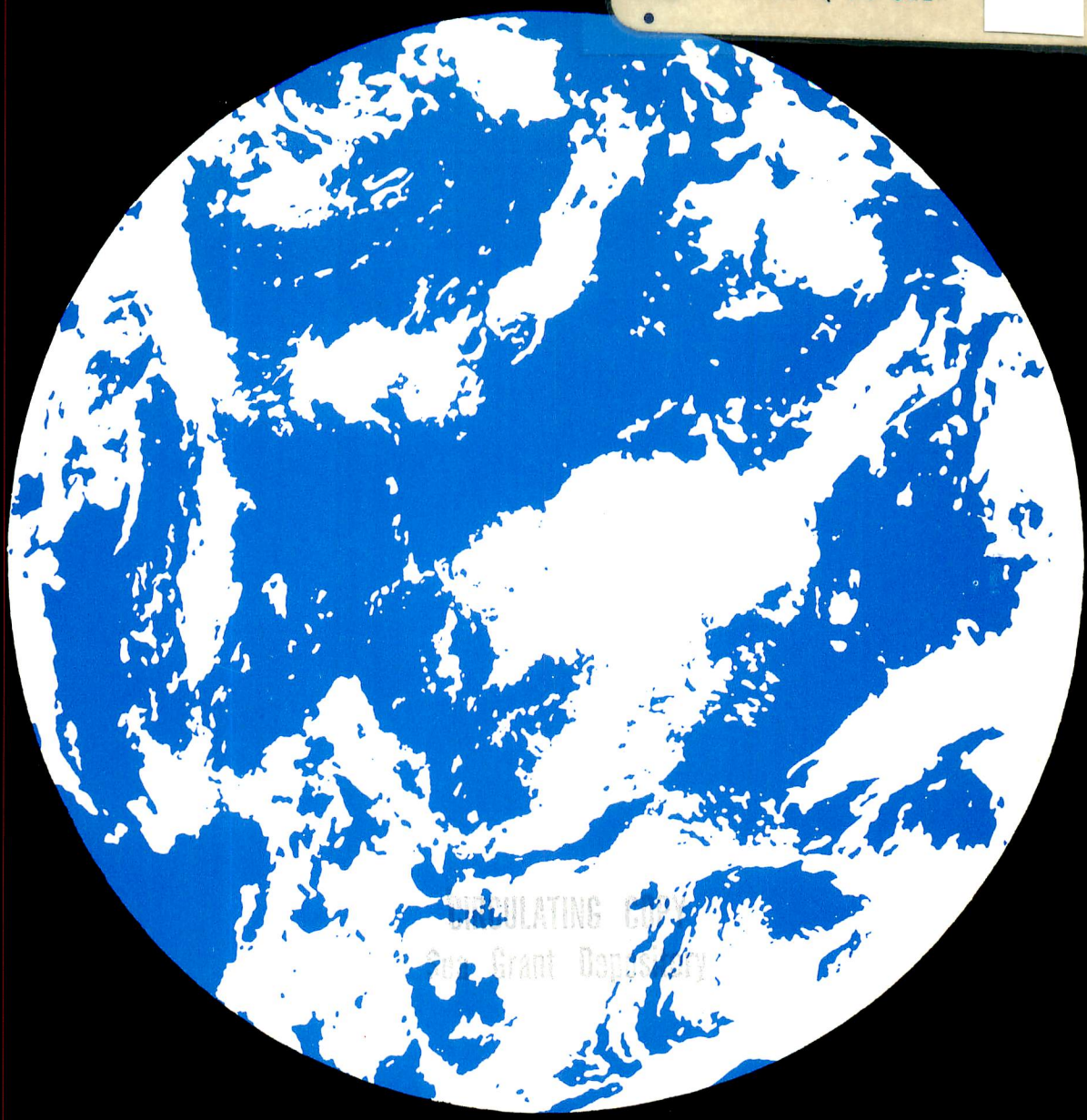
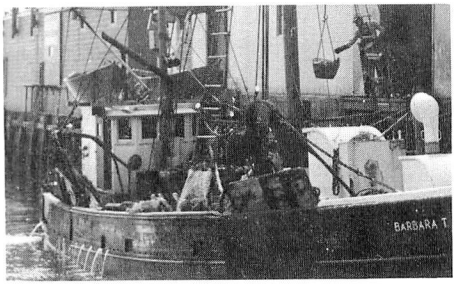
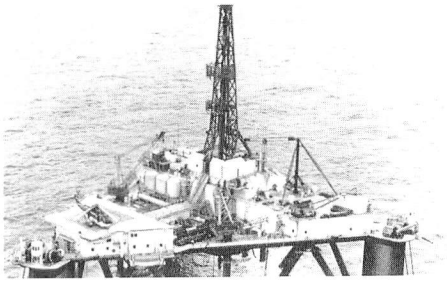


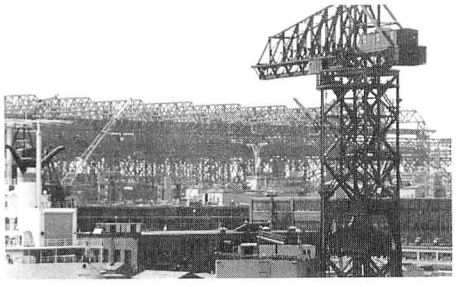
USING THE SEAS TO SERVE PEOPLE

A Report on the Massachusetts Institute of Technology Sea Grant Program: 1 July 1973 to 30 June 1974

M.I.T. SEA GRANT: USING THE SEAS TO SERVE PEOPLE







Report No. MITSG 75-4
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December 25, 1974

M.I.T.'s philosophy stresses the application of technology to opportunities for industrial growth, economic benefit, environmental safeguards, and social betterment. The Institute's participation in the National Sea Grant Program has brought this philosophy to bear on new opportunities in the oceans and coastal zones. Through Sea Grant, M.I.T. helps harness marine resources and the seas' environment for human use.

Oceans possess a two-fold wealth, in resources and in environment. Living and mineral marine resources are a reservoir of food for generations to come, of energy for factories, homes, and transportation, and of raw materials for industry. The ocean environment is a habitat and highway for human activity, and an arbiter of global biological, meteorological, and geological processes.

The Sea Grant Program is an important vehicle for developing new and better uses of marine resources and for ensuring wiser use of the oceans and coasts. This Sea Grant does in two ways: discovery, guiding marine research to find better ways of using the oceans and developing the coastal zones; and communication, transferring research results to those who can implement the information and derive new knowledge from it.

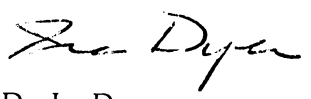
In discovering inventive approaches to new marine opportunities, Sea Grant research at M.I.T. concentrates interdisciplinary efforts on environmentally balanced use of coastal and ocean environments, on obtaining food from the sea, on marine energy and undersea minerals, and on engineering for ocean utilization.

In communicating research findings and advances in marine technology to Massachusetts, New England, and the nation, M.I.T. Sea Grant's Advisory Services help industries, government agencies, universities, and citizens put these advances to work. Sea Grant sponsors educational programs that give students multidisciplinary experience in ocean systems, ocean engineering, and coastal zone planning.

By discovering new ways of using the oceans' resources, and by communicating new approaches to marine opportunities, Sea Grant provides practical economic and environmental benefits to all who use the seas and coastal zones. Each Sea Grant project produces pragmatic innovations and improvements for ocean-related industries or for the marine environment.

On 30 June 1973, Dr. Alfred A. H. Keil moved on from Directorship of the M.I.T. Sea Grant Program, after guiding the program through its successful first year of Institutional grant status. As Dr. Keil's successor, I am working to have Sea Grant express even more fully M.I.T.'s philosophy of applying technology to marine resource development.

The essential support of Institute faculty, research staff, and students, and a similar commitment from participating organizations, institutions, and industries, have made M.I.T.'s second year as an Institutional Sea Grant Program a productive one. In this report, we present the results of the Institute's dedication, through Sea Grant, to balanced, beneficial use of the oceans and coastal zones.



Dr. Ira Dyer
Director

Bill Richardson - New England River Basins Commission

BALANCED USE OF OCEANS AND COASTS

Plans for using the coastal zones must reflect concern for the prolific natural environment of estuaries and bays. Sea Grant activities support the balanced utilization of coasts and offshore waters. Through Sea Grant research at M.I.T., mathematical models predict the course of physical processes in bays to facilitate environmentally sound disposal of wastes. Sterilization of sewage effluent by high energy electrons could turn wastes into nutrients for marine life. Courses sponsored by Sea Grant on coastal zone management communicate to students methods of planning coastal uses that are consistent with sound environmental policies.

The Massachusetts Bay Environment How can Massachusetts preserve its fertile estuaries and bays while encouraging the coastal zone development important to its economy? Mathematical models that describe and predict the hydrodynamics of Massachusetts Bay can help the state preserve environmental balance in its offshore waters. To develop such models, M.I.T. Sea Grant's major project on water circulation and dispersion in Massachusetts Bay completed its third year of intensive research and computer analysis.

Measuring Massachusetts Bay While natural decay and dispersal 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. Experts at M.I.T. are studying how the Massachusetts Bay is affected by dredging, dumping of solid waste and sewage, discharges of cooling water, and freshwater runoff flowing into the bay from the Merrimac and other New England rivers.

Researchers sponsored by Sea Grant in M.I.T.'s Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics have finished obtaining information on the bay's water. Sampling from the Institute's research vessel *R. R. Shrock* determined salinity, water temperature, currents, chemistry, and suspended sediments.

Variations from normal levels in any of these characteristics could indicate drastic changes in the bay's ability to support marine life. As an example of ecological interrelationships, the nitrogen level in the bay is one of the limiting factors for phytoplankton growth. The amount of nitrogen constantly fluctuates with changes in freshwater runoff from rivers or wastewater effluent from urban sewage systems. Exploring the effect of these changes, Sea Grant researchers studied the bay's nitrogen nutrient cycle in an intensive field experiment conducted over several days.

Modeling Massachusetts Bay Investigators have been incorporating data obtained on the bay's currents and chemical characteristics into computerized mathematical models. Computer models made operational this past year predict water circulation and dispersion in Massachusetts Bay, two processes that determine the transport and mixing of pollutants and sediments in seawater. Government agencies and environmental consultants will be able to use the models for optimal siting of industrial facilities and power plants, for coherent coastal zone planning, and for drafting pollution control guidelines. The New England Electric System has already used the circulation model in siting studies of Narragansett Bay.

Researchers devoted part of this year's project to testing and revising the models, preparing them for release to other users. Verification for the circulation model involved cataloging and analyzing data on tide and wind conditions in the bay, running the computer program with these data, and comparing the predicted result with actual observations. This type of analysis will be continued, and extended to other models that are being developed, to improve the programs as tools for environmental impact assessment.

First Doherty Professor Studies Red Tide A significant contribution to marine education and research at M.I.T. was inaugurated in February 1974. Dr. Francois M. M. Morel, of the Department of Civil Engineering, was chosen as recipient of the first Doherty Professorship in Ocean Utilization, a chair endowed under Sea Grant administration through the generosity of the Henry L. and Grace Doherty Charitable Foundation Inc.

For the coming year, Professor Morel will study mechanisms which may cause the destructive dinoflagellate blooms, or red tides, that have closed New England shellfish beds several times in recent years. Working in conjunction with investigators from the Massachusetts Bay project, Dr. Morel will test the hypothesis that increased amounts of organic substances in the bay may reduce the inhibiting effect of trace metals on the growth of red tide populations.

During the spring of 1974, the M.I.T. Sea Grant Advisory Services began planning its own contribution to solving the red tide problem. Cooperating with the Massachusetts Science and Technology Foundation, Sea Grant will cosponsor in November 1974 an international conference on toxic dinoflagellate blooms. Assembled experts will present current research on the oceanographic conditions associated with blooms, the biology of the dinoflagellate organisms responsible for red tides, toxin chemistry and pharmacology, and public health problems of the paralytic shellfish poisoning caused by the blooms.

Electrons for Pollution Control Through another Sea Grant project at M.I.T., scientists continued studies on wastewater and sewage irradiation with high energy electrons as a possible pollution control method. By inactivating disease-causing microorganisms, electron beams can turn large volumes of wastewater and sewage effluent into potential resources, such as reusable fresh water for cities or fertilizers for agriculture and aquaculture. On the strength of research results accomplished under Sea Grant support, the National Science Foundation underwrote a continuing effort for the coming year with funding from its Research Applied to National Needs program.

While the electron treatment process may be applicable to urban sewage treatment centers, its most feasible short-term use is in smaller, more specialized systems. For instance, during studies on oyster aquaculture systems with the Woods Hole Oceanographic Institution, irradiation achieved complete inactivation of selected viruses in water samples. Further experiments will extend the treatment to a wider spectrum of viruses and will tackle the problem of viral concentration in the water.

Joint studies have also been pursued with the U.S. Department of the Interior's Fish Disease Laboratory at Kearneysville, West Virginia. Complete inactivation was not attained with all the virus types tested, but research with a broader range of dosages should provide better results. At the laboratory, scientists are examining the potential of electron beam irradiation for treating both the influent and effluent waters of the experimental fish tanks.

The high energy electrons might also have a significant role in shipboard waste treatment. Moreover, hospital

wastewater, a potential source of pathogens, could also be sterilized by on-site electron beam irradiation systems.

Interdisciplinary Systems for the Coastal Zone Each year Sea Grant sponsors an interdisciplinary systems design course that puts students to work on a complex topical problem in marine and coastal resources use. Professors leading 1974's course had students evaluate alternative uses for the Boston Harbor land made available by the closing of Charlestown's Boston Navy Yard, the South Boston Naval Annex, and the Chelsea Naval Hospital. Coming at a time of renewed interest in the rejuvenation of Boston Harbor, the closing of the Navy Yard presented an opportunity for course participants to match disciplines with issues in balanced coastal zone development.

Students examined the viability of various uses for these urban waterfront lands. Representatives from Federal, state, and city agencies spoke with the class on the conversion of the Navy base to civilian purposes. Based on their semester's research, students generated potential plans for development that reflected the best economic, social, and architectural solutions to the problem of allocating uses for the waterfront lands. A formal presentation of these results was made to the public in May 1974, and the final report is now in preparation.

Teaching Coastal Zone Planning In 1974, M.I.T. Sea Grant introduced a graduate level course on management and planning for coastal utilization. Within the framework of integrated engineering, scientific, and social disciplines, professors and guest lecturers presented topics on the coastal environment. They spoke to students on the human activities which compete for the use of coastal space, the present and future impact of development on coastal aesthetic and cultural values, and the economic and political structure which determines many coastal zone uses. This new course fills a long-standing gap in marine education by giving student engineers and urban planners the broadened perspectives and analytical tools needed for rational management of complex coastal zone issues.

Cooperation with the Commonwealth on Coastal Zone Management Professor Judith T. Kildow, of M.I.T.'s Department of Ocean Engineering, is Sea Grant's representative on a special state task force. In January 1974 Governor Sargent of Massachusetts appointed the Task Force on Coastal Resources, a citizen's advisory group which works closely with the Executive Office of Environmental Affairs in formulating policies, identifying priorities, and developing programs for state coastal planning efforts. Professor Kildow speaks on behalf of technological and policy interests in the Commonwealth's coastal zone.

Sea Grant's Marine Resources Information Center (MARIC) is part of the program's Advisory Services. As one of its overall responsibilities, MARIC maintains extensive literature and reference services on coastal zone management. The Center was also the collection point for reading materials on the new coastal zone course sponsored by Sea Grant.

Arthur B. Clifton

FOOD FROM THE SEA

Sea Grant is working to increase the ocean's harvest of food and useful materials derived from ocean life. Innovative technology developed through M.I.T.'s program will make more marine protein available to domestic and foreign markets. Discovering and communicating new methods for aquaculture and seafood processing, new ways of converting sewage and shellfish wastes into resources, and new techniques for increasing offshore stocks of finfish are part of Sea Grant's commitment to greater human use of living marine resources.

Recycling Wastes into Nutrients Laboratory experiments have shown that secondary sewage and thermal effluent from power plants have a beneficial effect on shellfish growth rates. Although studies of reusing societal wastes in aquaculture to furnish food resources have indicated the technical and economic feasibility of such practices, nontechnical factors may prevent implementation of this innovative concept, at least for the next decade.

Sea Grant investigators studying this problem identified several categories of nontechnical constraints on waste-food recycling, such as public health, government regulations, economic feasibility, and consumer acceptance. The multidisciplinary group examined the public health risks from possible biological and chemical wastewater contaminants, and determined that adequate monitoring and control systems to eliminate hazards are essential for this type of aquaculture. Political processes and regulatory agencies controlling public decision making on commercial waste-grown foods were described, and recommendations made for achieving acceptance and approval of these foods.

The Sea Grant research group anticipated the social and economic impacts of waste-food recycling, including nonmarket or indirect costs. Since consumer reaction might be strongly negative to food products grown on treated sewage effluent, the research group mapped out effective ways of introducing and promoting these foods on the established seafood market. Finishing its second and final year of study, the Sea Grant group decided that, while the long-term outlook is good for the use of recycled wastes as nutrients for aquaculture, short-term emphasis should be placed on conventional aquaculture systems which do not entail added costs and risks from public health hazards.

Warm Water Aquaculture The recent scarcity of oysters harvested from Massachusetts waters has driven the market price up to levels that make commercial oyster farming an attractive possibility. Since oyster growth increases with water temperature (for Cape Cod oysters, eighty percent of annual growth occurs during the summer months), Sea Grant investigators saw excellent potential for using the warmed water discharged by power plants to maintain this high growth rate year-round.

Working at the University of Massachusetts Aquacultural Engineering Laboratory in Wareham, Massachusetts, experimenters designed a set of raceways to hold the young oysters, and a pumping system to bring water from the Wareham River to the raceways. One section of the raceways received unheated river water which reflected normal seasonal temperatures, while another section was supplied with heated water. Since raising the water's temperature lessens its ability to carry dissolved oxygen, the gas forms air bubbles that suffocate the oysters by collecting on the animals' gills. A deaeration unit was designed and built to prevent this problem of gas embolism among oysters in the heated raceways.

Results from the raceway experiments indicate that the heated water has significantly accelerated oyster growth. However, a limiting factor on the shellfish growth rate has been the availability of microscopic marine plants in the water during the winter months. Research in the coming year will tackle this problem of food supply. Project investigators are also planning further exploration of methods for eliminating shellfish embolism, and will use computer programs to perform economic and engineering analyses of large-scale oyster aquaculture systems.

Processing and Marketing Squid Sea Grant's continuing project on squid has studied the utilization of this cephalopod as a supplement for scarcer, more expensive seafoods. Past work has developed a prototype processing machine that cleans and skins the squid faster than the manual methods presently used. New seafood products created from squid could be inexpensive substitutes for clams, shrimp, and finfish in chowders, as snacks, or as entrées. Numerous requests for information from domestic and foreign seafood processors over the past year attest to a high level of interest in the squid machine and products.

During 1973-1974, Sea Grant researchers in M.I.T.'s Department of Nutrition and Food Science studied a new method of processing squid for human consumption. Testing various techniques for extracting concentrated protein from the squid muscle, they found that preparation of squid protein concentrates is possible. However, these concentrates are characterized by malodors, and further work is needed to make them acceptable food additives.

Another facet of this year's squid research was a marketing study conducted in cooperation with M.I.T.'s Sloan School of Management. Taste tests on fried squid rings, squid chowder, and squid cocktail, all of which the testing panel rated as excellent, were used to evaluate squid's salability on the current American market. Though people who had tasted the squid liked it, a survey showed that consumers were unwilling to try this food for the first time. Seafood industry representatives saw little chance for the successful introduction of squid on the domestic seafood market. However, export to Mediterranean and Oriental countries, where squid is a popular dietary staple, could be a lucrative use for domestic catches. For the final year of the squid project, researchers will complete market studies and prepare a comprehensive report on squid's potential as seafood.

Chitin and Chitosan Shellfish wastes from seafood processing plants can be turned into useful substances, according to Sea Grant researchers at M.I.T. and at the University of Washington. Chitin, the natural polysaccharide that occurs in the shells of crabs, lobsters, and other crustaceans, can be chemically transformed into chitosan, a material with apparently great potential in industry, food processing, and medicine. A pilot plant operated in Seattle by the University of Washington's Sea Grant Program has been producing bulk chitin and chitosan, and at M.I.T. scientists sponsored by Sea Grant have investigated the structure and properties of these materials.

During the M.I.T. project's first year, researchers used X-ray diffraction and small angle X-ray scattering techniques to ascertain the structure of chitin, chitosan, and the films made from them. Laboratory experiments show that the film structure depends on qualities of the bulk chitosan; these characteristics are affected both by the

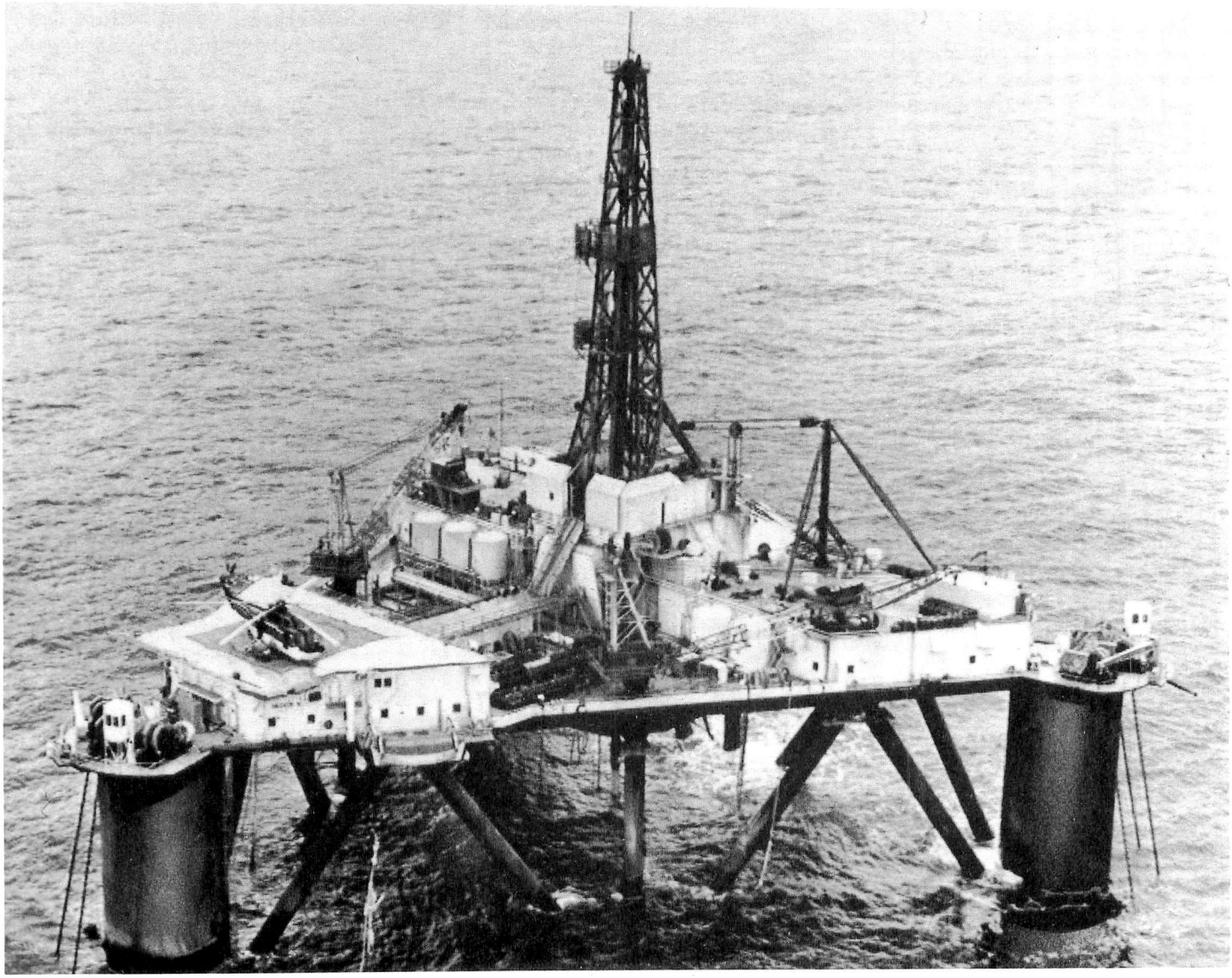
species of shellfish used and by the processing methods employed. Investigators have also discovered procedures for making a variety of reproducible chitosan films.

Improving Fisheries Stocks During the spring of 1974, M.I.T. Sea Grant Advisory Services participated in a field project designed to increase the numbers of herring spawned in brooks throughout southeastern Massachusetts and on Cape Cod. Herring swim up coastal streams to small ponds for spawning. But many brooks have become too shallow for the fish because of sedimentation. Moreover, plant overgrowth and man-made obstacles such as culverts can also obstruct these herring runs.

A joint M.I.T.-University of Massachusetts Sea Grant Advisory Services team looked for alternatives to traditional wooden or concrete fish ladders, which are expensive to design, build, and maintain, and which are subject to washouts and sedimentation. The investigators designed a low cost dam made from a sheet of flexible plastic, placed in a stream so that the long axis coincides with the direction of the water's flow. The sheet's center is drawn up with rope attached to a log placed across the stream banks, forming the dam face which traps sufficient water to raise the level of the stream.

The dam can be easily installed in coastal streams to provide the herring with swimmable passage to the spawning ponds. The deeper water also protects the fish from the seagulls that feed on them. Sea Grant staff expect that, with more herring able to navigate the once shallow streams and to reach the ponds, their numbers should increase, and thus improve the oceanic stocks of finfish which rely on the herring as a major food source. The plastic dam can also be used as a preliminary, temporary weir to determine the best site for a permanent dam, or as an inexpensive aid to the study of fish habits.

Advisory Services for Marine Fisheries Working on a spokesman-to-spokesman level, M.I.T.'s Sea Grant Advisory Services participates actively in programs with local organizations and agencies. In addition to the herring run project with the University of Massachusetts, cooperative planning has begun with the Massachusetts Maritime Academy to develop a curriculum for training commercial fishermen. Sea Grant staff also worked with the New England Fisheries Steering Committee, the Massachusetts Department of Natural Resources and Executive Office of Environmental Affairs, the Massachusetts Shellfish Wardens Association, and the Governor's Commission on Artificial Reefs to exchange information on needs and opportunities in marine technology for the commercial fisheries.



Wide World Photos

UNDERSEA MINERALS AND ENERGY

Petroleum and mineral deposits on the continental shelf could provide fuel and raw materials for future transportation and industry needs in New England and nationwide. Sea Grant's concern for the rational extraction and use of the ocean's resources has led to research at M.I.T. on economic and environmental tradeoffs associated with the exploitation of marine minerals. Through the program's Advisory Services, symposia have acquainted interested citizens with the ocean's role in national energy needs and offshore minerals development policy.

Offshore Oil Finances Sea Grant's research this year on offshore leasing and royalty policies complements its important study done in 1973 on the potential economic and environmental results of proposed petroleum extraction from Georges Bank off Cape Cod. Project investigators calculated how alternative policies and options for the regulation of oil production might affect public and private income. Their computer model on offshore petroleum development was extended so that, in addition to analyzing basic cost and production factors, the model would compare bonus and royalty policies.

Using eighteen years of data supplied by the U.S. Geological Survey in Denver, the research staff studied the competitiveness of recent lease bids and the effect of this competition on oil production. Analytical methods developed through the project's research will be furnished to government agencies for their use in making policies on lease frequency and size, and on production regulations.

Supporting the President's Council on Environmental Quality As part of its research on oil exploration and drilling on the Atlantic and Alaskan continental shelves, the President's Council on Environmental Quality commissioned two studies at M.I.T. during 1973-1974. Also based on techniques introduced in the 1973 Georges Bank work, these studies were to assess the possible physical and biological impacts on the coastal zones of offshore oil production. The research results were published by the Sea Grant Program to ensure wide dissemination of the information.

Investigators made qualitative predictions of oil's biological effect on various coastal habitats and natural communities. These predictions were based on environmental inventories and on the probability of accidental spills, spill trajectories, and the behavior of oil in marine ecosystems.

The research team found that oil spills from Atlantic offshore platforms in the Baltimore Trough and on Georges Bank would have little or no significant biological effects on natural plant and animal populations, while spills from drilling sites off Georgia would pose relatively higher environmental risks. For all sites, nearshore spills from coastal terminals would beach in less than two days, and the unweathered oil would cause high mortality among most exposed species. Because little ecological data exist for the Gulf of Alaska, conclusions on spill effects in this area are highly uncertain.

The companion report to this analysis compiled four separate studies on the initial physical effects of offshore oil development. One group of investigators created an Offshore Development Model that can be used to project optimal investment strategies, probable oil and gas production over time, number of platforms, amount of drilling activity, and amount of oil and gas transported by pipeline or tanker.

Another study used data on past spills to estimate the likelihood and sizes of spills from offshore towers, pipelines, tankers, and single buoy moorings on the Atlantic and Alaskan continental shelves. Some investigators analyzed the probable trajectories of oil spills originating from potential Atlantic and Alaskan sites and from three possible East Coast nearshore terminals. They also modeled the evaporation and dissolution into seawater of soluble hydrocarbons from weathering oil slicks of varying thicknesses.

Communications on Using the Ocean's Mineral Resources Through a joint program, members of M.I.T.'s Department of Ocean Engineering, sponsored by Sea Grant, are working with Harvard Law School faculty to identify the institutions, techniques, and perspectives needed for balanced use of marine mineral resources. During the project's first year, professors prepared teaching materials on interrelated facets of law and ocean engineering. Student reports described how technology and legal controls interact in the production of offshore oil, gas, and nuclear power, in mining of manganese nodules from the seabed, and in planning deepwater oil terminals.

On 18 October 1973, Dr. William E. Shoupp, Senior Vice President for Research of the Westinghouse Electric Corporation, gave the second annual Sea Grant Lecture. This lecture serves as a forum on the roles of engineering and the sciences in developing new approaches to the use of marine and coastal resources. Speaking on "World Energy and the Oceans," Dr. Shoupp called for action to maximize use of the seas for fuel resources, for fuel transport, and for sites of new power plants and superports. He also recommended research to find more efficient uses of energy to benefit both ecology and the national economy. Presenting symposium papers on related topics, M.I.T. Professor John W. Devanney III described key issues in offshore oil production, and Professor Donald R. F. Harleman spoke on recent innovations in oceanic disposal of waste heat.

Sea Grant's Advisory Services sponsored two conferences this year to acquaint the M.I.T. community and the public with issues in marine resources utilization and ocean energy development. In March, almost 1000 people attended the symposium on the Law of the Sea Conference, sponsored jointly by the Massachusetts League of Women Voters, the United Nations Association of Greater Boston, and the M.I.T. Sea Grant Program. The symposium focused on the Conference's impact on marine research, regimes for ocean regulation, pollution control in the oceans, and extraction of marine mineral resources. In June 1974, Sea Grant assisted the National Wildlife Federation in presenting a seminar on the impact of oil drilling off the northeast Atlantic Coast. The gathering presented viewpoints from environmentalists, fishermen, biologists, oil company representatives, and Federal and state agency officials.

Metropolitan Area Planning Council

ENGINEERING FOR OCEAN UTILIZATION

To advance people's capabilities for using the oceans, the M.I.T. Sea Grant Program seeks to improve engineering for marine commerce and industry. Sea Grant studies support the design of modern ports and shipping networks, and commercial fishing's utilization of improved gear and business opportunities. Through research on materials and methods for marine construction, M.I.T. Sea Grant helps ocean engineers develop and modify technology for expanding human activities at sea.

Ports and World Trade One important aspect of modern oceanic commerce that warrants attention is the redesign and renovation of traditional ports. Port planners need guidelines for developing and modernizing onshore and offshore facilities to accommodate modern systems of cargo handling, such as containerization. To provide such guidelines, a Sea Grant project completed this year studied the new methods and decision-making criteria needed by shippers, governmental agencies, and port authorities for up-to-date port planning.

Research involved analyses of the function, operation, design, and performance of modern ports and terminals, and evaluated decision making in harbor development. Two general assumptions guided the investigations: first, that a harbor's ability to expedite the flow of commodities is directly related to its facilities for vessel docking and transfer of goods to other ships or to on-land transportation; second, that ports' capacity for handling cargo can be improved by an analysis of harbor design and the decision-making routines of the port authority.

Researchers have created four computer models on aspects of port performance. These models project the costs and data involved in planning multipurpose ports, evaluate the cargo container terminals used for temporary storage and freight transfer, analyze sea-port-land transportation networks, and optimize commodity flow through these networks. The kinds of regulatory and jurisdictional codes needed for offshore docking and product delivery have also been documented. Guidelines deriving from these new methods created by Sea Grant research should assist port authorities and private industry in designing efficient modern ports.

Commerce and the Panama Canal During the past year, Sea Grant investigators completed a three-year project that studied the future of the Panama Canal in light of current trends in commerce, shipbuilding, and international politics. The waterway cannot accommodate the new class of supertankers plying the oceans, and several alternatives for enlarging or replacing the canal have been suggested. Also, treaty and tolls policies have been examined by the researchers.

The major results from the study will be incorporated into a comprehensive book entitled *Maritime Commerce and the Future of the Panama Canal.* According to the authors, the Panama Canal, properly maintained and operated, appears adequate to serve world shipping in the foreseeable future. Though valuable for promoting United States interests, the loss of the canal would not cripple the American economy. Now in press, the book could guide world shipping interests, the Panama Canal Company, and United States decision makers in determining the future role of the canal.

Working for the Commercial Fisherman On side trawling fishing boats — a type still common in New England waters — the net tow cables are held by the hook-up (or towing) block in position at the side of the vessel near the stern. The block releases the cables at the end of the trawl run so that the net can be hauled up and on board over the rail amidships. The hook-up blocks currently used are slow, difficult, and dangerous to operate, and have caused serious injuries and fatalities among fishermen.

Concerned Massachusetts fishermen requested that the M.I.T. Sea Grant Program design an improved block for New England's side trawlers. In mid-1973, investigators from the Institute's Department of Mechanical Engineering began research to invent a new hook-up block and system that would be safer and quicker to operate, be low in cost, and require minimum maintenance to meet the needs of fishing boats.

Researchers have cooperated closely with the fishermen since the project's inception. They have built up a working knowledge of the side trawling operation by trips on fishing boats and conversations with captains and crew, and have discussed with the fishermen various solutions which might improve the hook-up operation. Based on these field studies, a prototype block was designed, constructed, and successfully tested in the laboratory. At-sea testing of the block in the actual trawling operation will begin in July 1974. The project team anticipates that a better, faster hook-up block will increase fishing boat productivity and reduce the risk of operating hazards by improving safety.

Cooperatives for Fisheries Economics The New England fisherman is essentially a small businessman. On his own, he has little chance for revenues that could be realized through large-scale processing and marketing of fish. To organize fishermen for achieving these economies of scale in New England, more than thirteen cooperatives have been started with varying degrees of success. At the fishermen's request, Sea Grant began a project to study possible criteria for successful cooperative operations.

Researchers intend to work toward the direct improvement of existing fisheries cooperatives in New England, to provide guidelines for those considering the formation of a cooperative, and to assist Federal and state agencies in revising government fisheries aid programs. They are examining aspects of functioning New England cooperatives, including equipment, labor supply, and location, the landing, processing, and marketing of fish products, and organizational structure. Preliminary results indicate that large regional cooperatives have potential benefits, in theory; however, they will not be feasible in some specific instances.

Underwater Welding For underwater repairs of metal structures, such as pipelines, piers, or oil rigs, engineers have had to rely on dry welding, an expensive process requiring construction of an air chamber around the welding site. Sea Grant's three-year project on underwater welding and metal cutting may change this. Completed in 1974, project results could lead to an efficient, economical underwater repair methodology for metal structures at sea.

During the project's final year, fundamental research work demonstrated the changes an underwater environment makes in the metallurgy of welds. Researchers have recommended a new method to improve the accuracy of heat flow analysis in underwater welding. Experiments examined bubble formation through the welding arc's heat and the effect of these bubbles on heat flow, metal transfer, and weld strength.

Following investigations of arc bubble dynamics and experimental determination of the size of the weld metal puddle, a computer model of the heat transfer process in underwater welding was prepared and tested against measured data. Further laboratory experimentation on the metallurgy, microstructure, and metal transfer of welding underwater concentrated on the welding current and speed, the size and type of electrode used, and polarity. Initial studies have begun on the development of improved methods for underwater welding.

Education for Practitioners The joint Sea Grant Advisory Services/M.I.T. Special Summer Program is geared to the needs of professional engineers and businessmen in the marine field. Through week-long short courses, this advisory project brings practitioners up-to-date on technological and scientific advances in ocean engineering and marine resources utilization. This past summer the Sea Grant program organized two sessions of a course in transportation systems analysis and design, and a review of current and future trends in ocean engineering structures, materials, and fabrication.

Fracture Mechanics and Fiberglass Boat Hulls The shipbuilding industry needs data on the fracture mechanics of fiberglass-reinforced plastics being used to construct increasingly larger boats. Just as certain types of welded steel hulls are prone to sudden brittle fracture and breakup, so might the plastic hulls crack and break apart under rough conditions at sea. Fifty- and sixty-foot plastic-hulled craft are now common, and ships over 150 feet long are under construction. Sea Grant researchers have studied the cracking characteristics and fracture toughness of the reinforced plastic composites that would be used in fabricating these hulls.

During 1974, experiments continued on fatigue loading, in and out of seawater, of different sample composites made of woven fiberglass fabric and polyester. Theories and testing methods gauged the effect on sample failure of composite thickness, of crack propagation direction over the orientation of the woven reinforcing fibers, and of the type of notches machined into the samples as starting points for the cracks. From this testing, the investigators have developed a theory that predicts crack growth rates in wet or dry composites.

Researchers have concluded from their experiments that fiberglass-reinforced plastic hull materials are subject to catastrophic failures, and determined the critical notch sizes that would cause failure. When the investigators measured crack growth rates under sustained tensile loading, they found that seawater accelerated somewhat the failure of notched composite samples. Boat manufacturers and ship designers will be able to apply these studies of strength and crack resistance in the designing of reinforced plastic hulls. Materials manufacturers also will find the results helpful in developing and improving resins slated for marine uses.

Education for Ocean Engineering Sea Grant's student summer laboratory is designed to help Institute students benefit from the practical experience of developing equipment for and applying technology to man's marine activities. The laboratory provides students with the opportunity of creating solutions to real ocean engineering problems. Each year, students design and construct equipment during the fall and spring terms, then move to the Maine Maritime Academy in Castine, Maine, in the summer months for field trials of the instruments and techniques.

Students in this year's laboratory successfully designed and launched an underwater robot. Christened the *Albertross*, the 250-pound submersible is free-swimming, and will be programmed to carry out underwater oceanographic research tasks. Initial dives were conducted at the end of a 50-foot tether; eventually, the student engineers plan to install an autopilot and computer to instruct the robot on specific depth and path to be followed underwater, and the type of marine data desired by its users. Students also investigated the behavior of underwater cables, in an experimental program sponsored by the Office of Naval Research.

Under Sea Grant sponsorship, classroom education in marine sciences at MIT is being expanded as well. Three new subjects are being planned for the Department of Ocean Engineering on marine data systems engineering, on deep ocean engineering, and on the utilization of marine resources. One subject, on sound transmission in the oceans, has already been outlined and was first taught in the fall term of 1973. Faculty members are revising and updating selected ocean engineering curricula as part of fulfilling the Sea Grant goal of coherent educational programs in marine science and engineering.

FISCAL YEAR 1974
INSTITUTIONAL PROGRAM SUMMARY

Program Area	For Year Beginning July 1, 1973
Program Management	
Sea Grant Program Management, Dyer	C
Education and Training	
Interdisciplinary Systems Design Subject, Seifert	C
Student Summer Laboratory, Carmichael	C
Studies in Ocean Engineering/Law, Nyhart	N
Ocean Engineering Curricula, Dyer	N
Development of a Subject in Management and Planning for Coastal Utilization, Devanney	N, T-3
Advisory Services	
Advisory Services: Development, Operation, and Management, Dyer, Horn, and Pariser	C
Marine Resources Information Center, Pariser and Kyed	C
Symposia on Sea Grant Projects and Marine Resources-Related Projects, Pariser	C
Sea Grant-Related Reports and Information, Dyer and Pariser	C, T-2
Public Education and Training Short Courses, Austin	C
Annual Sea Grant Lectureship, Dyer	N
Analysis of Marine Advisory Services in Massachusetts, Pariser and Zahradnik	N, T-2
Research	
The Sea Environment of Massachusetts Bay and Adjacent Waters, Ippen and Mollo-Christensen	C
Nontechnical Problems of Marine Waste-Food Recycling Systems, Dyer and Huguenin	C, T-2
Sludge and Water Treatment with High Energy Electrons, Trump	N
An Improved Hook-Up Block for Side Trawling, Loutrel	N
Using Cooperatives to Aid the New England Fishing Industry, Marcus	N
Evaluation of Potential of Heated Finishing Plant for Oysters, Seifert and Zahradnik	N
Utilization of Squid for Processed Food Products, Goldblith	C
Structure of Chitosan, Averbach	N
An Analysis of Offshore Mineral Leasing and Royalty Policies, Lassiter	N, T-2
Ocean-Borne Commerce and Future Interoceanic Canal, Padelford	C, T-1
Port Design and Analysis Methodology, Frankel	C, T-2
Fundamental Research on Underwater Welding and Cutting, Masubuchi	C, T-2
Fracture Toughness of Reinforced Plastic Hull Materials, McGarry	C

N New Project
C Continued Project
T-1 Work will be completed; book to be published
T-2 Work will be completed; Sea Grant Report(s) to be published
T-3 Work will be completed; new subject will be developed.

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SUMMARY OF EXPENDITURES BY ACTIVITY

	NOAA Grant Funds	University Matching Funds
Program Management		
Program Administration	$ 47,400	$80,200
Program Development	24,000	—
Marine Education and Training		
College Level	76,500	99,400
Marine Resources Development		
Marine Economics	32,400	22,600
Socio-Political Studies	32,400	12,400
Marine Technology Research and Development		
Ocean Engineering	69,900	45,500
Resource Recovery and Utilization	62,500	31,800
Transportation Systems	21,200	20,700
Marine Environmental Research		
Environmental Models	125,800	39,200
Advisory Services		
Extension Programs	53,200	22,000
Other Advisory Services	60,800	89,700
TOTAL	$606,100	$463,500

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

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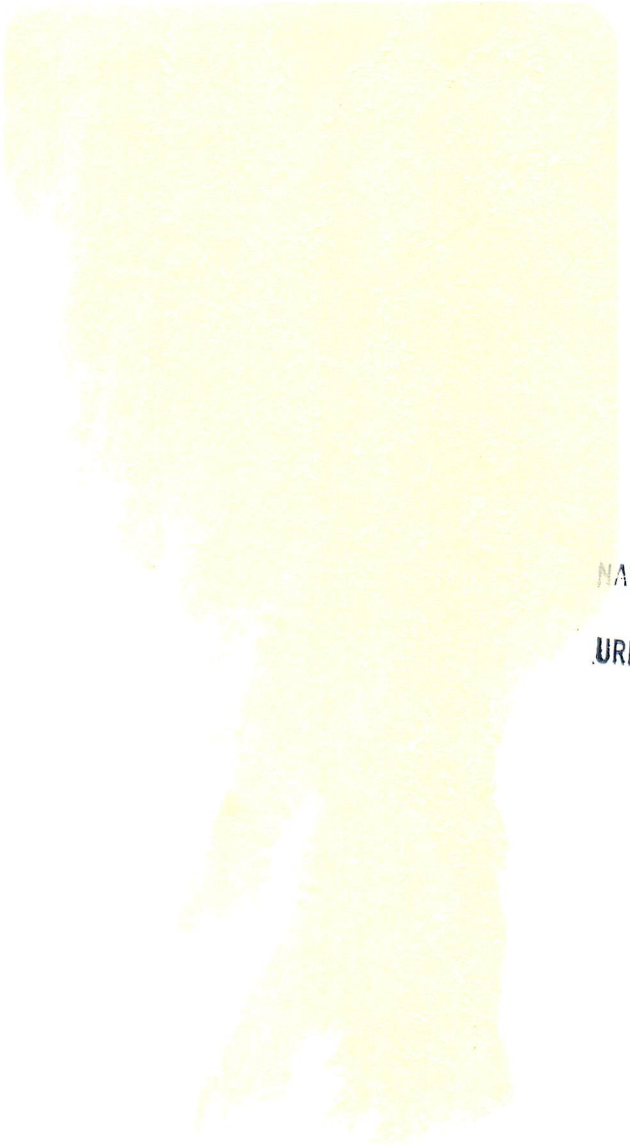

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