A report on the University of Delaware Sea Grant Program for September 1972 to August 1973

University of Delaware Sea Grant Annual Report 1972 - 73

CONTENTS

Director's Message	2
Research	4
Education	20
Advisory Services	22
Program Development	24
Budget and Program Statistics	25
Publications	26

SEA GRANT

The National Sea Grant Program was created on October 15, 1966, with the signing of Public Law 89-688, *The National Sea Grant College and Program Act.* The purpose of the Act is to accelerate national development of marine resources, including their conservation, proper management, and maximum social and economic utilization. The term "Sea Grant" was chosen to emphasize the parallel between the present needs of the nation in the marine environment and the need for development of the land at the time of the Morrill Act of 1862, which established the Land Grant Program. The Sea Grant Program follows the pattern of the Land Grant Program only to a limited extent: it provides the means through which scholars and institutions of higher education can apply their knowledge and talents to the practical needs of the nation and the world, and it includes the Land Grant concept of advisory services through which scientific research results may be most directly applied to real problems.

The National Sea Grant Program, originally assigned to the National Science Foundation, was transferred to the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under the President's Reorganization Plan #4, in October 1970. Within NOAA, the Program is administered by the Office of Sea Grant.

Director's Message

This report covers the second year of Sea Grant institutional status for the University of Delaware and its fifth successive year of Sea Grant program participation. The Sea Grant program is unique in the United States and in the world. This is because it is both broad and bold in its conception, encompassing these important catholic features:

- It is dedicated to solving marine resource problems and advancing commercial marine opportunities at the local, state, regional and national levels;

- It is university-based to involve the great depth and breadth of talent available in the nation's major coastal and Great Lakes states' universities;

- It requires a matching fund commitment by the participating institutions;

- It emphasizes information transfer through an advisory services program; and

- It provides incentives for institutional improvement by a series of steps which recognize academic and research excellence and reward accomplishment by stable, long-term funding.

In Delaware, marine research and education began in a formal way in 1950 when the Marine Laboratories were established with state funding, to organize "a program of research on past, present and potential products from the salt waters of the State; of instruction of special students, teachers, and public citizens on fishing, biology and conservation of aquatic resources; of encouragement of all types of investigations on salt and estuarine waters and their inhabitants; and for provision of advisory assistance to administrative and other agencies concerned with the utilization of marine and estuarine resources." (Laws of the State of Delaware, volume 48, chapter 73, pages 155-56).

In 1960, marine geology began to develop in the Department of Geology and in 1967 an ocean engineering program was started in the Department of Civil Engineering. In 1968 the first Sea Grant project award was made to the University. It was focused on the important problem of revitalizing the oyster industry, which had been a significant source of income and employment in the state but which had been decimated by both disease and pollution. New approaches were required involving biologists and engineers.

In 1970 the Delaware Sea Grant program was broadened to encompass the expansion of oyster research and ocean engineering education, and the establishment of a marine advisory service to transmit research results to users and to bring users' problems back to University researchers. A second important event in 1970 was the establishment of the interdisciplinary professional graduate College of Marine Studies by the University Board of Trustees. This college resulted from the problem-focused philosophy of the Sea Grant Program Act of 1965 and the recommendations of the Stratton Commission Report *Our Nation and the Sea* published in 1969. The College was also created to provide a 'home' for the Sea Grant program in the University of Delaware and in the regional community. This meant providing leadership, a management structure, and a solid working base from which the Sea Grant problem-solving approach could be shared with other units in the University, with regional industry, and with government.

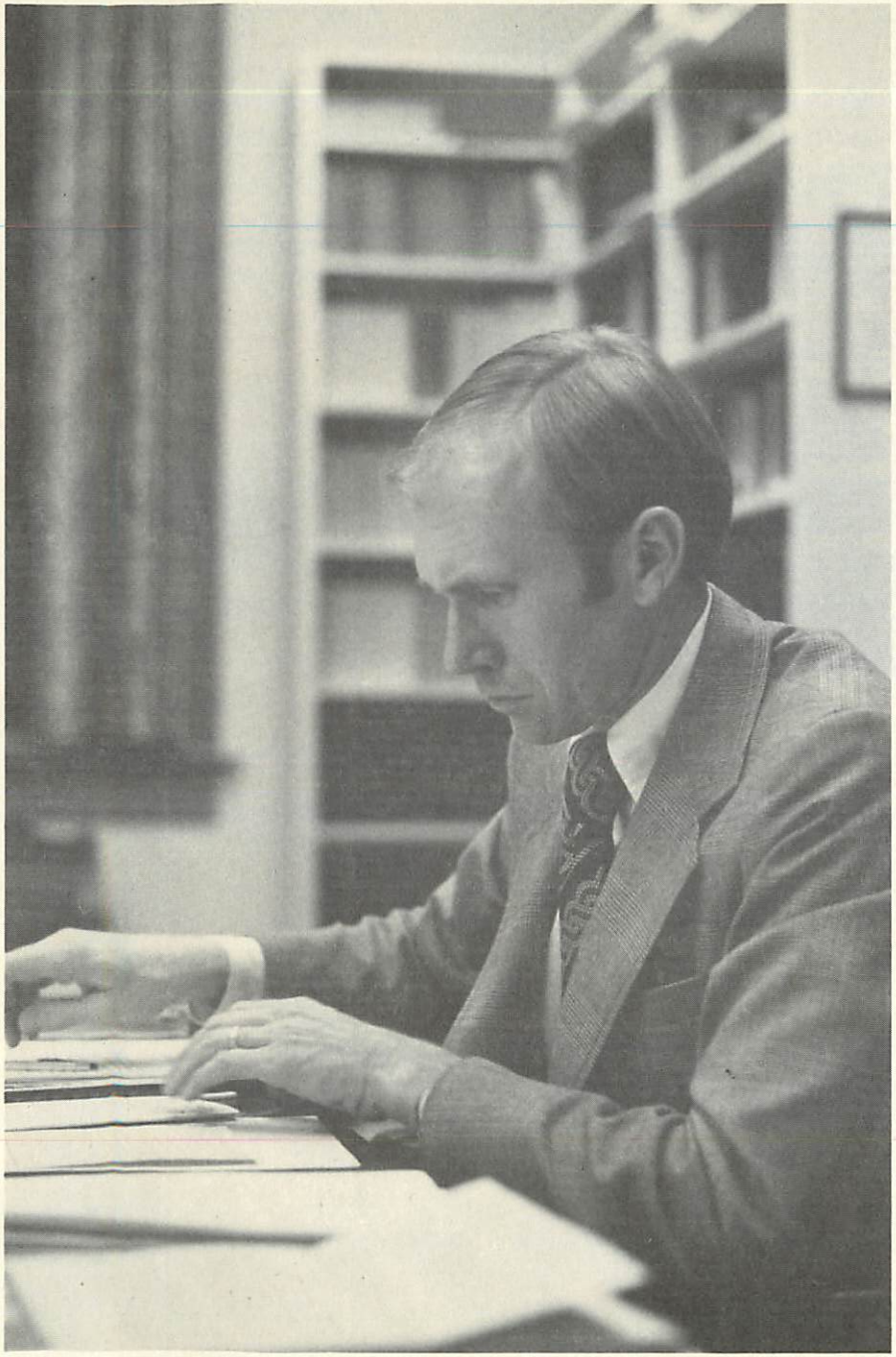
The 1972-73 Sea Grant program year was one of solid accomplishment and growth toward Sea Grant College status. Base funding was increased to $650,000 with an additional $69,000 assigned to conduct an assessment of national marine technician training. In research, the closed-cycle mariculture laboratory was moved systematically from its start-up stage into full research operational use with new and commercially promising results emerging. Experimental animals (clams and oysters) were maintained and matured in a closed-cycle system. Also, chemical assay methods were developed to monitor water quality in the recirculating system. All research efforts were directed toward ascertaining the technical feasibility of developing a commercially viable 'poultry house' type system for producing marine food animals.

In the resort-oriented Rehoboth Bay area of lower Delaware, a study was initiated on the White Creek watershed to evaluate the impact of development on small bay ecology. This research will make use of data from a similar study conducted in 1957-58 as a basis for quantifying change. For middle Delaware Bay, maps were developed to delineate bottom areas with trace metal contamination. Preliminary mapping began on the Delaware tidal wetlands using vegetation type as an indicator of relative productivity. Also for the tide marshes, a technique was perfected for the trapping of the voracious black flies. This project involved community participation and a future joint effort is expected to develop.

In education, three areas of major activity should be highlighted. First, the Office of Sea Grant Programs invited the University of Delaware to assume administrative responsibility for a national study of marine technician training. Second, under the direction of the College of Education, 50 marine environment curriculum classroom units, with visual aids, were completed and distributed in Delaware for test use in the public school system. Seven states purchased sets of the material for use in their K-12 school systems. Third, the first phase of a graduate marine affairs curriculum was developed and put into use in the College of Marine Studies. As part of the graduate curriculum development, a complete assessment of national marine affairs academic programs was published and distributed to the community. In addition, positive progress was made toward the establishment of a Center for the Study of Marine Policy.

In Advisory Service work, the most popular program was the Fisherman's Hotline which could be dialed toll-free from any point in the state to obtain up-to-the-minute fishing information for the ocean and bay. Over 68,000 calls were answered with regularly recorded information. A summer lecture series was well attended and work continued by a Sea Grant-stimulated fisherman's cooperative on the construction of an offshore artificial reef. The development of a modest lobster fishery continued on the baymouth stone breakwaters and the program of seed clam rearing and planting was expanded.

The relevance of Sea Grant research

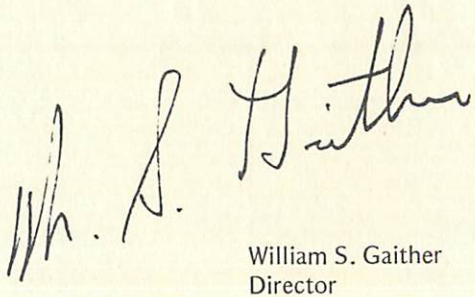


and the expertise of its faculty and staff members were recognized by new and continuing appointments to important state-wide committee activities. These included Drs. Price and Daiber on the Governor's Wetlands Action Committee (wetlands legislation was enacted), the Sea Grant Director as chairman of the Delaware Bay Oil Transport Committee (a comprehensive report was issued), and Mr. Goodman on the Technical Advisory Committee to the State Planning Office (a coastal zone comprehensive plan was adopted). At the national level, the Program Director was also named President-Elect of the Association of Sea Grant Program Institutions.

Working closely with the Sea Grant program management was the Sea Grant Advisory Council. This group of capable and dedicated individuals represented virtually all of the major interests in the coastal zone and provided valuable program guidance, review, and support.

As with many other Federal programs in 1972-73, some fiscal adjustments were required of the National Sea Grant Program during the early part of the program year. Budget growth rates were reduced and in some instances appropriated funds were withheld. As a result, therefore, the anticipated increase in Sea Grant funding for FY74 did not materialize. Rather, the budgets of participating institutions were reduced by 25% to 35% for FY74 to avoid overexpenditures. Fortunately for the University of Delaware, this situation was recognized early in the 1972-73 grant year and steps were taken to curtail or slow the pace of activities so that a nearly uniform level of effort can continue in the coming year.

In summary, the University of Delaware has made a strong and permanent commitment to the Sea Grant program both by the formation of the College of Marine Studies and by Sea Grant education, research, and advisory services. With the Sea Grant program as the cornerstone of its marine activities, the University has been able to undertake other important research which will benefit the state, the region, and the nation. One additional year remains before Delaware is eligible to be considered for designation as a Sea Grant College. The 1972-73 year was a solid year of progress to achieve that goal.



William S. Gaither
Director

RESEARCH

Research was an important part of the Delaware Sea Grant program during 1972-73. Many of the projects continued from the previous year, since the overall program is built around a three-year project completion cycle. As in the previous year, the program was organized into functional groups of projects concerned with a common theme, each under the direction of a group leader.

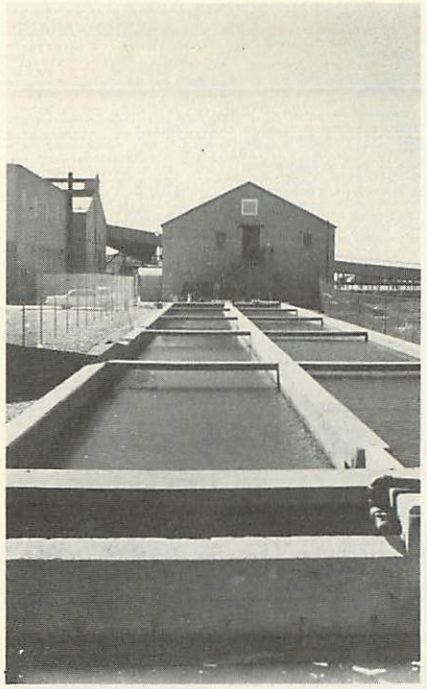
Five groups were organized, four continuing from the previous year and retaining the same group leaders. These were:

- Food From the Sea – A group of projects to explore the technical and economic feasibility of redeveloping Delaware's shellfisheries and developing the technology of closed-cycle mariculture, and to identify newly exploitable resources. Functional Group Leader: Dr. K.S. Price, Jr.

- Systems Engineering for Development Options – A group of projects to define engineering strategies for use in the coastal zone, with minimum resulting degradation. Functional Group Leader: Dr. R. Richards.

- Socio-Economic Aspects of Coastal Zone and Marine Resource Development – A group of projects to evaluate the impact of exploitation and development on the socio-economic structure of the coastal zone. Functional Group Leader: Dr. R. Agnello.

- Environmental Impact – A group of projects to develop an improved understanding of how man and nature interact with the coastal zone. Functional Group Leader: Dr. R.B.Biggs.

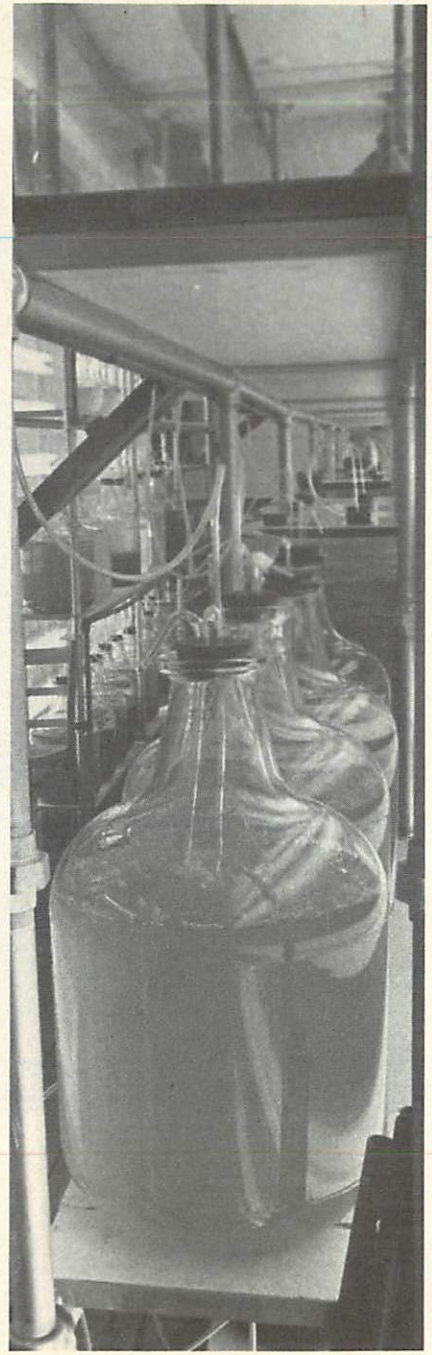


Project completions resulted in the Coastal Zone Management functional group now being phased out. A new functional group was formed to focus projects with near-term product potential. This group, called Exploratory Resource Development, is investigating the use of viral assay techniques for pollution monitoring and the use of shrimp and crab shell for packaging materials.

Food from the Sea

The focal point for the Food from the Sea projects has been the mariculture facility, designed to grow oysters to maturity in a closed-cycle system. Demonstrating the technical feasibility of the closed-cycle process was an important part of this year's work, as was investigation into the possibility of culturing other species under the same conditions. Work also continued on discovering the significance of *Fundulus heteroclitus* as a food fish in the salt marsh food web.

Research into food resources from the ocean is particularly relevant to Delawareans because it is a positive push toward revitalizing the industrial potential of the state's fisheries.



Mariculture Demonstration

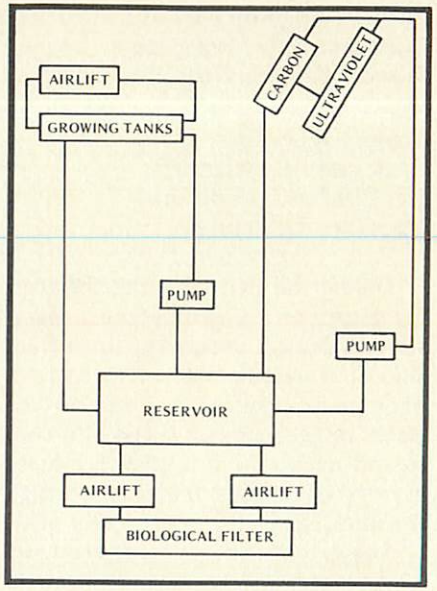
Project R/A-4
Principal Investigator:
Dr. Charles E. Epifanio

The mariculture demonstration project during the 1972-73 program year concentrated on an attempt to culture hard clams, *Mercenaria mercenaria,* from setting to commercial size in a totally recirculating seawater system. From a nutritional point of view, results show that the investigators at Delaware will very probably be successful in producing market-size clams in a recirculating system faster than would be possible in natural situations.

Several groups of clams were tested, each being fed a different diet, and shell height was used as an indicator of growth. An extrapolated growth rate for the fastest growing group would yield animals, after one year, with a shell height almost twice the size of Delaware Bay clams growing under natural conditions.

Investigators found that a diet of one diatom, *Phaeodactylum tricornutum,* alone is insufficient. Diets composed of two or more species of algae generally supported the fastest growth.

Maintaining adequate water quality in the recirculating system was a complex problem for the investigators. They had to define water quality requirements for shellfish, and engineer a suitable hardware configuration. To elucidate water quality requirements, a dual approach was used. Routine monitoring of chemical parameters (alkalinity, pH, dissolved oxygen, salinity, temperature, etc.) was initiated so that



RECIRCULATING CULTURE SYSTEM

significant changes could be detected early. Precise analysis of subsystem components was also done which lead to: toxicity studies; waste production, characterization, and decomposition studies; and nitrification filter toxicity and response studies.

Engineering Support of Demonstration Project: Process Engineering

Project R/A-2b
Principal Investigators:
Dr. Charles E. Epifanio
Mr. Gary D. Pruder

During the past year, the engineering effort of the mariculture demonstration project underwent three transitions: from laboratory construction, to experimentation, to the current status of analysis and design of a controlled environment system for rapid growth of bivalve mollusks in high densities, including waste treatment.

Subgravel filters are being evaluated as one method to support bacteria which are necessary to perform the nitrification step in the waste treatment. Nitrification is the conversion of toxic ammonia to non-toxic nitrate. Since sub-gravel filters also remove suspended particles from the water flowing through the bed, these filters are essentially competing with the animals under culture for available food particles. To discover the nature of this competition, a series of clearing rate experiments were carried out.

Investigators found that, using algae as a food, the rate of algal cell removal by the filter, after five months, was about 35 x 10^9 cells/ml/hr. They then ran a clearing rate experiment with adult clams and found that each animal removed algae from the water at a rate of only .155 x 10^9 cells/ml/hr. Comparing this rate to the rate of removal by the five-month-old filter indicated that the filter was equivalent to 225 adult clams.

At the current stage of engineering development of the controlled environment system, it is essential that more complete knowledge be obtained on the extent to which animal performance is affected by nutrients, oxygen, and metabolite concentration. The system must include a reliable means to balance upsetting forces and maintain concentrations of essential components within the limits which permit rapid animal growth.

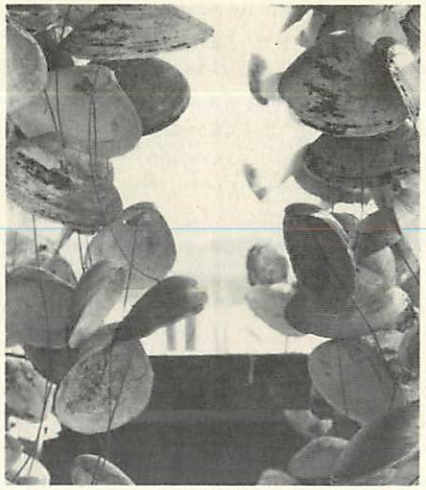
As an initial step in studying animal performance in a food-enriched environment, investigators observed the clearing performance of oysters exposed to differing algae concentrations. Study results indicated that the number of cells removed by each group of oysters was not a function of algal cell concentration. Also, as might be expected, food consumption rates were found to be directly related to how much an oyster had already eaten and the time elapsed from its last feeding.

Systems Engineering For Shellfish Production

Project R/M-4
Principal Investigator: Dr. Frederick A. Costello

The design of a commercial, closed environment oyster production system was analyzed, improved and optimized during the past year. Beginning in 1969, work began on a computer model of the system. The level of detail included piping, tank design, and material and installation costs. Based on the original design (following the American Cyanamid Report), a packaged cost per bushel of $64 was projected. Modifications to this design, in the areas of water recycling, recovering heat from the discharged water, and tank redesign, reduced the estimated cost to $23 per bushel. If expected results are obtained from the proposed and on-going research, this projected cost will be reduced to $13 per bushel, a competitive price for the half-shell gourmet quality oysters which would be produced.

To analyze the oyster production system, procedures were developed for 1) the automatic determination of the variables that most significantly influence system cost and performance, and 2) the assignment of statistical values to uncertainties in the process, such as uncertainty in growth rates, food requirements, etc.



New Species for Mariculture In Delaware

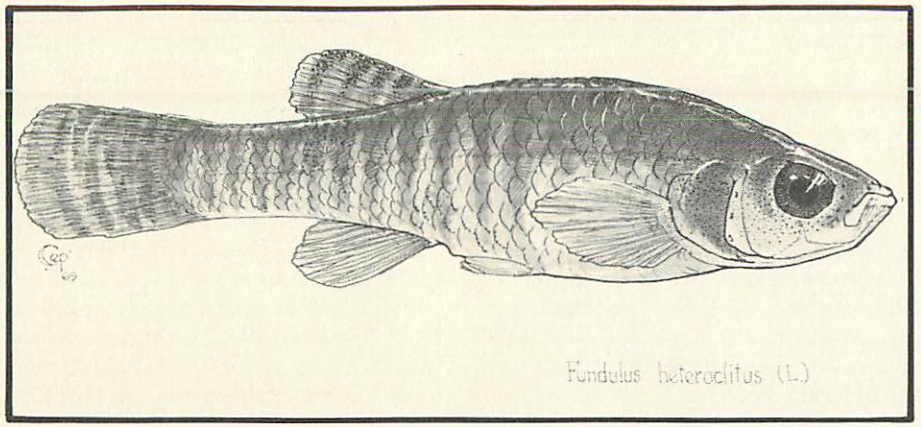
Project R/A-1
Principal Investigator: Dr. Charles E. Epifanio

Animal nutrition has been one of the more neglected areas of invertebrate biology although this situation is being partially remedied by the growing interest in commercial lobster, crab and shrimp mariculture, particularly in Japan and the United States. Very little was known about the nutritional requirements of the blue crab *(Callinectes sapidus)* before scientists at Delaware experimented with a series of manufactured and control diets. These diets, representing a wide range of protein concentration, were tested along with temperature and photoperiod to define optimum culture conditions for the blue crab. Seven experimental diets and one control diet were used. Lack of a consistent dietary effect was a noteworthy result of the study. Investigators found no significant dietary effects on molt cycle duration or on mortality. However, it is possible that food reserves stored while the crabs were still in the field could have influenced the results of the study. Because the molting process is linked with the utilization of food reserves, future nutritional experimentation will be performed on animals which have molted several times in the laboratory under controlled diets.

After examining data from these diet experiments, investigators came to the conclusion that, as yet, no one has produced an artificially prepared diet which compares favorably, in terms of animal growth, with natural diets. It was also clear that the blue crab did not grow as well in the laboratory as it appears to grow in nature.

Photoperiod was found to be a relatively unimportant growth regulator for the blue crab. Warm water is thought to be important for the crab's growth but results of the temperature experimentation showed that differential effects may occur which have opposing influences on growth rate. Choosing an optimal temperature may take considerable experimentation.

This study also brought to light a mortality problem in the blue crab culture. Mortality occurred even though each crab was isolated such that cannibalism was impossible, and as yet, the cause of the mortality is unknown. Before blue crab culture is feasible, this problem will need more attention.



Investigation of Potentially New Food Resources in Delaware Bay

Project R/B-1
Principal Investigator:
Dr. Victor A. Lotrich

For the past two years investigators have been studying the *in situ* biology of the mummichog *(Fundulus heteroclitus* Linnaeus), an important food fish in the salt marsh food web and an abundant resident of Delaware's tidal marsh creeks. They are studying the significance of the mummichog in the estuarine ecosystem so that man can manage and harvest it for his own benefit. Many uses are possible including: human consumption, chicken or cattle feed additives, crop fertilizer, oil extract products, a food source for cultivating other fish, mosquito control, etc.

The individual mummichog was found to have a summer home range of about 36 meters. Investigators found that this species was distributed along the entire length of a tidal creek in the summer. However, in the winter, as the water temperature cooled, the distribution shifted to the upper one-third of the creek, where the salinity was significantly lower than in the rest of the creek.

Population estimates taken in the early and mid-summer showed 39,000 fish per kilometer while late summer estimates showed only 22,000 fish per kilometer. Although the cause of this depletion is not yet known, the importance of the rapid change in population is likely to have a significant impact on the creek's energy budget. Just what that impact involves must be determined before man can expect to exploit the mummichog.

Summer growth rates under natural conditions were obtained and increments ranged from 1.5 cm for a fish initially 6.0 cm long to 0.5 cm for a fish 10.0 cm long. Possible winter growth is being investigated also.

The role of the mummichog in the marsh food web has been one of the most perplexing aspects in this particular study. While it is known what the mummichog eats, its susceptibility to predation is still uncertain. The American eel, however, seems to be an important predator: over 70% of 90 eel stomachs examined contained mummichog remains. Blue crabs, herons, terns, and egrets have also been observed preying on the mummichog. To determine fish predators, the investigators set up 2 six-foot-high hoop traps in the creek. White perch and weakfish were caught in the trap and both had mummichog remains in the stomach. However, more efficient methods of capturing the predators will have to be found, since the traps proved to have problems with substrate type, fast current, and detrital loads.

Feasibility Study of Raft Culture

Project R/A-4a
Principal Investigator:
Dr. Donald L. Maurer

A feasibility study of raising oysters to commercial size while suspended below rafts was made under the sponsorship of the Delaware River Basin Commission. Although oysters were successfully grown to market size in about two years, the culture method was determined to be too costly and thus not commercially feasible. Primary problems in Delaware Bay include sediment clogging of the animals, fouling organisms, and winter ice which damages surface rafts. Submerged rafts, designed to avoid ice problems, were tested at one-fifth scale. However, cost studies indicated that such rafts were too expensive to use commercially.

Systems Engineering

In dealing with engineering problems in the coastal zone, new knowledge is needed on how weather, sediment types and locations, erosion, and other natural processes affect structures. Knowledge of how to accommodate these environmental factors is essential in preparing strategies for coastal zone development alternatives. Projects undertaken in this group focused on analyzing regional marine transportation facilities, and examining natural processes along the shoreline and in Delaware Bay.

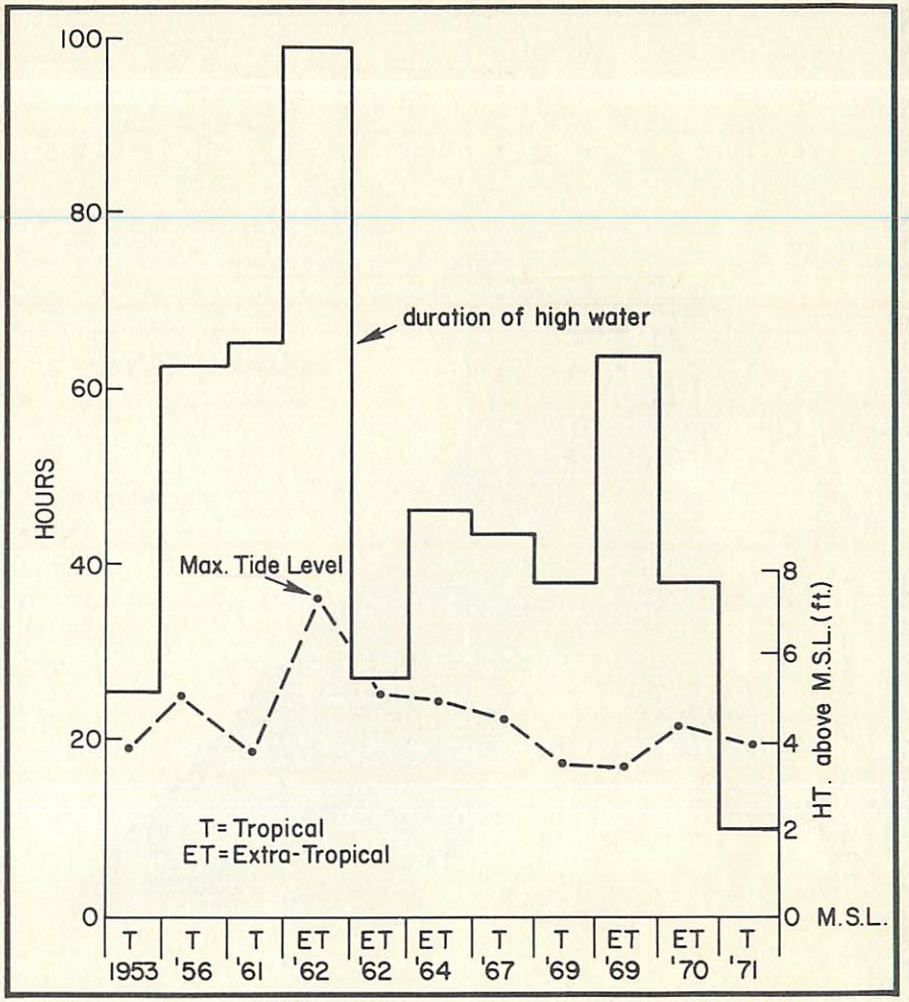
The Role of Meteorological And Human Factors in Coastal Storm Damage

Project R/C-1
Principal Investigator:
Mr. Frank J. Swaye, Jr.

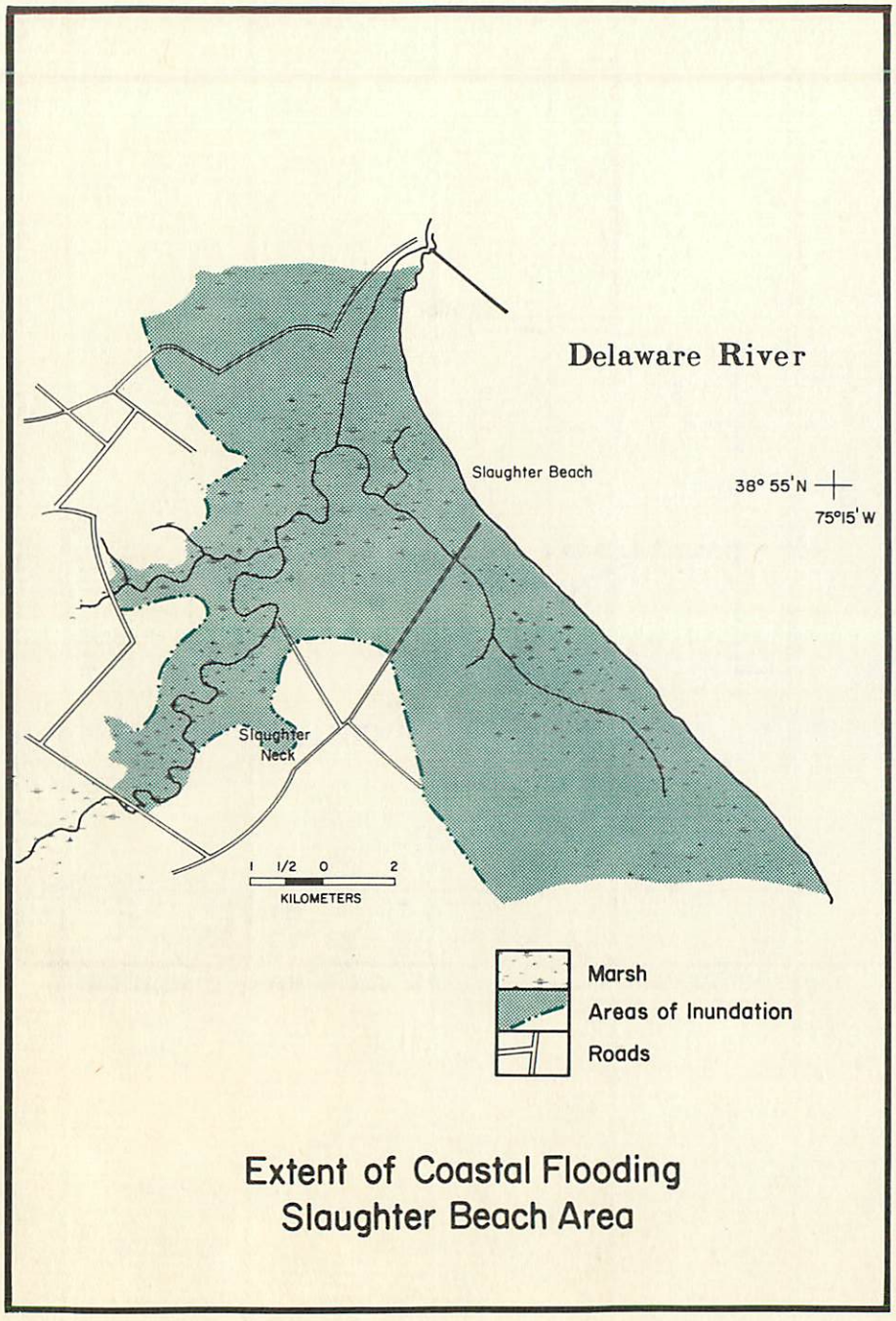
The susceptibility of Delaware's coastal zone to storm damage is of considerable importance in planning the future use of the Delaware Bay area. Analyses of hurricanes and extra-tropical storms has led to the compilation of a detailed catalog of storm impact for the period 1920 to 1970. Information includes the type, frequency and duration of coastal storms, areas flooded and depth of inundation. The accompanying illustrations show how land use maps of potentially inundated areas and case studies of selected regions were accomplished by field surveys and use of 1954, 1961, and 1968 aerial photographs.

Results show that hurricanes, tropical storms and extra-tropical cyclones regularly strike Delaware. In recorded history, destruction caused by the storm of March 5-9, 1962 has never been exceeded. Similar storms in 1929, 1933 and 1944 caused damage estimated at only 1% of that resulting from the March northeaster. Minor changes in storm tracks and a slightly lower central barometric pressure in recent storms cannot account for the increased destruction. Instead, the greater amount of damage was the result of rapid development and population increases in the coastal zone rather than any changes in the meteorological phenomena.

In contrast to the entire eastern seaboard, the coast of Delaware has experienced a decrease in the number of



Height and Duration of Coastal Storms at Breakwater Harbor, Lewes, Delaware



Extent of Coastal Flooding
Slaughter Beach Area

coastal storms in recent years. However, there is no evidence to suggest that this trend will continue. In the inundation map of a case study area, shown here, marsh and agricultural areas which would be flooded by a storm similar in magnitude and duration to the March 1962 northeaster are illustrated.

The overall results of this project will provide coastal residents, developers, planning agencies, and other interested persons the information necessary to understand the storm hazard potential in Delaware's coastal zone.

Geologic History of Shoreline Rates of Change and Bottom Sediment Morphology of Delaware Bay

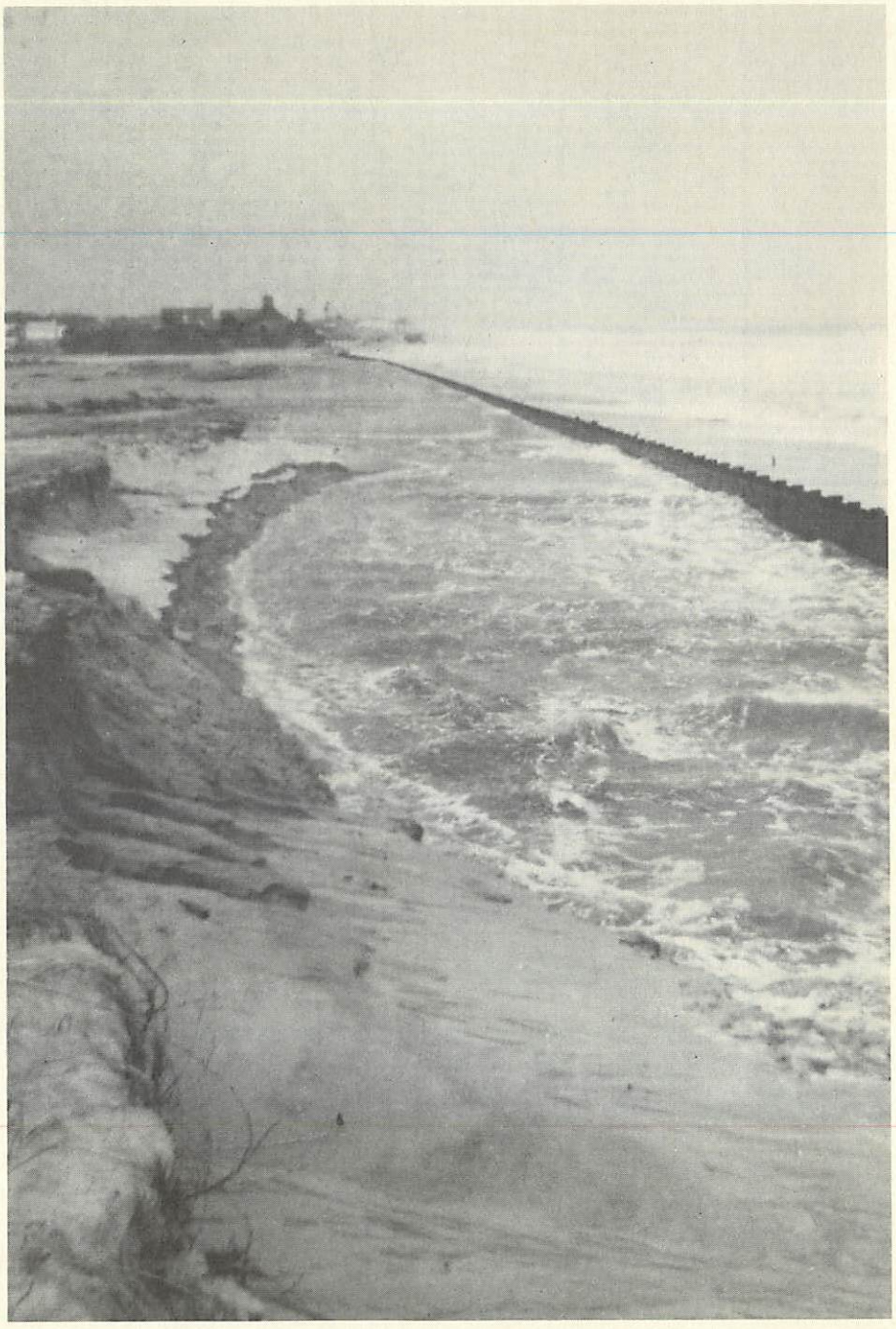
Project R/G-1
Principal Investigator: Dr. John C. Kraft

A study was made of the geology of the shoreline areas of Delaware Bay which involved a study of the surface conditions and established a correlation between coastal sedimentary units and the subsurface under the shoreline area.

The shoreline of Delaware Bay is transgressing landward at a fairly rapid rate in geologic terms. Investigators have found that in some areas, erosion of the coast has continued landward up to 1/5 of a mile over a 100-year period. In addition, because the relative sea level rise continues, the barrier beaches are migrating landward and upward in space and time. The net result is a drowning or submergence of the coast. In the southern part of the coastal area studied (near the Delaware-Maryland border), the shoreline is comprised of sand-gravel washover barriers and thin, relatively narrow

sandy beaches. However, toward the north, along the Delaware Bay shoreline and the shoreline of the lower part of the Delaware River, sandy shorelines are discontinuous and do not occur as often. In this area, the coastal salt marshes form the Bay shoreline. The amount of sand or gravel which is moved in the littoral drift system along the shore by wave action is dependent upon distance from the sources of eroding sand and gravel sediments. These sediments are part of the Pleistocene highlands that impinge upon the shoreline of the bay area.

Detailed geological cross-sectional studies have been made at 16 sites along the Delaware Bay shoreline and show the surface and subsurface geology of these areas (Holly Oak, Pigeon Point, Reedy Point, Augustine Creek, Duck Creek/Woodland Beach, Port Mahon, Kitts Hummock (2), North Bowers, South Bowers, Big Stone Beach, Bennett's Pier, Fowler Beach, Slaughter Beach, Broadkill Beach and Lewes). Three-dimensional models of the sandy shoreline areas frequented by the public will be useful to developers and planners in determining types of short and long term coastal protection that can be successfully installed.



Analysis of Shoal Development Process at Potential Construction Sites in Delaware Bay

Project R/G-2
Principal Investigator:
Dr. Robert E. Sheridan

Details of the sediment structures and types of sediments in the shallow sub-bottom of Delaware Bay must be known for analysis and evaluation of possible near-term construction along the shore, in the Bay and on the inner continental shelf. During the past year, investigators working to interpret the sediment structures have made progress in several areas.

Current measurements were made in the vicinity of Joe Flogger Shoal and Crow Shoal in an attempt to quantify differences in ebb and flood tide flow on different sides of the shoals (sandbanks or sandbars which make the water shallow). These data are being analyzed.

Several closely spaced high resolution seismic reflection profiles were made across Crow Shoal. These data revealed a consistent structure of internal cross-bedding inclined away from the steeper face of the shoal, an identical bedding relationship to that observed on Joe Flogger Shoal. This indicates migration of the crest of Crow Shoal to the southwest, and southwestward net transport of the sand which is building Crow Shoal. This shoal movement will have important implications for certain types of development which might take place on the shelf.

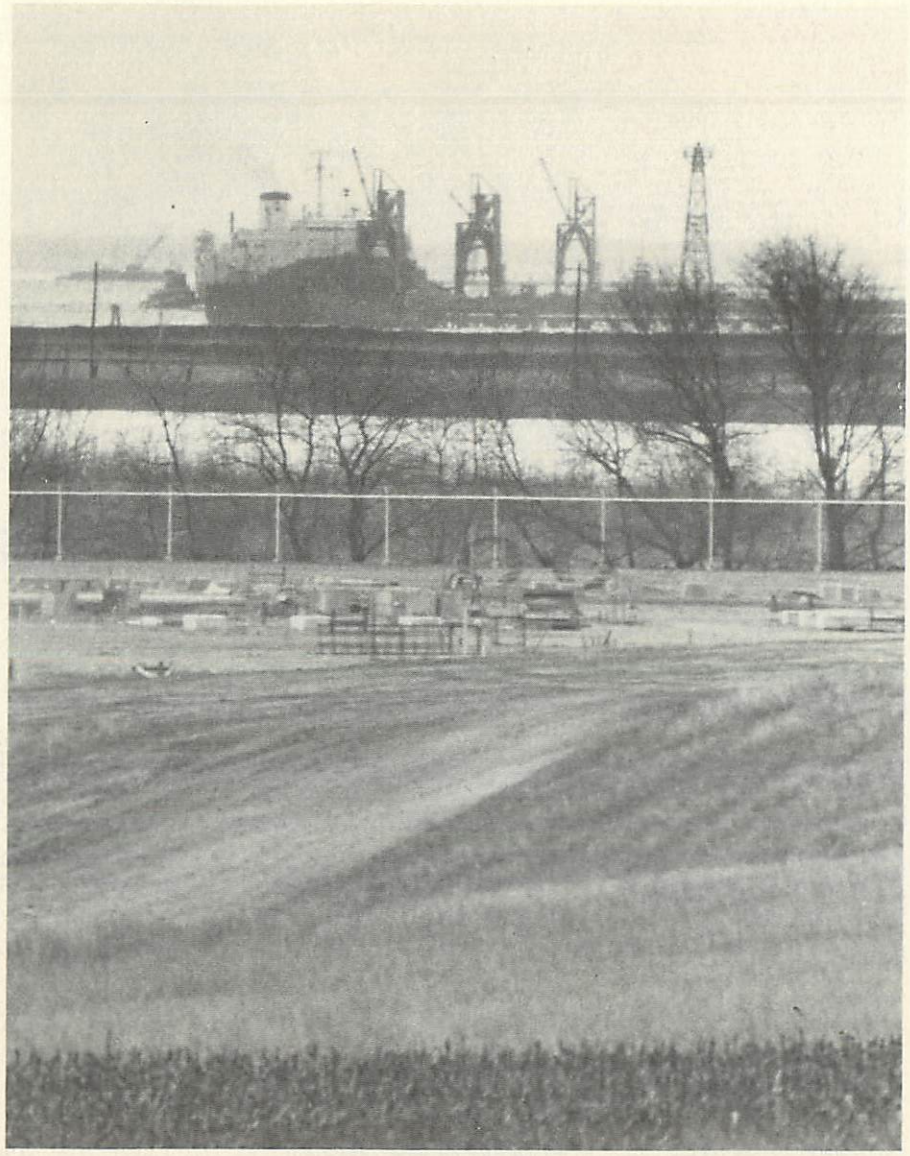
In cooperation with oceanographers from MIT and Duke University, several linear sand ridges on the North Caro-

lina inner shelf were studied using high resolution seismic reflection profiling and vibracoring. It was proved that these ridges are indeed formed by accretion and migration of sand, just as in Delaware Bay. Current measurements near these Carolina ridges are being analyzed to detect differences in tidal flow which might be the cause of the ridges.

Port Development and Management

Project R/T-3
Principal Investigator:
Dr. Frederick E. Camfield

A survey was undertaken of marine transportation users in the state of Delaware to determine commodities and amounts being imported and exported and facilities being used. Investigators found that the majority of marine commerce in the state is in the import category, with the main port of entry at Wilmington. However, various private facilities are used by individual companies or agencies. In conjunction with the Delaware State Department of Highways and Transportation, a survey was conducted of port authorities in the United States. Data from that survey are now being evaluated to determine a possible future framework for management of marine commerce in Delaware. This work will contribute to the study now being undertaken by the state to determine the future of the Port of Wilmington and the possible formation of a state port authority.



Local Thermally Convective Flow In the Ocean

Project R/T-2
Principal Investigator:
Dr. Frederick A. Costello

In order to predict thermal and chemical pollution in the ocean or in lakes due to submerged discharge, the interaction between the effluent (material discharged) and the surface of the water is highly important. However, prediction techniques for 'surfacing' jets or plumes had been unavailable prior to this study. As a result of the analysis performed under this study, design charts have been prepared, from which the polluting effects of the surfacing discharged fluid can be readily assessed.

Socio-Economic Systems

Pressure from both social and economic forces continually affects decisions on coastal zone development. At the same time, the future development of an area may be noticeably affected by development which has already taken place. Since land use patterns are a key element in preserving and improving the quality of life on shore and the quality of the marine environment, analysis of these patterns has been a central focus of this year's work.

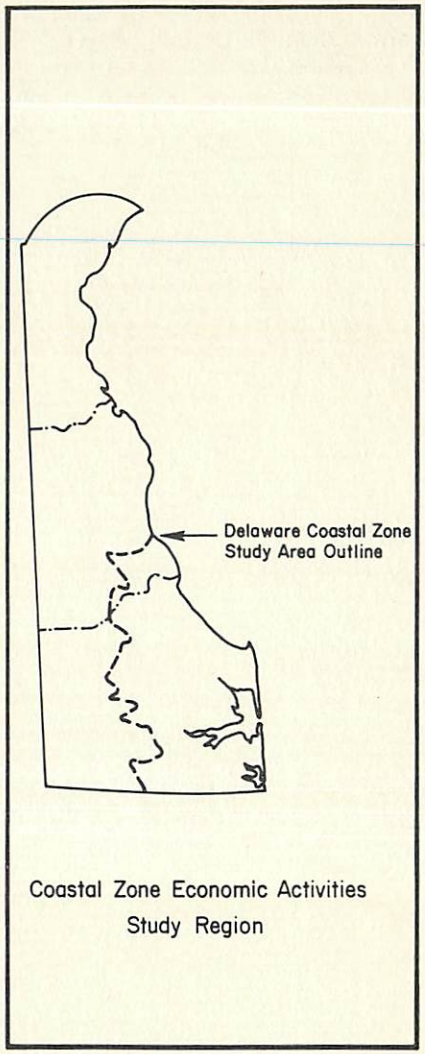
Pressure to develop areas of the Delaware coast for recreational activities has led to Sea Grant studies which will provide a better understanding of both the environmental and socio-economic impact of such development. This work will be of direct value in developing state coastal zone plans.

Delaware's Coastal Zone Economy: Its Changing Structure And the Impact of Alternative Economic Activities

Project R/E-1
Principal Investigator: Dr. Dennis K. Smith

Coastal zone planners and policy-makers will be the ones to benefit from this on-going study of Delaware's coastal zone economy. An inter-industry (input-output) model of the coastal zone region is being developed which will help public administrators, legislators, and private citizens identify and quantify the economic structure of their area. They will be able to determine which economic activities are most important in terms of the direct and indirect (multiplier) effects they have on the region. The model will also provide information on what can be expected from changes in economic activity levels in one or more business sectors.

Investigators have worked within a framework of 55 business sectors in the coastal zone. They identified 2300 business and institutional establishments in the region and collected, using sample survey techniques, income and expenditure data from 300 of these establishments. The same type of data was obtained for farm production units and both seasonal and permanent households. These data are being processed to identify the parameters necessary for developing the regional inter-industry model. In upcoming research using this model, emphasis will be placed on the study of the impact of tourist-based recreational activity on this area's economy.



Coastal Zone Economic Activities
Study Region

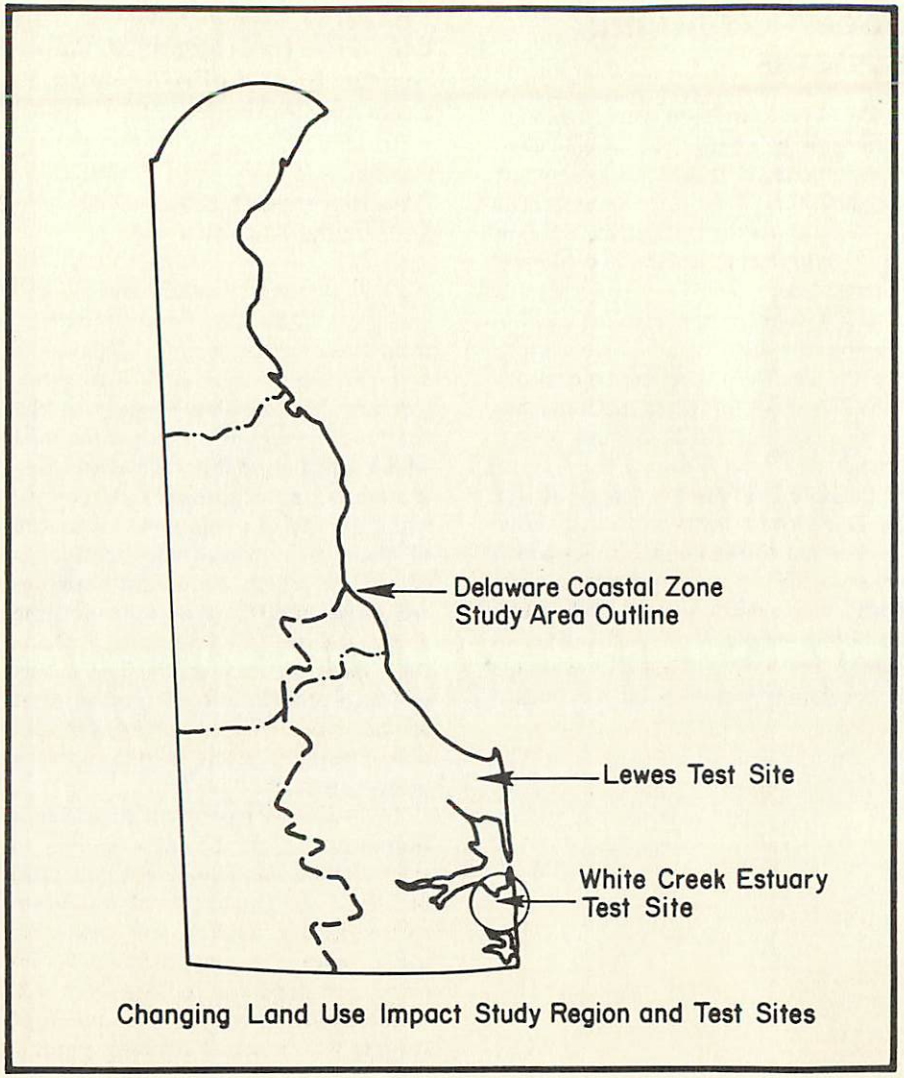
Development Strategies For Marine Related Resources

Project R/E-2
Principal Investigators:
Dr. Richard J. Agnello
Dr. Lawrence P. Donnelley

Research was focused on integrating economic, biological, and legal forces into a model explaining changes in quantities and prices for the mid-Atlantic oyster industry. High elasticities are apparent in both the Delaware Bay area and mid-Atlantic region implying that if supplies were to increase in the future, one would expect increasing revenues for the oyster industry.

Empirical results of the study lend optimism to the current rehabilitation efforts directed toward the oyster industry. Biological and secular environmental problems have clearly had a debilitating effect, however, and must be solved as a condition to successful oyster tonging industry recovery.

Empirical testing of the effects of property rights on economic efficiency in the oyster industry indicates that private property rights (private leasing of oyster beds and subaqueous land parcels) make a significant difference in a state's average labor productivity in oyster harvesting. Private property rights are associated with high productivity and efficiency. Therefore one could conclude that social benefit would be increased by encouraging private leasing of oyster beds as an alternative to the common property structure utilized by many states. The Chesapeake Bay states of Maryland and Virginia, where common property rights are prevalent, have a much more serious over-fishing and depletion problem than the Delaware Bay states of Delaware and New Jersey, which are essentially private property states.



Changing Land Use Impact Study Region and Test Sites

Analysis and Evaluation Of the Effect of Evolving Land Use Patterns in the Delaware Coastal Zone As Perceived Through Aerial Imagery

Project R/E-3a
Principal Investigators:
Dr. Dennis K. Smith
Dr. Kent S. Price, Jr.

Land use is becoming increasingly important in Delaware's coastal zone as citizens and public officials contend with problems arising from the pressures of expanding economic activity on environmental processes and ultimately on the quality of life. There is no doubt that dramatic and far-reaching changes have already occurred in the land use patterns of this region. This three-year, multidisciplinary study is correlating these land use changes with changes in economic activity in the region and is measuring the impact of land use changes on environmental conditions and ecological processes of the region.

Two initial test sites in southern Delaware were selected to develop and verify methodology. The White Creek estuary is being studied to determine the impact of changing land use patterns on ecological processes. There is existing 1957-58 data on fish species and water quality in this area, and identical field data is now being collected to reflect present conditions. The change in conditions will be correlated with the change in land use patterns. The other test site is the Lewes area, where investigators hope to discover the relationships between the 1938 and 1968 land use patterns and the associated changes in economic activity. Historical aerial photos are undergoing analysis to determine land use changes at a detailed level.

Investigators are establishing a feasible (in terms of cost and time) methodology in these two areas so they can extend analysis to other coastal zone regions. In the future, they plan to use these analytic techniques for the entire state of Delaware assuming that cost and time efficiencies have been achieved. Using these techniques, Delaware's decision-makers will, in the future, have available to them, up-to-date analyses of changing land use patterns.

Sociological Aspects of Seashore Recreation

Project R/S-1
Principal Investigator:
Dr. Wallace A. Dynes

To estimate the level of support for several development options in seashore recreation and to ascertain the factors that are associated with these levels of support, a comprehensive questionnaire was developed during early 1972. It was mailed in September, 1972, to a set of persons who were known users of three state-supported seashore campgrounds. Analysis thus far has concentrated on the factors that are allegedly associated with the several patterns of recreational participation by our subjects.

One part of the analysis of the data generated from the questionnaire results was presented in a paper entitled 'Intrusion of Family Structure on the Leisure Behavior of Four Categories of Married Males,' at the national meeting of the Rural Sociological Society in College Park, Maryland, August 26, 1973.

Another part of the preliminary analysis of the questionnaire data led to the questioning of several of the assumptions made in the provisional analytical scheme which was presented to the Second Shallow Water Research Conference in October, 1971. This scheme formed the basis for the questionnaire which was mailed in 1972. As a consequence, a series of extended interviews of a sub-set of the original subjects was carried out during the spring of 1973 but the analysis of these data has not yet begun. The results are expected to reveal factors which motivate individuals to use coastal recreational facilities.

Environmental Impact

Man's use of coastal areas, whether for recreation, industry, or conservation, means that he must interact with the environment. Before he tackles the engineering problems of coastal zone development, man must solve specific ecological problems which inhibit certain types of development or the use of marine resources.

Pesty biting flies and unsightly algal blooms appear along the Delaware coast and near salt marshes. Contamination of oysters and clams from Delaware Bay could be a potential problem. These kinds of pervasive problems, which could affect man and/or plants and animals of the coastal zone, were examined by the Environmental Impact group.

The Role of Algae In Nutrient Cycles In Tidal Marshes

Project R/N-3
Principal Investigator: Dr. G. Fred Somers

The first objective of investigators in this study was to understand the cation exchange properties of tidal marsh soil algae. From this they could evaluate the role of these algae in the cycling of mineral nutrients in estuarine ecosystems.

It has been established that a number of species of blue-green algae can be isolated from a tide marsh. Some are present as relatively small components of the population, but are presumed potential candidates for an undesirable algal bloom under suitable conditions. The distribution of species varies with both the season and the kind of vegetation of the marsh. The most abundant production of blue-green algae is upon pannes (shallow areas, barren except for algae, not usually flooded by average tides). Here, a mat is produced which commonly consists of only a few species.

During the first year of research, investigators collected and dried mats of algae from the pannes on the marsh. They used this field-grown material instead of laboratory-grown algae since they suspected the latter might have somewhat different exchange properties.

To measure affinity for cations, the field material had to be made into a unialgal preparation, i.e., freed of inorganic and organic contamination and reduced from a mixture of species to only one. Investigators used the calcium electrode to evaluate cation exchange properties and found that the field-grown algae exhibited an affinity for calcium similar to that of higher plants' cell walls. Subsequent research is aimed at assessing the contribution of the role of this calcium exchange in the nutrition of higher plants growing in coastal marshes.

Local Control of Salt Marsh Tabanid Fly Populations

Project R/W-4
Principal Investigator: Dr. E. Paul Catts

Capturing and controlling the pesty biting flies which inhabit salt marshes and beach areas proved to be quite a task for Delaware researchers this year. Their efforts were focused on perfecting and testing traps for catching deerflies and greenhead flies during the May-September "fly season".

Of three designs tested during the summer of 1973, the canopy-type trap proved best. This is a trap made of polyethylene which looks like a wall-less tent when set up. Although two types of deerflies were captured in canopy traps baited with dry ice as an attractant, the investigators had much more success with the salt marsh greenhead fly. They set the traps in groups of three at specific "fly-through" locations (certain routes which the flies take regularly). Results were impressive – the traps removed up to 100,000 greenheads per week during July in the coastal community where testing was done. If they baited the traps with dry ice, a three- to four-fold increase in fly catches occurred, but baiting was necessary only once or twice per week during July.

The researchers found that canopy traps were more effective than box-like traps, however both types could be economically fabricated by residents of beach communities and maintained with little effort to reduce the midsummer fly problem.

Activity and Variations Of Trace Contaminants in Estuarine Organisms And Sediments

Project R/W-2
Principal Investigators:
Dr. Allan M. Thompson
Mr. Charles A. Lesser
Mr. Theodore P. Ritchie

Information researched under this project was intended to help develop and initiate an Ecological Warning System for continuous evaluation of water quality in Delaware Bay under the control of the Delaware Department of Natural Resources and Environmental Control.

A survey was taken of sediment distribution patterns in the area of oyster banks in Delaware Bay. Indications were that fine-grained sediments are concentrated to a large extent on the Delaware side of the Bay. Investigators then used a simple inorganic extraction technique, approximating natural processes, and compiled an atlas of the distribution of 14 environmentally active trace metals (those which could be mobilized by changes in environmental conditions) in Delaware Bay sediments.

Four significant groups of trace metals became apparent after statistical analysis of the data. The distribution patterns of the four groups appear to co-vary, with one of the patterns representing the influence of river-borne trace metals (natural load plus pollutant load) in the vicinity of oyster banks. Based upon this analysis, a map was prepared showing the best estimate of potentially hazardous areas for the culturing of oysters.

Since living organisms may remove environmentally active extraneous materials from sediments, a knowledge of where in the sediments these materials occur, i.e., in what size fractions and chemical phases most of these materials are located, is critical. Through the application of an arduous physical and chemical procedure, a model of the locations of several environmentally active trace metals has been produced, thereby refining estimates of potentially hazardous growing areas.

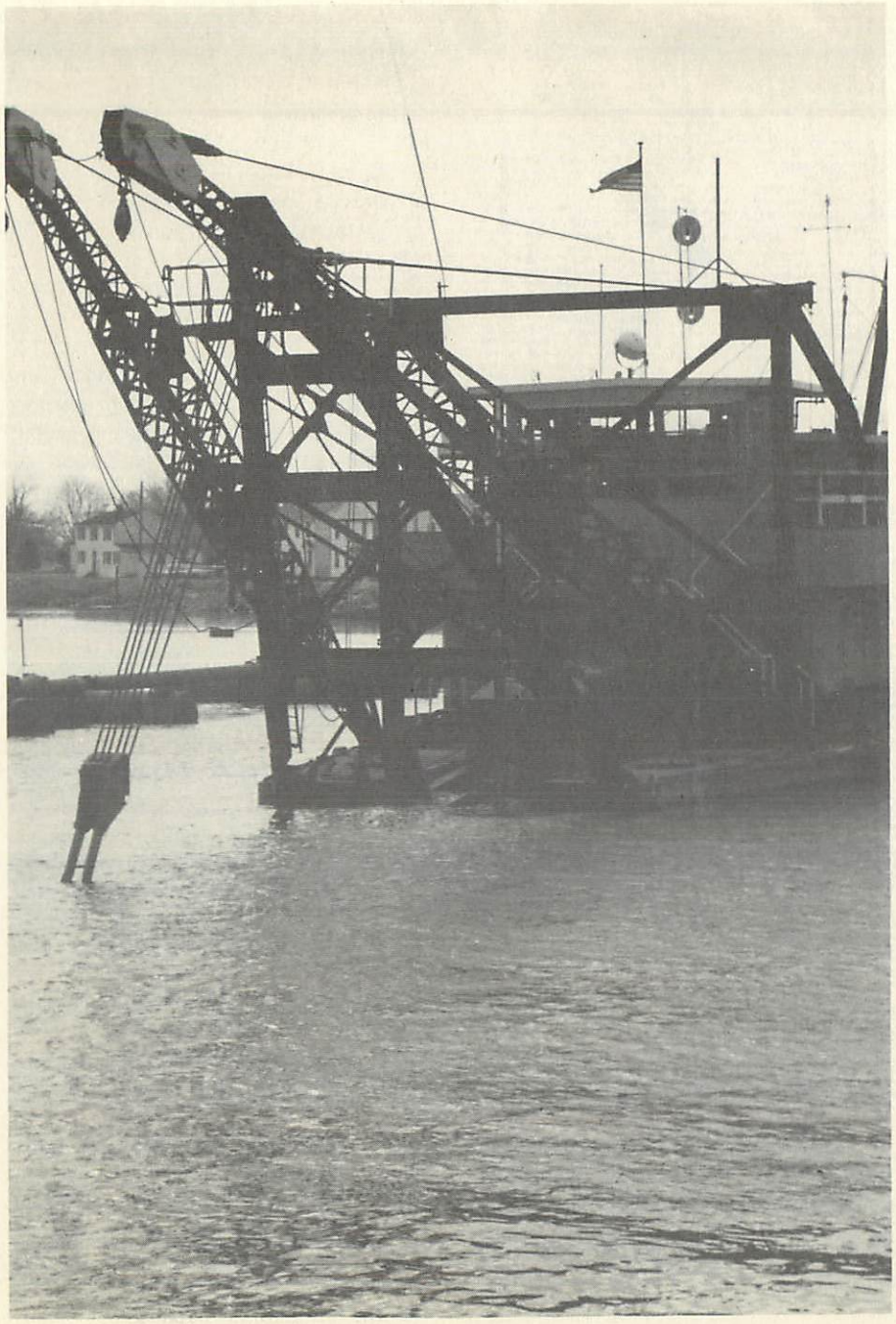
In another aspect of this study, the objective was to determine base levels and seasonal rates of trace metal accumulation in oysters throughout the Bay. Efforts were made to construct oyster-holding trays for placement in major rivers leading to the Bay and in oyster beds. However budget limitations, vessel maintenance difficulty, withdrawal of one investigator and a decision by the Department of Natural Resources and Environmental Control to delay work on the Ecological Warning System made further work impractical.

To document the ability of the eastern oyster to concentrate metals from its environment, a survey of oyster tissues from 25 oyster banks in Delaware Bay and nearby coastal plain estuaries was made. Data are now available on the distribution of 12 environmentally active trace metals in these tissues and in the adjoining bank sediments.

Overboard Spoil Disposal

Project R/W-2d
Principal Investigator:
Dr. Donald L. Maurer

Marine transportation in silt-laden estuarine areas frequently requires dredging for the maintenance of navigable waterways. The ecological impact of this type of maintenance dredging and spoil disposal activity was studied and evaluated for the Lewes-Cape May ferry terminal at Lewes, Delaware. The study noted that all dredging and disposal projects will cause some environmental damage; however, this damage can be reduced by having consideration for spawning areas, fishing grounds, environmental setting of the particular area, and time of year. In lower Delaware Bay, the period of least harm for benthic invertebrates would be between December and March.



Offshore Terminal Impact

Project R/O-1
Principal Investigator:
Dr. Donald L. Maurer

During the program year, the Council on Environmental Quality sponsored a series of studies of the ecological impact of offshore oil transfer terminals in a number of areas along the eastern seaboard. Three Delaware Bay and continental shelf areas were studied, and voluminous results were provided to the sponsoring agency. These studies, together with others concerned with socio-economic impact, will form the basis for recommendations to the President concerning site locations for future superports.

Exploratory Resource Development

As a major program such as Sea Grant progresses, it is not unusual for new research opportunities to be perceived by highly creative and imaginative members of the academic and research community. When new projects are identified, resources can either be re-allocated to further their development, as with the chitin project described below, or changes made in existing program objectives to emphasize the new research opportunities, as with the development of the viral assay methodology also described below.

Genetic Control of Blue-green Algae In the Estuarine Economy

Project R/W-1
Principal Investigators:
Dr. Conrad N. Trumbore
Mrs. Marjorie P. Kraus

Researchers working with blue-green algae this year have succeeded in isolating a large number of different blue-green algal strains which have the capability of discriminating among viruses in the aquatic environment. Using this methodology and a blue-green-algal-host-virus model they developed, the investigators interpreted algal productivity and succession in polluted waters. It was determined that viruses which enter streams by way of sewage effluent can become adapted to algal hosts. Thus, in using the model, the investigators can show how viruses play a role both in bacterial degradation of organic wastes and in the building up of primary productivity in the establishment of a food web.

The algal-host-virus model also proved to be an economic and efficient monitor of virus transfer in determining what virus hazards could be found in sludge disposal either by land or sea.

Currently, the blue-green algal research methodology is being put to use in establishing procedures for the examination of fish kills. Investigators are using a recent fish kill in Biscayne Bay, Florida, as a proving ground.

Utilization of Renatured Chitin

Project R/N-4
Principal Investigator:
Dr. Paul R. Austin

Chitin, an intractable, cellulose-like material, is a potentially valuable by-product from the exo-skeletal waste of crab and other crustacean seafood processing. Investigators at Delaware who are studying chitin have discovered new solvent systems which make chitin easier to handle and which facilitate the formation of small crystalline fibers that can be seen by the naked eye. The technique of making these small fibrils is being extended to the preparation of unsupported films and filaments for possible use in specialty food wraps, absorbable surgical sutures, and fish line.

EDUCATION

Through education and training, coastal zone resource utilization can be improved. Delaware's three-part approach to this vital aspect of the Sea Grant program involves vocational training, professional education and training, and an attempt to increase general awareness of the marine environment.

Public school programs throughout the state are the vehicles for the latter approach while the University of Delaware is a means for professional education and training. Marine technician training, although not yet started in Delaware, is under thorough examination and may be an important component of future marine vocational education programs.

K-12 Marine Environment Education

Project E/Z-1
Principal Investigator: Dr. Robert W. Stegner

During this second year of development research, 19 primary and secondary school teachers gained experience in the development of marine environment curriculum materials. They were under the direct supervision of Dr. Maura Geens, marine biologist.

A collection of 50 learning experiences was revised, refined, and prepared for dissemination to 30 selected Delaware schools having an interest in integrating environmental studies into their curricula on a multidisciplinary scale at all grade levels, kindergarten through 12th. These learning experiences (lesson plans) are now being distributed to Delaware schools for trial and evaluation leading to revision and continual development. Seven other states purchased sets of the material, including extensive visual material, to use in their school systems.

Introduction of the collection of marine environment learning experiences into school programs will continue in order to increase the general knowledge and understanding of the marine environment so essential to orderly and democratic solutions to environmental problems.

INSTITUTIONS	JD (OCEAN LAW)	LLM (OCEAN LAW)	MA MARINE AFFAIRS	PhD MARINE AFFAIRS	MPA (MARINE AFFAIRS)	MS MARINE ENVIRON. SCIENCE	MS/MBA MARINE RES. MGMT.	PhD ECONOMICS (MAR. RES.)
UNIVERSITY OF DELAWARE			●	●				
UNIVERSITY OF HOUSTON	●							
LOUISIANA STATE UNIVERSITY		●						
UNIVERSITY OF MIAMI	●	●						
UNIVERSITY OF MISSISSIPPI		●						
UNIVERSITY OF OREGON	●							
UNIVERSITY OF RHODE ISLAND			●					●
UNIVERSITY OF SOUTHERN CALIF.					●			
SUNY STONY BROOK						●		
TEXAS A&M UNIVERSITY							●	
UNIVERSITY OF WASHINGTON		●						
DEGREES IN MARINE AFFAIRS								

DEGREE PROGRAM
( ) DENOTES DEGREE WITH SPECIALIZATION

Development of an Integrated Marine Affairs Curriculum

Project E/T–2
Principal Investigator:
Dr. Gerard J. Mangone

Marine affairs has been a rapidly growing area of academic interest, leading to new degrees in higher education, combinations of curricula offerings to form a program in marine affairs, or at a minimum, the refocusing of traditional courses around special problems of the marine environment, including the coastal zone. Law schools have played a significant role in these developments, especially due to the projected Law of the Sea Conference under United Nations auspices. Political science, public administration, and marine resource economics as well as history and anthropology have been involved in shaping new marine affairs degrees or programs.

Fifty-seven universities were surveyed to ascertain their specific course offerings that dealt with the oceans, the seabed, and the coastal zone. Two goals were achieved: a baseline analysis of the state-of-the-art of marine affairs in colleges and universities in 1973; and a special collection of curricula, syllabi and readings that could be analyzed to improve the marine affairs curriculum in Delaware.

As part of an experiment with the marine affairs curriculum at the University of Delaware, a special seminar was organized, involving an historian, a lawyer, two economists, and a political scientist, to offer general concepts of marine affairs to graduate students in marine biology, physical oceanography, and other marine sciences.

Survey of Marine Technician Training

Project E/T-3
Principal Investigators:
Mr. Joel M. Goodman
Mr. Leonard Mitchell

Marine technician training programs exist at a large number of academic institutions in the coastal states and appear to be proliferating. An appraisal of these programs on a national basis to develop a clear understanding of the relationship between supply and demand was carried out in order to provide agencies which sponsor technician training programs with the information necessary to adjust their program objectives.

ADVISORY SERVICES

As the "communicator" in Delaware's Sea Grant program, the Marine Advisory Service is an aggressive force not only in coastal communities but in the entire state as well. It is a major part of the theme of Delaware's program, "cooperation between universities, government, and industry in the study and development of regional marine resources." The Advisory Service is the liaison between campus and coast, between researcher and user. It is a catalyst for individual and group actions on marine-related issues.

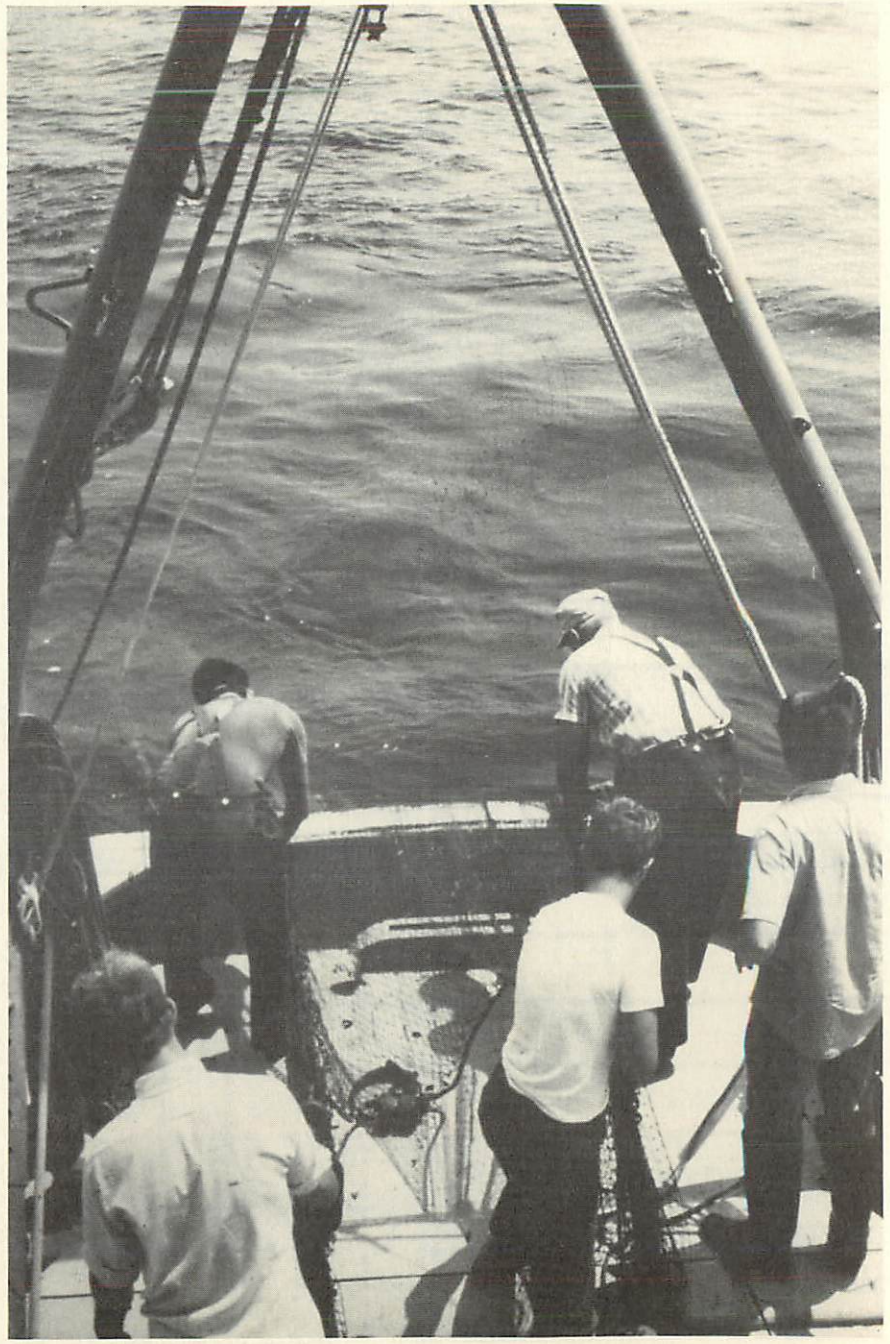
Industrial growth and development, advisory education, and information dissemination are three areas which Marine Advisory Service personnel stressed this year.

Marine Advisory Services

Project A/I-1
Principal Investigators:
Dr. Samuel M. Gwinn
Dr. Kent S. Price, Jr.

Delaware's Marine Advisory Service (MAS) was initiated as part of the University's first Sea Grant Project in September 1968. In order to reduce parallel administrative structure and to make use of a highly experienced and developed extension system, the MAS is administered via the Agricultural Extension Service within the College of Agricultural Sciences by Dr. Samuel Gwinn, director of the Agricultural Extension Service. However, MAS personnel receive program direction and immediate supervision from Dr. Kent S. Price, Jr., Associate Dean of the College of Marine Studies and Director of the MAS. This permits maximum integration of the broad spectrum of College of Marine Studies activities with the advisory service function. The MAS program has grown from one half-time extension specialist to four full-time equivalent professionals. Although the initial emphasis of the MAS program at Delaware was local in scope and concentrated on commercial fisheries problems, in recent years much greater emphasis has been placed on the recreation industry, coastal zone management, and public marine education on a regional basis.

Vehicles for information transfer in Delaware's Advisory Services program were diverse, primarily concentrating on the person-to-person aspect. A broad-based public marine educational program included:



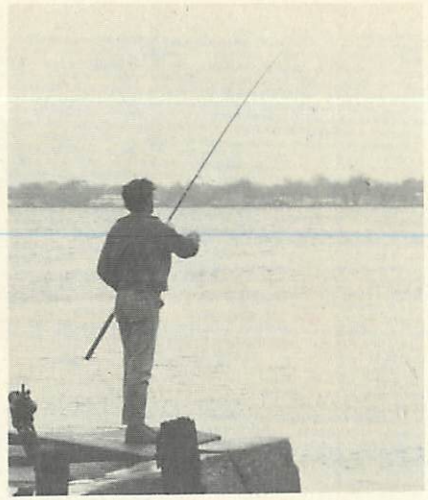
- Conducting guided field trips and tours of marine research facilities for approximately 5050 people from university, college, secondary, and elementary school groups;
- Presenting illustrated lectures about the marine environment to 43 civic and educational groups involving 1410 persons;
- Assisting in conducting a state 4-H camp by presenting one-week marine study courses involving 70 students;
- Providing, during the summer, a series of weekly articles on the marine environment to a weekly newspaper in the resort area of the state's coastal zone;
- Conducting a summer public lecture series on the coastal zone which drew 100-150 people per lecture;
- Continuing the Marine Advisory Bulletin and Marine Advisory Notes series as public information publications;
- Preparing 17 articles for publication in a new guide to salt water fishing, *Delaware Salt Water Sportsman;*
- Co-teaching an adult education oceanography course in Milford.

Work with recreational audiences included:

- Accelerating work on an artificial reef project east of Indian River Inlet which involves local charter boat captains and sports fishermen. The tire reef, when built, will assure these fishermen of fish in the area of the Inlet.
- Installing the "Fisherman's Hotline" to provide daily one-minute phone messages on local fishing and weather conditions for Delaware residents. The number was called more than 68,000 times during the summer.
- Cooperating with the Agricultural Extension agents to present a program on the marine environment and exotic seafood recipes to an audience of 300 homemakers.

In the area of legislative and governmental assistance:

- The Director of the Marine Advisory Service, as a member of the Governor's Wetlands Action Committee, assisted in drafting wetlands legislation which allows for strong protection and public management of Delaware's 120,000 acres of tidal wetlands.
- The MAS helped promote improved communications between regulatory agencies, particularly the State Department of Natural Resources and Environmental Control, and their audiences, especially sports and commercial fishermen and the menhaden industry during conflict over menhaden fishing.
- Agents conducted a small meeting for marina and campground owners and representatives from the Army Corps of Engineers, the Federal Fish and Wildlife Bureau, and the State, where permit problems were discussed, and two permits were issued as a result.



Program Development

	FY71	FY72	FY73
PROGRAM MANAGEMENT			
Leadership and Coordination, M/M-1	C	C	C
FOOD FROM THE SEA			
Mariculture Demonstration, R/A-4	C	R	C
New Species for Mariculture, R/A-1	C	R	C
Mariculture Controlled Systems, R/A-2	C	R	R
New Food Resources, R/B-1		N	C
Systems Eng., Oyster Production, R/M-4	C	T	
Food and Nutrition Consultation	N/T		
SYSTEMS ENGINEERING			
Factors in Coastal Storm Damage, R/C-1		N	R/T
Shoreline Rates of Change, R/G-1		N	T
Shoal Development Processes, R/G-2	C	C	R/T
Port Development, Management, R/T-3			N/T
Concentration of Trace Metals, R/G-3	N	R/T	
Sedimentary Organic Matter, R/G-4		N/T	
Heavy Mineral Distribution, R/G-5		N/T	
Sediments in Delaware Estuary, R/G-6		N/T	
Local Convective Flow, R/T-2		N	C
Climatic Water Balance	T		
Marine Research/Industrial Development	N/T		
Strategies for Eng. Development, R/T-1		N/T	
Bottom Sediment Distribution	N/T		
SOCIO-ECONOMIC SYSTEMS			
Economic Change in Coastal Zone, R/E-1		N	C
Analysis of C.Z. Industry, R/E-2		N	R/T
C.Z. Land Use Patterns, R/E-3a			N
Seashore Recreation Options, R/S-1	N	C	T

	FY71	FY72	FY73
EXPLORATORY RESOURCE DEVELOPMENT			
Role of Algae in Tidal Marsh, R/N-3		N	T
Blue-green Algal Viruses, R/W-1		N	C
Renatured Chitin, R/N-4			N
COASTAL ZONE MANAGEMENT			
C.Z. Development Objectives, R/M-1		N/T	
C.Z. Laboratory Concepts, R/M-3		N/T	
Analysis of Coastal Resource Dev.	N/T		
ENVIRONMENTAL IMPACT			
Ecological Warning System, R/W-2		N	T
Local Control of Biting Flies, R/W-4		N	T
EDUCATION			
Ocean Eng. Lab, Course Work, E/T-1	N	T	
Marine Affairs Curriculum, E/T-2			N
K-12 Marine Environment Studies, E/Z-1	N	C	T
Marine Technician Training, E/T-3			N
MARINE ADVISORY SERVICE	C	C	C

N=New Project
C=Continued Project
R=Restructured Project
T=Terminated Project

Budget

	Sea Grant	Matching
PROGRAM MANAGEMENT	$ 67,042	$ 49,616
RESEARCH		
Food From The Sea		
Aquaculture	184,413	89,760
Commercial Fisheries	8,504	3,562
Systems Engineering	66,441	49,349
Socio-Economic Systems	89,259	36,766
Environmental Impact	80,111	57,910
Exploratory Resource Development	19,995	15,690
EDUCATION		
K-12 Curriculum Development	15,039	14,291
Marine Affairs Curriculum Development	49,375	73,019
Marine Technician Training	67,287	3,200
ADVISORY SERVICES	72,452	22,513
	$719,918	$415,676

Sources of Matching Funds

Fish Products Company
State Department of Natural Resources and Environmental Control
Delaware River and Bay Authority
Delaware River Basin Commission
Wilmington Port Authority
University of Delaware Research Foundation
Delaware State Planning Office
Delaware Oil Transport Committee
State Department of Highways and Transportation
General Electric, Space Systems Division
Bendix Aerospace Systems Division
University of Delaware
Unidel Foundation

Program Summary

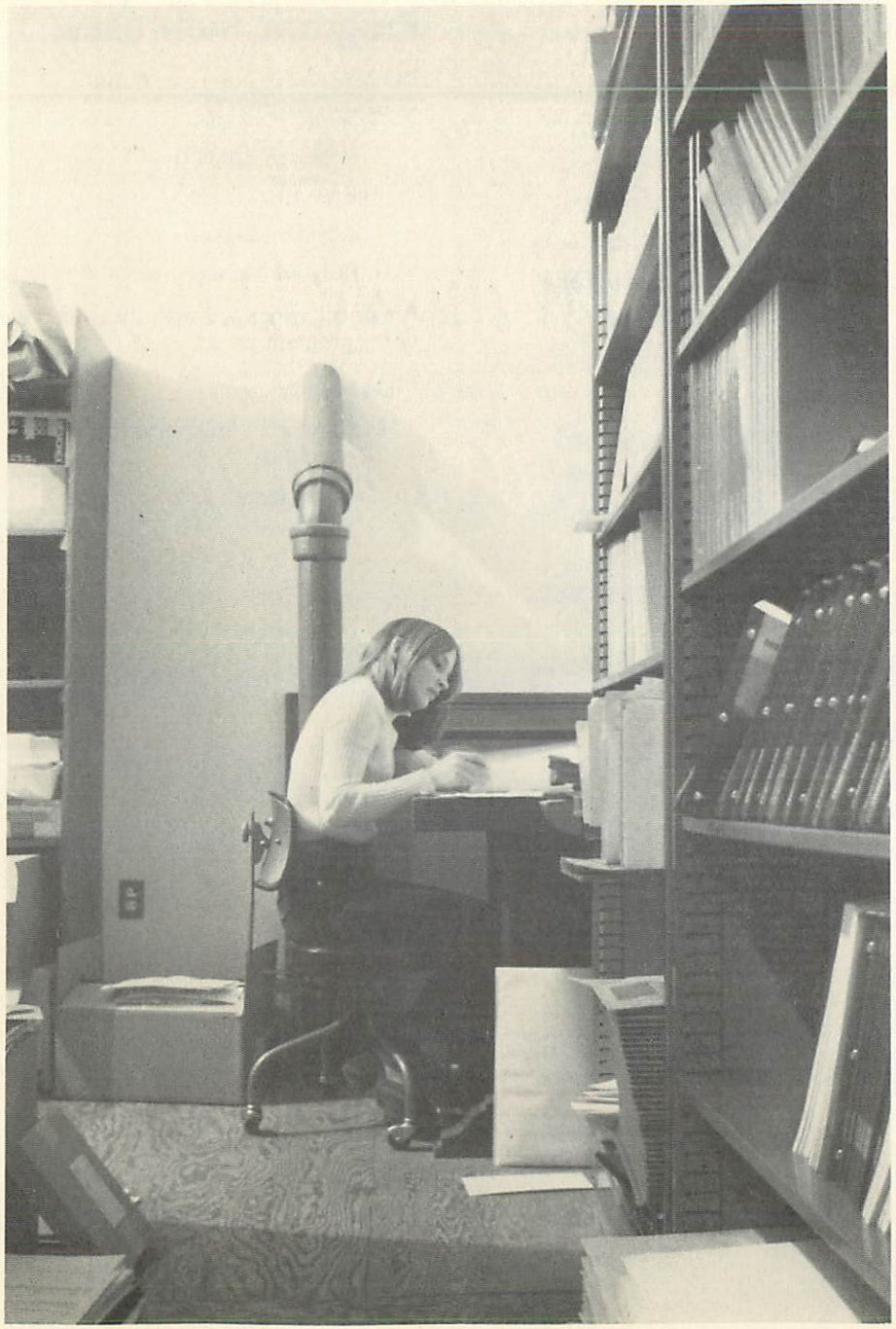
In FY73 the Delaware Sea Grant Program consisted of:

25 Research Projects
3 Education Projects
Advisory Services
Program Management

Personnel associated with the Sea Grant program were:

34 Faculty
21 Graduate Students as research assistants
15 Professional Staff

Publications



Technical Reports

DEL-SG-1-73
Stochastic Optimization of Convective-Fin Design. B.L. Marsh and F.A. Costello. Reprint from Journal of Heat Transfer, 1973

DEL-SG-2-73
A Program in Ocean Engineering Education. F.E. Camfield, W.L. Preslan and H. Wang. Reprint from Proceedings of the 8th Annual Conference of the Marine Technology Society, September, 1972

DEL-SG-3-73
Occurrence of Gas-Bubble Disease in Three Species of Bivalve Molluscs. R. Malouf, R. Keck, D. Maurer and C. Epifanio. Reprint from Journal Fisheries Research Board of Canada, vol. 29, no. 5, 1972

DEL-SG-4-73
Development of Closed System Oyster Culture. D. Maurer. Reprint from Bulletin of the American Malacological Union, February, 1972

DEL-SG-5-73
The Influence of the Climatic Water Balance on Conditions in the Estuarine Environment. J.R. Mather, F.J. Swaye, Jr. and B.J. Hartman

DEL-SG-6-73
Shallow Water Hydroids of the Delaware Bay Region. L. Watling and D. Maurer. Reprint from Journal of Natural History, vol. 6, 1972

DEL-SG-7-73
The Design and Construction of the University of Delaware Mariculture Laboratory. G. Pruder, C. Epifanio and R. Malouf

DEL-SG-8-73
Mercury in the Environment: A global review including recent studies in the Delaware Bay region. F.K. Lepple

DEL-SG-9-73
Inventory and Evaluation of Information on Delaware Bay, Volume I. D.F. Polis, ed.

DEL-SG-11-73
Techniques and Instrumentation to Control Some Environmental Factors for Shellfish Nutritional Studies. R.C. Dwivedy

DEL-SG-12-73
Inventory and Evaluation of Information on Delaware Bay, Volume II. D.F. Polis, ed.

DEL-SG-13-73
Inventory and Evaluation of Information on Delaware Bay, Volume III. D.F. Polis, ed.

DEL-SG-14-73
The Use of Ion Specific Electrodes for Chemical Monitoring of Marine Systems. R. Srna, C. Epifanio, M. Hartman, G. Pruder and A. Stubbs

DEL-SG-15-73
Coastal Vegetation of Delaware: The Mapping of Delaware's Coastal Marshes. V. Klemas, F.C. Daiber, D.S. Bartlett, O.W. Crichton and A.O. Fornes

DEL-SG-16-73
Instrumentation and Technique of Electrophysiological Studies of Chemoreceptors on Labial Palps of the American Oyster. R.C. Dwivedy. Reprint from Transactions of the American Society of Agricultural Engineers, 1973

DEL-SG-17-73
Marine Affairs and Higher Education. G.J. Mangone and J.L. Pedrick, Jr.

DEL-SG-18-73
A New Euryhaline Species of Parapleustes *(Amphipoda) from the East Coast of North America.* L. Watling and D. Maurer. Reprint from Proceedings of the Biological Society of Washington, May, 1973

DEL-SG-19-73
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DEL-SG-20-73
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