MIT SEA GRANT PROGRAM
COMPLETION REPORT FOR
COHERENT AREA PROJECT
GRANT NO. 2-35150 FOR
1 JULY 1971 TO 30 JUNE 1973

OCEAN UTILIZATION AND COASTAL ZONE DEVELOPMENT

MIT Sea Grant Program

Completion Report

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Nancy Poling Guest
MIT Sea Grant Editor

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INTRODUCTION

The Massachusetts Institute of Technology was the first American university to offer a degree program in naval architecture. The year was 1893. Currently, it now offers both baccalaurate and graduate ocean engineering degrees and is the largest such graduate program in the nation. There are, in addition, MIT degree programs in oceanography and coastal engineering; and joint degree programs with Woods Hole Oceanographic Institute (WHOI) were established in 1966 in oceanography and later in ocean engineering and biological oceanography.

It was fitting, therefore, that MIT enter the national Sea Grant Program in 1968 with a project that has resulted in the publication of eight textbooks on ocean engineering. From this successful initial effort, the program was expanded into the GH-88 Coherent Area Project, (CAP), "Ocean Utilization and Coastal Zone Management." The CAP was renewed in 1971-1972, and we are pleased to summarize our activities under our renewal grant, Sea Grant No. 2-35150, and to present this second completion report.

The Coherent Area Project for 1971-1972 involved eighteen projects, both interdisciplinary and highly specialized, and an expanding program of education and training in ocean utilization and coastal zone management. The continuing strength of the effort looks forward to a significantly larger advisory services program, which will combine the research efforts of interest nationally with concerted local efforts to help those concerned with the sea and seacoast to use it wisely, to the advantage of Massachusetts and the New England region.

In particular, the overall goals continue to be:

- to transfer and apply MIT research experience in ocean engineering and related fields to ocean utilization and coastal zone development in a way that avoids or minimizes detrimental ecological change;

- to plan and execute research and development projects to achieve this first goal;

- to broaden MIT's educational program in ocean utilization and coastal zone development; and

- to assure expeditious dissemination and utilization of the results of marine-related research and development at MIT.

The MIT Sea Grant Project Office, under Sea Grant Director, Professor Alfred H. Keil, with Dean A. Horn as its executive officer, provides the focal point for all the separate Sea Grant projects and related programs at the Institute that have a common interest in ocean utilization and coastal zone development. While there is ongoing emphasis on interdisciplinary research, the office in the past year has worked hard to develop the invaluable liaisons between MIT and government and private institutions, industries and those who want help on sea-related research.

In the past year, there has been an important increase in participation - from just two institutions in 1970 to five in our 1971-1972 program. Perhaps the most important accomplishment has been to develop a close liaison with several state agencies and regional commissions. We have provided briefings on current important topics to state officials on an ad hoc basis and plan to continue this service. In November 1971, we held our first MIT Sea Grant State-Industry Workshop,and the reactions and responses have been significant and positive. We have also established a State-Industry Advisory Council for our Sea Grant Program. Eleven prominent individuals, including the Executive Vice-President of the Greater Boston Chamber of Commerce, the Director of Massachusetts Science and Technology Foundation, and the representative of the Commonwealth's Secretary for Environmental Affairs, have agreed to serve on the Council.

The report that follows this introduction gives a detailed accounting of all the projects funded in the 1971-1972 Coherent Area Program, Grant No. 2-35150. However, here we briefly highlight four large projects of significance that have been completed and one project initiated under this program that is of central importance in the successor grants.

- Ocean Transportation, under the direction of Professor E.G. Frankel. The project has been completed with the publication by The MIT Press of the book Ocean Transportation by E.G. Frankel and Henry S. Marcus. It provides the most comprehensive review and discussion to date of the factors that affect ocean transportation and will, we believe, serve as a valuable reference work for many years.

- Estuary Modeling, under the direction of Professor A.T. Ippen. The researchers here have devised, successfully tested, and published three reports on mathematical models of estuaries. The models show (1) salinity distribution in a one-dimensional frame-

work as a function of longitudinal distance and time, and (2) salinity and velocity distributions in vertical directions. These models promise much greater efficiency in predicting the effects of effluents discharged than the present, cumbersome physical models.

- Future of Atlantic Ports, under the direction of Professor E. G. Frankel. In the published report, "Studies on the Future of Atlantic Ports," Professor Frankel has forecasted future needs by first projecting demand and then analyzing the type and form of commodity movements required, as well as the most current trends in transportation technology.

- Environmental Impact of a Superport in the Machias Bay Area, under the direction of Professor Stephen F. Moore. The study, which was urgently requested by the Council of Environmental Quality, considered in detail first the specific effects of oil spills on marine organisms and then the potential geographic distribution of oil spills. The research concluded that although oil spills occurring from day-to-day transshipment operations at the tanker berths are relatively insignificant environmentally, the overall environment vulnerability of the Machias Bay region to oil supertankers is very high.

- Offshore Petroleum and New England, under the direction of Professor John W. Devanney, III. The high probability of offshore petroleum deposits on Georges Bank and their utilization with the necessary refineries have posed a challenging project, begun in the spring of 1972 at the request of and sponsored jointly by the New England Regional Commission and the New England River Basins Commission, with additional Sea Grant funding. The aim is to concentrate professional and academic expertise in an urgent study intended to generate estimates of the change in real New England income and regional environmental quality associated with a range of hypothetical petroleum developments on Georges Bank. There are two interrelated and important questions addressed in the work: In the search for oil and in extracting it, what is the net environmental impact and what is the net change in regional income?

In all, we feel that this past year has been extraordinarily successful in showing the possibilities for the enormous contribution MIT can make to the national Sea Grant endeavor.

RESEARCH

Ocean Transportation

PROFESSOR E.G. FRANKEL, DIRECTOR, COMMODITY TRANSPORTATION AND ECONOMIC DEVELOPMENT LABORATORY AND PROFESSOR OF MARINE SYSTEMS, DEPARTMENT OF OCEAN ENGINEERING

The worldwide transportation study, under the direction of Professor E.G. Frankel has been completed with the publication by The MIT Press of Ocean Transportation by Ernst G. Frankel and Henry S. Marcus. The book provides an up-to-date review and discussion of the factors that affect ocean transportation. While there is already much material on ship technology -- summarized here in a chapter on the recent development of ship forms, propulsion systems, control techniques, and terminal designs -- very little has been published on the subjects to which the major portion of the book is devoted: ocean transportation investment and finance, trade commodity flows, management, and labor relations and operations.

The intriguing theme of the book emphasizes that ocean transportation decisions should no longer be made by determining performance on a particular route or in a particular trade. Ocean transportation is today a synthesis of many components and is itself included in a complex system that joins together all the modes of transportation and storage. Decisions can be based only partly on ship design and operation characteristics.

The increasing complexities of finance, labor management, government involvement, and international considerations introduce a multitude of factors quite as significant as those of ship design and operation.

The studies presented in Ocean Transportation are independent and cover each topic as a separate issue, as far as this is possible. The nine parts of the book include: Demand and Supply of Shipping: A World Review, Ocean Transportation Technology, Developing and Using Data on Trade Commodity Flows, Shipbuilding Costs, Ocean Barging: A Review, A Review of Maritime Labor and a Study of the Longshore Industry, Financing of U.S. Shipping, Factors Affecting Shipping Operations, and A Review of Merchant Marine Subsidies with An Analysis of Planning Subsidized Liner Replacement.

Future of Atlantic Ports

PROFESSOR E.G. FRANKEL, DIRECTOR, COMMODITY TRANSPORTATION AND ECONOMIC DEVELOPMENT LABORATORY AND PROFESSOR OF MARINE SYSTEMS DEPARTMENT OF OCEAN ENGINEERING

As the shipping trade is increasing enormously, innovations are required in ships, ship operations, port handling, warehousing, and in particular, cargo handling. It is now urgent that ship cargo connect efficiently with inland transportation systems, thus enhancing the rapidly growing use of intermodal systems in the shipping industry. The new demands placed upon shipping are increasingly making conventional port locations and operations obsolete, with the exception of new container terminals, some dry bulk berths, and certain specialized cargo berths.

The project, headed by Professor E. G. Frankel, is now completed and has published a report entitled "Studies on the Future of Atlantic Ports," which outlines what the eastern seacoast must do to keep pace with international trade. The researchers first undertook to ascertain the needs of the various seaports, considering long-term projections of their traffic and facilities. This seemed an important first objective since technology will be adopted more because of demonstrated need than because of availability of more modern methods. The report forecasts future needs by first projecting demand and then analyzing the type and form of commodity movements required, as well as the most current trends in transportation technology.

Models developed in the study were run for individual ports, sets of regional ports, and the total set of the nine major Atlantic ports, considering both major bulk and unitized commodity flows.

The study has shown that the capacity of the Atlantic ports to handle general cargo will continue to be substantially over projected needs. Ample container terminal capacity also exists, although the unplanned (haphazard) location of terminals results in inefficient use of the overall capacity.

However, the study points up the primary importance of improved handling of liquid and dry bulk commodities. Although Atlantic ports are insignificant as a percentage of U. S. grain exports, on the other hand, over 5.4 percent of U.S. iron ore imports are handled through these ports and 98 percent of their liquid bulk commodities are crude petroleum and petroleum products. With the same port facilities, a far greater volume of material will have to be handled more efficiently. The economy of utilizing huge deep draft vessels must be urgently considered, which requires considerable innovation since Atlantic

ports are not deep enough to accomodate them. (The transport costs of the average small and medium size tanker are more than double those of VLCC or mammoth tankers.)

The report outlines the economic advantages of the regional port, based on the multiport, multipurpose models which allow analysis of different uses and development. The regional port would:

1. eliminate costly competition for the traffic to the hinterlands;
2. provide the most efficient planning of port facilities; and
3. allow the instigation of more effective work rules, employing the cost-benefits of the latest technology.

Estuary Modeling

PROFESSOR ARTHUR T. IPPEN, INSTITUTE PROFESSOR AND DIRECTOR, RALPH M. PARSONS LABORATORY FOR WATER RESOURCES AND HYDRODYNAMICS, DEPARTMENT OF CIVIL ENGINEERING

Coastal zones and estuaries, in particular, provide major resources for both the economic and social well-being of man. These valuable resources must be protected from needless deterioration. Estuaries are presently being used as sinks for industrial and municipal waste. Although wastes, when properly treated, are not necessarily detrimental, it is important to be able to judge the effects of the types and amounts of effluents discharged in order not to endanger biological productivity and the use of the water for recreation.

While the definition of estuaries is broad and includes almost any body of water which joins the ocean at the coast, this project has been specifically concerned with those bodies of water which are connected to the ocean at one end and fed by sources of fresh water as the water body's boundaries extend landward. The geometry of each estuary has its effect on the circulation and salinity distribution; however, given a particular geometry, the two primary factors influencing the salinity intrusion are the time history of the fresh water inflows and the range and mean tidal elevation at the ocean entrance.

There are two main methods for modeling estuaries: physical and mathematical. A physical hydraulic model, which is the most widely used technique at the present time, provides direct visual observation of flow. But there are serious drawbacks in its large size, the great expense in building it, and the time required for operation. In addition, there are important limitations in the ability of a physical model to handle the complex biochemical interactions which are important to water quality. The advantage of developing mathematical models of estuaries is that the complex physical and biochemical laws governing the composition of the estuaries can be most efficiently integrated by computers.

Three reports published by the project cover two topics: (1) salinity distribution in a one-dimensional framework as a function of longitudinal distance and time and (2) salinity and velocity distributions in vertical directions.

In "Prediction of Unsteady Salinity Intrusion in Estuaries: Mathematical Model and User's Manual" and "A Mathematical Model for the Prediction of Unsteady Salinity Intrusion in Estuaries" the authors, M. Llewellyn Thatcher and Donald R.F. Harleman, present a predictive numerical model of unsteady salinity in-

trusion in estuaries by formulating the problem in finite-difference terms using the one-dimensional, tidal time, variable area equations for the conservation of water mass, conservation of momentum, and conservation of salt. The tidal dynamic equations are coupled to the conservation of salt equation through a salinity-density relationship and the ocean boundary condition for salt is formulated in a manner which depends on the direction of flow at the entrance to the estuary. The prediction of salinity as a function of distance and time by this method has been a definite advance over previous methods. The model, which successfully predicted 107 tidal cycles for the Delaware estuary, was also successfully tested using salinity flume and field data from the Potomac and Hudson estuaries.

Another mathematical model developed by John S. Fisher, John D. Ditmars, and Arthur T. Ippen, "Mathematical Simulation of Tidal Time-Averages of Salinity and Velocity Profiles in Estuaries," uses analytical techniques to determine the longitudinal and vertical distributions of velocities and salinities, averaged over a tidal period, for mixed but partially stratified estuaries. The analytical model can be used as a predictor of the velocity and salinity profiles in estuaries and to relate changes in freshwater discharge to possible changes in the location of shoaling zones. Results indicate it has practical application in the prediction of salinity stratification and shoaling changes as might result from engineering modification, such as dredging, of the factors that control estuarine circulation.

A fourth report, "Numerical Model for the Prediction of Transient Water Quality in Estuary Networks," by James E. Dailey and Donald R.F. Harleman, considers, in addition to salinity, the biochemical oxygen demand and the dissolved oxygen resulting from industrial and municipal waste. In solving the conservation of mass equations for the various water quality constituents, tidal time permits formulation of an ocean boundary condition that is related to the direction of tidal flow. This has a distinct advantage over previous models which required the user to specify the ocean boundary concentration over the entire tidal cycle. The model has been successfully used to show, for instance, the benefits of intermittant rather than continuous injection of wastes near the ocean boundary. This work will continue with the addition of phosphates and nitrates to the equation. The effort, initiated under the Sea Grant Project, now has funding from the Environmental Protection Agency to complete the study.

Utilization of Squid for Processed Food Products

PROFESSOR SAMUEL A. GOLDBLITH, PROFESSOR OF FOOD SCIENCE AND DEPUTY HEAD, DEPARTMENT OF NUTRITION AND FOOD SCIENCE

For years, squid, this common cousin of the octopus, has been ignored by New England fishermen in favor of the more lucrative and traditionally accepted fish. But as the fin fish supplies rapidly diminish, the squid is being eyed favorably for the first time in the United States for its nutritional value and as a source of income. Squid is considered a delicacy in Italy, Japan, and the countries bordering the Mediterranean.

The objectives of this continuing program are to develop economical squid products that appeal to the American palate. Specifically, the project aims to develop canned, frozen, and dried squid products and to complete the development of a mechanized means of evisceration and skinning of squid.

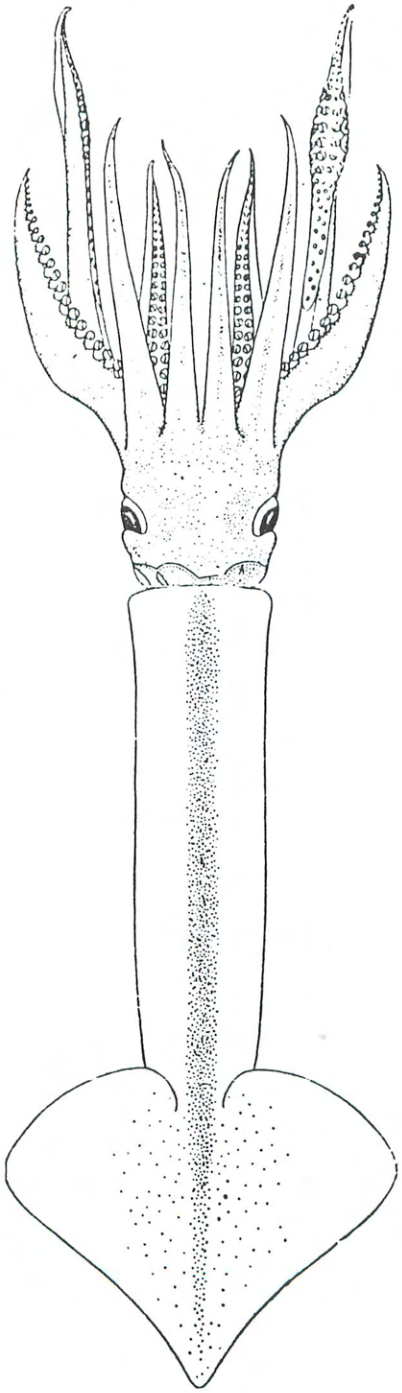
A new product for the United States market -- frozen breaded squid -- has been developed. The squid product is dipped in flour, beaten egg, unseasoned bread crumbs, packed in boxes and frozen. Thus it is similar to the uncooked fish portions sold for the institutional trade (in means of final preparation), yet in terms of flavor and consistency it is similar to fried clams in portion size. Recipes have also been compiled for canned and frozen "specialty" products, such as chowder. Formal acceptability studies were begun. Samples were provided for, and demonstrations were made, to some of the largest seafood processors in the northeast.

A major problem of squid production is now being tackled. Squid is at present eviscerated manually, a very wasteful process. Concerted efforts are under way to develop an automated prototype with sufficient capacity to be tested on a pilot-plant scale.

The fact that the water-soluble portion of the total protein of squid muscle is high makes it of particular value in the fortification of foods. An additional advantage is that it is comparatively bland. To justify the fortification of food with squid protein, a complete investigation of the biochemical characteristics of squid is under way.

These data, which are now being prepared for publication, serve two purposes. First, they characterize squid protein in terms of solubility of protein in different extractants, the effect of pH of the extracting solution, the solubility of the protein as a function of particle size of the squid muscle, and

the effect of time and temperature on the extraction of the protein. The data should be of value in designing a process for the preparation of stable, dehydrated squid protein concentrate. These data also serve to provide a solid fundamental basis for the developmental aspects of new processed products from squid with minimal protein losses.



Ocean Commerce and the Future of the Oceanic Canal

PROFESSOR NORMAN J. PADELFORD, EMERITUS, DEPARTMENT OF POLITICAL SCIENCE AND SENIOR LECTURER, DEPARTMENT OF NAVAL ARCHITECTURE

As ocean transport of goods develops to meet the increasing demands of recent times and as the ever-present problems of nationalism complicate U.S. control of the Canal Zone, the United States has had to consider the future of the Panama Canal. Strategies are being studied that are as advanced as those which produced the canal in 1914, then technologically far superior to its time.

The objective of the present research is to examine the trends in world oceanborne commerce and shipping, projected to the year 2000, for their implications with respect to U.S. interests in policy regarding the existing canal and any other interoceanic waterway that may be constructed between the Atlantic and Pacific oceans.

A fundamental problem of the canal, in light of present interoceanic technology, is that it cannot accommodate deep draft ships, such as oil supertankers. Thus companies must consider the time advantages versus the economies of scale. In placing the canal in perspective of the larger transportation network, the ongoing research considers the pilotage and scheduling of transits, the navigational problems in the canal, and long-range planning to expedite the current load of vessels able to transit. In addition, research will attempt to analyze the present effect of superships on canal demand and to project this to future use. It is hoped that from these various studies new alternatives for U.S. policy will be produced.

Sea Environment in Massachusetts Bay and Adjacent Waters

PROFESSOR ARTHUR T. IPPEN, INSTITUTE PROFESSOR AND DIRECTOR, RALPH M. PARSONS LABORATORY FOR WATER RESOURCES AND HYDRODYNAMICS, DEPARTMENT OF CIVIL ENGINEERING, AND PROFESSOR ERIK L. MOLLO-CHRISTENSEN, PROFESSOR OF METEOROLOGY, DEPARTMENT OF METEOROLOGY

A major Sea Grant objective is that local universities work with people in their states to explore problems having to do with their coastal areas and coastal industrial activity. This study now under way is an interdisciplinary and interdepartmental approach to a comprehensive understanding of the physical environment of the waters of Massachusetts Bay and adjacent waters. A particular concern is the description of the mixing processes that enable the large-scale drift to carry pollutants and dilute them.

The two most difficult problems in a study of this sort are,first, that isolated local measurements are inadequate in the absence of knowledge of the large-scale field and properties, and that second, the large-scale observations are difficult to interpret without an understanding of the microscale mixing processes.

The first major task of organizing methods and instruments for data acquisition and analysis and for designing an integrated computational system has begun. This is essential, for otherwise one is faced with isolated pieces of data out of context and in formats which cannot be effectively processed on the computer. The project's continuing aim is to develop a method of approach and then a mathematical model describing the physical environment of Massachusetts Bay that can be replicated for other embayments.

Specific study areas include Deer Island sewage outlet, Pilgrim Nuclear Power Station discharge, Mystic and Edgar Power Plant discharges and hydrodynamics of Boston Harbor, and the Oceanography of Massachusetts Bay.

In preliminary field observations conducted during the first year of the project as well as from studies of data obtained in the past, large variations in water quality parameters in Massachusetts Bay are apparent. The water qualities with large variances are salinity, temperature,and chemical properties such as phosphate and nitrite concentrations especially in the first few meters below the sea surface. This variability seems to persist forty kilometers away from the Boston Harbor entrances. Most characteristically, there is evidence that pools of sewage waste waters are emitted from the harbor during ebb tide which are torn off and carried out to sea by the long-shore currents and the current circulation in the bay. This appearance of clearly identifiable pools of polluted water in the upper strata of the Bay is contrary to the usual concepts of depth-averaged concentrations of pollutants and their dispersion with

distance from the source.

In retrospect such variabilities might have been expected; their existence presents a number of opportunities for further work on the processes of absorption of pollutants in the coastal zone and on the dynamics of such processes.

Three instrument prototypes have been designed for the measurement of temperature and salinity for different applications. These instruments, developed during the first months, have been built and field-tested. They are: Bathythermograph (BT) for use on a number of small boats with computer-compatible output; Towed Thermistor array with computer-compatible output; and Conductivity-Temperature-Depth instrument (CTD) with computer-compatible output.

In addition to these instruments, work has been done on devices for onboard collection and analysis for suspended sediment. This system will operate in conjunction with an automatic chemistry analyzer so as to utilize the same pump-out and filter arrangement. The design of this system is continuing under separate funding by the U.S. Army Corps of Engineers but constitutes an integral part of the present project.

The course of the instrumentation development with computer compatibility has brought to the fore the need for a better navigation system.

If we can afford it, such a system would enable us to acquire profiles of nutrient concentration, temperature, salinity, oxygen, suspended sediments and other variables while under way at five knots. Using the computer to generate S-T, Phosphate-T, Nitrite-T, and other characteristic water mass diagrams, one can map out the extent and characteristics of the polluted water masses. This possibility is an exciting one and will be pursued.

Underwater Welding

PROFESSOR KOICHI MASUBUCHI, PROFESSOR OF NAVAL ARCHITECTURE, DEPARTMENT OF OCEAN ENGINEERING

There are two categories of underwater welding, wet and dry welding. Wet welding occurs when the operator and the process are completely surrounded by the liquid environment. Dry welding occurs when both the operator and the process are surrounded by a gas atmosphere. Normally, for dry welding, a caisson or chamber is constructed around the work and pressurized to depth pressure.

To the present time, wet welding has been considered to be only a temporary repair method, and the strength of the weld is not considered a priority. Dry welding, a very costly process, is used for such projects as underwater pipelines and offshore oil drilling rigs.

Underwater wet welding technology is best characterized by a singular lack of theoretical analysis or empirical data. The objective of this study is to generate fundamental information on underwater welding and cutting with the hope in particular of improving wet welding techniques. Such information,it is expected, can be useful for further developing improved joining and cutting techniques. It is of special importance that these advances be brought about if such concepts as ocean-bottom nuclear reactors for power generation are ever to reach fruition.

Before the use of underwater welding can be expanded to permanent repairs and structural fabrication, present methods must be modified or radically changed. One basic approach has been to conduct a fundamental study in which the various areas, heat transfer, metallurgical and physical phenomena may be modeled. This information can be used in a more rational development of new processes, and is particularly compatible to the university's education and research objectives.

The project has completed two phases centering on a description of the state of the art of the technical aspects of underwater welding and a survey of the mechanisms of heat transfer during underwater welding. The goal is to be able to understand the mechanisms leading to the final weld quality. Mechanical properties of the weld are necessarily a direct consequence of the weld metal microstructure, as well as any defects caused by the welding process, such as hydrogen embrittlement. Any change in microstructure is the result of the temperature history of the welded zone, a direct consequence of the heat transfer. These last processes are the particular properties of a specific underwater welding process. Working from a given welding technique, the heat transfer and metal transfer must be

understood.

The processes of three mechanisms have been analyzed: shielded metal-arc, gas metal-arc, and shrouded underwater welding. Results revealed an anticipated weakness in the boiling models due to the highly transient and radical nature of the processes. However, the arc bubble and spread heat studies indicated very definite guidelines for future processes, especially in the area of gas supplemented shrouded welding.

Work on this important problem is planned to be continued through the next two project years and completed in early 1974.

Coastal Zone and Offshore Resources Management

PROFESSOR JOHN W. DEVANNEY III, ASSOCIATE PROFESSOR OF MARINE SYSTEMS, DEPARTMENT OF OCEAN ENGINEERING, AND ROBERT C. BLUMBERG, DIRECTOR, DIVISION OF MINERAL RESOURCES, MASSACHUSETTS DEPARTMENT OF NATURAL RESOURCES AND VISITING LECTURER AT MIT, DEPARTMENT OF OCEAN ENGINEERING

"Coastal Zone and Offshores Management" comprised a student course organized to investigate the possibilities of joint research between state authorities and engineers at MIT, working under the direction of Professor John W. Devanney and Visiting Lecturer Robert C. Blumberg. The questions in mind when the experimental course began were two: Could it produce innovative research results and could it give some perspective to the overall problem of resolving those issues that also require political savvy? The specific objectives were to develop solutions to practical coastal zone and offshore management problems facing the State of Massachusetts, to introduce a number of selected students to the real world problems facing a state natural resources organization, and to bridge the gap between the development of working principles and their political implementation. It was concluded that for the students to be effective the amount of faculty and advisory supervision did not merit continued support.

Yet, the course produced three reports of merit. Two are included in "Student Projects on Coastal and Offshore Resources Management": The Brayton Point project and the Woods Hole Outfall study. The Brayton Point project, which attempted to integrate the political process with modern cost-benefit analysis, faced the difficulties involved with politically sensitive environmental restraints. In this project it was learned that in the absence of explicit agency guidelines, there is an impasse between the two sides' entirely different objectives. The Woods Hole (Falmouth) Outfall study investigated the sewage outfall located 200 yards offshore in Great Harbor. Falmouth is currently under state orders to cease dumping raw sewage.

A third report, published separately is entitled "A Preliminary Feasibility Study of Irish Moss Harvesting Systems." As general enthusiasm continues to mount in the exploitation of the "untapped resources" of the sea, interest has been expressed in increasing the use of marine algae, or seaweed. The main purpose of this project was to determine the feasibility of developing and operating a mechanized Irish Moss (chondrus crispus) harvesting system for use in the United States.

Irish Moss is economically valuable as a source for carrageenan, which is used extensively in dairy products as a stabilizer or gelling agent. It is also used in baby foods, dietetic foods, and instant foods, and is finding increasing use

in the cosmetic industry and in the textile industry.

In Canada, most Irish Moss is found in waters that have level accessible bottoms. This is not so in Maine, the primary U.S. source. The report concludes that while power harvesters have been developed, economic considerations (the need for divers, several men per boat, and the very low per pound price of Irish Moss) overwhelm their mechanical efficiency. The researchers recommend instead the design, manufacture, and sale of an improved hand harvester (essentially a more efficient rake). A prototype of this rake has been built and tested.

Offshore Petroleum and New England

PROFESSOR J.W. DEVANNEY III, ASSOCIATE PROFESSOR OF MARINE SYSTEMS, DEPARTMENT OF OCEAN ENGINEERING, AND PROFESSOR J.B.LASSITER III, ASSISTANT PROFESSOR OF OCEAN ENGINEERING, DEPARTMENT OF OCEAN ENGINEERING

The high probability of offshore petroleum deposits on Georges Bank and their utilization with the necessary refineries has posed a challenging project, begun in the spring of 1972 at the request of and sponsored jointly by the New England Regional Commission and the New England River Basins Commission, with additional Sea Grant Funding. The aim is to concentrate professional and academic expertise in an urgent study intended to generate estimates of the change in real New England income and regional environmental quality associated with a range of hypothetical petroleum developments on Georges Bank.

There will be two interrelated reports that address two important questions: In the search for oil and in extracting it, what is the possible potential damage to the coastal environment and ecosystem and what changes in regional income would occur?

The project, more specifically, will (1) review the information available on prospects, locations, and scales of oil and gas; (2) develop a sequence of the steps involved in considering its development; (3) make educated guesses of the nature and extent of the resource; and (4) - of major importance - for selected theories of the size and extent of the resource, assess the economic costs and benefits and the environmental effects of drilling on commercial fishing operations and the prospects of oil spills.

The regional sponsors of this project have recognized the important policy decisions presented here for New England and have sought to identify viable policy options that will enable more thoughtful political decisions in this vital area. The plan of action in the study is to publish a complete report of the project findings and to bring together within the year all those involved in making important decisions for New England and to present them with the results of the research that they may discuss and evaluate the findings.

Environmental Impact of a Superport in the Machias Bay Area

PROFESSOR STEPHEN F. MOORE, ASSISTANT PROFESSOR, DEPARTMENT OF CIVIL ENGINEERING

This project, requested by the Council on Environmental Quality, considered in detail first the specific effects of oil spills on marine organisms and then potential geographic distribution of oil spills. Most microscopic marine organisms are affected by aromatic compounds in concentrations in water of less than 50 ppm. The effect may range from immediate death to disruption of behavioral characteristics. All types of hydrocarbons may be incorporated into the tissue of fish, which may lead to tainting or the accumulation of polycyclic aromatic hydrocarbons in food chains.

The incorporation of hydrocarbons in the tissue of fish is primarily of interest to those concerned with the public's health, since the individual organisms are apparently not affected. Whether or not cancer can be induced in humans from ingestion of carcinogens accumulated in seafood is as yet unknown. However, the potential seriousness of the problem implies that careful consideration be given to these issues.

The research has concluded that oil spills occurring from day-to-day transshipment operations at the tanker berths are relatively insignificant environmentally. Flushing would be rapid due to tidal currents. While terminal construction and tanker operations are activities potentially leading to biological changes, no dredging is required and the proposed structures do not involve major shifts in habitats.

However, the overall environment vulnerability of the Machias Bay region to oil supertankers is very high. A major oil spill of 30,000 tons, which could be expected to occur as frequently as once in twenty years, is virtually certain to cause extensive biological damage. A 500 ton oil spill, likely to occur once a year, could also cause permanent localized shore damage of from 10 to 20 miles. Considering prevailing wind-induced currents, these spills might extend as far south as the New Hampshire coast and as far north as the northern end of the Bay of Fundy.

A detailed analysis of these findings is given in the published report of the completed project, "A Preliminary Assessment of the Environmental Vulnerability of Machias Bay, Maine to Oil Supertankers" by Stephan F. Moore, Robert L. Dwyer, and Arthur M. Katz.

Education and Training

INTERDISCIPLINARY SYSTEMS DESIGN SUBJECT

PROFESSOR WILLIAM W. SEIFERT, PROFESSOR OF CIVIL ENGINEERING AND ELECTRICAL ENGINEERING, DEPARTMENTS OF CIVIL AND ELECTRICAL ENGINEERING

While Saudi Arabia receives substantial income from its oil operations, the country is making a major effort to broaden the base of its economy. In the spring of 1971, an interdisciplinary group of MIT students undertook to examine the economic and technical possibility of a major program that could offer an important potential for the development of the western region of Saudi Arabia. This project was undertaken as a case study, under optimum conditions, as a prototype for possible application to arid and semiarid land in the United States. The report of this 1971 study is one element of the 1972 project. Research also began in the spring term, 1972, on a number of suggestions that have been put forward for development of the Maine coastal area in the light of a serious need for power plants, oil refineries, ports and other facilities to support growth.

The class report of the Saudi Arabia project has been published by The MIT Press (1973), entitled Energy and Development: A Case Study.

It is based on an effort to utilize natural gas, a by-product of Saudi Arabia's enormous oil production. At present, a large portion of this gas is burned off merely to dispose of it. The students specifically investigated the possibilities of using this natural energy source for electric power generation, the desalination of water for crop irrigation, the production of liquified natural gas and petrochemicals, the extraction of magnesium from sea water, and the development of a variety of industries: aluminum, steel, cement, glass, and fertilizer.

The gas available in Saudi Arabia is estimated to be five times as great as the country could conceivably use if the gas were used as LNG for instance, rather than burned. Thus the country has an opportunity to export LNG to the rapidly expanding energy markets of Europe, Japan, or the United States.

Included in the book as well is a study by Professor Ali Kettani, Visiting Lecturer to the seminar, and his associates at the College of Petroleum and Minerals in Dhaksan. Based on a novel means of hydroelectric power generation, it proposes that a dam be constructed across the mouth of the Gulf of Bahrain. Natural evaporation of water behind this dam would produce, first, a difference in water level making possible the heliohydroelectric generation of power and, second, a concentrated brine from which materials might be recovered. Aquaculture, land reclamation, and improved transportation are other benefits considered.

The results of the spring term research project on the Maine coast indicate that Maine cannot and should not stop all further development of her coastal area, but careful planning will be required to prevent further degradation of one of her greatest assets: her beautiful shoreline. The study examines the technical, economic and environmental impacts of a variety of projects and appraises how implementation of these projects would influence growth of the population, the economy of Maine, the opportunities for employment, requirements for additional transportation facilities, and other elements of the infrastructure. It identifies the legal, political and regulatory steps which should be taken if the State is to achieve a balance between a reasonable rate of economic growth and preservation of its natural assets.

Ocean Engineering Student Summer Laboratory

PROFESSOR DAMON CUMMINGS, ASSISTANT PROFESSOR OF OCEAN ENGINEERING, DEPARTMENT OF OCEAN ENGINEERING

The Summer Ocean Engineering Laboratory at M.I.T., conducted jointly with the Maine Maritime Academy, provides undergraduate ocean engineering students an opportunity to combine theory and practice when they design equipment and test and operate this equipment in the real environment. It has served an invaluable educational purpose that is essential early in the students' Ocean Engineering education by coordinating classroom theory with the actual sea environment. As such it provides a perspective on a small scale that may well help to eliminate much more costly mistakes in industrial or governmental projects.

The two major projects in the summer of 1972 were an oceanographic and biological survey of Holbrook Cove and a successful underwater search for the remains of a Revolutionary War privateer.

In the Holbrook Cove study, published as "Holbrook Cove Survey", the students sought to gain an understanding of the hydraulics and ecology of the cove in order to ascertain the effect on it of the effluent from the Callahan mine outfall. As the mine was relatively new, the research could give important indications of the ecological effect of more extensive mining operations. The students surveyed tidal currents, temperature and salinity, chlorophyll 'A' content, benthic infauna distribution, tidal height fluctuations, detailed bottom topography, bottom soil structure, and the oxygen content of the cove water. In carrying out these surveys, they designed, built, and tested a tide gauge; prepared a nomograph to permit soundings to be related to datum on the mean lower-low waterline; designed a corer and release mechanism; and designed and constructed an oxygen meter for use with an oxygen probe borrowed from the Woods Hole Oceanographic Institution.

Important management and scientific lessons were learned in that (1) a project that must be concluded quickly - this time for ecological reasons - requires meticulous planning; and (2) failure analysis of equipment is of utmost importance if an entire project depends on the interrelationship of many surveys. In the latter case, the corer was lost on first test when its messenger line was severed.

Although much more needs to be done, the research objectives were partially met. The investigations into the hydraulics of the cove indicate that there may be a seiche that significantly affects the current velocity magnitudes. Temperature and salinity measurements reveal no anomalies in the absence of flow from the mine outfall and there seemed to be no effect upon chlorophyll 'A'

distributions in the vicinity of mine outfall. A most important finding still being assessed is that the benthic infauna distribution does suggest that there is a detectable adverse effect upon the ecology in the vicinity of the mine outfall.

The second report concerns a search and salvage operation for the American Revolutionary War vessel "Defence", sunk in 1779. The project was not only successful but visually spectacular, for the students were able to locate the vessel and lift a cannon and other items. Their success is reported in "The Search for Defence and Other Ocean Engineering Projects".

Ocean search and salvage is an important discipline of Ocean Engineering. Technical competence is required, particularly in the use of sonar, metal detectors, bottom projectiles, and navigational fixing equipment. Research into the history of a particular naval episode is also of primary importance.

In this case, the students first familiarized themselves with all accounts of the sinking of the ship in order to define the probable wreck locations. They augmented this "book" knowledge with conversations with local fishermen. Technically, sonar searches were used and then verified by diver checks in a sophisticated diving program.

The summer students also undertook to design and then partially assembled a radio navigational system; designed and partially constructed and tested an air life pump; designed a nonpolluting, tidal-powered electrical generator; and designed, constructed, and tested a can buoy and a spar buoy, as well as a tower on Nautilus Rock. Finally, two studies of marine life were begun: a lobster behavior study and the fabrication of a new scallop dredge.

Public Education and Training Short Courses

PROFESSOR JAMES M. AUSTIN, PROFESSOR OF METEOROLOGY,
DEPARTMENT OF METEOROLOGY, AND DIRECTOR OF SUMMER SESSION

MIT Sea Grant has collaborated with the MIT Summer School in order to allow working professionals to take advantage of short-term summer courses which can keep them abreast of the most current developments in many areas having to do with the sea. In the summer of 1971, the courses offered presented research results or reflected efforts on Sea Grant projects by participating faculty members. They were: "Transportation System Analysis", Professors Frankel, Lang, Manheim and Simpson: "Engineering Aspects of Heat Disposal from Power Generation",Professor Devanney, Instructor Lassiter; and "Principles of New Processes in Food Concentration", Professor Goldblith. The courses were well attended, with participation from all over the United States and some foreign countries, as well as the New England region.

Advisory Services

Marine Resources Information Center

PROFESSOR NORMAN N. JONES, ASSOCIATE PROFESSOR OF OCEAN ENGINEERING, DEPARTMENT OF OCEAN ENGINEERING

The Marine Resources Information Center (MARIC) continues to serve as a very important public base for expanding the MIT Sea Grant liaison operations. As such, it provides access to all marine-related information at MIT and referral services with Woods Hole Oceanographic Institution and with the New England Marine Resources Information Program at the University of Rhode Island.

During the past year, the Information Center librarian, Mrs. Passero, and her assistant, Mrs. Burr, finished cataloging all materials directly concerned with Sea Grant activities at MIT and other participating universities and have started work on Sea-Grant related areas.

The Center now has working collections in or access to information on living resources; aquaculture; fisheries technology; nonrenewable resources; law of the sea; marine economics; shipping and marine transportation; naval architecture; ocean engineering; and marine recreation. Current issues of approximately 100 journals and sea-related magazines are displayed conveniently for the browser in the newly renovated informal reading lounge beside the study area.

Other features of the Center include foreign reports on naval architecture; files of slides, pamphlets, and answers to questions that users frequently ask; a microfilm collection with reader/printer; and National Ocean Survey (NOS) charts of New England waters and other area charts and maps.

To continue to improve the Center's services to the public, plans are under way to issue a MARIC bulletin periodically.

Symposia on Sea Grant Projects and Marine Resource Related Topics

Dean A. Horn, Executive Officer, MIT Sea Grant Program

The objective of this important aspect of Sea Grant advisory liaison services is to broadly disseminate information and research results by means of symposia which are open to the general public as well as to the MIT community.

During 1971-1972, two special seminars were held to acquaint the MIT community with Sea Grant. A one-day symposium, "Working in the Ocean" was held. On September 22, 1971 over 250 people attended this meeting. Practical, working problems were discussed by recognized experts in the industrial and operating field with technological and engineering responses from equally expert engineers and scientists. Another one-day symposium on "Ocean Transportation" was held on October 28, 1971, sponsored jointly with the MIT Industrial Liaison Program. About 100 persons attended this program, which was based largely on Sea Grant project research by Professors Frankel, Padelford, Devanney, and Mr. Lassiter.

On November 4, 1971, the first annual MIT Sea Grant-State-Industry Workshop was held to acquaint key representatives from government agencies, industry, and communities of the Commonwealth with the current Sea Grant Program, the plans for the next year, and to solicit recommendations and participation by those attending to help MIT develop a strong, viable program for Massachusetts.

On November 9, 1971, Dr. John Mero, presented an afternoon seminar on "Mining in the Ocean" to an audience of over 200 M.I.T. students, faculty, and visitors. The outstanding presentation kept the question and answer exchange, primarily with the students over an hour beyond the scheduled time.

The results to date amply demonstrate the effectiveness of these special seminars and symposia as an advisory service.

SEA GRANT RELATED REPORTS AND INFORMATION

DEAN ALFRED A.H. KEIL, DIRECTOR, MIT SEA GRANT PROGRAM AND DEAN, SCHOOL OF ENGINEERING

As a result of MIT's long-time interest in naval engineering and marine activities, there are, of course, many projects at the Institute that are not funded by Sea Grant. There are also projects which began with Sea Grant seed money and are now being independently funded. The reports emerging from these grants are distributed by the MIT Sea Grant Information Center in addition to the Sea Grant Project reports. Last year the following reports were distributed:

MITSG Number	
MITSG 72-1	A BUOY SYSTEM FOR AIR-SEA INTERACTION STUDIES BUOY DESIGN AND OPERATION, E.L. Mollo-Christensen, C. E. Dorman NTIS: AD 887165
MITSG 72-2	STUDY OF AUTOMATIC MEANS OF DETERMINING THE AGE OF FISH, L. Sutro NTIS: COM 72-10326
MITSG 72-4	WAVE FORCES ON A SUBMERGED OBJECT, John Halkyard NTIS: COM 72-10126
MITSG 72-5	PROSPECTS FOR A NEW REGIME OF THE SEAS: INTERNATIONAL POLITICAL CONSIDERATIONS, N. J. Padelford NTIS: 72-10522
MITSG 72-6	AN ANALYSIS OF THE SMALL-SCALE STRENGTH TESTING OF ICE, K. R. Maser NTIS: COM 72-10294
MITSG 72-8	THE APPLICATION OF HYDROACOUSTIC METHODS FOR AQUATIC BIOMASS MEASUREMENTS, J. B. Lozow and J. B. Suomala NTIS: COM 72-10664
MITSG 72-10	DIRECTORY OF M.I.T RESEARCH PROJECTS RELATED TO MARINE RESOURCES, OCEAN UTILIZATION AND COASTAL ZONE DEVELOPMENT, B. Passero, D. Horn NTIS: COM 72-10861
MITSG 72-12	ESTIMATION OF DYNAMIC CHARACTERISTICS OF DEEP OCEAN TOWER STRUCTURES, E. H. Vanmarke and R. N. Iascone NTIS: COM 72-10919

Support to Other Institutions

DEAN ALFRED A.H. KEIL, DIRECTOR, MIT SEA GRANT PROGRAM AND DEAN, SCHOOL OF ENGINEERING

The aim of this special project was to make both faculty and staff personnel available to other academic institutions on a consulting basis to assist in developing course offerings, full curricula, and/or research projects in marine resources utilization. To this end, MIT assisted the Maine Maritime Academy and the Massachusetts Maritime Academy in broadening their technical programs and consulted with Howard University. In the process of getting the program under way, however, it was found that although the spirit of the endeavor was sound, making this a separate project was not practically effective. These advisory services are now being pursued at the program management level.

Publications under Sea Grant Number 2-35150

MITSG Number	
MITSG 72-1	A BUOY SYSTEM FOR AIR-SEA INTERACTION STUDIES BUOY DESIGN AND OPERATION, E. L. Mollo-Christensen, C. E. Dorman, NTIS: AD 887165
MITSG 72-2	STUDY OF AUTOMATIC MEANS OF DETERMINING THE AGE OF FISH, L. Sutro NTIS: COM 72-10326
MITSG 72-4	WAVE FORCES ON A SUBMERGED OBJECT, J. Halkyard NTIS: COM 72-10126
MITSG 72-5	PROSPECTS FOR A NEW REGIME OF THE SEAS: INTERNATIONAL POLITICAL CONSIDERATIONS, N.J. Padelford (xerox copy) NTIS: 72-10522
MITSG 72-6	AN ANALYSIS OF THE SMALL-SCALE STRENGTH TESTING OF ICE, K.R. Maser NTIS: COM 72-10294
MITSG 72-7	A MATHEMATICAL MODEL FOR THE PREDICTION OF UNSTEADY SALINITY INTRUSION IN ESTUARIES, M.L. Thatcher, D. Harleman NTIS: COM 72-10670
MITSG 72-8	THE APPLICATION OF HYDROACOUSTIC METHODS FOR AQUATIC BIOMASS MEASUREMENTS, J.B. Lozow and J.B. Suomala NTIS: COM 72-10664
MITSG 72-9	THE EVOLUTION AND UTILIZATION OF MARINE MINERAL RESOURCES, D.H. Lahman, J.B. Lassiter, III NTIS: COM 72-11043
MITSG 72-10	DIRECTORY OF M.I.T.RRESEARCH PROJECTS RELATED TO MARINE RESOURCES, OCEAN UTILIZATION AND COASTAL ZONE DEVELOPMENT, B. Passero, D. Horn NTIS: COM 72-10861
MITSG 72-11	MATHEMATICAL SIMULATION OF TIDAL TIME AVERAGES OF SALINITY AND VELOCITY PROFILES IN ESTUARIES, J.S. Fisher, J.D. Ditmars, and A.T. Ippen, NTIS: COM 73-10053
MITSG 72-12	ESTIMATION OF DYNAMIC CHARACTERISTICS OF DEEP OCEAN TOWER STRUCTURES, E.H. Vanmarke and R.N. Iascone NTIS: COM 72-10919
MITSG 72-13	STUDENT PROJECTS ON COASTAL ZONE AND OFFSHORE RESOURCES MANAGEMENT, J.W. Devanney,III, R. Blumberg, NTIS: COM 73-10262

MITSG Number	
MITSG 72-14	A PRELIMINARY FEASIBILITY STUDY OF IRISH MOSS HARVESTING SYSTEMS, J. Patell, NTIS: COM 73-10152
MITSG 72-15	NUMERICAL MODEL FOR THE PREDICITON OF TRANSIENT WATER QUALITY IN ESTUARY NETWORKS, J. E. Dailey and D. R. F. Harleman NTIS: COM 73-10147
MITSG 72-16	ENERGY AND DEVELOPMENT, A CASE STUDY, W. W. Seifert, M. A. Bakr, and M. A. Kettani. Cambridge, Mass.: The MIT Press. NTIS: COM 73-11834AS
MITSG 72-18	THE FUTURE OF ATLANTIC PORTS, E. Frankel, NTIS: COM 73-11834AS
MITSG 72-19	HOLBROOK-COVE SURVEY, A 1972 STUDENT SUMMER OCEAN ENGINEERING LABORATORY RESEARCH PROJECT, K. Keays et. al. NTIS: COM 73-10621
MITSG 72-20	THE SEARCH FOR DEFENSE AND OTHER OCEAN ENGINEERING PROJECTS, K. Keays et. al. NTIS: COM 73-10622
MITSG 72-21	A PRELIMINARY ASSESSMENT OF THE ENVIRONMENTAL VULNERABILITY OF MACHIAS BAY, MAINE TO OIL SUPERTANKERS, S. F. Moore, R. J. Dwyer, A. M. Katz NTIS: COM 73-10564
MITSG 73-6	DIRECTORY OF M.I.T. RESEARCH PROJECTS RELATED TO MARINE RESOURCES, OCEAN UTILIZATION AND COASTAL ZONE DEVELOPMENT, B. Passero, D. Horn NTIS: COM 72-11043

PROGRAM SUMMARY

PROGRAM AREA - COHERENT AREA PROJECT GRANT NO. (FOR YEAR BEGINNING JULY)	GH88 '70	2-35150 '71
PROGRAM OPERATIONS		
Program Management, Keil	N	C
EDUCATION AND TRAINING		
Interdisciplinary Systems Design Subject, Seifert	N	C
Coastal Zone and Offshore Research Mgmt, Devanney	-	NT-2
Student Summer Laboratory, Cummings	N	C
O. E./Marine Transportation, Devanney	N,T-1	
O. E./Ocean Environment, Keil	N,T-2	
Public Education and Training Short Courses, Austin	-	N
ADVISORY SERVICES		
Marine Resources Reading Reference Center, Jones	N	C
Symposia, Horn	-	N*
Support to other Institutions, Horn	-	N*,T-3
Sea Grant Related Reports, Horn	N*	C
RESEARCH		
MASSACHUSETTS BAY FOCUS		
Sea Environment of Mass Bay & Adjacent Waters, Ippen and Mollo-Christensen	-	N
Estuary Modeling, Ippen	N	C,T-2
NEW ENGLAND FOCUS		
Offshore Petroleum and New England, Devanney	-	N
Supertanker Study, Moore	-	N,T-2

PROGRAM AREA - Year Beginning July	'70	'71
OCEAN UTILIZATION		
Utilization of Squid, Goldblith	N*	C
Ocean Transportation, Frankel	N	C,T-1
Future of Atlantic Ports, Frankel	N	C,T-2
National Ocean Policy, Padelford	N,T-1	
Ocean Encyclopaedia, Davidson	-	N*,T-3
Diving Technology, Allen	-	N*,T-3
Sensory Neuroanatomy of Fish, Karten	-	N*,T-3
Oil Oxidation by Marine Bacteria, Robbins	N*,T-2	
Interoceanic Canal, Padelford	-	N
Underwater Welding, Masubuchi	-	N

N - New Project

C - Continued Project

T - Terminated Project, Numerals indicate results in foot notes

* - Started with "seed" funds

T-1 Work completed, book published

T-2 Work completed, Sea Grant report (s) published

T-3 Work completed, results useful to MIT program only

Summary of Expenditures

	Sea Grant	Matching
Program Management	-	$ 76,700
Education and Training	$ 28,001	64,220
Research	356,052	138,250
Advisory Services	7,947	44,080
	392,000	323,250

This summary is only approximate. The official financial report will be submitted by the M.I.T. Comptroller to the Office of Sea Grant in accordance with the federal grant requirements.

PARTICIPANTS AND CONTRIBUTORS FROM OUTSIDE SOURCES

Massachusetts Institute of Technology
Massachusetts-Department of Natural Resources
Henry L. and Grace Doherty Charitable Foundation, Inc.
New England River Basin Commission
Professor Norman J. Padelford
New England Regional Commission
Maine Maritime Academy