000	53,472
	Commercial Fisheries	59,200	—
Marine Environmental Research	Ecosystem Research	36,800	30,811
	Pollution—Oil Spills	27,100	10,094
	Environmental Models—Physical Processes	84,100	51,044
	Biological Processes	63,300	66,255
Advisory Services	Extension Programs	262,800	136,983
	Other Advisory Services	118,000	8,000
	Total	$1,476,400	$1,087,887

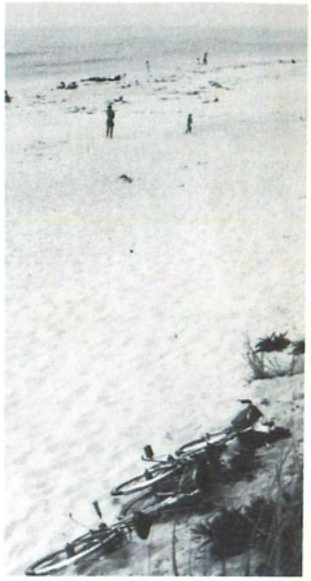
This summary is only approximate. In accordance with Federal grant requirements, the official financial report will be submitted by the MIT Comptroller to the Office of Sea Grant.

Student Participants

Albert C. Ansorge III
Michael E. Barrett
George W. Blossom
Clive C. Bolton
Liza C. Bronaugh
Francesca D. Brown
Joseph A. Carnevale Jr.
Stephen R. Cassella
Randall B. Clark
A.M. Davis, Jr.
David N. Deleeuw
Gregory L. Duckworth
Brian B. Haggerty
James N. Hancock
William H. Hanot
Alan J. Heureux
William B. Hoff III
Jeffrey S. Hovis
Joshua K. Hoyt
Zanda Ilori
M. Inoue
John T. Kaufman
Michael Kavvadas
Bruce W. Kirch
Tapio L. Kuusinen
Jacques-Noel Levadoux
Timothy Lewis
Joseph Lombardi
Robert C. Lowry
Steven J. Mardeuz
Stephen R. Menno
Roy Y. Nakagawa
Tetsuichi Odahara
Amy Philipson
Jaggath Raju
David C. Ricks
Antonio Sa da Costa
Elias F. Samaras
M.J. Saylor
Peter C. Schecter
Rebecca Jones Siebert
Gregory M. Smith
James Spawl
S. Shyam Sunder
Beth Tavrow
Marc Taylor
Benjamin A. Teno
Matthew Thompson
Sui Shing Tong
Koji Tsunokawa
Kathryn A. Vanden Bosche
Vitoon Vivatrat
Peter S. Waldo
Gordon R. Whicher
James W. White
Chee Wong
Dana Yoerger
Jennifer J. Zeien

Publications

The Coastal Zone	Sa da Costa, A.A.G. and J.L. Wilson III	A Numerical Model of Seawater Intrusion in Aquifers	MITSG 79-27 Massachusetts Institute of Technology Cambridge, Massachusetts
	Greer, M.N. and O.S. Madsen	Longshore Sediment Transport Data: A Review	MITSG 79-28J Massachusetts Institute of Technology Cambridge, Massachusetts Proceedings of the 16th Coastal Engineering Conference, ASCE/Hamburg, 1978
	Ostendorf, D.W. and O.S. Madsen	An Analysis of Longshore Currents and Associated Sediment Transport in the Surf Zone	MITSG 79-13 Massachusetts Institute of Technology Cambridge, Massachusetts
	Curtis, E.M., III	Wave-Induced Longshore Current Outside the Surf Zone	S.M. Thesis Department of Civil Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts
	Greer, M.N.	Development and Application of a Field Instrumentation System for the Investigation of Surf Zone Hydrodynamics	S.M. Thesis Department of Ocean Engineering Massachusetts Institute of Technology Cambridge, Massachusetts
	Stefanick, T.	A Realistic Model of Wave Attenuation due to Bottom Friction	S.M. Thesis Department of Civil Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts



Marine Pollution	B.L. Averbach	The Permeation of Copper Sulfate Ions into Chitosan Membranes	AIChE, November 1979
	Clark, R.B. and B.L. Averbach	The Mechanical Properties of Chitosan Membranes	IEEE, Ocean '78
	Gaboury, D.R. and K.D. Stolzenbach	Dispersion Characteristics of Ocean Discharges	Ralph Parsons Laboratory for Water Resources and Hydrodynamics Report No. 244 Massachusetts Institute of Technology Cambridge, Massachusetts
	Tong, S.S. and K.D. Stolzenbach	Submerged Discharges of of Dense Effluents	Ralph Parsons Laboratory for Water Resources and Hydrodynamics Report No. 243 Massachusetts Institute of Technology Cambridge, Massachusetts
	Siebert, R.J.	Trace Metal Measurement by Differential Pulse Anodic Stripping in the Presence of Surface Active Agents	Ph.D. Thesis Department of Chemistry, Massachusetts Institute of Technology Cambridge, Massachusetts

Food from the Seas	Morel, F.M.M., D.M. Anderson, J.G. Rueter and R.R.L. Guillard	Aquil: A Chemically Defined Phytoplankton Culture Medium for Trace Metal Studies	MITSG 79-24J Massachusetts Institute of Technology Cambridge, Massachusetts Journal of Phycology, 15, 1979
	Anderson, D.M. and F.M.M. Morel	The Seeding of Two Red Tide Blooms by the Germination of *G. Tamarensis* Hypnocysts	MITSG 79-26J Massachusetts Institute of Technology Cambridge, Massachusetts Estuarine and Coastal Marine Science, 8, 1979
	Menjiver, J.A., R. Chen and C. Rha	Investigation of Mechanical Properties of Raw Flesh and Skin of Spiny Dogfish (*Squalus Acanthias*)	MITSG 79-30J Massachusetts Institute of Technology Cambridge, Massachusetts Journal of Textural Studies, 10, 1979
Offshore Resource Development	Brooks, T.L. and T.B. Sheridan	Superman: A System for Supervisory Manipulation and the Study of Human/ Computer Interactions	MITSG 79-20 Massachusetts Institute of Technology Cambridge, Massachusetts
	Davis, G.M., Jr.	Design and Construction of the Second Generation MIT Robot Submarine	O.E. Thesis Department of Ocean Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts
	Inoue, M.	Control System Synthesis of a Computer-Piloted Submarine	S.M. Thesis Department of Ocean Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts

Saylor, M.J.	Electronics Systems Design and Control Algorithms for a Robot Submarine	S.M. Thesis Department of Ocean Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts
Tsai, C.L. and K. Masubuchi	Mechanisms of Rapid Cooling in Underwater Welding	Applied Ocean Research, Vol. 1, No. 2 April 1979
Tsai, C.L. and K. Masubuchi	Mechanisms of Rapid Cooling and Their Design Considerations in Underwater Welding	Offshore Technology Conference 1979, Paper #3469
Baligh, M.M., V. Vivatrat and C.C. Ladd	Exploration and Evaluation of Engineering Properties for Foundation Design of Offshore Structures	MITSG 79-8 Massachusetts Institute of Technology Cambridge, Massachusetts
Baligh, M.M. and V. Vivatrat	In Situ Measurements in a Marine Clay	BOSS '79 Proceedings, Vol. 1
Vivatrat, V.	Cone Penetration in Clays	Sc.D. Thesis Department of Civil Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts
Baecher, G.B.	Modeling for Decision Analysis	TIMS/ORSA Annual Meeting, New Orleans, 1979
Baecher, G.B. and T.S. Ingra	Equivalent Properties in Soil Profile Modeling	ASCE Specialty Conference on Probabilistic Mechanics and Structural Reliability, Tucson, 1979

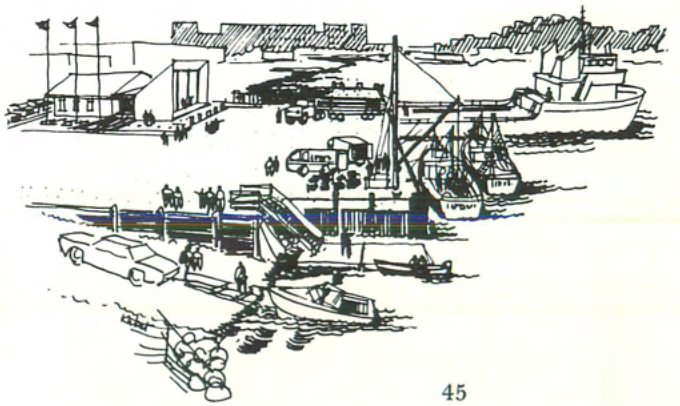
Baecher, G.B.	Search Theory in Geotechnical Explorations	3rd International Conference on Applications of Statistics and Probability to Soil and Structural Engineering, 1979
Baecher, G.B.	The Current State of Exploration Modeling	ASCE National Convention, Boston, 1979
Baecher, G.B.	Probabilistic Modeling of Site Exploration	Department of Civil Engineering, Report No. R79-9, Massachusetts Institute of Technology Cambridge, Massachusetts
Baecher, G.B. and T. Lee	Models for Settlement Predictions	Department of Civil Engineering, Report No. R79-11, Massachusetts Institute of Technology Cambridge, Massachusetts
Fazal, R. and J.H. Milgram	The Effects of Surface Phenomena on the Spreading of Oil on Water	MITSG 79-31 Massachusetts Institute of Technology Cambridge, Massachusetts
Mynett, A.E., D.D. Serman and C.C. Mei	Characteristics of Salter's Cam for Extracting Energy from Ocean Waves	MITSG 79-12J Massachusetts Institute of Technology Cambridge, Massachusetts Applied Ocean Research, Vol. 1, No. 1
Devanney, J.W., III, S. Protopapa and R. Klock	Tanker Spills, Collisions and Groundings	MITSG 79-14 Massachusetts Institute of Technology Cambridge, Massachusetts

Technology for Ocean Uses	Mansouri, S.H.	Nondestructive Thermal Testing for Delamination and Inclusion Defects in Fiberglass Laminates Using Liquid Crystals	S.M. and Engineering Thesis Department of Mechanical Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts
	Williams, J.H., Jr., S.H. Mansouri and S.S. Lee	One-Dimensional Analysis of Thermal Nondestructive Detection of Delamination and Inclusion Flaws	Composite Materials and Nondestructive Evaluation Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts
	Williams, J.H., Jr., S.H. Mansouri and S.S. Lee	Thermal Nondestructive Testing of Fiberglass Laminates Using Liquid Crystals	Composite Materials and Nondestructive Evaluation Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts
	Noblesse, F.	Alternative Expressions for the Green Function Theory of Ship Wave Resistance	MITSG 79-23 Massachusetts Institute of Technology Cambridge, Massachusetts
	Chen, C.	Evaluation of a New Wave-Resistance Formula for a Wedge-like Ship-bow Form	S.M. Thesis Department of Ocean Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts
Education	Naess, E.D., W.M. Benkert, J.A. Cole, Jr., J.H. Milgram and E.F. Murphy	Oil Pollution of the Oceans: A Tanker Owner's Perspective. Seventh Annual Sea Grant Lecture: Proceedings	MITSG 79-1 Massachusetts Institute of Technology Cambridge, Massachusetts

Seifert, W.W. and L.T. Rosenbaum	Suggestions for the Revitalization of the Village of Hyannis	MITSG 79-21 Massachusetts Institute of Technology Cambridge, Massachusetts
Pariser, E.R.	Reducing Postharvest Losses of Fish in the Third World	MITSG 79-11J Massachusetts Institute of Technology Cambridge, Massachusetts Oceanus, Vol. 22, No. 1
Bismut, P. and O. Buyukozturk	Fatigue Analysis of Steel Offshore Structures	Report No. R79-32 Department of Civil Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts 1979
Sunder, S.S.	Stochastic Modeling of Ocean Storm	S.M. Thesis Department of Civil Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts 1979
Vanmarcke, E.H. and D. Angelides	Probabilistic Modeling and Risk Analysis for Offshore Structures	Lecture Notes Department of Civil Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts 1979
Whicher, G.R.	Structural Dynamic Analysis Techniques with Application to Steel-Jacket Platforms	S.M. Thesis Department of Civil Engineering, Massachusetts Institute of Technology Cambridge, Massachusetts 1979

Advisory Services	Doelling, N.	The MIT/Marine Industry Advisory Service: A Critical Review and Progress Report	MITSG 79-10 Massachusetts Institute of Technology Cambridge, Massachusetts
	MIT/Marine Industry Collegium	Opportunity Brief No. 14 Teleoperators Under the Sea	MITSG 79-15 Massachusetts Institute of Technology Cambridge, Massachusetts
	MIT/Marine Industry Collegium	Opportunity Brief No. 15 Wave Power Systems	MITSG 79-16 Massachusetts Institute of Technology Cambridge, Massachusetts
	MIT/Marine Industry Collegium	Opportunity Brief No. 16 Towards Improved Techniques for Predicting Soil Strength in Offshore Environments	MITSG 79-17 Massachusetts Institute of Technology Cambridge, Massachusetts
	MIT/Marine Industry Collegium	Opportunity Brief No. 17 Risks and Costs for Ocean Structures	MITSG 79-18 Massachusetts Institute of Technology Cambridge, Massachusetts
	Goudey, C.	An Improved Trawl Door Hook-up System	MITSG 79-22 Massachusetts Institute of Technology Cambridge, Massachusetts
	Gutman, A.L.	Nantucket Shoreline Survey	MITSG 79-7 Massachusetts Institute of Technology Cambridge, Massachusetts
	Gutman, A.L.	Low-Cost Shoreline Protection in Massachusetts	MITSG 79-19J Massachusetts Institute of Technology Cambridge, Massachusetts Proceedings of Specialty Conference on Coastal Structures '79, ASCE/Virginia

Keil, A.A.H.	Strengthening Ocean Engineering in the Sea Grant Program	MITSG 79-3 Massachusetts Institute of Technology Cambridge, Massachusetts Sea Grant Association, 1978
Horn, D.A.	All the Water on Earth Is All the Water There Is	MITSG 79-5 Massachusetts Institute of Technology Cambridge, Massachusetts David B. Stone Award, 1978
Steen-Elton, B.	Marine-Related Research at MIT	MITSG 79-6 Massachusetts Institute of Technology Cambridge, Massachusetts
	A Citizen's Guide to Sources for Marine and Coastal Information in Massachusetts	MITSG 79-29 Massachusetts Institute of Technology Cambridge, Massachusetts
	A Report on the Massachusetts Institute of Technology Sea Grant College Program: 1 July 1977 to 30 June 1978	MITSG 79-2 Massachusetts Institute of Technology Cambridge, Massachusetts



Matching Fund Support: Participants and Contributors

The Boston Shipping Association
Environmental Devices Corporation
Fishing Industry Support—Massachusetts
Fugro Geotechnical Consultants—Holland
Henry L. and Grace Doherty Charitable Foundation Inc.
Hunts Crabmeat Company
International Copper Research Association
Intevep Project
Kawasaki Heavy Industries
Massachusetts Institute of Technology
Marine Industry Advisory Services Collegium Members
Mobil Chemical Company
Multi-Sponsor Industrial Support
New Bedford School System
New England Aquarium
New England Fisheries Steering Committee
Sea Grant Lecture Endowment Funds
University of Massachusetts
Woods Hole Oceanographic Institution

MIT/Marine Industry Collegium Membership

30 June 1979

Akzona, Incorporated
American Cyanamid Company
The Anaconda Company
Aquatec International, Inc.
Arcair Company
Arthur D. Little, Inc.
Avco Everett Research Laboratory, Inc.
Beatrice Foods Company
Bechtel National Inc.
Becton, Dickinson Research Center
Bell Aerospace Textron
Bell Laboratories
The Boeing Company
BOC Limited
Bolt Beranek & Newman Inc.
Boston Edison Company
Campbell Soup Company
Caterpillar Tractor Company
Celanese Research Company
Central Research Laboratories, Inc.
Chevron Research Company
Combustion Engineering, Inc.
Compass Publications, Inc.
Continental Group, Inc.
Continental Oil Company
Dames and Moore, Inc.
The DeLaval Separator Company
Dow Chemical Company
Dravo Corporation
E.I. du Pont de Nemours Company, Inc.
E G & G, Inc.
Environmental Devices Corporation
Exxon Research & Engineering Company
Fiat, Inc.
Foxboro/Trans-Sonics, Inc.
General Dynamics Corporation, Electric Boat Division
General Electric Company, Industrial & Marine Steam Turbine Operations Division
General Electric Company, Re-entry & Environmental Systems Division
Getty Oil Company
Goodyear Aerospace Corporation
Gould, Inc.
Grumman Aerospace Corporation
Gulf Oil Company
Hercules, Inc.
Honeywell Inc.
IHC Holland (IHC SMIT BV)
Imperial Chemical Industries Limited
International Proteins Corporation
International Underwater Contractors, Inc.
InterOcean Systems, Inc.
ITT Cable—Hydrospace Division
JBF Scientific Corporation
Kennecott Copper Corporation
Litton Industries, Ingalls Shipbuilding Division
Lockheed Missiles and Space Company, Inc.
Lord Kinematics
MacLaren Atlantic Ltd.
Marathon Oil Company
Massachusetts Science and Technology Foundation
Massachusetts Port Authority
McLelland Engineers, Inc.
Mitsui & Company, Ltd.
Mobil Research and Development Corporation
Montedison S.p.A.
New England Power Company
Oceaneering International, Inc.
The Plessey Company Ltd.
Raytheon Company, Submarine Signal Division
RCA Corporation
Rockwell International Corporation
Sanders Associates, Inc.
Sea Land Services, Inc.
Shell Oil Company
Spar Areospace Products Ltd.
Sperry Marine Systems
Standard Oil Company of Indiana
Stone & Webster Engineering Corporation
Sun Shipbuilding & Dry Dock Company
Tecnomare S.p.A.
Texaco, Inc.
TRW, Inc.
Unilever Ltd.
Union Oil Company of California
U.S. Coast Guard, Office of Research & Development
U.S. Geological Survey
U.S. Maritime Administration
U.S. Naval Explosive Ordnance Disposal Facility
Union Carbide Corporation
United Technologies Research Center
Westinghouse Electric Corporation, Oceanic Division
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

Manager of the Marine Industry Advisory Service
Mr. Norman A. 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

Chairman, Sea Grant State-Industry Advisory Council
Mrs. Jeptha H. Wade
Private Citizen

Photography Credits

Clifford A. Goudey
page 22

Andrew L. Gutman
pages 3, 8, 17, 19, 20, 33
36, 37, 38, 49

Harold M. Lambert
cover

Kathy Mannix
page 10

Francis W. Sargent, Jr.
page 25