Bringing the Oceans into America's Future

A Report on the Massachusetts Institute of Technology Sea Grant Program

1 July 1975 to 30 June 1976

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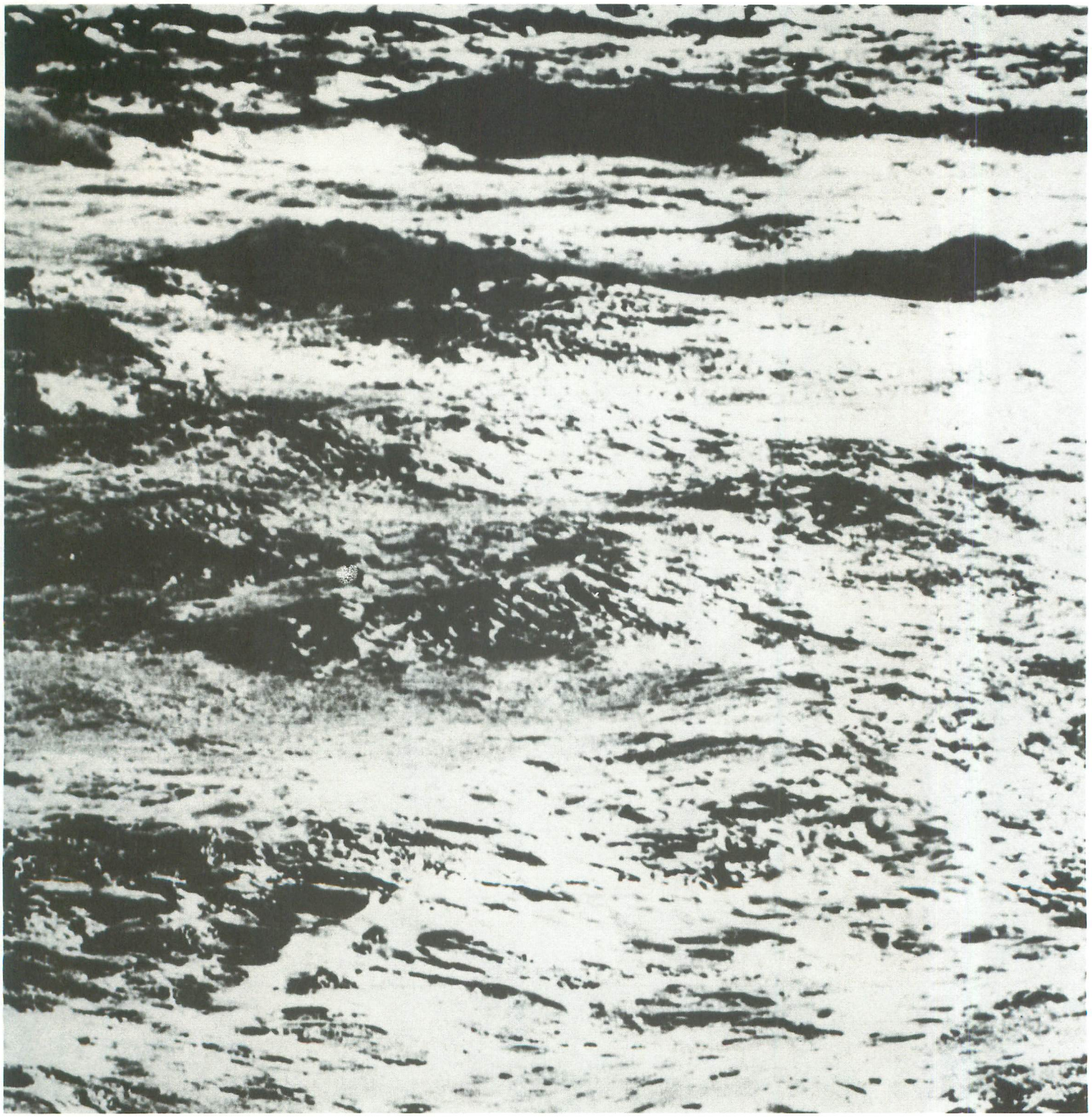


With new awareness of the tremendous opportunities for economic and societal growth offered by the ocean's resources, the United States is searching for policies and practices that will foster industrial advancement in the seas while promoting ecological balance in productive ocean and coastal environments.

MIT is already working to achieve these goals through its participation in the National Sea Grant Program, a division of the National Oceanic and Atmospheric Administration in the U.S. Department of Commerce. The MIT Sea Grant Program focuses the Institute's philosophy—to create and apply useful technologies for industrial growth, economic benefit, environmental safeguards, and social betterment—on the development for the nation's use of resources in the seas and coasts.

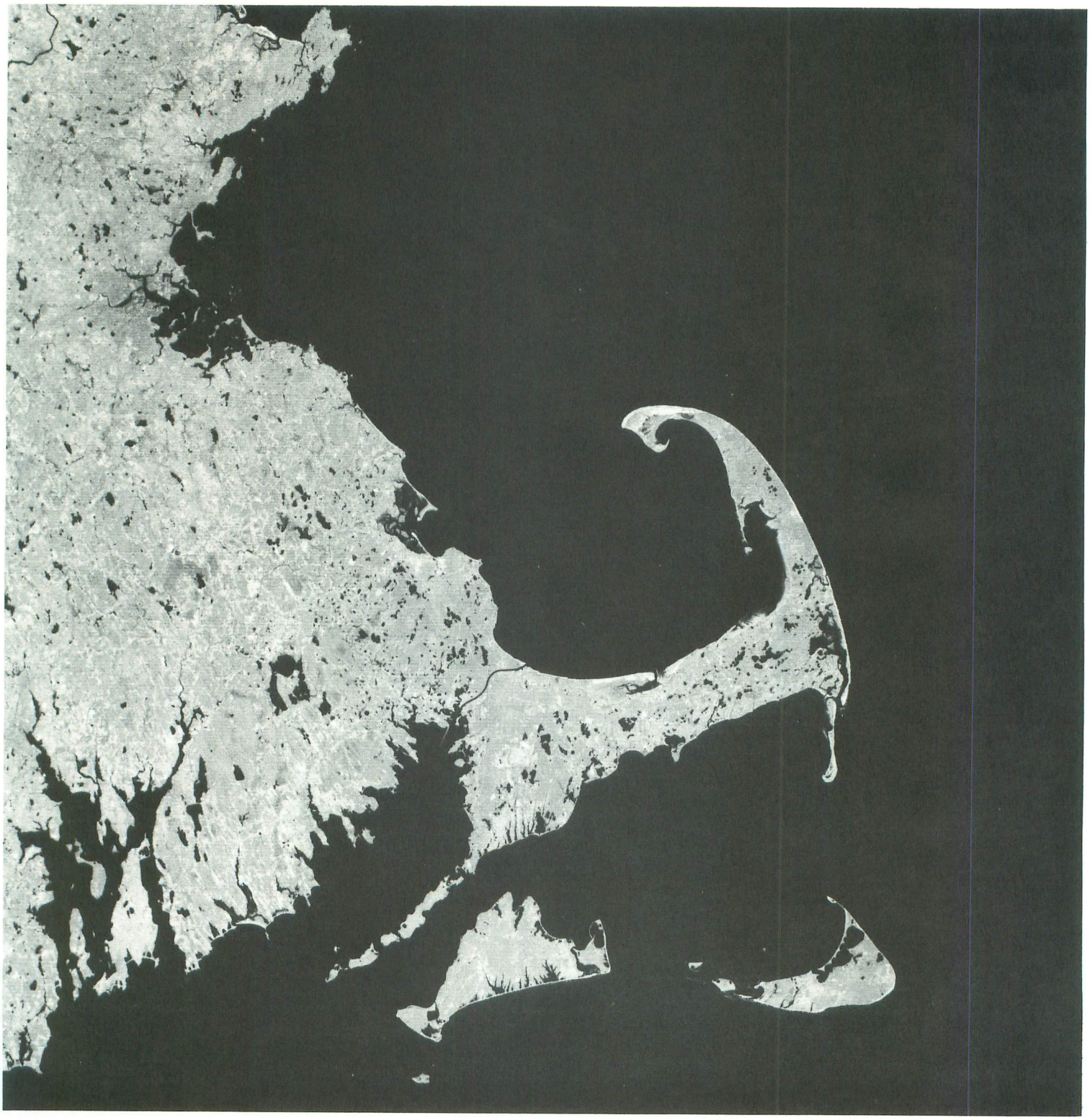
Sea Grant research, education, and advisory services create a continuous process for bringing about advances in ocean industry and coastal management. First, each research project undertaken as part of MIT's program identifies the benefits of investigating a specific marine opportunity or problem, and addresses potential users of the project's results. In this pragmatic fashion, Sea Grant research reflects and responds to current technological and societal needs.

Second, Sea Grant synthesizes interdisciplinary approaches to ocean opportunities, and draws together scientific and engineering talents that collaborate in solving marine problems. Users often participate directly in projects by contributing matching funds, data, and "real-world" perspectives. Students involved in Sea Grant research and education gain practical, career-oriented experience in ocean and coastal engineering, marine policy, and coastal land use management.

Third, the program's advisory services translate research findings into usable forms and transmit these results to users who can apply the new technologies in industry and government. As well, advisory assistance to industrial and civic constituencies often uncovers further marine opportunities and problems that Sea Grant researchers can tackle.

During MIT's fourth year as an institutional Sea Grant program, the commitment of Institute faculty, research staff, and students to Sea Grant goals, corresponding support from participating industries, organizations, and agencies, and the enthusiasm of program staff have made our Sea Grant process a productive source of accomplishments for advancing the nation's use of ocean and coastal resources. In November 1976, Dr. Ira Dyer, Head of the Institute's Department of Ocean Engineering, resigned the directorship of the MIT Sea Grant Program to devote full attention to his departmental and teaching duties. As his successor, and in recognition of their roles in guiding the program's founding and successful growth since 1970, I dedicate this MIT Sea Grant Program annual report for 1975-1976 to Dr. Alfred A. H. Keil, the program's first director and Dean of MIT's School of Engineering, to Dr. Dyer, and to all who are working to bring the oceans into America's future.

Dean A. Horn
Director



Advising Industry on the Ocean's Potential

United States industry will play a major role in augmenting the nation's uses of the oceans. Through pragmatic research and innovative advisory services, the MIT Sea Grant Program serves industry's interests in the seas.

The MIT Sea Grant Program's Marine Industry Advisory Service joins industry and academia to promote the application of new technologies to business opportunities in the oceans.

The oceans offer American industry both a rich source of raw materials and opportunities for developing innovative products and technologies for marine markets. Seeking to advance industry's uses of the seas, and building upon the Institute's tradition of working ties with the nation's business community, Sea Grant's Marine Industry Advisory Service (MIDAS) has established a mutually beneficial partnership between the MIT Sea Grant Program and more than eighty member companies of national and international stature.

As one component of MIDAS, the MIT/Marine Industry Collegium keeps participating firms abreast of economically significant opportunities for new enterprises in marine-related areas. During this past year, MIDAS's first, the Collegium issued five briefs on aspects of marine resource or product development. These briefs, "Chitin and Chitin Derivatives," "Offshore Mining of Sand and Gravel," "Telemanipulators for Undersea Tasks," "Advances in Underwater Welding," and "Untethered Robot Submersible Instrumentation Systems," help members to identify and exploit profitable marine business opportunities. During workshops based on selected briefs, Collegium companies discussed their interests with subject experts and with each other.

Through these briefs, and through information services and personal advisory contact, Sea Grant's Collegium affords industry direct access to university-based knowledge that companies can use to make sound, profitable decisions. In turn, Collegium members give Institute faculty and the MIT Sea Grant Program a business perspective that makes the Institute's research even more responsive to industry's needs. As an example, members' response to the opportunity brief on undersea telemanipulators has resulted in a Sea Grant project for 1976-1977 that, with industry participation, will explore marine applications of these devices.

The Collegium's companion effort in MIDAS is the Marine Industries Business Strategy Program (Maribus), an intensive study of a selected marine resource, product, or service that has high economic potential for industry. The first Maribus investigation, being completed by researchers in MIT's Center for Policy Alternatives, examines the technical and economic factors affecting prospects for industrial use of chitin and protein obtained from shellfish processing wastes. Companies can use the data and business strategies generated through this study for developing and marketing chitin-based products and recovered shellfish protein.

Sea Grant research results, adopted by commercial users, may bring economic benefits to the United States's foreign and domestic trade.

Periodically, the National Oceanic and Atmospheric Administration's Office of Sea Grant supports research with a national public interest focus that is administered separately from an institution's established Sea Grant program. During the past year, investigators in the Institute's Center for Policy Alternatives have analyzed the potential economic impact of selected research projects from Sea Grant programs around the country, with special reference to the United States's balance of payments. Projects fall primarily into the category of living marine resources, such as fishing, food processing, aquaculture, and pharmaceuticals and fine chemicals, as well as categories including marine mining and waste treatment. The study's results should be invaluable in demonstrating issues in technology innovation and in providing policy guidance to enhance the National Sea Grant Program's economic and foreign trade impact.

Engineering New Uses of the Oceans

As the United States turns toward the seas, new technologies developed by ocean engineers will be essential for extracting marine resources and constructing offshore facilities. The MIT Sea Grant Program produces innovative techniques for using the seas through research on materials and methods for ocean engineering, and prepares Institute students for careers in the oceans.

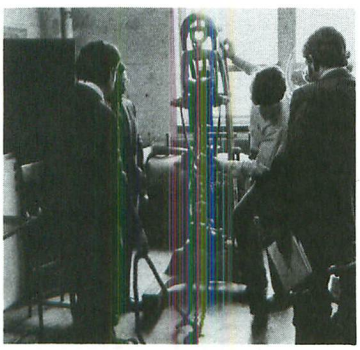
New methods for welding and cutting metals underwater will make possible more efficient and economical repairs on metal structures in the sea.

Building on their basic studies of underwater welding and metal cutting, Sea Grant researchers at MIT continued during 1975-1976 the development of new and improved techniques and equipment for the construction and repair of pipelines, piers, and oil rigs at sea. Tests of their new invention, a stud welding system for joining underwater the components of large offshore structures, show that strengths of these welds are comparable to those of stud welding done in air. Patents are pending on the underwater stud welding equipment.

Researchers are also working on a new process, flux-shielded arc welding, that shows promise for deep-sea tasks. Within a watertight enclosure, the flux shield provides thermal insulation that can prevent the embrittlement and rapid cooling that weakens welds. During June 1976, the Sea Grant project investigators field-tested flux-shielded arc welding at a site in the Baltic Sea as participants in the joint U.S.-West German scientific program of the National Oceanic and Atmospheric Administration's Office of Manned Undersea Science and Technology.

Design criteria for multipurpose offshore platforms, developed through Sea Grant studies, may help to expand the effective use of ocean space.

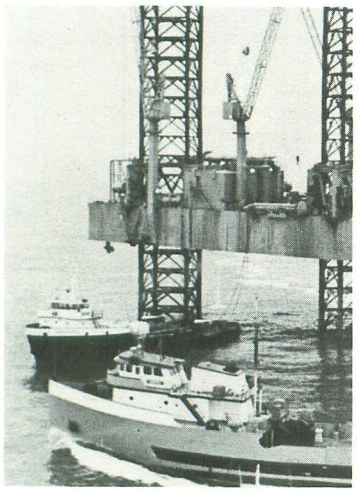
Offshore platforms could house a variety of industrial activities such as oil unloading and storage, fish processing, and power generation. Joining several compatible functions on a single platform could make possible more efficient use of an offshore structure, and Sea Grant research on design criteria for these types of platforms can guide the government agencies and industries that will plan them. Working on multipurpose offshore platform design, ocean engineers at MIT have completed conceptual plans and cost/benefit analyses for one type of platform that would combine an oil storage terminal with a processing plant to convert natural gas into ammonia or urea for fertilizers.



Art Clifton, Sea Grant's Marine Liaison Officer, and Cliff Goudey, MIT graduate student, demonstrate new trawl door hook-up gear to Phil Coates, Assistant Director, and Jim Costakes, Senior Information Officer, Massachusetts Division of Marine Fisheries.

Sea Grant contributes to fishermen's safety through improved gear for hooking up trawl doors on fishing vessels.

Before a side or stern trawler can haul aboard its net, the otter doors, which spread the net's mouth during a tow, must be secured by crewmen at the gallows frames before the filled net can be emptied on deck. The traditional dog chain and "G" link method used to disconnect and suspend the doors is hazardous, especially in rough seas when hand and arm injuries are common. To lessen this danger, and to increase efficiency in the trawling operation, Sea Grant researchers at MIT have invented a system that uses a simple attachment to the hanging bollard through which the net tow cables run, and ball and socket couplers to hook up each door. The crewmen need not approach the gallows until the doors are securely in place, when the rest of the trawl can be uncoupled and hauled in. The new trawl door hook-up system can be used with the standard "G" links, but couplers offer the added advantages of a built-in swivel, faster operation, and a spring to prevent accidental uncoupling of the doors if the tow cables slacken. Not only will the redesigned door hook-up gear speed net hauling and setting, but it will also improve fishing vessel safety to reduce injuries and bolster crew morale.



The United States's extended jurisdiction in the oceans will require the seaward implementation of regulations governing offshore technologies.

As the nation's industries move into the oceans, and as the United States extends its Federal jurisdiction offshore through domestic legislation such as the Fishery Conservation and Management Act of 1976 or through treaty arrangements from the United Nations Law of the Sea Conference, new regulatory frameworks will be required to guide offshore developments. To assist the agencies and organizations responsible for such regulations, the MIT Sea Grant Program has initiated a study on regulatory regimes governing industrial activities at sea under extended national jurisdiction. Working with concerned agencies and representatives of ocean industries, project investigators have created dynamic models of the regulatory process governing three major uses of the ocean—oil and gas extraction, fisheries, and dumping of wastes. When these first models are extended to other offshore activities, the Sea Grant researchers expect that their examination of Federal regulatory objectives under extended jurisdiction, and of options for new technology needed to implement the regulations, will benefit government agencies, congressional committees with related legislative interests, ocean industries, and coastal states.

Dr. Harold E. Edgerton, Institute Professor Emeritus, operates side-scan sonar for summer ocean engineering laboratory participants.

Sea Grant's summer laboratory enables Institute students to apply classroom knowledge to practical ocean engineering problems.

For the past several summers, MIT and Maine Maritime Academy students participating in the MIT Sea Grant Program's summer ocean engineering laboratory have gained practical experience in developing equipment for and applying technology to marine activities. Following fall and spring terms spent in classrooms and laboratories, where experimental equipment is designed and constructed, the undergraduate students spend the summer months performing field trials of instruments and techniques. This past summer, in Castine, Maine, a group of Institute sophomores and Academy students built and tested small, buoy-mounted electric generators powered by winds or by tidal currents; measured forces in a mooring leg and constructed a line tension meter; adapted an Australian scallop dredge handling device for use with an oceanographic bottom sampling drag; and developed equipment for measuring the efficiency of the Maine Maritime Academy's floating breakwater, among other projects.

A second group of MIT juniors and seniors remained in Cambridge to work on improving the reliability and accuracy of a free-swimming underwater robot that can be programmed to collect oceanographic and ocean engineering data. This robot submersible, which has been the summer laboratory's major project since 1973, inspired the MIT/Marine Industry Collegium's opportunity brief and workshop on "Untethered Robot Submersible Instrumentation Systems." The students also built a preliminary model of a tethered vehicle designed to pick up small objects on the ocean floor, and refined their operating model of the "undercycle," a pedalled underwater vehicle for scuba divers.

Sea Grant fosters coherent educational programs in marine science and engineering at MIT.

In February, 1976, Professor J. Kim Vandiver of MIT's Department of Ocean Engineering was named the second Henry L. Doherty Assistant Professor in Ocean Utilization (chairs endowed under Sea Grant administration through the generosity of the Henry L. and Grace Doherty Charitable Foundation, Inc.). During the coming year, Professor Vandiver will apply this career development support in his research on analytic techniques for predicting the dynamic response of offshore structures to random ocean waves.

Through curriculum development related to Sea Grant goals, during academic year 1975-1976 the MIT Department of Ocean Engineering offered four new subjects, Hydrostatics, New Linear Wave Propagation, The Sea and Society, and Offshore Petroleum Exploration and Development. With Sea Grant support, professors in the department are also preparing a much-needed textbook for advanced undergraduates on random processes in ocean engineering.

The nation's coastlines, with their dense concentrations of people, industry, and commerce, are also fragile environments enormously productive of marine life and invaluable areas for recreation. Research and education sponsored by the MIT Sea Grant Program aid Massachusetts's attempts to balance such conflicting uses of the coastal zone.

A Sea Grant-sponsored methodology for evaluating shoreland uses could be a useful coastal management tool for state agencies.

The MIT Sea Grant Program's continuing interest in and involvement with the Commonwealth's efforts in planning for coastal management under the Federal Coastal Zone Management Act of 1972 was reflected during 1975-1976 in research on public sector and private industry needs in the New England coastal zone. Assuming that industry's voice as well as environmental concerns are essential for a workable coastal management plan, the project investigators used case studies from Massachusetts of three state environmental laws, the Wetlands Protection Act, the Massachusetts Environmental Policy Act, and the Energy Facilities Siting Act, to identify the motivations of users of the coast and to determine these users' methods of communicating their interests. This Sea Grant research should increase understanding of private industry's perspective on and involvement in public environmental issues, and should assist state planners to construct a governing framework more conducive to private sector participation in evolving Commonwealth policies.

Student internships with state agencies and marine industries provide practical training in environmental management and ocean engineering.

Seeking to broaden students' educational experiences, the MIT Sea Grant Program in 1976 sponsored a trial project to determine the value of student internships with Massachusetts government agencies. Through such internships, participating students would gain real perspectives on putting their learned skills to work, while the designated agencies would have assistance in resolving a current issue or problem. During the spring term, an intern from MIT's Department of Ocean Engineering worked in the Commonwealth's Executive Office of Environmental Affairs evaluating the progress of Massachusetts's construction grants for the building of wastewater treatment facilities. This agency's favorable response to the student's accomplishments assures Sea Grant's efforts to continue these internships.

Sea Grant's interdisciplinary systems design subject puts students to work on complex current problems in the use of coastal resources.

During the 1976 spring term, Institute students enrolled in the interdisciplinary systems design subject sponsored by the MIT Sea Grant Program studied the technical, economic, and legal factors that affect possible development of the harbor area in Lynn, Massachusetts. Slowed economic growth in the state has meant difficult times for this coastal industrial city, and the students' research shows that new uses for the once-bustling harbor could help to revitalize Lynn's commercial base. City officials, presented with preliminary findings in May, 1976, are so interested in this project that a more comprehensive investigation will be undertaken during the summer months by two MIT graduate students, one from the Department of Urban Studies and Planning and the other from the Department of Ocean Engineering.

Technologies for Coastal Waters

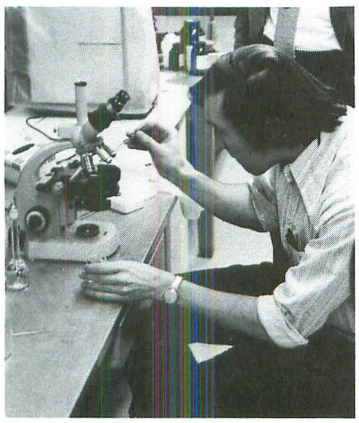
America's continued use of its rich ocean and coastal resources depends upon our ability to understand and hence maintain stable, productive environments in offshore waters and shorelands. To advance this understanding, MIT Sea Grant researchers discover new methods for describing hydrodynamic and biochemical processes in bays and estuaries.

Determining physical processes in bays and making possible the rational use of coastal waters are goals of Sea Grant's major study on Massachusetts Bay.

Mathematical models that predict the hydrodynamics of Massachusetts Bay will help the Commonwealth preserve its fertile coastal waters while fostering the onshore development that is crucial for its economy. While natural decay and dispersion now maintain the bay's environmental stability, coastal zone planners and environmental engineers need to know the limits of these processes for handling fresh- and wastewater effluents. The MIT Sea Grant Program's major research project on the physical processes and seawater environment in Massachusetts Bay provides such information.

Sea Grant researchers in the Institute's Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics have developed descriptive computer models in addition to conducting field measurement programs on the Massachusetts Bay's currents and chemical composition. CAFE-1 and DISPER-1, two-dimensional models that predict the bay's circulation and pollutant dispersion processes, have been verified through observed data, and are now being documented for dissemination to industries, utilities, and environmental engineering consulting firms. Project investigators are also creating a stochastic dispersion model that will estimate the sensitivity of the bay's response to variations in winds, tides, and effluents, and allow environmental planners to establish a range of confidence in the circulation and dispersion models.

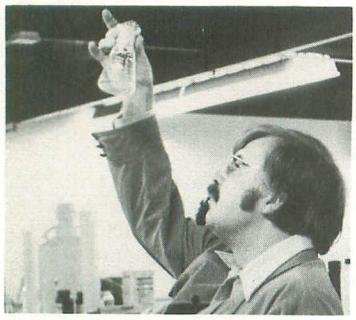
The Massachusetts Bay models are applicable to hydrodynamic processes in other offshore waters as well. During the past year, the models have been used for thermal outfall studies at the Boston Edison Company's Pilgrim Nuclear Power Plant in Plymouth, Massachusetts, and for site evaluations of the B. L. England Station at Great Egg Harbor, New Jersey, and in Moreton Bay, Australia. With techniques from estimation and optimization theory, researchers have incorporated into the models a capacity for improving the design of cost-effective water quality monitoring systems and sampling stations.



Don Anderson, MIT graduate student in civil engineering, studies red tide algae under the microscope.

Understanding the causes of toxic dinoflagellate blooms may aid prediction and management of red tides.

During 1975-1976, Professor Francois M. M. Morel, Sea Grant's first Henry L. Doherty Associate Professor in Ocean Utilization, continued his research on the role of heavy metals in the destructive dinoflagellate blooms, or red tides, that have occurred regularly in New England waters during the past four years. Recent findings in Professor Morel's laboratory indicate that trace amounts of copper in seawater may inhibit the growth of Gonyaulax tamarensis, the red tide alga, and that an influx of organic substances into coastal waters may bind up the dissolved copper, thus preventing its toxic effect on G. tamarensis and allowing the organisms to bloom.



Sea Grant site visit 1976: Dr. B. J. Copeland, Director of the North Carolina Sea Grant Program, observes a flask of Gonyaulax tamarensis in Professor Morel's laboratory.

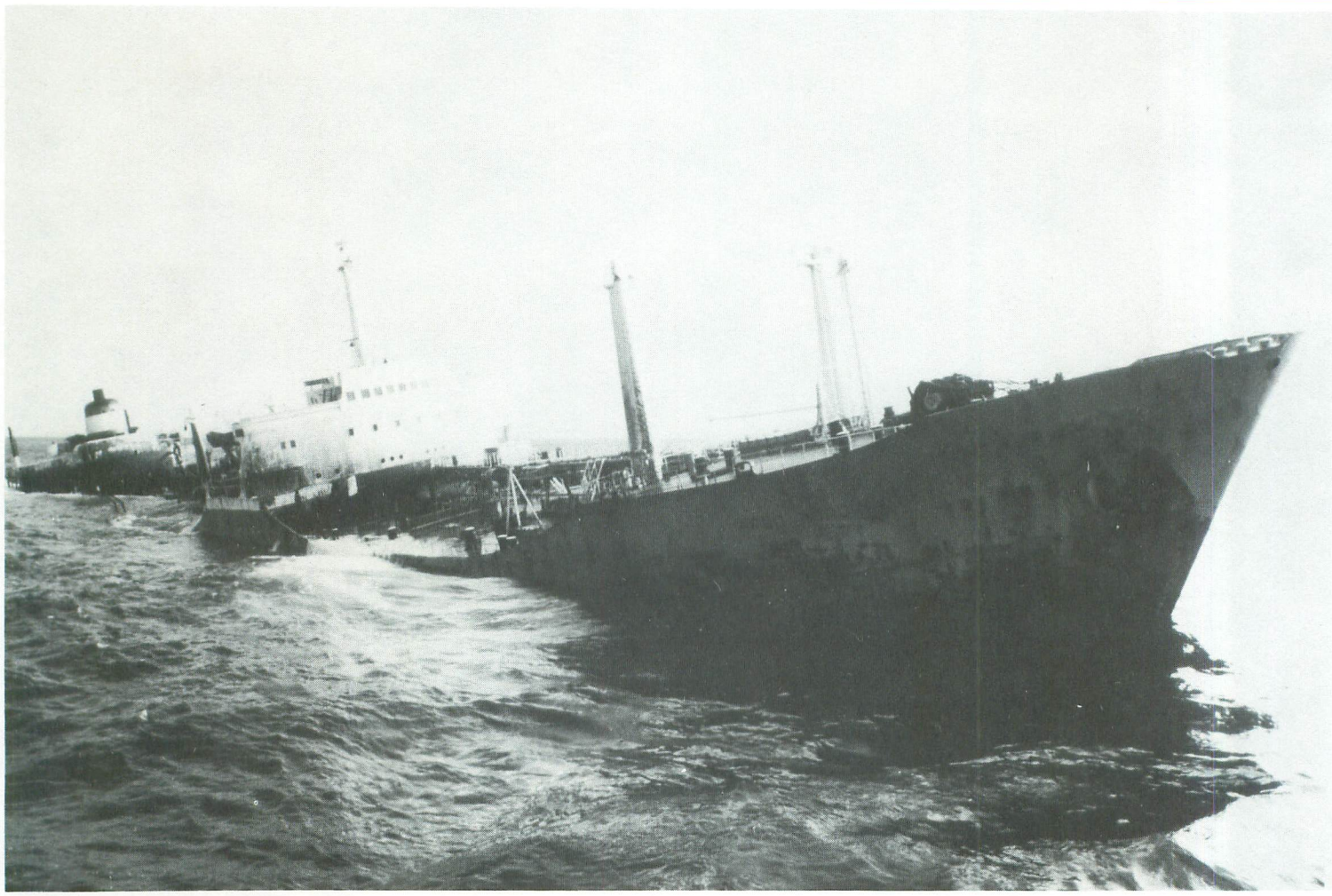
An innovative method for predicting red tides may be of value to the New England shellfishing industry.

When red tides appear in New England waters, filter-feeding clams and mussels concentrate the algal toxins and cause paralytic shellfish poisoning in persons who may eat the molluscs. To help local shellfishermen anticipate blooms of Gonyaulax tamarensis and plan appropriate harvesting and marketing strategies, the MIT Sea Grant Program and the Environmental Management Institute are examining the feasibility of an airborne, remote-sensing, spectrofluorometric system for detecting the dinoflagellate before its population reaches bloom levels. Thus far, researchers have determined how the typical algal pigmentation and fluorescence of G. tamarensis differ from those of other common algae and chemicals in the seawater to establish the practicability of the sensing concept and equipment.

A mathematical model of wave action on large objects in the sea will assist designers of offshore structures.

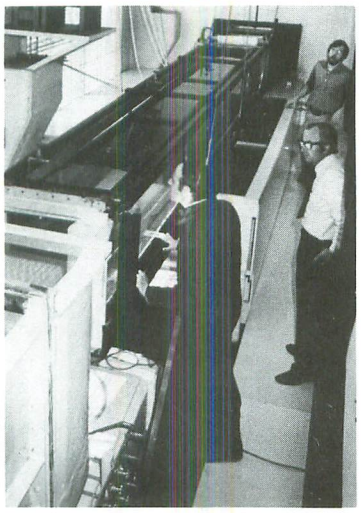
Energy industries that build offshore structures for oil extraction and storage or for power generation must be able to estimate the effects of ocean waves on the platforms or man-made islands that they construct. Because laboratory tests to gather design data on ocean structures are often expensive and limited in scope, Sea Grant researchers at MIT have developed a computational method for calculating and predicting the effects of ocean waves on stationary, three-dimensional objects at sea. This mathematical technique that can supplement simulated tests in wave tanks allows planners to determine how waves of various heights will scatter around the boundaries of offshore structures, and to account for wave forces in designing deepwater ports, oil terminals, man-made islands, floating platforms, or submerged storage tanks.

Civil engineers involved in this research presented their findings to the 11th Symposium on Naval Hydrodynamics at Imperial College in London in the spring of 1976. In a related Sea Grant project, a professor in MIT's Department of Ocean Engineering has prepared a review paper on current methods for determining wave forces on man-made structures at sea; the paper will be delivered in Trondheim, Norway, at the International Conference on the Behavior of Offshore Structures in August 1976.



Liberian tanker, "Argo Merchant" grounded on Nantucket Shoals, December 1976. Photograph by Edward C. Kern, Jr., Celerity Offshore.

The oceans not only hold vital reservoirs of petroleum beneath the continental shelves, but also serve as highways for shipping imported oil. The MIT Sea Grant Program seeks ways to understand and control the environmental impacts of oil spilled upon the sea's surface during transit or offshore drilling.



Dr. Jerome H. Milgram, associate professor of ocean engineering, Norman Doelling, MIDAS Manager, and Bob Van Houten, ocean engineering graduate student, with the precision flume.

Sea Grant studies of oil spills at sea should improve design and deployment of spill containment and collection devices.

Continuing the MIT Sea Grant Program's commitment to research on the economic and environmental impacts of offshore oil development, ocean engineers embarked during 1975-1976 on a new project designed to demonstrate the behavior of oil slicks on the surface of the ocean. Supported by Sea Grant and the National Science Foundation's Division of Engineering, project investigators have constructed in their laboratory a unique precision flume. This thirty-foot long channel has exactly aligned sides that minimize turbulence, allowing accurate measurement of the effect on spilled oil of simulated seawater currents.

Because floating barriers and booms have proved unable to contain spreading slicks in the presence of currents faster than one knot, researchers will use the flume, the first of its kind known to exist, to observe the unstable boundary between oil and the moving water that pulls bubbles of oil beneath containment barriers. Scientists' exact understanding of such instabilities will rely on the kinds of experimental measurements made possible by the new flume. The Sea Grant researchers will use their test results to specify the most effective methods and equipment for cleaning up the spills at sea.

Clues from World War II may serve environmental engineers analyzing potential offshore oil impacts.

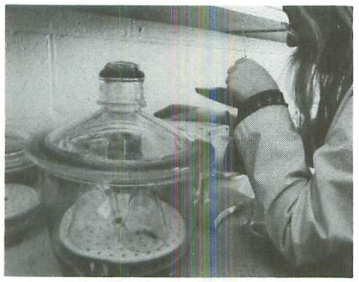
During World War II, primarily in 1942, a number of tankers transporting oil along the United States's Atlantic Coast were torpedoed and sunk offshore. Cleanup efforts were minimal, and slicks from these shipwrecks fouled miles of coastline with spilled oil and sludge. To augment current efforts at predicting the environmental effects of major oil spills, an MIT Sea Grant project is analyzing available information on tanker sinkings within fifty miles of shore, including the amount of oil spilled, type of crude or refined product carried, and the location of spill origins and beachings. For the most severely affected shorelands, project investigators are attempting to document natural environmental recovery and residual damage from fouling by cargo oil spilled from the sunken ships. They have correlated computer simulations of the movements of the oil spills with historical data on sightings. The researchers expect their findings to prove valuable in current debates that surround the estimated environmental impacts of offshore petroleum and deepwater ports.

Computer models of oil spill trajectories provide a useful tool for environmental impact analysis.

Several studies supported by the MIT Sea Grant Program have resulted in mathematical models that predict statistically the directions in which seaborne oil spills are carried by winds, currents, and waves. To ensure that these models reach the government agencies, public utilities and industries, and consulting firms that can use them, a Sea Grant advisory project has documented and prepared standardized input data and users' manuals for four computer programs on offshore oil spill trajectory simulation, nearshore spill tracking simulation, wind transition matrices for both the offshore and onshore models, and, in a model useful for ocean engineering design analysis, two-dimensional lifting flow around two symmetrical bodies.

Sea Grant's proven capacity to augment MIT's marine research has brought the Institute significant additional funding, passed through the Office of Sea Grant from the National Oceanic and Atmospheric Administration's Office of Deepwater Ports. Administered through the MIT Sea Grant Program, this support will enable Institute researchers to evaluate all of the various computer models created for practical application in predicting the trajectories of oil slicks from the original spill sites at sea. The project's goal is to determine the best methods for assessing the environmental risks associated with deepwater port development.

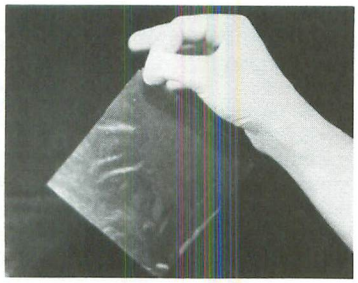
With proper management, the ocean's living resources can furnish vastly increased amounts of food and useful raw materials to mankind. The MIT Sea Grant Program is working to expand United States markets for seafood and marine products.



Sea Grant studies on cholesterol in finfish and shellfish will provide nutritional information for preventive medicine and public health programs.

Doctors and dieticians who prescribe dietary regimens for persons with high blood cholesterol levels, arteriosclerosis, and heart disease need detailed data on lipid components in commonly eaten seafoods. Thus, MIT food scientists supported by Sea Grant are determining the content and composition of physiologically important lipids, such as cholesterol, in raw and cooked finfish and shellfish. Using analytical methods for lipid extraction, and gas chromatography for cholesterol identification, the researchers have tested samples from more than thirty species of fish and shellfish; for some species, they have been able to analyze several samples that differ in time and place of capture.

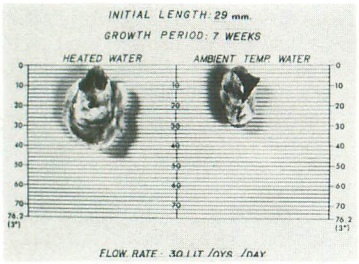
During 1975-1976, the food scientists completed a comparative study of oil- and water-packed canned tunas, and verified their findings that finfish and, contrary to most previously published data, lobster, contain less cholesterol than meats and dairy products. The researchers anticipate extensive applied use of their results in the fields of medicine and nutrition, and by food processors who must quantify the nutritional values of seafoods to meet labeling requirements.



Sea Grant research on the structure of chitin and chitosan promotes the application of these useful materials in numerous commercial products and processes.

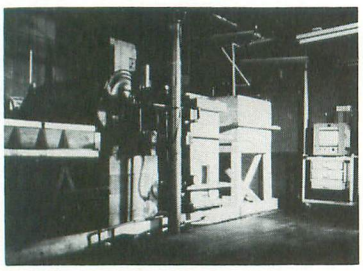
Chitin, the natural polysaccharide related to cellulose, is abundant in shellfish-processing wastes. Its derivative, chitosan, may have many promising applications in medicine, papermaking, adhesives, natural and synthetic fibers, pharmaceuticals, waste treatment and monitoring, agriculture, and food processing. Seeking to foster commercial uses for chitin and chitosan, researchers in a continuing MIT Sea Grant project have developed clear, flexible films cast of chitosan. They have found that chitosans obtained from several shellfish species have similar crystalline structures, but that processing methods cause variations in chitosan's properties that affect the usefulness of the films. The best films that project investigators have made thus far rival commercial plastic food wraps: they have a high tensile strength and are insoluble in water and impervious to air. Additional Sea Grant data on the chemical and structural characteristics of chitin and its derivatives should prove valuable to industries that wish to develop new products from these materials.

Spurred by industry's growing interest in chitin and chitosan, and by new research findings at MIT and other universities, the MIT Sea Grant Program and the Massachusetts Science and Technology Foundation have begun planning a major symposium on the properties and potential uses of these polymers. The First International Conference on Chitin/Chitosan is scheduled for April 11-13, 1977, in Boston, and will draw participants from industry and academia worldwide.



The productivity of oyster aquacultural systems could be augmented by the use of power plants' thermal effluents.

Studies show that the heated cooling water discharged from electric power plants can be used to maintain cultivated oysters' high summer growth rates year-round. During 1975-1976, researchers in a joint project of the MIT Sea Grant Program and the University of Massachusetts Aquacultural Engineering Laboratory in Wareham, Massachusetts, completed their demonstration of the indirect use of thermal effluents from power generation for raising oysters in a small-scale aquacultural system. The Sea Grant investigators analyzed the technical efficiency and the capital and operating costs of various types of heat exchangers, which are required to transfer heat from the warmed effluents to the seawater in which the oysters are actually raised. Results indicate that economic operation of such a system may require supplemental winter feeding to maintain nutrient levels adequate for the oysters' increased growth rates. This study's findings may spark "recycling" of presently unused heated effluent water for producing commercially grown shellfish.



Aquacultural engineering advisory services have helped to boost the productivity of shellfisheries in Massachusetts and New England.

Working with the University of Massachusetts Aquacultural Engineering Laboratory in Wareham in an advisory program that ended this year, Sea Grant staff provided expert assistance to shellfishermen, aquacultural concerns, and local seacoast towns on technical and scientific problems in the shellfishing and aquacultural industries. Individual staff contacts, workshops, and special advisory projects for several towns formed the foundation of this innovative service. Upon completion of the project, a thorough survey of users revealed general satisfaction with the concept and some activities of Sea Grant's aquacultural engineering advisory service, and brought forth concrete recommendations for improvements in operation should the service be reestablished in response to future needs.


CLIPPER
SOLE

Advisory Services for Tomorrow's Oceans

Sea Grant's value to society comes not only from pragmatic research projects and education for marine careers, but even more from its commitment to translating the results of marine and coastal research into usable forms for those who will put these results to work.

Through its advisory services to industries, local and regional government, institutions, and individuals, the MIT Sea Grant Program ensures that research dollars will go far in advancing society's wise use of the seas and coasts.

Sea Grant symposia, short courses, and lectures educate public and professional audiences on marine issues facing the nation.

The highlight of Sea Grant advisory services symposia during 1975-1976 was October's Fourth Annual Sea Grant Lecture, "The Science, Engineering, Economics, and Politics of Ocean Hard Mineral Development." Participating in a lively discussion of industrial, governmental, and academic perspectives on the mining of seabed manganese nodules were John E. Flipse, President of Deepsea Ventures, Inc., who delivered this year's lecture, and panel respondents Professor Roger G. Burns of MIT's Department of Earth and Planetary Sciences; Marne A. Dubs, Director of the Kennecott Copper Corporation's Ocean Resources Department; Leigh S. Ratiner, Administrator of the Ocean Mining Administration, U.S. Department of the Interior; and Sergio Martins Thompson-Flores, Counsellor of Embassy, Brazilian Mission to the United Nations.

The MIT Sea Grant Program presented several other well-attended symposia during the past year. Eight lectures on "Energy and the Environment" were given by Sea Grant and the New England Aquarium with support from The Lowell Institute. Speaking to audiences of concerned citizens, experts discussed current topics in the economics and environmental impacts of offshore oil, deepwater ports and supertankers, and alternative energy sources. In April 1976, Sea Grant and the MIT/Marine Industry Collegium hosted a workshop for representatives from industry and government agencies that explained the new precision flume's potential role in oil spill studies and presented new findings related to oil slick behavior in ocean currents. Also during April, the MIT Sea Grant Program was one cosponsor of "Coastal Recreation Resources in an Urbanizing Environment," a conference held on Cape Cod by the University of Massachusetts Cooperative Extension Service.

During the summer of 1975, the Sea Grant Program cooperated with the MIT Office of the Summer Session in offering to practicing professionals from industry and government four week-long courses, Detection, Estimation, and Modulation Theory; Engineering and Environmental Aspects of Heat Disposal from Power Generation; Ocean Resources Management: Legal and Policy Aspects; and Analysis and Design of Transportation Systems.

Through its advisory services, the MIT Sea Grant Program continues its successful interactions with local and regional constituencies.

To promote more effective marine advisory services for citizens of the Commonwealth, the MIT Sea Grant Program is collaborating with the University of Massachusetts Cooperative Extension Service to establish a joint marine advisory service that will be inaugurated in July 1976. This extension educational program will be an important vehicle for disseminating the results of Sea Grant and other marine research to coastal and consumer clienteles in Massachusetts.

The MIT Sea Grant Program also participates in the New England Marine Advisory Service (NEMAS), a consortium of the region's Sea Grant schools and marine-oriented institutions. Through advisory talent-sharing and cooperative projects, NEMAS responds to regional needs for information pertinent to ocean and coastal zone activities. Sea Grant's Advisory Services Officer is a member and Vice Chairman of the NEMAS Board of Directors.

The MIT Sea Grant Program maintained its advisory links with state government over the past year. Professor Judith T. Kildow of MIT's Department of Ocean Engineering was the Sea Grant representative on the Governor's Task Force on Coastal Resources, a citizens' group appointed to as-

sist the Commonwealth's Office of Coastal Zone Management in policy matters; the Program's editor serves on the Task Force's Public Participation Committee. Sea Grant's Marine Liaison Officer is a member of the Lieutenant Governor's Massachusetts 200-Mile Work Group, and has participated in a national planning meeting on advisory activities related to the 200-mile fisheries management zone.

The Massachusetts Division of Marine Fisheries joined the MIT Sea Grant Program, NEMAS, and the New England Fisheries Steering Committee to ensure efficient manufacture of the new Sea Grant towing block and its distribution to the region's side trawlers. The Division of Marine Fisheries was instrumental in obtaining a New England Regional Commission grant for the construction of ten prototype blocks that will be tested under actual fishing conditions. The MIT Sea Grant Program also continued its cooperative project with the Massachusetts Beach Buggy Association to demonstrate the effectiveness of a new, vigorous strain of American beach grass for stabilizing a washed-over section of Nauset Beach on Cape Cod.

MIT's seagoing research capabilities were increased in August 1975 by the long-term charter to the Institute of a U.S. Army T-Boat, loaned on arrangement through the Oceanographer of the Navy. Under the direction of Sea Grant's Marine Liaison Officer, the vessel was activated in Charleston, South Carolina, and brought under its own power to winter berthing at the Massachusetts Maritime Academy on Buzzards Bay. The T-Boat's equipment and accommodations will be adapted to meet Institute needs for a full-fledged research ship. The first conversion phase was completed at a local shipyard in June 1976, and the vessel has been moved to a permanent mooring at the New England Aquarium on Boston's Central Wharf.

Program Management	Sea Grant Program Management	Dr. I. Dyer	Continued project
	Project Development Opportunities	Dr. Dyer and Mr. D.A. Horn	Continued project
	Henry L. Doherty Professorships in Ocean Utilization	Dean A.A.H. Keil	Continued project, combined with Sea Grant Program Management project
Education and Training	Interdisciplinary Systems Design Subject	Professor W.W. Seifert	Continued project
	Student Summer Laboratory	Professor A.D. Carmichael	Continued project
	Ocean Engineering Curricula	Dr. Dyer	Continued project
	State Industry Internships	Professor J.T. Kildow	New project; completed project
	Preparation of a Text for a New Course; Random Processes in Ocean Engineering	Professor J.H. Milgram	New and completed project; new subject will be developed
Advisory Services	Advisory Services; Development, Operation, and Management	Mr. E.R. Pariser	Continued project
	Marine Resources Information Center	Mr. Pariser and Mr. J.M. Kyed	Continued project, combined with Sea Grant Communications/ Information Project
	Development of a Marine Industry Advisory Service	Mr. Pariser and Mr. N. Doelling	New project
	Public Education and Training Short Courses	Professor J.M. Austin	Continued project
	Annual Sea Grant Lectureship	Dean Keil	Continued project
	Program Documentation and Preparation of User Oriented Modules	Professor R. Yeung	New and completed project; report will be published
	Aquaculture Engineering Advisory Services	Professor J.W. Zahradnik and Mr. A.B. Clifton	Continued and completed project; report will be published

Research	The Sea Environment of Massachusetts Bay and Adjacent Waters	Professor J.J. Connor, Jr.	Continued project
	A Biochemical Model for Coastal Waters with an Application to Red Tide Outbreaks	Professor F.M.M. Morel	New project
	Evaluation of Potential of Heated Finishing Plant for Oysters	Professors Seifert and Zahradnik	Continued and completed project; report will be published
	Multipurpose Offshore Platform Design	Professor C. Chryssostomidis	Continued and completed project; report will be published
	An Improved Trawl Door Hook-up System	Professor S.P. Loutrel	New project
	Perspectives for Building Public-Private Cooperation in the Coastal Zone	Professor Kildow	New and completed project; report will be published
	Structure of Chitosan	Professor B.L. Averbach	Continued and completed project; report will be published
	Content, Composition, and Fate of Physiologically Important Lipid Components in Raw and Processed Shell- and Finfish	Professor S.A. Goldblith	Continued project
	Numerical Theory of Wave Effects on Offshore Structures	Professor C.C. Mei	New project
	Development of New, Improved Techniques for Underwater Welding and Cutting	Professor K. Masubuchi	Continued and completed project; report will be published
	Oil Slick Control in Offshore Engineering	Professor Milgram	New project
	Oil Spillage Impact Study on World War II Tanker Sinkings	Professor E. Kern	New and completed project; report will be published
	Review and Evaluation of Oil Spill Trajectory Models for Use in Risk Assessment Associated with Proposed Deep Water Ports	Professors Connor and B.R. Pearce	New project
	Regulation of Offshore Technology Under Extended Jurisdiction	Professor J.D. Nyhart	New project
	Spectrofluorometric Remote Sensing of the Red Tide Algae	Professor S. Ezekiel and Mr. G. White	New project
	Survey of Methods of Determining Wave Forces on Offshore Structures	Professor Milgram	New project
	An Analysis of the Potential Foreign Trade Impacts of the Sea Grant Program	Professor J.H. Hollomon	New project

Advising Industry on the Ocean's Potential	Doelling, Norman	The MIT/Marine Industry Collegium	Reprinted from Proceedings of Oceans '76 (The Marine Technology Society and The Institute of Electrical and Electronics Engineers), Washington, D.C., September 1976; paper 4C.
	MIT/Marine Industry Collegium	Advances in Underwater Welding	Opportunity Brief 4. MITSG 76-8. Massachusetts Institute of Technology, Cambridge, Mass.
	MIT/Marine Industry Collegium	Chitin and Chitin Derivatives	Opportunity Brief 1. MITSG 76-5. Massachusetts Institute of Technology, Cambridge, Mass.
	MIT/Marine Industry Collegium	Offshore Mining of Sand and Gravel	Opportunity Brief 2. MITSG 76-6. Massachusetts Institute of Technology, Cambridge, Mass.
	MIT/Marine Industry Collegium	Telemanipulators for Underwater Tasks	Opportunity Brief 3. MITSG 76-7. Massachusetts Institute of Technology, Cambridge, Mass.
	MIT/Marine Industry Collegium	Untethered Robot Submersible Instrumentation Systems	Opportunity Brief 5. MITSG 76-9. Massachusetts Institute of Technology, Cambridge, Mass.
Engineering New Uses of the Oceans	Carmichael, A.D., and D.B. Wyman	Ocean Engineering Summer Laboratory; Massachusetts Institute of Technology and Maine Maritime Academy	MITSG 76-3. Massachusetts Institute of Technology, Cambridge, Mass.
	Keller, G.J., A.D. Carmichael, and S.D. Jessup	A Small Robot Submarine for Oceanographic Applications	MITSG 76-15. Reprinted from Proceedings of Oceans '76 (The Marine Technology Society and The Institute of Electrical and Electronics Engineers), Washington, D.C., September 1976; paper 19D.
Managing Coastal Environments	Kildow, J.T., D. Cramer, L. Newhouse, and K. Barrington	Building Public/Private Cooperation in the Coastal Zone	MITSG 76-4. Massachusetts Institute of Technology, Cambridge, Mass.
	Kubat, Charles	Interim Report on Lynn Harbor Development	Massachusetts Institute of Technology, Cambridge, Mass.

Anderson, D.M.	Copper-Induced Encystment in Gonyaulax Tamarensis	S.M. Thesis, Department of Civil Engineering, Massachusetts Institute of Technology. Cambridge, Mass., 1976.
Christodoulou, G.C., J.R. Pagenkopf, B.R. Pearce, and J.J. Connor, Jr.	CAFE-1: A Two-Dimensional Finite Element Circulation Model	MITSG 76-11. Massachusetts Institute of Technology, Cambridge, Mass.
Christodoulou, G.C., J.R. Pagenkopf, B.R. Pearce, and J.J. Connor, Jr.	DISPER-1: A Two-Dimensional Finite Element Dispersion Model	MITSG 76-12. Massachusetts Institute of Technology, Cambridge, Mass.
Christodoulou, G.C., J.J. Connor, Jr., and B.R. Pearce	Mathematical Modeling of Dispersion in Stratified Waters	MITSG 76-14. Massachusetts Institute of Technology, Cambridge, Mass.
Christodoulou, G.C., and J.J. Connor, Jr.	Numerical Modeling of Dispersion in Stratified Waters	MITSG 76-17. Reprinted from Proceedings of Fifteenth International Conference on Coastal Engineering, Honolulu, Hawaii, July 1976.
DeGuida, R.N., J.J. Connor, Jr., and B.R. Pearce	Application of Estimation Theory to Design of Sampling Programs for Verification of Coastal Dispersion Predictions	MITSG 76-16. Reprinted from Proceedings of International Conference on Finite Element Methods in Water Resources, Princeton University, July 1976.
Milgram, J.H.	Waves and Wave Forces	MITSG 76-19. Reprinted from Proceedings of the International Conference on the Behavior of Offshore Structures, Trondheim, Norway, August 1976.
Morel, F.M.M., J.C. Westall, J.G. Rueter, and J.P. Chaplick	Description of the Algal Growth Media "Aquil" and "Fraquil"	Technical Note No. 16. Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Massachusetts Institute of Technology, Cambridge, Mass.
Morel, F.M.M., and D.M. Anderson	On the Subject of Red Tide Predictions from Temperature Patterns	In Limnology and Oceanography, vol. 21(4):625, 1976.
Morey, K., and E.L. Mollo-Christensen	Design, Development, and Field Trials of a Towed, Instrumented Glider	MITSG 76-20. Massachusetts Institute of Technology, Cambridge, Mass.
Pearce, B.R., and G.C. Christodoulou	Application of a Finite Element Dispersion Model for Coastal Waters	Proceedings of the Sixteenth International Association for Hydraulic Research Conference, Sao Paulo, Brazil, August 1975.
Pearce, B.R., R.N. DeGuida, G.C. Dandy, and S.F. Moore	Sampling Network Design for Dispersion Verification	Proceedings of the Second Annual Symposium on Modeling Techniques for Waterways, Harbors, and Coastal Engineering, San Francisco, California, September 1975.

	Yue, D.K.P., H.S. Chen, and C.C. Mei	A Hybrid Element Method for Calculating Three-Dimensional Water Wave Scattering	MITSG 76-10. Massachusetts Institute of Technology, Cambridge, Mass.
	Yue, D.K.P., H.S. Chen, and C.C. Mei	Three-Dimensional Calculations of Wave Forces by a Hybrid Element Method	Proceedings of the Eleventh Naval Hydrodynamics Symposium, Imperial College, London, England, April 1976.
Oil upon the Oceans	Yeung, R.	Documentation of Four Ocean-Related Computer Models	MITSG 76-18. Massachusetts Institute of Technology, Cambridge, Mass.
Advisory Services for Tomorrow's Oceans	Flipse, J.E., R.G. Burns, M.A. Dubs, L.S. Ratiner, S.M. Thompson-Flores	The Science, Engineering, Economics, and Politics of Ocean Hard Mineral Development; Fourth Annual Sea Grant Lecture and Symposium	MITSG 76-1. Massachusetts Institute of Technology, Cambridge, Mass.
		Industries and Oceans, Citizens and Coasts; a Report on the Massachusetts Institute of Technology Sea Grant Program: 1 July 1974 to 30 June 1975	MITSG 76-2. Massachusetts Institute of Technology, Cambridge, Mass.
	Passero, B.	1976 Directory of MIT Research Projects Related to Marine Resources, Ocean Utilization, and Coastal Zone Management	MITSG 76-13. Massachusetts Institute of Technology, Cambridge, Mass.

Summary of Expenditures by Activity

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.

		NOAA Grant Funds	University Matching Funds
Program Management	Program Administration	$ 48,000	$105,983
	Program Development	48,400	23,590
Marine Education & Training	College Level	38,600	74,700
Socio-Economic & Legal Studies	Marine Economics	197,300	5,531
	Socio-Political Studies	20,000	6,310
Marine Resources Development	Marine Extracts — Other	20,900	12,013
Marine Technology Research & Development	Ocean Engineering	66,500	40,203
	Resources Recovery & Utilization	32,400	23,286
	Transportation Systems	8,800	2,542
Marine Environmental Research	Pollution — Oil Spills	54,200	10,854
	Environmental Models	224,900	119,418
Advisory Services	Extension Programs	186,100	203,233
	Other Advisory Services	52,500	77,441
	TOTAL	$998,600	$705,104

MIT/Marine Industry Collegium Membership 1975-1976

Airco Products Inc.

Arcair Company

Boston Edison Company

Environmental Management Institute

Henry L. and Grace Doherty Charitable Foundation, Inc.

Hobart Brothers Company

International Copper Research Association

Ishikawajima - Harima Heavy Industries Co., Ltd.

Maine Maritime Academy

Massachusetts Division of Marine Fisheries

Massachusetts Energy Policy Office

Massachusetts Institute of Technology

MIT/Marine Industry Collegium Membership

Massachusetts Science and Technology Foundation

National Fisheries Institute

Public Service Electric and Gas Company (Newark, N.J.)

Sea Grant Lecture Endowment Funds

University of Massachusetts

Welding Research Council

Akzona, Inc.

American Cyanamid Company

American Innerspace Corporation

Arthur D. Little, Inc.

BASF Wyandotte Corporation

Becton, Dickinson and Company

Bird-Johnson, Marine Division

The Boeing Company

Bolt Beranek and Newman, Inc.

Boston Edison Company

Carter Chemicals & Services, Inc.

Castle & Cooke, Inc.

Chevron Research Company

Combustion Engineering, Inc.

Continental Oil Company

Deepsea Ventures, Inc.

DeLaval Separator Company

E G & G, Inc.

Environmental Devices Corporation

Environmental Research and Technology, Inc.

Exxon Research & Engineering Corporation

Food, Chemical & Research Laboratories, Inc.

General Dynamics Corporation, Electric Boat Division

General Electric Company, Industrial and Marine Steam Turbine Operations

General Electric Company, Re-Entry and Environmental Systems Division

Gibbs & Cox, Inc.

Gould, Inc.

Grumman Ecosystems Corporation

Harbridge House, Inc.

Frederic R. Harris, Inc.

J.J. Henry Co., Inc.

Hercules, Inc.

High Voltage Engineering Corporation

Hydroacoustics, Inc.

Hydronautics, Inc.

International Minerals & Chemical Corporation

InterTechnology Corporation

Kennecott Copper Corporation

Kimberly Clark

Klein Associates, Inc.

Kockums Mekaniska Verkstads AB

Lockheed Missiles & Space Corporation, Inc.

John J. McMullen Associates, Inc.

Marine Colloids, Inc.

Marine Commodities International, Inc.

Marine Research, Inc.

Massa Corporation

Massachusetts Science and Technology Foundation

Massport

Mitsui and Co., Ltd.

Mobil Oil Corporation

Monterey Transportation Co., Inc.

National Forge Company

New England Electric System

Nomura Research Institute

Oceaneering International, Inc.

Oceanics, Inc.

Pearlson Engineering Co., Inc.

Pechiney Ugine Kuhlmann Development, Inc.

Perry Oceanographics

Pine State By-Products, Inc.

The Plessey Company Limited

Purex Corporation

RCA Corporation

Raytheon Company, Submarine Signal Division

The Rochester Corporation

Sanders Associates, Inc.

Specialized Systems, Inc.

Standard Oil Company (Indiana)

Stanwick Corporation

Stone & Webster Engineering Corporation

Sun Shipbuilding & Dry Dock Company

Texaco, Inc.

Thermo Electron Corporation

Tracor, Inc.

UOP (Universal Oil Products)

Unilever Limited

Union Carbide Corporation

U.S. Coast Guard, Office of Research & Development

Westinghouse Electric Corporation, Oceanic Division

Zapata Technical Services Corporation

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