SEA GRANT PROGRAM OPERATIONS 1969-70

TAMU-SG-71-104
Texas A&M University Sea Grant Program
December 1970

TEXAS A&M UNIVERSITY SEA GRANT PROGRAM

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Partially supported by the National Sea Grant Program

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The Sea Grant Program has just completed its second full year of effort and has embarked upon a third year. During these two years, the program was identified, initiated and organized. Its magnitude is now in excess of $1,800,000 annually, including both federal funds and institutional contributions. The program has been launched successfully. On the other hand, a program of this scope cannot emerge within such a short period of time without some deficiencies. The initial trajectory now can be assessed and corrections can be made so that the future course will be improved. The current year and the year ahead are periods of evaluation and consolidation for the program.

At this point in time, the Sea Grant Program at Texas A&M University can be understood best by considering (1) its relationship to the total University program in marine resources, (2) its relationship to the statewide community, including other educational institutions and industry of marine resource interests, and (3) its internal organization.

The University Program In Marine Resources

Texas A&M University has a broad program in marine affairs of which the Sea Grant activity is a part. However, the Sea Grant Program has become the catalyst for the further development of and focal point for administration of the marine resources program. A survey of expenditures for marine resource programs at Texas A&M University for the period ending August 1970 estimated that $4.35 million were expended during the preceding year in programs whose primary reason for being was based on the sea. This figure does not include programs which have a high relevancy to marine related problems (such as biology) or programs which in some way contribute (such as economics). These expenditures, by organizational units, were estimated to be: Department of Oceanography, $1.96 million; Sea Grant Office, $1.28 million; Maritime Academy, $.57 million; and other departments, $.53 million. The distribution of these costs by functions was estimated as: Instruction, $1.7 million; Research, $2.37; and Extension, $.23 million. Virtually all of the University's extension activity in this field is to be found in the Sea Grant Office.

Of the University's total marine program expenditures, approximately 40 percent are estimated to be in Galveston. Marine related programs in

Galveston have been grouped under the Moody Marine Institute. At Galveston, Texas students may take year-round resident work toward graduate degrees in oceanography or marine related fields. Twelve graduate students were in residence during the fall and spring semesters of 1969-70, 61 students were enrolled in the first summer session of 1970, and 58 during the second summer session. It is expected that approval will soon be obtained for resident degrees at Galveston. The University has a major commitment to Galveston as a coastal city base and this commitment is expected to increase to encompass marine academic programs which would qualify Galveston as a Branch Campus of the University.

The Department of Oceanography, the Sea Grant Program Office, the Maritime Academy, and the Marine Laboratory exist solely because Texas A&M has a marine program. Organizational units which exist for non-marine reasons also have programs germane to the marine field. In the College of Geosciences, this includes programs in Geography, Geology, Geophysics, and Meteorology. In the College of Engineering, a number of engineering academic departments have marine related competence such as a fish protein pilot plant and the Morgan's Point Water Pollution Research Laboratory on the Houston Ship Channel. The College of Agriculture conducts a number of programs related to marine affairs, particularly in the fisheries and land-use areas. In Brazoria County, the Texas Agricultural Extension Service has developed a mariculture facility consisting of some 13 ponds, a mobile trailer laboratory, marsh buggies, and analytical laboratory facilities. The College of Veterinary Medicine has developed a special program devoted to diseases of marine species. The Department of Biology of the College of Science has a strong component which is oriented to marine biology, although there is no specific degree offered in this field.

The University has begun construction on an $8 million Oceanography and Meteorology building on the main campus; a master plan has been adopted for the Mitchell Campus in Galveston; and to date, $1,890,000 has been appropriated and is being spent for docking, paving, and academic buildings at the Mitchell Campus facility. Sea-going facilities include the *R/V Alaminos*, the *R/V Orca*, the *R/V Excellence*, and the *R/V Mariner*, as well as the *Texas Clipper*, operated as a training vessel by the Maritime Academy. The *R/V Orca* is a research vessel for continental shelf work, the *R/V Mariner* and *R/V Excellence* are primarily for near shore and estuarine work.

The Sea Grant Program is established as a distinct major program of the University. It is under the supervision of a University Vice President, and has the strong backing of the University administration. The active support of the University administrators is demonstrated by the fact that contributory costs are allocated through existing budget channels. In addition, two year ago, Texas A&M University requested, and the Legislature appropriated to the Sea Grant Program a line item of $200,000 for each year of the biennium. The University has requested increased appropriations from the current Legislature.

The program has produced a university-wide involvement; it has created a campus-wide force that applies the maximum university resources on the Sea Grant goals. This is evidenced by the large number of ideas that are brought to the attention of the Sea Grant Office (proposals requesting more than $3 million in funds were screened for the 1969-70 proposal); by the joint working groups which have formed either for research or for educational programs; by the personal interest of every dean on campus; and by the willingness of operating units to recast their programs so that the Sea Grant contributory funding provisions can be met.

During the 1969-70 funding year, one hundred university staff and faculty members were involved in Sea Grant sponsored activities. Sixty-three students were actively supported by Sea Grant in their research activities. The result has been a broad program which reaches into 21 departments or divisions in eight of the University's nine academic Colleges. In addition, staff members and students from other schools and universities as well as industrialists have worked on Sea Grant supported projects. It is estimated that 500 key leaders of the State have been involved over the past year to 18 months in the various workshops and discussion programs through the Sea Grant Program effort.

The extent of Sea Grant work is indicated on the accompanying map of the Texas Coastal Zone which shows the locations for marine work, including work carried on in cooperation with other institutions.

Although the Sea Grant Program is a major and separate activity within the administrative structure, the project work is based upon the strength of the various academic departments and Colleges. The actual work done by the Sea Grant Office staff is limited to the direction and administration of the program, to the development of an integrated and cohesive program, including planning and conferences for this purpose, to the supervision and issuance of publications, and to centralized advisory services. The Sea Grant Program is wholly dependent upon the Colleges and departments, therefore, for the majority of institutional contributions to meet the conditions of the Sea Grant award and for the expertise to carry on the work. The consolidation and further development of the Sea Grant Program at Texas A&M, therefore, must take into account a diversified set of academic units, related to program commitments which go beyond the Sea Grant format, an emerging importance to the Galveston region, and a strong administrative desire to achieve.

The Statewide Community

Marine resources questions are very lively topics for discussion in Texas. The Sea Grant Program in Texas has played an active and dominant role in the emergence of this subject as one of broad public concern. Public officials now see possibilities for program sponsorship in the area of marine resources. Virtually every top Texas State official has made a statement of public record on this matter.

The State Involvement. On January 20, 1970, Governor Preston Smith was presented with a report -- "Goals for Texas in the Coastal Zone and the Sea," prepared by a Governor's Advisory Committee on Marine Resources. The report was printed by the Sea Grant Program Office and much of the background work on the report was done by the Sea Grant Program staff. Among the recommendations of the report are that a new State authority be established; that there be increased attention to research in the marine resources field; that public awareness and understanding of marine resource problems and opportunities be increased; and that specific action be taken to improve intergovernmental relationships within the State government structure with other states and with federal programs. A specific recommendation states that Texas should give State support to the establishment of a Sea Grant College in Texas.

This report to the Governor is based on a conference, conducted in September 1970, in the name of the Governor and co-sponsored by the Sea Grant Program. This State-wide conference was preceded by a number of smaller workshops sponsored by the Sea Grant Program and structured to consider individual marine resource subjects. Separate reports on each of these workshops have been published. These include "Marine Resources--The Industrial View; "Marine Resources--The Educational View;" "Marine Resources--The Fishery View;" "Marine Resources--The Recreation and Tourism View."

During the past 18 months, hearings have been held by the Interim Committee of the House of Representatives established to consider the needs of the State of Texas for an Institute of Oceanography. The Sea Grant Program had no formal ties to the hearings of this Committee, but individual workers in the Sea Grant Program were called upon to supply background information. A project to the House Interim Committee was awarded by the Texas A&M University Sea Grant Program for funds to support dissemination of information resulting from its hearings. A report of this Committee is due before the Texas Legislature at its current session.

Within the Governor's immediate office, a staff effort for a coastal zone study for Texas was initiated. This study was authorized by the last Texas Legislature and funds were provided for initiating the effort. The Planning Division of the Governor's staff has hired a full-time staff member to direct this study and prepare a preliminary report. A summary of the report has been printed and the full report will be available for this session of the Legislature. The Governor's Office has called upon the Sea Grant Office for assistance in preparing its report and the complete document will contain several sections prepared through staff members at Texas A&M University.

Multi-Institutional Involvement. The emergence of the Sea Grant Program also has stimulated concern for marine resources programs among other educational institutions of the State. The Sea Grant Program Office of Texas A&M University has maintained an awareness of the developments, has assisted some of them with project funds, and has initiated efforts to coordinate programs. The program has made definite progress in these respects. This is evidenced by (1) the group of institutions engaged in

technician training; (2) a start on marine law educational programs; (3) assistance to Lamar State College of Technology; and (4) plans for coastal zone laboratories. A resume of inter-institutional programs and plans for the future is presented below.

Relationships with Other Texas Institutions

For the 1968-69 program under the Sea Grant Institutional Award, no projects were proposed for work at other Texas institutions. A technician training project was included in the proposal, however, for James Connally Technical Institute, which at that time was a part of the Texas A&M University System.

During the first year of operation (1969-70), a research project was begun at Lamar State College of Technology, and part of the technician training program was transferred from Connally Technical Institute to the Galveston Community College. By the end of the first year, agreements in the form of letters were in effect with James Connally Technical Institute, Galveston Community College, and Lamar State College of Technology.

The second year proposal included continuation of these inter-institutional arrangements. During the second year, James Connally Technical Institute became a separate institution.

During the course of the second year operation, an agreement was executed with the University of Houston to provide for the conduct of a Marine Law Seminar. Also, joint discussions were held with the National Sea Grant Program Office and Del Mar College with respect to assuming responsibility for a technician training program that had been initiated earlier at Del Mar College under a separate grant from the federal Sea Grant Office. The following table shows the growth of the inter-institutional effort and the funds allocated for each.

SEA GRANT COOPERATIVE PROJECTS

	S/G	OTHER
1968-69		
J.C.T.I. (WACO) TECHNICIAN TRAINING	$ 14,720	$ 14,020
GALVESTON COMMUNITY COLLEGE TECHNICIAN TRAINING	$ 25,280	$ 3,365
1969-70		
T.S.T.I. (WACO) TECHNICIAN TRAINING	$ 10,000	$ 9,133
GALVESTON COMMUNITY COLLEGE TECHNICIAN TRAINING	$ 50,000	$ 15,898
LAMAR TECHNOLOGY COLLEGE RESEARCH	$ 20,085	$ 14,730

The third year proposal (1970-71) for the Institutional Award to Texas A&M University included continuation of the projects at Lamar State College of Technology, Galveston Community College, and Texas State Technical Institute. New projects were added to provide for a program in law at the University of Houston, a technician training program at Brazosport Junior College, and the technician training program at Del Mar College which had been funded spearately. Furthermore, a research project with Dow Chemical Company was initiated.

Before the third year program started, the program in technician training at Galveston College was discontinued at the request of the National Sea Grant Office, and with the agreement of Galveston College.

During the course of the current year and in preparation for the program next year, there have been have been discussions concerning new institutional relationships for recognizing coastal zone laboratories. One project would be with Lamar State College of Technology to plan a coastal zone laboratory for the Sabine region.

The program for next year will continue the relationships with Del Mar College, the University of Houston, Brazosport Junior College, Texas State Technical Institute, Lamar State College of Technology, and Dow Chemical.

The Industrial Involvement. Support for Sea Grant activities has come from industry as well as university funds. During 1969-70, contributory funds and services amounting to more than $26,000 have come from four sources -- Texaco, Inc., Oceanonics, Brazoria County Mosquito Control, and Well Reconnaissance, Inc. By 1970-71, industrial support is expected to provide as much as $72,000 for Sea Grant activities.

Organization of the Program

The process of organizing the Sea Grant Program has included the matters of defining marine resources, establishing the subject matter needs to be worked on, providing a structure under which the various program elements can be compared and evaluated, and creating administrative and service activities to support project workers.

The original approach to organization of the program has been essentially the same as that used in other institutions. A call was made for proposals and projects were initiated by faculty interested in marine resources, the net result being essentially a package of project ideas. As the program has grown, it has moved in the direction of a directed program made up of projects responsive to goals that have been enunciated. New projects of higher priority are replacing some of the initial projects. The program is evolving into a coherent attack on well defined problems.

Program coherency has not been achieved yet in the academic sense. There is no organized body of knowledge that can be called marine resources. The term does not even have a standard meaning. Moreover, there are

incompletely defined bodies of knowledge related to marine fisheries, marine transportation, marine recreation, and the other component parts of marine resources. This lack of knowledge has been a deterrent to the organization of the Sea Grant Program. Solving this problem is one of the principle challenges facing the Sea Grant Program. An academic identity for marine resources must evolve and organization of the Sea Grant Program will not be complete until the identity has been achieved.

Nor has coherency for the Program been possible because of an identifiable community known as the "marine resource industry," a marine resource government entity or a unique professional society concerned with this subject. One of the first major tasks undertaken was that of identifying the several industries, state agencies, and other groups playing a role in this field. They were found to be many and diverse. Each has its own point of view. It is not surprising that each and every coastal region of the nation is different from any other with respect to the details of its marine community. This became obvious as more key persons in Texas marine resources were identified.

It has fallen to the Sea Grant Office itself, therefore, to enunciate the program organization and to develop a structure into which will fit the concerns expressed by resource users as well as the projects proposed by academic groups. This has been an evolutionary process leading to the current eight major program areas:

Program Management
Marine Fisheries
Marine Commerce
Marine Sciences
Marine Environmental Quality
Marine Engineering and Technology
Marine Resources Management
Coastal Zone Laboratories System

Each of these programs has been developed and expanded for 1970-71 funding year. During the second year of the Sea Grant effort (1969-70), however, no projects were identified with Marine Commerce and no effort was made to initiate activities under the Coastal Zone Laboratories Systems program.

The eventual goal of each program is to obtain results that can be used for making decisions with respect of marine resources or for increasing the value of these resources in economic or other terms. The following sections of this report deal with these programs in greater detail.

Within each of the eight major program areas enumerated, there are specific projects identified in the education, research and advisory service categories. In developing a coherent Sea Grant Program, there has been increasing attention to educational and advisory projects in place of research projects. Research activities will have a resurgence when the need for new knowledge becomes better defined. In advisory services, better methods are being sought to transmit, organize and use the existing knowledge base.

Educational projects in the Texas A&M University's Sea Grant Program involve (a) instruction for science teachers of primary and secondary schools; (b) technical and vocational training; (c) general and special courses for undergraduates; (d) general and special courses for graduate students; and (e) special curricula areas.

Advisory services have been initiated with full-time advisory specialists in several subject matter fields: (a) for fisheries (located at Galveston); (b) for marine recreation (located at College Station); (c) for the marine transportation industry (located at College Station). Other advisory service groups being contemplated for the immediate future include those for marine small business activities, fishing processing, and oceanographic services. The Sea Grant Program Office staff have been deeply involved in the coordination and organization of Advisory Services activities. Through 1969-70, in fact most of the identifiable activities in this area have been the result of program office staff, particularly in the areas of workshops and publications.

The percentage break-down by category of Sea Grant funds for 1969-70 is given in the accompanying table.

FY 1969-70	National S/G funds	State Contribution	Total	% of Total
Administration and New Program Development	98,499	64,174	162,673	13.82
Education and Training	122,964	69,747	192,711	16.37
Research	458,256	244,798	703,054	59.74
Advisory Services	70,281	48,217	118,498	10.07
TOTALS	750,000	426,936	1,176,936	100.00

The Sea Grant Program Office also has established a Department of Marine Resources Information under a full-time Department Head and Editor. A series of publications have been generated for general and technical purposes. These consist of general informational documents; technical reports; brochures and announcements; occasional papers; pictures, slides, and filmstrips; news releases and clippings; bulletins; and technical papers.

During the 1969-70 period, the marine resources information department generated 47 technical/general reports and 12 newsletters. In addition, the Sea Grant Program editor was awarded a separate grant from the National Science Foundation, Office of Science Information Services, to prepare a monthly review of all Sea Grant activities around the nation.

In the area of public information, the Sea Grant Program prepared an exhibit on behalf of the national Sea Grant effort for display at the Offshore Technology Conference held in Houston in April 1970. More than 6,000 persons attended the OTC exposition. As a result of the exhibit, approximately 600 requests for Sea Grant publications were made to the national office.

During the 1970 spring months, the Sea Grant Office agreed to cosponsor an ocean pavillion with the State Fair of Texas. Assistance in contacting appropriate exhibitors and planning for the layout of the 33,000 square-foot pavillion, called Oceanus, was provided. During the State Fair (October 1970), approximately 400,000 persons attended Oceanus. The event was so successful that the State Fair held the pavillion open for almost three months after the close of the Fair. Oceanus represented the first educational oceanographic exposition ever held in the State.

The broad subject of marine affairs is multi-faceted and at Texas A&M University acceptance of a Sea Grant Institutional award has been interpreted to include acceptance of a responsibility to explore and develop all avenues leading to better uses of marine resources available to the State. This means broad communication and coordination, enhancing the capabilities of existing institutions, and working in support of industry, commerce, State agencies, and local communities. The steps taken in the first two years of the Sea Grant Program give ample evidence that the role of Texas A&M in marine affairs is well understood.

PUBLICATIONS AND DOCUMENTATION

A Summary of Recent Texas Acts and Resolutions Related to Marine Resource Development. Texas A&M University. College Station, Texas. TAMU-SG-70-106. February 1970. 12pp.

Calhoun, John C. "Sea Grant . . . Goals and Accomplishments." Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-201. March 1970. 19pp.

Coastscripts - Distributed to one hundred selected people affiliated with Texas A&M University. It consists of periodical newspaper clippings of interest.

Gunn, Clare A. *Annotated Bibliography of Resource Use: Texas Gulf Coast.* Texas A&M University Sea Grant Program. College Station, Texas TAMU-SG-70-204. November 1969. 387 pp.

Law and the Coastal Margin. Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-108. April 1970. 83pp.

Lemmon, Ray. "The Gulf States' Role in the Coastal Zone." Texas A&M University Sea Grant Program. College Station, Texas TAMU-SG-70-302. May 1970. 13 pp.

Marine Affairs in Texas: A Report for 1968-69. Texas A&M University Sea Grant Program. College Station, Texas.. TAMU-SG-70-103. December 1969. 17 pp.

Mutscher, Gus F. "Political Consideration in the Management of the Coastal Zone." Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-303. August 1970. 6 pp.

Proceedings of the Second Dredging Seminar, November 21, 1969. Texas A&M University Sea Grant Program. College Station, Texas TAMU-SG-70-113. June 1970. 93 pp.

Report of Sea Grant Project Activities 1968-69. Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-104. December 1969. 115 pp.

Staff Report. *Handbook for Sea Grant Activity Leaders.* Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-601. March 1970. 75 pp.

Texas Marine Resources and the Sea Grant Program. Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-102. October 1969. 165 pp.

Texas Marine Resources Series:

"The Educational View." Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-109. May 1970. 8 pp.

"The Fisheries View." by Bryant F. Cobb, III. Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-115. August 1970. 8 pp.

"The Industrial View." Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-107. April 1970. 8 pp.

"The Leisure View." by Clare A. Gunn. Texas A&M University Sea Grant Program. College Station, Texas TAMU-SG-70-110. June 1970. 16 pp.

"The Legal-Administrative View." Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-112. June 1970. 16 pp.

"The Ports and Waterways View." Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-114. August 1970. 13 pp.

Texas Studies the Ocean. Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-101. October 1969. 15 pp.

University and the Sea - Six-page newsletter distributed bi-monthly to over two thousand subscribers. It contains interesting notes on various aspects of the Texas A&M University Sea Grant Program and other related oceanographic programs.

MARINE ENVIRONMENTAL QUALITY

The quality of the environment has been the topic of many activities during the past year. Within Sea Grant, a program to analyze water quality in estuaries through studies of the pollutant removal rate by sedimentation and to provide basic information on the effects of salinity on pollutants has completed its second year. Two projects have been at work in this area thus far. During the 1970-71 period, however, two other studies will be added to the program.

Biological Response to Organic Chemicals in Estuaries

Activity Leader: William B. Davis, Environmental Engineering Division, Civil Engineering

Estuaries provide the environment for biological action on certain pollutants discharged by industries and municipalities located along the thousands of miles of coastline. Salinity variation is likely to influence the matabolic response of the biomass which may either originate in the estuary or in a treatment plant and be discharged into the estuary. Salinity change is also a major problem in the treatment operation of wastes from some manufacturing processes like cheese manufacture, pickling processing and so forth where salinity is in the order of 20,000, to 25,000 mg/l. In addition, shipboard waste treatment on ocean going vessels may be significantly influenced by salinity variations.

Therefore, basic and definitive information pertaining to the effect of salinity is important to determine the fate of different pollutants discharged into the estuaries, and to determine design and operation parameters of plants subjected to salinity variation. Obtaining the mentioned information was the purpose of this project.

Project Description and Report of Work and Accomplishments

This research was carried out by running five series of test (A,B,C,D, and E) utilizing heterogeneous cultures acclimated to acetone, and grown on acetone, 2-butanone and 2-pentanone. Each series was operated at a different salinity. The objectives of this study were:

1. To study the long term effects of various salinity levels on the microbial behavior.
2. To study the shock effect of selected levels of salinity on culture established in various salinities.

3. To describe the apparent reaction kinetics of each system.

4. To demonstrate the accuracy and precision of the analytical tools such as the Total Carbon Analyzer, Gas Liquid Chromatograph, Gilson Oxygraph and to correlate between the results.

In previous reports, cultures A,B,C,D, and E were defined as cultures originally acclimated to acetone and acclimated to salinities of 0, 5,000, 10,000, 20,000 and 35,000 mg/l. Test series A,B,C, and D were run to determine the effect of salinity on microbial behavior of cultures A,B, C and D respectively. The results of these tests were reported earlier in an Annual and Semi-Annual report (October 1, 1969 and March 19, 1970).

The organisms diversity of cultures A,B, and C were determined and reported in an earlier Quarterly report (December 19, 1969). Cultures D and E were identified and reported in the Semi-Annual report of March 19, 1970.

During the past six months (March through September) test series E was run to determine the effect of various salinity levels on a culture acclimated in sea water (35,000 mg/l salinity). The results of this series were correlated with the results of the other test series (A,B,C, and D) and the following conclusions were made:

1. The decrease in the substrate removal rates was proportional to magnitude of the salinity shock.

2. The oxygen requirement per unit ketone removed increased for a culture acclimated to a certain salinity and shocked with lower salinities.

3. The biomass increase per unit ketone removed was higher for cultures established and tested at low salinities.

4. The results of long term salinity studies clearly indicated that cultures established in fresh water and low salinities have a higher unit rate of removal than the cultures established at greater salinities.

5. The removal of 2-butanone and 2-pentanone occurred first in all test series. The acetone removal started when the concentration of the other two ketones reached low levels.

The diversity of organisms of cultures A,B,C,D and E are presented in Table I on the following page.

From this table the following were observed:

1. Two predominant genera, Cephalosporium and Pseudomonas, were common to all salinity levels.

2. Minor species were eliminated with the progressive increase in salinity level.

These two observations lend evidence that a reduced removal rate at a higher salinity level was due not to the change in population structure but to the physiological effects of the increased salinity on the uptake and metabolism of the substrate by organisms.

TABLE I. Predominate Organisms in Cells Per Milliliter

ORGANISM	CULTURE				
	A	B	C	D	E
Pseudomonas Gp IV	6×10^5	8×10^5	4×10^6	22×10^6	13×10^6
Pseudomonas Gp IV	5×10^4	5×10^4	13×10^3	-	-
Baccillus cereus	6×10^3	9×10^3	23×10^3	Nil	-
Aeromonas sp.	4×10^3	6×10^3	3×10^3	-	-
Aeromonas formicans	$<10^3$	$<10^3$	Nil	-	-
Cephalosporium	*	*	*	*	*
Saccharomycetaceae	500×10^3	450×10^3	12×10^3	-	-
Chlorella	*	*	*	*	*

* Present, but not countable by this method

\- Not present

Two technical reports (TAMU-36-70-216 and TAMU-36-70-701) covered the procedure and the results of the five test series along with the organisms identifications. These two reports were submitted to the Sea Grant office in July and August of this year.

The problem associated with biological treatment of wastes under variable salt concentrations is tremendous while the process and unit design is even more challenging. The fact that the oxygen requirement is a function of both organic load and varying salinity conditions will add to the complexity of aerator design. In addition, the effect of salinity on the settling characteristics which are observed in this study may result in adding new considerations to the design of the final clarifiers. Configuration and size may differ from the conventional design.

Because these studies were carried out exclusively in batch systems, the effect of variable salinities on the organic and hydraulic loadings could not be determined. This information must be obtained from cultures developed in continuous flow reactors. This work is presently underway.

Bottom Sludge Accumulation and Oxygen Demand in a Polluted Estuary

Activity Leader: Roy W. Hann, Jr., Environmental Engineering Division, Civil Engineering

Two major components in the analysis of the water quality in an estuary are the pollutant removal rate by sedimentation and the resultant oxygen demand of the bottom deposits. This project involves a study of the solids balance and the oxygen balance of an arm of the Houston Ship Channel to develop methodology for evaluating these parameters.

A study will be made of each of the components of the mass balances and a computer model constructed to duplicate the process taking place. A major field effort will be carried out as a part of the studies to evaluate the mass balance components and to demonstrate the validity and usefulness of the techniques.

Project Description and Report of Work and Accomplishment

Project Organization. This project is one of two being carried out by the Estuarine Systems Project Research group within the Environmental Engineering Division of the Civil Engineering Department at Texas A&M University. The second project entitled *Management of Industrial Waste Discharges in Complex Estuarine Systems* is a joint Federal Water Quality Administration - Texas A&M University effort.

The two projects are managed together under the direction of Dr. Roy W. Hann, Jr. They are highly interrelated in that they share facilities, equipment and personnel. Those activities dealing with the evaluation of mass balance components and sedimentation rates are considered to be primarily sea grant project efforts along with the other specific activities spelled out in the sea grant proposal. Specific project accomplishments are documented in a series of Estuarine Systems Project Technical Reports with credit being given to both funded projects. A total staff ranging from 18-20 persons is associated with the Estuarine Systems Project.

Specific Project Technical Activities. During the first project year, technical activities were divided into seven groups; namely, equipment specification and design, facility development, literature review, laboratory methodology, barbours cut sampling, anaerobic digestion, and sludge profile and deposition rates. The first four of these are of a reoccurring nature and continued during the second year, but at a reduced level. The barbours cut sampling and the sludge activity, as well as biological oriented oxygen uptake study constituted a major project effort during the second year.

The barbours cut sampling or study will be carried into the third project year. A considerable amount of base data was collected and evaluated during the second year, but further analysis is necessary to develop a model for the system. The sludge activity was evaluated extensively and published as Welford S. Hutton's Master's thesis as well as a

technical report generated by this project. The oxygen uptake study was also a thesis research topic and published by David L. Parmer. Each of the three activities will be discussed in the following paragraphs.

Barbours Cut Study. Two major study efforts were accomplished during the second project year. A 72 hour study that monitored temperature, conductivity, salinity and dissolved oxygen was conducted aboard the RV/Excellence in February. Water surface elevation was also continuously recorded aboard the vessel. Light transmission, wind direction and speed, and air temperature were measured every two to four hours and water and bottom deposits samples were taken daily for analytical work. BOD,DO, total carbon and ammonia - Kjeldahl Nitrogen Series were run on these samples.

A second study was made in July. The same type data was collected, but on a different schedule. Data was taken during the week of July 14, but sampling during the daytime only.

The results of these studies are displayed in Figures 1 - 5. Figure 1 is a schematic of the cross section of Barbours Cut illustrating the layers in which oxygen is produced or used in various ways. Figures 2 - 5 are displays of the data. Initial data indicate that algal activity is significant since a super saturation of oxygen is occasionally present, and that BOD levels are relatively insignificant. The effect of nutrients from sludge deposits are yet to be evaluated. Turbulence due to ship traffic may be of greater significance to reaeration than tidal activity.

Sludge Activity. The primary project activity involved the evaluation of the pollutional input into the channel in terms of organic material and the evaluation of fraction thereof which was deposited as bottom sediment and removed by dredging.

The total sediment deposition rates in the Houston Ship Channel over the two dredging cycles in the late 1960's is shown in Figure 6.

Figure 7 shows the results plotted on a finer grid for the lower four miles of the channel.

Sedimentation rates generally averaged 2.5 feet per year in the upper 12 miles, slightly under 2.0 feet per year from mile 5 to mile 12, and 4.0 feet per year in the lower 5 mile stretch.

This variation is due partially to channel construction and partially to source of sediment materials.

The organic quality of material found in the bottom sediments as expressed by BOD_5 is shown in Figure 8. The total deposition rate in the upper 12 miles of the channel during the last dredging cycle was 80,300 pounds per day and in the lower 12 miles the deposition rate is 64,800 pounds per day. The total organic material load in the channel is 145,100 pounds of BOD_5 per day. Similar although somewhat less accurate, mass balances are available for the other measures of organic material but the results are not presented herein. The quantity of organic material added to the channel at various locations is shown in Figure 9.

The total loading in terms of BOD_5 in the upper 12 miles of the channel is 326,000 pounds per day and in the lower 12 miles is 126,000 pounds per day; making a total load to the channel of 452,000 pounds per day.

The removal to the bottom sludges thus amounts to 24.8% in the upper channel, 51.8% in the lower channel and 32.0% for the channel as a whole.

Three Bays, upper San Jacinto Bay, Burnett Bay, and Scott Bay, were studied in order to estimate the rate of build-up of sludge deposits in side bays of the Houston Ship Channel system. By using the average sludge depth of each along with the sludge density, surface area, and the BOD_5 concentration in each bay the total organics, in terms of BOD_5, accumulated in upper San Jacinto, Burnett, and Scott bays were computed to be 2,930,000 5,860,000, and 20,720,000 pounds respectively. The sum of these totals yield a quantity of 30,510,000 pounds of BOD_5 for the three bays.

The analysis of the side bay deposition utilizing the history of waste loading shown in Figure 10 and a decay rate of .1 per year indicates a deposition rate of 14,000 pounds BOD_5 per day. Thus an additional 3.1% of the organic sediment is deposited in the side bays along the Houston Ship Channel. This analysis is, however, highly dependent in the decay rate function. Future work will attempt to define this rate more accurately.

The results for other parameters closely correlated with the results based on BOD_5. The use of the modified oil and grease test yielded interesting results when examined with regard to industrial outfall location. The general background level for this parameter in the channel was on the order of 1/2% extractable organics in the sediments. Near two petrochemical complex outfalls the value increased to almost 2% extractable organics. Additional work is planned to examine if this test can be used to determine the sedimentation pattern from these industries.

Several other studies were carried out by the project staff in support of this activity.

Sludge spoil area: The runoff from a sludge spoil area was analyzed during dredging operations. In this one instance the organic loading was comparable to that of the channel water outside of the dredging area and as a result of a high algal activity, the runoff water carried a high level of dissolved oxygen which was not present in the channel waters.

Benthal decay: A study was initiated and is continuing to evaluate the decay characteristics of the bottom sediments. In several places in the channel, toxic constituents or nutrient imbalance result in no apparent decay taking place. This negligible decay will effect future use of the extensive sludge spoil areas.

Since this decay is negligible and material deposited on the bottom is thus stored until removed by dredging, methods of improving

sedimentation for in-channel removal of wastes to the bottom is a definite possibility.

Correlation of organic sediment buildup to load source: It had been hoped that the organic sediment pattern would be sufficiently defined to permit an analytical model to be calibrated which would permit the prediction of organic sediments for altered waste loading conditions. Although useful trends were observed, additional study of sediment pattern from single outfalls is needed before such a model can be calibrated.

Oxygen Uptake. Oxygen uptake is perhaps a misleading title for Parmer's work. He mainly concerned himself with mechanisms of organism limitations in the Inland Houston Ship Channel. Much of his work pertained to oxygen and toxic substance levels' effect on aquatic life.

It is believed that oxygen limitations are the primary, if not the exclusive cause of the numerous fish kills. Toxic substances (e.g., heavy metal ions) were demonstrated by Parmer to act synergistically with limiting oxygen conditions. The result is a highly toxic environment at very low concentrations of these substances. Tests by Parmer also indicate that lower levels of toxicity do not result in immediate death of the organism but in other metabolic abnormalities (e.g., high oxygen utilization rate).

There are, therefore, two basic problems associated with maintenance of aquatic life in the Houston Ship Channel-Galveston Bay System: absence of an adequate oxygen supply available; and the presence of materials which alone or in conjunction with low dissolved oxygen levels cause death or metabolic strain to aquatic life.

Marine Bioengineering

Activity Leader: Daniel T. Hanson, Department of Chemical Engineering

Studies of marine species of presently known potential for production of proteolytic, enzymes, production of food-grade materials, gas exchange, and for destructive proliferations are underway. Procedures to isolate, select, identify, and to maintain stock cultures of marine species with specifically desired and newly identified potentials will be initiated.

Project Description and Report of Work and Accomplishments

From present criteria of potential usefulness, some 48 bacteria, 11 fungi, and 6 algae have been isolated. These are classified according to where they are likely to be useful in pollutant removal from streams that flow into marine waters of the Gulf Coast. However, procedures required to obtain and classify these microflora have produced other results. Perhaps the most notable of these is the partial demonstration of economically viable methods through which collaboration and exchange of information and materials among industrial firms may be accomplished for efficient improvements of industrial biodegradation and pollutant removal processes.

The last stated result is to be further used and demonstrated here. It is felt that the same result can also be achieved elsewhere by others for more widespread and immediate usefulness in improved pollution control.

Gymnodinium breve. Continuous culturing of *G. breve* has not yet been achieved due to difficulties encountered in maintaining stock cultures of this species. Procedures to achieve reproducible survival and growth of transferred inocula have not yet been described. A 10-liter batch culture has been obtained for inoculation of the continuous propagators. Since this species appears extremely sensitive to shearing stresses, its continuous growth will be attempted in the helical gas lift apparatus similar to that subsequently described.

Aeromonas Proteolytica. Continuous, steady-state growth of *Aeromonas proteolytica* has been achieved in turbulent continuous cultures. Antifoam agents have been routinely used by others in batchwise ferementation of casein by *A. proteolytica*. The surfactants which have been used appear to interfere with subsequent enzyme separation. Casein concentrations both equal to and greater than those of conventional batch media are deleted from the feed. In contrast to batch systems, it is observed that foaming does not occur in the steady-state continuous culture at sufficiently high dilution rates. Therefore, the problems of inoperability and inefficiency caused by foaming are eliminated without the use of surfactants. Interference of the surfactants with subsequent enzyme separation is likewise obviated.

While the required set of simultaneous quantitative data was not taken without the prior mentioned analyzer, the observations above indicate the following. While concentrations of soluble protein are high in the feed medium, such concentrations appear negligibly low within the culture. This is evident from lack of foaming characteristic of aerated cultures which contain soluble proteins in the aqueous fraction. Therefore, cleavage of protein by aminopeptidase appears to occur at essentially the same rate at which protein is fed to the well-stirred continuous culture. Aminopeptidase activity (per unit volume of culture) is thus expected to be essentially equivalent in continuous culture, with given feed medium, to that of final harvested batch culture that is initiated in identical medium. Concentration of protein in feed to continuous culture can be increased without causing substantial change of concentration in the continuous culture. This is not possible in an initial batch change where ability to initiate the culture is deterred by substantial increase above presently normal concentrations.

While aminopeptidase activity may increase with increased concentrations of protein in feed media, the extent to which enzyme concentration may be increased thereby is not yet known. Furthermore, simultaneous increases due to increased aeration rates are not now known for continuous cultures. This information is expected from this research. However, based on comparable feed and initial protein concentrations in respective continuous and batch systems, it appears that a continuous culture of

similar volume produces an order of magnitude more of aminopeptidase (or comparable activity) in the same time as the batch system. Alternatively, a continuous culture approximately one-tenth the size of the batch system may be expected to produce the same amount of enzyme in the same time. Extents to which these factors may be improved are to be quantitatively determined for design purposes.

Dunaliella percei. Continuous, steady-state growth of *D.percei* has been achieved in well-stirred continuous cultures. This species is rather delicate and apparently cannot be continuously maintained in turbulent cultures of the kind used for more rugged microflora (e.g., species of chlorella or the bacteriam *a. proteolytica*). Therefore, to reduce shearing stresses it was necessary to eliminate the centrifugal pump with other cultures used for both recirculative mixing and gas induction. At the same time it is necessary to achieve good gas-liquid contacting efficiencies and well-stirred culture. These are necessary both for applications of these continuous culture to useful purposes in large-scale systems and to simplify experimental accumulation of local rate data that are required to make those applications.

For the stated purposes, *D. percei* is continuously cultured with gas-driven recirculative flow. This is accomplished in an helical gas lift to which a side-arm is attached for completion of the recirculative loop. Gas bubbles sparged into the bottom of the helical lift maintain their spacing and do not appear to coalesce as they rise along the helical path. (This does not occur with freely using bubbles). Uniform cell dispersion is maintained and recirculative holding time is three orders of magnitude less than specific growth rate. This is expected to fulfill conditions that are required for a well-stirred culture. This is with exception of gas phase components that are transferred between the gas and liquid phases. However, data reduction is simplified by the fact that composition of the dispersed gas phase is ordered with path length along the helix.

Simultaneous data on growth rates, substrate assimilation rates, metabolite production rates, and local culture conditions which give these rates, are expected from this research. This is to be done both to obtain design data and to demonstrate usefulness of these systems to obtain these data. It is to be noted that neither efficiency design of large-scale systems nor knowledge of the effects of variables on growth and metabolism in the natural habitat are likely to be achieved without similar data.

PUBLICATIONS AND DOCUMENTATION

The following reports and papers resulted from Sea Grant work in Marine Environmental Quality during the 1969-70 reporting period.

Technical and General Reports

Hann, Roy W. Jr. and Welford S. Hutton. *A Quantitative and Qualitative Survey of Benthal Deposits Contained in the Houston Ship Channel* - ESP Tech. Report No. 8. August 1970. 179 pp.

Hann, Roy W., Jr. et al. *Houston Ship Channel Data Summary* - ESP Tech. Report No. 9. August 1970. 66 pp.

Hann, Roy W. Jr., Gary R. Kramer and Stewart B. Carpenter. *Completely Mixed Model* - ESP Tech. Report No. 11. August 1970. 34 pp.

Hann, Roy W., Ted M. Sparr, and Charles R. Sprague. *A Study of the Flushing Times of the Houston Ship Channel and Galveston Bay* - ESP Tech. Report No. 12. August 1970. 52 pp.

Hann, Roy W. Jr., *Neches Estuary Water Quality Study* - ESP Tech. Report No. 14. August 1970. 59 pp.

Hann, Roy W. Jr. and Stewart B. Carpenter. *Problem Oriented Language Package* - ESP Tech. Report No. 16. August 1970. 53 pp.

Mahmoud, T.A. and W.B. Davis, *The Effect of Salinity on the Removal of Some Aliphatic Ketones*. The Sea Grant Program, Texas A&M University, Report TAMU-SG-70-216. July 1970. 106 pp.

Mahmoud, T.A. and W.B. Davis, and R.L. Irvine. *The Biological Removal of Organics Under Variable Salinity Conditions*. The Sea Grant Program, Texas A&M University. Report TAMU-SG-70-701. August 1970. 13 pp.

Parmer, David C. *Some Mechanisms of Organism Limitations in the Inland Houston Ship Channel*. Texas A&M University. August 1970. 152 pp.

Professional Journals and Periodicals

Hann, Roy W. Jr. "Mathematical Modeling of Gulf Coast Estuaries," *Journal of the American Water Resources Association*. June 1970.

Hann, Roy W. Jr. "Systems Simulation for Analysis and Design," *Journal American Waterworks Association*. May 1970.

Hann, Roy W. Jr. "Analysis Techniques for the Houston Ship Channel." *Journal of the Waterways and Harbors-Division Proceedings of the ASCE*. May 1970.

Conference Papers Presented

Hann, Roy W. Jr. and Stewart B. Carpenter. "Small Scale Problem Oriented Languages for Civil Engineering Analysis." Joint Conference on Mathematical and Computer Aids to Design. October 1970.

Hutton, W.S. "A Quantative and Qualitative Survey of Benthal Deposits Contained in the Houston Ship Channel." Graduate Symposium. March 1970.

Hutton W.S. "The Pollution Significance of Benthal Deposits in the Houston Ship Channel." TWPCA Conference. July 1970.

Langley, W.D. and W.B. Davis, "Chemical Aspects of Marine Water Quality and its Relation to the Sea Grant Program." Presented at the 159th National Meeting of the ACS in Houston, Texas. February 1970.

Mahmoud, T.A., W.B. Davis, and R.L. Irvine, "The Biological Removal of Organics Under Variable Salinity Conditions." Presented at the 33rd Annual Meeting of the ASLO at the University of Rhode Island, Kingston, Rhode Island. August 1970.

Sparr, Ted M. "A Water Quality Storage and Retrieval System for Regional Application." National Symposium on Data and Instrumentation for Water Quality Management. July 1970.

Withers, Richard E. Jr. "Analytical Analysis As an Aid to Decision Making." Graduate Symposium. March 1970.

MARINE RESOURCES MANAGEMENT

Studies to assist in planning and managing the state's marine resources involve many disciplines in the Texas A&M University Sea Grant Program. Projects in this program area include education, research, and advisory services activities.

Optimal Investment and Financial Decisions for a Representative Fishing Firm (Research and Advisory Services)

Activity Leader: Russell G. Thompson, Institute of Statistics

In the proposal research, the first objective was to develop a dynamic investment model for a representative fishing firm; the second objective was to derive the decision rules for optimal investment; and the remaining objectives were to estimate the parameters in the model and to compute solutions to the problem. The proposed procedure was to formulate the model in an optimal control setting, and to use these methods to derive the decision rules. This set of results was then to be interpreted to obtain the qualitative character of the decision making. Also, so that the work would be operational, efforts were to be made to develop appropriate algorithms and computer programs. In addition, estimates of the parameters were to be made and solutions by which to test the results were to be computed.

Project Description and Report of Work and Accomplishments

During the 1969/70 academic year, two dynamic investment models for the representative fishing firm were developed, analyzed, programmed, and tested. The first model is dynamic, but deterministic; whereas, the second model is dynamic and stochastic. Decision rules for both models were derived and interpreted. Operational computer programs were developed and tested. Estimates of the parameters were made in each case for one type of shrimp fishing operation. Solutions to both models were computed and analyzed. The first set of results were reported in TAMU-SG-70-205, and the second set in TAMU-SG-70-218. Commendable reviews are presently being received on the first report. Papers have also been submitted for journal publications.

In the first technical report, the shrimp industry was briefly reviewed historically. Some of the factors influencing the demand for shrimp as well as the supply were discussed. The need for better investment aids was emphasized. This was followed by the development of the

dynamic investment model for the representative fishing firm. Each facet of the model was discussed with a rigorous statement of the complete model. The model was transformed into a sequential linear programming form for computing. An economic interpretation of the possible solutions was provided.

Using this mathematical framework, the model was applied to a relatively small shrimp fishing firm with one 73 foot steel hull vessel. It was assumed that the investor had borrowed 75 percent of the value of the $100,000 investment and had $5,000 in savings. Values for the remaining parameters in the model were specified in accordance with information received from knowledgeable industry people in the Aransas Pass, Texas area. The expected shrimp prices and landings per vessel were varied systematically (one at a time) over a range of values observed in the 1960's. Solutions to six feasible problems were computed and discussed. The results clearly indicate the sensitivity of the investment problem in shrimp fishing to variations in catch and price.

In the second technical report, the model developed allows for random prices and catches and, in addition, takes into account all of the information known to the decision maker at the time of each decision. Survival is regarded as a fundamental factor influencing the firm's investment decisions.

In making each decision, the fisherman evaluates the firm's net equity position, the worst possible sequence of revenues that might materialize, and all of the firm's forthcoming obligations. He derives from this information a survivable set of capacity purchases, and then selects from this set the investment maximizing his net worth at the end of the planning period. After each year's operations and before the next year begins, the random revenue variable for the first year has been observed. It is now a part of the information for decision making in the next year. The fisherman repeats the above reasoning process in making his investment decision for the second year and in every year thereafter. Survival must be guaranteed before any investment is undertaken; moreover, investment decisions are always conditioned by experience.

In accordance with information obtained from cooperating firms, values for all of the parameters were specified. Initially, the firm was assumed to have had purchased one new 73 foot steel hull vessel, or to have the money equivalent in savings. To reflect inflation, prices were assumed to increase 3 percent per year. For tax purposes, the depreciation period was 11 years, and the income tax rate was 25 percent. The length of the planning period was taken to be 5 years.

Since the shrimp price is highly influenced by the rate of growth in per capita income, expected prices for the years 1970 through 1974 were projected for a modest rate of economic growth (as observed in the late 1950's) and for a high rate of economic growth (as observed in the mid 1960's). Investment solutions were calculated for both growth rates. The marginal value of another vessel was found to be initially larger and to be positive for a longer period of years at the high growth rate than at the lower. Success in shrimp fishing is clearly influenced by the rate of income growth in the economy.

The value of better than average management was also clearly illustrated. Almost six more vessels were purchased than in the case of average management.

In evaluating the rate of return over cost from fishing in relation to the savings alternative, investments in fishing capacity were found to be a better alternative than savings as long as the interest rate was less than 9.5 percent per year. Then a switch occurred in favor of the savings alternative. Thus, given the present borrowing rates, investments in fishing capacity are near the margin of profitability (in a survival sense), as far as interest rates are concerned.

Solutions were calculated for the case where price was random as well as landings. Only slight differences were found between the results in the two sets of problems. Vagrancies in landings per vessel seem to be much more important than unexpected variations in price.

In addition to the above research, efforts have continued to be directed to the dynamic investment problem of the sole ownership fishery problem. The results, to date, are largely negative. We presently seriously question the meaningfulness of the biological model as developed by Schaffer and studied by Crutchfield and Zellner. Efforts need to be directed to developing a well-posed dynamic economic-biological model for the sole ownership fishery. The importance of this can hardly be overemphasized given policy needs. There does not presently appear to be any rigorous dynamic theory (or model on which to base it) for the sole ownership fishery.

Sea Grant Program Management Model (Research)

Activity Leader: Donald E. Walsh, Sea Grant Program Office

The Sea Grant Institutional Program as sponsored by the National Science Foundation is an example of the comprehensive programs that have begun to appear on the academic scene. The institutional program is much broader in scope than most university programs, and in its best sense involves the entire university. The purpose of this study was to develop a scheme or model for the efficient and effective management of a Sea Grant Institutional Program.

Project Description and Report of Work and Accomplishments

The first step in the conduct of the study was the construction of a questionnaire. The questionnaire was used to survey various management techniques currently in use by Institutional grantees and selected others. All of the then extant Sea Grant Institutional directors were requested to complete the questionnaire--Texas A&M University, Oregon State University, University of Rhode Island, University of Washington, University of Wisconsin, University of Michigan, University of Hawaii and the University of Miami. All eight directors completed and returned the questionnaire and were otherwise very cooperative in supplying additional comment and clarification regarding their management activities.

At the suggestion of Mr. Robert B. Abel of the Office of Sea Grant Programs, the directors of Coherent Area Projects were later invited to respond to the questionnaire. Over half of these directors responded to the questionnaire and provided additional information. Project directors invited to respond were from Louisiana State University, Humboldt State College, Viriginia Institute of Marine Science, Scripps Institution of Oceanography and the University of Delaware.

The questionnaire was designed to gather factual information regarding management practices within the Program offices. It consisted of eighteen forced choice questions and four essay questions designed to get at the techniques used in the four major functions of management--planning, organizing, control and coordination.

The forced choice items were constructed to seek answers in five general categories:

(1) Techniques for identifying appropriate proposals and judging the degree to which proposals fit the objectives of the program.

(2) Techniques for evaluating the progress and final results of projects.

(3) Allocation of funds and other elements of program control.

(4) Techniques for encouraging loyalty to the objectives of the program.

(5) Techniques for the articulation of special elements of the program, e.g., extension activities and technician training programs.

The essay questions were related to program control, program focus or goals, program objectives and evaluation, and the structure of the program office staff.

An ancillary purpose of the questionnaire was to identify those elements of program management at the institutions that might be classed "exceptionally good" or "highly innovative." The purpose of the survey was not necessarily to incorporate these techniques into the model, although some of them did find their way therein. The responses served as a backdrop against which to cast the model. The responses served this purpose very well.

The model as it finally emerged drew from the theories of a number of researchers in areas of extension administration, industrial management, educational administration and research management. The central theme of the study was a discussion of means of coordinating the interdependencies of activities within a multi-disciplinary mission-oriented program. Then an over-arching control mechanism was designed to integrate the marine resource development needs of a given region over the existing expertise base within the program. The model considered the educational, extension, research, and information capabilities of the institution and brought them together into a meaningfully coordinated system. It also considered mechanisms for the coordination of off-campus, branch-campus and inter-institutional cooperative activities.

The final part of the study was a suggested model for the program office staff. As an interim step it was suggested that the division of labor among the staff be along the lines of existing university organization; that is, extension, research, education, and information. Looking forward to future growth of the program and to a wider acceptance, on university campuses, of interdisciplinary investigations, carefully planned restructuring of the program office staff was suggested. This restructuring would parallel the programatic structuring of the National Office of Sea Grant Programs. By this plan, the division of labor could be by living and mineral resources, engineering and technology, and law and socio-economics, for example. Under this plan individuals (or groups) affiliated with the program office would be responsible for developing and coordinating all extension, research, information, and education activities in those respective areas of the total program. Such a structuring would go far toward the encouragement of multi-disciplinary solutions to coastal zone and marine resource development problems.

Apparently the study has generated some interest in the educational community. The technical report which was published as a result of the study has been ordered by several academic administrators. These administrators represent institutions including, but not limited to, those interested in marine science programs.

A Marine Resources Information Center (Research)

Activity Leader: Eugene B. Smith, Department of Business Analysis and Research

This project was directed to the design of a specialized information center which would respond to and complement a broad, multidisciplinary program. The model was developed within the framework of the marine resources program of Texas A&M University. It is an attempt to fill the existing void resulting from an absence of a codified body of information in the area of marine resources.

The primary goal of the project was to provide a focus for information activities within the Sea Grant Program. The major effort was directed to three areas: 1) Resource Information, 2) The Information Distribution System, and 3) Auxiliary Services Information Activities.

Project Description and Report of Work and Accomplishments

The information center resulting from this project attempts to provide routine user information service to cover all types of information. Computer and microfilm technology have been utilized where practical in conjunction with four major information sub-systems. These systems include: 1) a microfiche file of technical information, 2) an expertise file, 3) an activities file, and 4) a facilities file.

Standard acquisition, storage and dissemination procedures for each file are operational. These four files provide a basis for the identification of marine resource information. The information distribution system, developed to make such information available to the marine community on a routine basis, is based on the establishment of user information

sub-centers. At present, three of these centers are in operation, two centers on the main campus and one located in Galveston at the Marine Laboratory.

In the area of auxiliary information services, a highly versatile computer program for maintaining name and address files has been developed. This system is currently being utilized to assist in the distribution of all Sea Grant material within the local program and for one nationally oriented Sea Grant project.

As a result of this project it is apparent that there is an urgent need for increased information activities in the marine resources program. From an overall point of view, two of the most pressing deficiencies are the lack of a marine oriented thesaurus and the absence of a national marine resources information center. It will be extremely difficult to provide suitable abstracting, indexing and retrieval of marine resources information without such a thesaurus. Without the establishment of a national information center, information activities at the regional level will lack the necessary direction and coordination that should enable the information services to grow with the program.

Development of M.S. Curriculum In Marine Resources Management (Education)

Activity Leader: Clinton A. Phillips, Department of Finance

The purpose of this project is to develop a degree program in the College of Business Administration in the management of marine commerce and industry. The degree will be multi-disciplinary with about half the work to be in the departments of the College of Business. The remaining hours will be selected by the student from courses in science, geoscience, and/or engineering. As a part of this program, four new courses will be developed: Planning, Programming, Budgeting Systems, Coastal Zone and Ocean Law, Natural Resource Accounting and Marine Resource Management. As an integral part of the degree program, students will spend up to three months in a marine resource related business or governmental organization analyzing a problem and preparing a case study for integration into classroom materials.

Project Description and Report of Work and Accomplishments

Some project funds were allocated for the period June 1 to August 31, 1970 for preliminary work prior to September 1, 1970 when the project was orginally scheduled to begin. The summer months were used to contact sources, both private and governmental, for relevant material and to begin developing annotated bibliographies of this material. Concurrently, an effort was initiated to prepare a monograph consolidating in one source a current profile of marine resources of Texas' coastal zone and the Gulf of Mexico, related urban-industrial development, administrative and legal relationships involving local, state, and federal agencies and other pertinent information. It is expected that this monograph will serve as one of several source materials for use in the course in marine resource management.

Also, during the summer preliminary outlines for three new courses were prepared for submission to the Graduate Council where they were approved. Subsequently, they were approved by the Academic Council and thus will appear in the 1971-72 Bulletin of the Graduate College. The courses are:

Management 660	Marine Resource Management
Manggement 661	Marine and Coastal Zone Law
Finance 671	Planning, Programming,Budgeting Systems

Finally, preliminary discussions have been initiated with certain departments deemed likely to wish to participate in this M.S. program by providing course work for a supporting field.

Because of the summer support provided by the Sea Grant Program Office, the development of the curriculum for an M.S. in Marine Resources Management is proceeding ahead of schedule.

Economic Impact Analysis of Texas Marine Resources and Industries (Research)

Program Development Planning for Coastal Industries (Advisory)

Activity Leader: John Miloy, Industrial Economics Research Division

Two projects were completed during the past year as summarized below:

1. "Economic Impact Analysis of Texas Marine Resources and Industries," by John Miloy and E. Anthony Copp, is a study incorporating concepts of regional economic growth theory and resource economics to the problems of marine resources and industries. In addition to clarifying the dynamic role each sector plays within identified growth core areas along the Texas coast, the report included sales and employment projections of future growth estimates of individual sectors.

2. Program Development Planning for Coastal Industries was undertaken to develop a specific plan of action for working with coastal industries to encourage economic expansion and growth. Initial efforts are to provide technical information and assistance to a 36-county coastal region with emphasis in three directions: engineering, port facilities and transportation; commercial and small business firms; and companies participating in recreation and tourism activities. Personal and questionnaire surveys are to be utilized to determine information needed and technical assistance desired including procedural steps required for implementation of such services. Publications and seminars will be developed as needed to assist coastal industries.

Project Description and Report of Work and Accomplishments

Research activities to develop primary and secondary information for inclusion in the study "Economic Impact Analysis of Texas Marine Resources and Industries" predominated during the period ending August 31, 1970. Visits and interviews were held with port directors, Federal and State agencies, associations, fisheries personnel, and commercial and industrial firms. In regard to the latter, 950 questionnaires were sent to marine-oriented industrial firms located in the coastal zone of Texas. Economic data requested included annual sales, employment and estimated projections of growth in marine-related activities. John Miloy and Tony Copp attended the annual meeting of the Texas Shrimp Association, January 8-9, 1970, which was held in Galveston.

Personal interviews and secondary library research were used to complete the project, "Program Development Planning for Coastal Industries." The research produced a plan of action to provide technical information and assistance to coastal industries. Ultimate goal of the plan is to accelerate economic expansion of firms operating in the coastal zone of Texas.

James R. Bradley participated in the first Sea Grant Program workshop, "Marine Resources: The Industrial View," which was conducted November 13-14, 1969 in Houston.

John Miloy attended the Sea Grant workshop, "Marine Resources: Leisure Uses," which was held on January 22-23, 1970 in Corpus Christi.

In addition, the Industrial Economics Research Division co-sponsored the Sea Grant Program workshop, "Texas Marine Resources: The Ports and Waterways," which was held in Port Arthur on May 27-28, 1970.

James R. Bradley attended hearings of the Interim Study Committee on Oceanography (Chairman: Representative Ray Lemmon) at Dallas, May 4-5, 1970 and at Corpus Christi, July 13-14, 1970. John Miloy and Norman C. Whitehorn attended the hearing of the Lemmon Committee held at College Station, September 14-15, 1970.

PUBLICATIONS AND DOCUMENTATION

The following reports and papers resulted from Sea Grant work in Marine Resources Management during the 1969-70 reporting period.

Technical and General Reports

Miloy, John and E. Anthony Copp. *Economic Impact Analysis of Texas Marine Resources and Industries.* TAMU-SG70-217. June 1970.

Miloy, John and Worth M. Blake. *Texas Marine Resources: A Summary of Coastal Activities.* Sea Grant Publication No. 105. February 1970.

Texas Marine Resources: The Ports and Waterways View. TAMU-SG-70-217. June 1970.

Smith, Eugene B. *The Design of a Specialized Information Center for the Marine Resources Program.* Ph.D. Dissertation, Texas A&M University. June 1970.

Smith, Eugene B. *The Design of a Specialized Information Center for the Marine Resources Program.* Texas A&M University Sea Grant Program Technical Report. TAMU-SG-70-214. June 1970.

Smith, Eugene B. and Johnny H. Butler. *An Expertise System for the Marine Resources Information Center.* Texas A&M University Sea Grant Program Technical Report. TAMU-SG-70-204. January 1970.

Thompson, R.G., R.W. Callen, and L.C. Wolken. *Optimal Investment and Financial Decisions for a Model Shrimp Fishing Firm.* Texas A&M University Sea Grant Technical Report. TAMU-SG-70-205. April 1970.

Thompson, R.G., R.W. Callen, and L.C. Wolken. *A Stochastic Investment Model for a Survival Conscious Fishing Firm.* Texas A&M University Sea Grant Technical Report. TAMU-SG-70-218. July 1970.

Walsh, Donald E. *A Suggested Model for the Management of a Sea Grant Institutional Program.*

Professional Journals and Periodicals

Thompson, R.G., R.R. Hocking, and M.D. George. "A Nonconvex Control Problem for the Competitive Firm," to appear in *Econometrica.*

Thompson, R.G. and M.D. George. "A Stochastic Investment Model for the Survival Conscious Fishing Firm," submitted to *Management Science* for review.

MARINE FISHERIES

The marine fisheries program of the Texas A & M University Sea Grant operation involves elements of research, education, and advisory services. In some instances it is impractical to separate any one of these functions from the others since much of the research grows directly out of directions gained from advisory services. Educational elements are easier to distinguish--individual projects are identified in this program but these are well integrated and the opportunities to share facilities and research results are expensive. The marine fisheries program encompasses work in fish diseases, pond culture, and seafood processing and technology.

Occurrence and Significance of Parasites in Ocean Fish (Research)

Activity Leaders: James E. Joy and F. C. Faries, Jr., Department of Veterinary Parasitology

Infections with protozoan, helminth, or copepod parasites may contribute to mortality of fish directly by mechanical injury and indirectly by traumatic stresses that lower host resistance to environmental factors. Parasites may also damage fish to such an extent that their food value is esentially nil. This can occur by reduction in total quantity of edible tissue and/or reduction of quality. In addition some fish are condemned for aesthetic reasons. A fish with copepods attached to the body surface or with tapeworm larvae entwined in the muscle tissue is a marketable item of little or no value.

With the above points in mind we find it necessary to: 1) accurately identify the parasites and the hosts they most frequently attack, 2) determine the seasonal occurrence and geographical distribution of the parasites, 3) evaluate the influence of the parasite on the fish as it affects the fish for human consumption, and 4) study the relationship of the parasites of commercial food fish to mammals and birds.

Project Description and Report of Work and Accomplishments

During September, 1969, and January and February, 1970, 81 marine fishes were examined for parasites. At that time nine different species

of helminths--seven nematodes and two acanthocephalans--had been identified. Since that report we have improved our collecting methods through the assistance of the Texas Parks and Wildlife Department, Seabrook, Texas. In addition, we now have experienced personnel who can quickly and accurately recognize parasites and in some instances the gross pathological conditions that they cause.

The results have been gratifying. To date 20 species of parasites have been identified from a total of 316 marine fishes. A seminar given to the staff of the Bureau of Commercial Fisheries, Biological Laboratory, Galveston, Texas by James E. Joy on 10 September 1970 was based on the parasites discussed in this report. The following is a summary of those species, accompanied by a short discussion.

PROTOZOA: Spores of a myxosporidian parasite in the genus Henneguya were collected from cysts located in the intestine of a black drum, Pogonias cromis. A similar Henneguya was found on the Atlantic Coast on the soft-ray fins of the weakfish, Cynoscion regalis, by Jakowska in 1954. We have corresponded with Dr. Sophie Jakowska, Universidad Autonoma de Santo Domingo, and she has kindly supplied us with her records and drawings of this heretofore unnamed species. This particular group of parasites is of interest since Kudo (1966, Protozoology, 5th Ed., C. C. Thomas) has noted, "Severe epidemic diseases of fishes are frequently found to be due to myxosporidian infections."

TREMATODA--MONOGENEA: Two monogenetic trematodes have been found during the course of this study. Heteraxinoides xanthophilus was collected from the gills of the spot, Leiostomus xanthurus, in Galveston Bay. Tagia micropogoni (Macrovalvitrematoides micropogoni) was collected from the gills of the croaker, M. undulatus in Galveston Bay. Specimens of T. micropogoni have been sent to Dr. William J. Hargis Jr. of the Virginia Institute of Marine Science, Gloucester Point, Virginia for confirmation.

TREMATODA--DIGENEA: To date the following three species of digenetic trematodes have been found: Homalometron sp. from the intestine of M. undulatus, Megapera sp. from the intestine of the red snapper, Lutjanus aya, and Crassicutis archosargii from the intestine of the sheepshead, Archosargus probatocephalus. C. archosargii is new to the Texas Coast. It had previously been reported only from Grand Isle, Louisiana.

CRESTODA: Larvae of Poecilancistrium caryophyllum have been found in the muscle tissue of Cynoscion nebulosus, the speckled trout. Larval tapeworms have also been found in the intestine of the red snapper and muscle tissue of the flounder.

ACANTHOCEPHALA: Two species of these intestinal helminths have been identified as Floridosentis elongatus and Telosentis tenuicornis. The holotype specimen of Illiosentis longispinus has been studied to avoid confusing it with T. tenuicornis.

NEMATODA: Contracaecum robustum, C. collieri, C. parvum, and Raphidascaris anchoviellae have been found in the larval stage in mullet and croaker during the course of this study. C. parvum was fed to day old chicks in an attempt to establish a laboratory infection. It is too early to determine the results of this experiment.

Other nematodes, all adults, and their hosts are: Goezia minuta from Ictalurus furcatus, Agamonema vomitor also from I. furcatus, Cucullanus sp. from L. aya, and Spirocamallanus pereirai from M. undulatus. S. pereirai is new to the helminth fauna of the Texas Coast.

A one year investigation was initiated in July 1970 to determine the seasonal occurrence and intensity of infection of S. pereirai in M. undulatus in Galveston Bay.

COPEPODA: Ergasilus lizae has been reported from the gills of Mugil from Florida, Georgia, Louisiana, Puerto Rico, Chile, and Israel. In our work this parasite has been found on the gills of over 90% of the spot, L. xanthurus, collected from Galveston Bay. Thus new host (the spot) and locality (Texas Coast) records for this copepod parasite have been established.

Pesticide Residues In Gulf Coast Fish (Research)

Activity Leaders: Bennie J. Camp, Department of Veterinary Physiology and Pharmacology

The objectives of these research activities include investigations of brain acetylcholinesterase levels of marine fish of the Gulf Coast waters and determination of organophosphorus pesticide pollution by measuring the degree of inhibition of fish brain acetylcholinesterase.

Project Description and Report of Work and Accomplishments

Brain acetylcholinesterase levels have been determined on three hundred and sixty samples collected during May, June, and July of 1969. These samples were composed of eight species of Gulf Coast Fish collected from four locations.

Preliminary data indicates that brain acetylcholinesterase activity decreases as the brain size increases.

A sample of mullet collected on June 25 in Aransas Bay shows a uniform inhibition of brain acetylcholinesterase activity below that of a prior sample taken at Rockport, Texas on May 27. Additional data will be required to determine the significance of this inhibition.

Brain acetylcholinesterase activity at a given brain weight is variable between different species of fish. Of these samples angel fish and pinfish showed greater activity than others.

In view of the time initiation of this project, it is felt that control values for normal fish brain acetylcholinesterase activity should be obtained from fish during the months of January, February, and March. This would allow making comparisons of brain acetylcholinesterase activity

between control fish and fish examined during the season of pesticide use.

A Histologic Study of Marine Fish (Research)

Activity Leader: Raymond F. Sis, Veterinary Anatomy

In an attempt to solve the food shortage in the world, an increasing number of investigators are studying the diseases of food-producing fish. There is a particular need for base line studies in microscopic anatomy of fish in support of the research of fish diseases. We will study the gross and microscopic appearance of tissues and organs of fish from the Gulf of Mexico. Information will be obtained on the comparative histology of different species of fish to be used for experimentation by marine fish investigators in the College of Veterinary Medicine at Texas A & M University. Such a description will be valuable in determining the normal and abnormal appearance of fish tissue when studying fish diseases. This investigation will contribute to our knowledge of comparative histology and provide a collection of histologic material for future teaching and research.

Our long range objectives of this research project are:

1. Study the gross and microscopic appearance of tissues and organs of fish from the Gulf of Mexico.
2. Obtain information on the comparative histology of different species of fish to be used for experimentation.
3. Describe the normal microscopic appearance of tissues and organs collected from control fish in the support of a marine fish study in the Departments of Veterinary Pathology, Veterinary Microbiology and Veterinary Parasitology.
4. Collection of fish tissue and organs for future research projects and for undergraduate and graduate training.

Project Description and Report of Work and Accomplishments

Histologic studies of the tissues and organs were made of mullet, croaker, menhaden and redfish. A concentrated effort was made on the study of the mullet digestive tract. We found that the digestive tract of the mullet, a bottom feeder, possessed many similar characteristics of the domestic chicken. Sand was found throughout the digestive tract.

Gross Anatomy of Mullet Digestive Tract

The buccal cavity extends from the lips to the first gill slit. It is a dorsoventrally flattened cavity. The floor of the cavity contains only a rudimentary tongue. The roof has three depressions (one medial and two lateral). The epithelium of the dorsal surface has longitudinal ridges that are continuous with ridges on the anterior region of the pharynx.

The pharynx is divided into anterior and posterior regions. The anterior region extends from the first through the last gill slit. The posterior region includes the dorsal callous pad. The floor shows only gills and their attachments and prominences of the three unpaired basibranchial bones. The roof (anterior region) has longitudinal ridges continuous with those of the buccal cavity. Anterior to each callous pad of the posterior pharynx are two conspicuous folds that project laterally from their point of attachment at the base of the callous pads. The callous pads are covered with papillae of various sizes resembling the tongue of a mammal. The anterior margin has larger papillae that are regular and flattened, contrasting with the small conical papillae of the remainder of the callous pad. The small conical papillae become smaller going posteriorly. The callous pads are feebly supported. They are domed toad stool-like structures hanging from the roof, supported by flattened stalks running posterolaterally.

The esophagus leaves the pharynx dorsally as a funnel-shaped structure, perforates the false diaphragm, and enters the anterior dorsal part of the stomach.

The stomach forms a posterior cone shaped structure that blends anteriorly with the gizzard. Internally the division between the stomach and gizzard can be differentiated by the thickness of the muscular wall and the horny lamina of the gizzard.

The gizzard is a bulbous structure that blends posteriorly with the stomach. The intestine leaves anteriorly through a very small lumen.

The intestine as it leaves the gizzard anteriorly has two appendages or diverticula, the pyloric ceca. Pancreatic tissue is related to the proximal part of the intestine, to the region where the common bile duct enters, and to the pyloric ceca. The intestine passes laterally to the right of the gizzard. The common bile duct enters at the point where the intestine turns posteriorly. The intestine from the gizzard to the anus is a tube of more or less constant diameter. The total length is about 4 to 5 times as long as the fish. It forms loops of variable length that run back to the region of the gizzard. The intestine terminates at the anus, which is anterior to the urogenital orifice.

Histology of Mullet Digestive Tract: Selected tissues and organs were fixed by a variety of fixing procedures in order to find the best fixatives for the fish tissue. Bouin's was the most satisfactory fixative used. The tissues were then washed in running water, dehydrated with graded alcohols, cleared in xylene, infiltrated and embedded in paraffin. The tissues were sectioned and stained for microscopic examination.

The buccal cavity, extending from the lips to the pharynx, is lined with stratified squamous epithelium and possesses taste buds. The taste buds, found in a slender papilla, are a common element in the mucosa. They are especially abundant on the surface of the callous pad in the pharynx.

There are three definite layers in the wall of the esophagus where many goblet cells appear in the epithelium. These goblet cells increase in number near the stomach where they are abundant in crypts of the mucosa. The epithelial coat is composed of a stratified squamous epithelium at the beginning of the esophagus and changes to a simple columnar epithelium near the stomach. Between the muscular and epithelial coats is a layer of submucous connective tissue. The muscular coat is divided into two layers, an inner longitudinal and an outer circular layer.

Upon entering the stomach the mucosa is composed of simple tall columnar cells associated with tubular gastric glands. While the size of the lumen of the stomach remains constant, a transition is made from the glandular stomach to the muscular stomach. The muscular stomach (gizzard) possesses a thick wall of smooth muscle arranged in a circular layer. Central to the muscle layer one finds a connective tissue submucosa and next a glandular layer consisting of straight tubules lined with cuboidal epithelium. The secretion of these glands forms a hard plate lining the lumen of the gizzard.

The mucosa of the intestine is thrown into numerous high folds covered by columnar cells with a striated border and goblet cells. The muscularis coat is represented by an inner circular layer and an outer longitudinal layer. Pancreatic tissue is located adjacent to the intestines throughout the entire intestinal tract.

A set of reference slides were prepared for use by other departments engaged in fish disease research. Some serial sections of whole small shrimp were prepared for both the Veterinary Microbiology and Veterinary Parasitology Departments in support of Sea Grant Projects.

The material obtained from this project was specifically needed by marine fish investigators in the College of Veterinary Medicine at Texas A & M University. The information obtained from these histological slides of normal microscopic anatomy of fish will contribute to fish disease research.

This year we will concentrate our efforts on the histology of the Gulf killifish, Fundulus grandis. This fish is representative of many bony fishes and is used in the laboratory for disease research.

Cell Cultures, Viruses and Pathogenic Bacteria of Marine Species

Activity Leaders: L. C. Grumbles, A. I. Flowers, and G. W. Klontz, Veterinary Microbiology, Veterinary Public Health

If the marine fish and shellfish resources of the Gulf of Mexico are to be utilized to their fullest capability as food, attention must be paid to the infectious and non-infectious diseases of these animals. These studies must be broad-based to encompass the diseases of fish and shellfish in nature as well as those disease processes occurring in artificially propagated fish and shellfish.

At this time there are no accurate data on the distribution and economic significance of bacterial and viral diseases of wild, commercially-important fish and shellfish in the Gulf of Mexico. The objectives of this project are to investigate reported disease outbreaks from the standpoints of cause, degree of involvement, course or dutation, and relationship to other outbreaks.

Additional objectives are to investigate the known bacterial and viral causes of diseases in marine fish and shellfish from the standpoints of antigenic and biochemical characterization. This information will lead to studies of prevention and control of the diseases considered.

It is anticipated that the realization of these objectives will enable us to provide adequate training to qualified personnel to apply infectious disease control and prevention on a practical basis at facilities where fish and shellfish are raised.

Project Description and Report of Work and Accomplishments

During this fiscal year, work efforts were directed along five lines: 1) Development of facilities to hold marine fish for extended periods; 2) Development of techniques for virological examination of marine fish; 3) Development of techniques to detect specific bacteria pathogenic for marine fish and shellfish; 4) Compilation of a partially annotated bibliography of infectious diseases of marine fish; 5) Extension and training services.

Development of marine fish holding facilities: Early in the year, 20 all-glass aquaria (12"h x 18"w x 30"l) were purchased and equipped with sand-gravel-charcoal-oystershell filters and recirculating pumps. A commercially available sea salt mixture was reconstituted to desired salinities using a refractometer.

To date several individuals of 12 species of fish captured in bays and estuaries of the Texas Gulf Coast have been held in the laboratory on the College Station campus. They are as follows:

Striped mullet	(Mugil cephalus)
Southern flounder	(Paralichthys lethostigma)
Sea catfish	(Galeichthys felis)
Sheepshead	(Archosargus probatocephalus)
Red drum	(Sciaenops ocellata)
Atlantic croaker	(Micropogon undulatus)
Spotted seatrout	(Cynoscion nebulosus)
Longnose killifish	(Fundulus similis)
Sheepshead minnow	(Cyprinodon variegatus)
Horned searobin	(Bellator militaris)
Ladyfish	(Elops saurus)
Gulf killifish	(Fundulus grandis)

The most significant occurrence in our development of fish holding facilities was the approval of a proposal for "Environmental and Nutritional Requirements for Marine and Freshwater Fish in Closed Systems" by the Texas A & M University Research Council. The funds will be available during 1970 - 71 to renovate an existing facility on the Veterinary Research Farm so that the initial studies may be expanded.

Development of virological techniques: Development of techniques to establish and maintain primary and continuous marine fish cell cultures is progressing. Several tissue explants from southern flounder (P. lethostigma), spotted seatrout (C. nebulosus), long nose killifish (F. similis), red drum (S. ocellata), and Atlantic croaker (M. undulatus) have been established in culture medium with varying degrees of success. Initial growths have been obtained; however, the epithelial-like cells have undergone rapid degeneration making confluent cell monolayers difficult to obtain.

Two cell lines -- fin and swimbladder -- have been obtained from Atlantic croaker (M. undulatus). These cells have been designated Muf and Musb, respectively. The Muf cells are in the 13th passage and the Musb cells are in the 8th passage and vials of each have been placed in a liquid nitrogen regrigerator for future studies. The cells have not been characterized as to their chromosone complement, virus spectrum or ability to survive storage in liquid nitrogen.

Tissue suspensions from squid, southern flounder, (P. lethostigma), alligator gar (L. spatula) tumor, American eel (A. rostrata) and Atlantic midshipman (P. porosissims) have been screened for the presence of virus. The following established fish cell lines were used for the screening: fathead minnow (FHM), rainbow trout gonad (RTG-2), rainbow trout hepatoma (RTHC), and grunt fin (GF). Three blind passages of each sample in FHM incubated at two temperatures (19 C and 24 C) gave no indication of cytopathogenicity.

Tissue from an Atlantic croaker (M. undulatus) clinically suspected of having lymphocystis disease was examined by electron microscopy. In the electron photomicrographs there were "lymphocystis-like" particles; however, there has been no indication of the virus in any cell line tested. Further studies are continuing.

Development of bacteriologica techniques: Primary emphasis has been placed upon isolating and identifying bacteria causing disease in wild and propagated marine fish and shellfish. Also being considered are the oranisms inhabiting marine fish that are potential pathogens in warm-blooded animals.

To facilitate screening large numbers of samples for motile Aeromonas sp. pathogenic for fish -- both marine and freshwater -- a selective medium was developed and tested. The medium is designed to detect 2,3-butanediol, a breakdown product of glucose by the motile aeromonads. The 2,3-butanediol in the presence of piperazine and prussic acid contained in the medium imparts a blue color to the colony thus facilitating its selection for further biochemical analysis. The instability of the constituents has limited usefulness of the technique for field use. Further studies are in progress.

Also to facilitate rapid detection of A. liquefaciens, a frequent pathogen of freshwater and estuarine fish, a highly sensitive and specific immunofluorescent technique has been developed. It has been tested on the many biochemically defined isolates of the organism from the U. S. and Canada. It has also been tested against other organisms. In all cases the technique detected only the A. liquefaciens isolates. Further modification of the technique indicated that it would be very useful in detecting A. liquefaciens in clinically ill, propagaged fish submitted for diagnostic purposes thereby virtually eliminating the delay between submission of samples and definitive diagnosis. This would permit chemotherapeutic measures to be initiated sooner thus decreasing the overall mortality.

Another selective medium is being tested to detect the presence of pathogenic Vibrio sp. Its selectivity is based upon the specific decarboxylation of lysine by these organisms.

During this past year a contract was negotiated between the Department of Microbiology and the Manned Spacecraft Center, NASA, in Houston. The purpose of the contract is to follow the changes in bacterial flora of fish exposed to lunar materials returned to earth.

Compilation of partially annotated bibliography: During this past year over 2,500 literature citations pertaining to infectious and non-infectious diseases of marine fish and to the host response of fish were compiled into a cross-referenced, partially annotated bibliography. It has been submitted for publication and distribution by the Sea Grant Program Office.

Advisory Services Activities

Several lectures and seminars on some phase of acquatic animal medicine were presented during the course of the year. In addition, a week-long short course on fish diseases was presented to 24 personnel of the Coastal Fisheries Division of Texas Parks and Wildlife Department.

Drs. Lewis and Klontz served on the Texas A & M University Marine Laboratory Advisory Committee. Dr. Klontz also served on the following committees: Fish Disease Committee of the American Fisheries Society, Subcommittee on Aquatic Animal Health of the National Research Council, and the Program Committee for the 2nd Annual World Mariculture Society Meeting. Dr. Lewis served as a consultant to the Manned Spacecraft Center, NASA, Houston.

A Histopathological Study and Description of Acute Inflammatory Response in Speckled Trout (Cynoscion nebulosus):

Activity Leader: R. M. Robinson, Department of Veterinary Pathology

This experimental project will provide basic research data on the histological changes involved in acute inflammation in the fish. The presently available data are not adequate and this study is imperative for pathological interpretation of lesions induced by various mechanisms as they relate to spontaneous and experimental diseases of fish. Eighty-eight fish are to be experimentally subjected to surgical, chemical, and antigenic insult. The histological response will be observed and recorded for future interpretations in spontaneous disease.

Project Description and Report of Work and Accomplishments

The last of the necessary equipment for holding and maintaining salt-water fish has recently arrived and been installed in the Veterinary Pathology Wildlife Disease Laboratory. Several species of marine fish were subsequently acquired and placed in the aquariums as test fish for the given salinity, temperature, aquarium size, filter system, and feeding techniques that previously had been outlined as a starting point. The primary concern was that of being able to maintain Cynoscion nebulosus since it had not been successfully accomplished previously under these aquarium conditions.

To date, ten members of this species have been successfully maintained for a period of seven weeks. The knowledge that has been gained will now permit the acquisition of the required number of this species and the beginning of the proposed research.

Post-mortum Characteristics and Biochemical Properties Affecting the Organoleptic Quality of Fish Muscle (Research and Advisory Services)

Activity Leaders: Bryant F. Cobb, III, and Zerle L. Carpenter, Department of Animal Science

Project Description and Report of Work and Accomplishments

Four projects have been concentrated on during 1969 - 70:

(1) the analysis of post-mortem changes in shrimp (this work overlaps the project "Role of Microorganisms in the quality Deterioration of Seafoods" and is reported there);

(2) the formation of a sausage or sausage-like product from the Atlantic Croaker;

(3) the occurrence of trimethylamine oxide in fish from the Gulf of Mexico;

(4) biochemical changes in speckled trout preserved with ice.

All of these projects except project 2 are in the final stages and are being written up for publication.

The formation of a sausage or sausage-like product from the Atlantic Croaker has provided a valuable discovery. As the result of an effort to remove off-flavors and fishy flavors in the croaker, a fish protein concentrate (FPC) like material has been made. This material will rehydrate and readily forms emulsions with fats, qualities not attributed to any other FPC. This material will rehydrate to approximately its original weight, has a faint, pleasing odor and taste and no toxic residue. Production costs should be similar to conventional FPC, but the final product appears to be much more valuable.

The role of trimethylamine oxide in the post-mortem quality deterioration of fish is well recognized. Analysis of samples indicates that trimethylamine oxide content of Texas fishes, although very low, increases with the distance from shore.

The biochemical changes in speckled trout (Cynoscion Nebulosus) preserved with ice were studied. One hundred-sixty speckled trout were purchased from retail fish markets and directly from fishing boats. Fillets were analyzed for appearance and odor, water and salt, soluble protein, trimethylamine nitrogen, total volatile nitrogen, non-protein nitrogen, total protein, fat, moisture, collagen (soluble and insoluble). Fifty samples were used for organoleptic tests.

Spoilage odors developed most rapidly on the exterior surfaces of retail market fish. Softening and gaping of speckled trout fillets increased as the time on ice progressed. The storage time for retail market fish was eight to twelve days while storage time for fish obtained directly from fishing boats was fourteen to sixteen days. This difference in spoilage time was attributed mainly to poor sanitation and handling procedures in market channels.

No consistent changes were found in any of the parameters studied. There was some correlation between trimethylamine nitrogen, total volatile nitrogen, and organoleptic scores in that none of these parameters changed significantly during the storage period. Some changes were noticed in the buoyant denisty of insoluble proteins (salt soluble protein extract) and caused problems in the extraction procedure. Further work is suggested to develop new methods for analyzing this change in the insoluble proteins.

Advisory Services Activities

The year 1969-70 was a year of considerable progress in making contracts with the industry. Besides individual contracts with much of the fishing industry, three meetings with industry leaders were held: 1) The leaders of the Texas Shrimping Association were invited to Texas A & M University campus on April 4, 1970. A brief program of University research of interest to the industry was presented; then members of the industry were invited to present their comments. A very good exchange of ideas was the result of the discussion between the two groups. 2) Meetings with the producers in Corpus Christi on June 2, 1970, were held to determine the program to be presented to the Governor's Conference. 3) Meetings with the processors in Corpus Christi were held on June 16, 1970, to discuss the program to be presented to the Governor's Conference.

A research project on the deterioration of shrimp in market channels has been established with the National Shrimp Processors, Inc. of Brownsville, Texas.

Aquaculture of Commercial Crustaceans and Fishes on the Upper Texas Coast (Research)

Activity Leader: R. Kirk Strawn, Wildlife Science

An increased need for protein foods coupled with the rapidly growing human utilization of estuarine areas has produced a critical need for new information which will permit the wisest use of land and water in the bay environment. Galveston Bay represents a good case in point, having a rapidly increasing human population in the immediate area, and supporting large natural populations of fishes and invertebrates, some of which sustain commercial fisheries. The conflicts of interest are heightening between real estate, navigation, mineral, fresh water and waste disposal needs on the one hand and fishery resource needs on the other. This type of conflict is also increasing as a result of growing demand for electric power, the production of which generates large volumes of "thermally polluted" water.

Lack of knowledge as to environmental requirements of commercially important species is at present an obstacle to intelligent resolution of these conflicting interests and needs. The purpose of this project is to provide such information for several fishes and crustaceans first in laboratory aquarium experiments and later in pond and cage studies.

The present proposal represents a promising opportunity to exploit a waste product, heated water from a power plant, to the advantage of survival and growth of commercially important poikilothermal animals. The effective liason between the project investigators, a private power company, and the Bureau of Commercial Fisheries should make it possible to carry out such studies in an unusual atmosphere of cooperation between university, industry and government.

Project Description and Report of Work and Accomplishments

Variation in salinity is one of the most basic and far-reaching characteristics of estuarine waters. In view of the need for large volumes of bay water for cooling in electric power plants, we have carried out several experiments designed to determine the influence of salinity on the high-temperature resistance of postlarval brown shrimp (Penaeus aztecus). Individual groups of postlarval shrimp were kept in the laboratory, each group at a fixed level of salinity and temperature. Nine combinations of three salinity levels (5 o/oo, 15 o/oo and 25 o/oo) and three temperature levels 24°, 29°, and 34°C) were used, with replication. Subsequently animals from each experimental group were exposed to two lethally high temperatures at three salinity levels (5 o/oo, 15 o/oo and 25 o/oo) and survival times recorded. Results indicated that survival times were optimized by low salinity before exposure to heat, and by higher salinity during exposure. This information provides new insight into the importance of fresh water in the extuarine nursery areas of our natural brown shrimp resource. In addition, it should be useful in the development of guidelines for improving survival in shrimp hatchery and pond stocking practice.

In other experiments, brown shrimp postlarvae spawned in the USBCF laboratory appeared to be less heat tolerant than specimens of the same size and species collected from Galveston Bay.

Another source of variation in heat resistance within this species is age (or size). Very young hatchery-reared brown shrimp postlarvae from the BCF were much more sensitive to high temperature than slightly older, larger animals from the same source. When 6-7 mm long, about 2 weeks after hatching, only 30% of a test group survived in a 24-hour exposure to 37°C. Several weeks later, shrimp from the same batch had doubled in length. One hundred percent of such postlarvae survived a 37° exposure identical to the previous one. A similar study to confirm these results and test other temperatures is presently underway.

Field experiments started with 4-6 mm postlarvae by the Texas Parks and Wildlife Department indicated that most pond mortalities of shrimp occur at stocking or immediately afterward. Our findings can provide valuable guidelines in regard to choosing a suitable stage of shrimp for stocking of ponds.

Some other results:

1. White shrimp (Penaeus setiferus) 3 to 4 inches long survive only 1/2 to 1/7 as long as 1/2-inch long postlarvae at upper lethal temperatures (38.0 - 39.6C).

2. Despite this difference, acclimation rates for white shrimp of these two size ranges are similar.

3. Survival of variegated minnows (Cyprinodon variegatus) held at salinity levels of 1 o/oo, 10 o/oo, 20 o/oo, and 30 o/oo, was 77%, 80%, 62%, and 33%, respectively (1000 fish tested at each level).

4. When fish from these four groups were challenged with lethally high temperatures, the 10 o/oo group yielded the longest survival times.

5. Galveston Bay oysters held in the laboratory at temperatures of 27° - 35°C died within a few weeks. Deaths were associated with infections of Labyrinthomixa (Dermocystidium) marinum, a microscopic parasite of oysters. This parasite is endemic on the Gulf and South Atlantic Coasts of the U. S. It appears that control of this pathogen will be essential to successful tank culture of oysters from these areas.

6. Young blue crabs grew in 80-gal. aquaria at temperatures of 27° - 35°C. Most rapid growth and least mortality occurred at the lower end of this range, and a trend toward the reverse situation was observed toward the upper end of this temperature range.

Other activities:

Mahmudul Karim, an AID-sponsored fishery student who worked in this project completed requirements for the Ph. D. degree in Wildlife Science. Larry M. Wiesepape, another graduate student working within this project, completed requirements for the M. S. degree in Wildlife Science.

Drs. Kirk Strawn and David Aldrich and student Larry Wiesepape attended the World Mariculture Society meeting at Baton Rouge, La, and Dr. Strawn attended the earlier meeting at Ocean Springs, Mississippi.

Dr. Aldrich attended a conference on artificial propogation of commercially valuable shellfish (University of Delaware), the Atlantic Estuarine Research Society meeting, and the Governor's Conference on Goals of Texas in the Coastal Zone and the Sea.

Mariculture Demonstration (Research and Advisory)

Advisory Leader: Jack C. Parker, Department of Agricultural Extension Service

Demonstration and research efforts have established the potential of mariculture in Texas coastal lowlands. Emphasis has been placed on shrimp culture because this form of mariculture holds the highest expectations for commercial production and economic gain. Findings have indicated that both natural and reservoir ponds are suitable for culturing shrimp. However, poor survival and inconsistent supply of seed stock, as well as inadequate artificial feeds and inefficient harvest techniques, have prevented the establishment of economically feasible commercial practices. The significant support of this project by coastal-based agriculture and industry has dictated the need to expand efforts in this field. To satisfy these needs, it is necessary (a) to identify factors causing mortality in ponds, (b) to evaluate artificial feeds and shrimp stocking rates on a field-scale basis, and (c) to develop commercially suitable techniques for harvesting shrimp in both natural and reservoir ponds.

Project Description and Report of Work and Accomplishments

Following is a brief summary of experimental shrimp pond culture results obtained during the past fiscal year.

Predator Control: In order to evaluate the effect of fish predation on shrimp, two natural ponds measuring 1 1/4 - and 2 1/2 acres were stocked in early August, 1969 with juvenile white shrimp (averaging 2 1/2 - inches) at a rate of 20,000 per acre supplied from West Galveston Bay by a local fisherman. A fish toxicant, Chem Fish Collector, which

contains rotenone, was applied to the 2 1/2 - acre pond to remove predators, and Diuron was applied to control all aquatic vegetation. A commercial catfish food (sinking variety) was introduced into each pond to supplement natural foods.

Survival was good in both ponds. Over a 70-day period, shrimp in the pond without predators averaged 5 1/2 - inches (33 per pound) while those growing with predators averaged only 4 1/2 - inches (45 per pound). Using a 150-foot seine, 350 pounds per acre were harvested from the larger ponds. Attempts to harvest these shrimp via the drain flume in the manner described in the previous years annual report proved unsuccessful for white shrimp. Harvesting was terminated in this pond because cold weather necessitated a redirection of effort. At that time, an estimated 100 pounds per acre still remained. Before further attempts could be made to complete harvesting these ponds, the crop was destroyed as a result of a killing freeze on November 15th. It was evident from the data obtained, however, that it is necessary to remove all shrimp predators before stocking. These organisms not only prey on the shrimp but also compete with them for food. Predators can be removed easily and effectively with rotenone at a concentration of 2 parts per million.

To evaluate the effect of predator control on the production of brown shrimp, these same ponds were stocked again in April, 1970 with postlarvae brown shrimp at a rate of 20,000 per acre. The same toxicant, Chem Fish Collector, was used to remove predators in the 2 1/2 - acre pond and Diuron was applied to control all aquatic vegetation. A commercial catfish food (sinking variety) was introduced into each pond to supplement natural foods. This experiment has not yet been completed, but preliminary results indicate that brown shrimp are much less susceptible to predators than white shrimp.

Feeding: A number of questions have been raised concerning protein sources in artificial shrimp foods, and it is generally conceded by most researchers that fish meal is desirable. The proportion of fish meal, however, is questionable. For this reason, an experiment was initiated in ten 1/2 - acre reservoir ponds to examine the quality of high and low fish meal diets. The ponds were stocked the latter part of August with juvenile white shrimp (averaging 2 1/] - inches) at a rate of 20,000 per acre. In five of the ponds, shrimp were fed a 50-percent protein diet, of which 60-percent of the protein was fish meal, and in the other five ponds, shrimp were fed a 50-percent protein diet with fish meal accounting for only 20-percent of the total protein. In both diets the remaining protein consisted of a mixture of poultry by-products, blood, and bone meal. These diets were submitted to the shrimp in 1/4 - inch diameter pellers (sinking variety).

Survival in these ponds varied from 20-80 percent, and production varied from 145-300 pounds per acre. The growth period covered approximately 45 days, and the shrimp ranged in size from 35-45 count per pound (heads on) at times of harvest.

The results of these feeding experiments were inconclusive as far as evaluating the amount of fish meal was concerned. The diet lowest in fish meal appeared to significantly increase growth. It is doubtful, however, that the protein content was the causative factor. Rather, the differences in weight gain were probably due to the different consistency of the pellets in water. When immersed, the high fish meal pellets disintegrated rapidly; consequently, they were available to feeding shrimp for a much shorter time. Since the nutritive content of the feed affects the pellet consistency, it is doubtful that much will be gained from nutrition studies in ponds until suitable tightly bound pellets are available. Efforts are being made to interest commercial feed producers in assisting us in developing suitable feeds.

No significant growth in any pond was observed after October 15th. At that time, water temperature dropped below 60°F. Although higher temperatures were recorded thereafter, it appeared that warming was not sufficient to produce adequate temperatures for significant growth.

In June, 1970, these same ponds were stocked with juvenile brown shrimp (averaging 2 1/2 - inches) in an effort to evaluate feeding rates using the better of the two pellets developed the previous year. Three feeding rates, based on 5, 7 1/2, and 10 percent of total body weight, were replicated three times each and one pond was used as a control. Brown shrimp did not do well on this ration and, in fact, grew very little over a four month period. Survival, however, was good (between 60 and 80 percent) but laboratory tests revealed that brown shrimp did not eat the ration as readily as white shrimp. To further substantiate the difference, in food preference for these species, four of the ponds were drained, and the brown shrimp removed, and the pond stocked with juvenile white shrimp. The white shrimp have been growing very well and, with the present pond technology and nutritional knowledge, appear to be much more suited for pond culture on the upper Texas coast than brown shrimp. Should further replication of this study substantiate these results, a major revision in hatchery production may take place. Most hatcheries in Texas have much better capabilities for producing brown shrimp seed stock and will have to conduct a considerable amount of additional research to develop equivalent capabilities for white shrimp production.

The biggest problems in experiments to date have been an inconsistant supply of postlarvae for stocking purposes and an inability to maintain adequate survival of seed stock in ponds. In April, 1970, the Dow Chemical Company began constructing a pilot shrimp hatchery at Freeport, Texas and should shortly be producing an adequate supply of seed stock for experimental purposes. This hatchery may be the forerunner of the first commercial operation in Texas.

New Research: Most studies now in progress in shrimp culture are intended primarily to facilitate relatively low-density practices for use on inexpensive coastal lands--synonymous to pasture grazing practices in the beef industry. In order for industry to participate profitably,

however, techniques for a high-density (intensive) culture system--along the lines of a beef cattle feeder lot--are needed. Both low-and high-density rearing practices are presently employed successfully in catfish culture, and with additional research, techniques for intensive shrimp culture should also be developed. In order to augment the present field efforts of the Texas Agriculture Extension Service, a cooperative project with the Dow Chemical Company and Ralston-Purina Company will explore the feasibility of an intensive shrimp culture system. Extension personnel presently involved in the mariculture program will cooperate in this effort and have access to the results of this research.

The possibilities look good to those associated with research in this field. Undoubtedly, many problems will arise as research progresses, but success in these initial experiments could lead the way toward development of a new means of food production and an additional means of utilizing our coastal marshlands.

Role of Microorganisms in the Quality Deterioration of Seafoods (Research)

Activity Leaders: Carl Vanderzant, and Bryant F. Cobb, III, Department of Animal Science

Description of Project and Report of Work and Accomplishments

The first objective of this study was to obtain an accurate and current picture of the initial level and type of microbial population of shrimp and the changes caused by handling, processing and storage conditions. This phase has been completed, and the results were published (see publication and attached reprints). The microbial flora of Gulf shrimp was dominated by coryneform bacteria and species of Pseudomonas, Moraxella and Micrococcus. Refrigerated storage of shrimp usually caused an increase in Pseudomonas species. The type of growth medium and conditions of plate incubation influenced the number of bacteria isolated from seafoods. Bacterial counts on media prepared with seawater or distilled water were higher than those of media prepared with artificial seawater. Counts on fresh shrimp were higher with plate incubation at 28 than at 5C. With stored shrimp there was little difference in count at the two plate incubation temperatures. Bacterial counts of pond shrimp were lower than those of Gulf shrimp. In some samples of pond shrimp Bacillus and Lactobacillus species were predominant.

A high mortality among brown shrimp used in nutritional experiments in the Sea Grant Program prompted a microbiological study of possible causes. Vibrio parahaemolyticus, a major cause of gastroenteritis in Japan, was isolated from white shrimp. The organism was pathogenic for brown shrimp from the Gulf of Mexico. These results were published in the Journal of Milk and Food Technology (see publications and attached reprints).

Individual bacterial species isolated from shrimp were inoculated into washed shrimp and in sterile shrimp juice to study the biochemical changes in shrimp during storage. Four organisms, a fluorescent Pseudomonas (I), an atypical Pseudomonas (II), a coryneform (III), and a Bacillus (IV), were used.

Volatile nitrogen (TVN), volatile acids (TVA), trimethylamine nitrogen (TMN), volatile reducing substance (VRS), pH, non-protein nitrogen (NPN), water soluble protein (WSP), salt soluble protein (SSP), and amino acids were measured. Organisms I and II caused significant changes in pH, TVN, NPN, WSP (I only) and in the proteins of the shrimp press juice. Organisms II and III caused no significant changes in any of the parameters measured except II caused changes in the level of NPN. The analysis of the amino acids is incomplete.

In conjunction with these major objectives, an attempt was made to develop a simple, rapid test to evaluate the potential shelf life of shrimp. Results indicated that water holding capacity of proteins, (ERV) as used for beef and chicken, could not be used to evaluate the freshness or spoilage of stored iced shrimp. Little correlation existed between ERV and bacterial counts, ERV and pH, and pH and bacterial count. The data indicated that the pH of shrimp perhaps could be used as a simple screening test to evaluate degree of freshness. The results of this study were written up in a technical paper which was submitted for publication to the Journal of Milk and Food Technology.

Current research is a continuation and expansion of the results reported here. One phase of study on the biochemical changes in shrimp inoculated with bacterial species is completed, and the results are compiled in one technical paper to be submitted for publication during 1970-71. Studies are initiated on the types and activities of coryneform bacteria which were the predominant species isolated from shrimp. Investigations on the types and activities of microorganisms from pond shrimp will be completed during 1970-71. Extensive studies are under way on the importance of Vibrio parahaemolyticus in seafoods from the Gulf of Mexico.

Seafood Technology Course (Education)

Activity Leader: Bryant F. Cobb, III, Department of Animal Science

The development of a seafoods course has required the accumulation of a large number of references. These references have been assembled under the appropiate lectures. An extensive outline of the course will shortly be ready for publication. However, not all reference material has been received so the course is not quite complete.

It was originally proposed to offer the course on an experimental basis this year, but due to slowness in University approval, the course will not be offered until next summer.

Fisheries and Coastal Land Use
(Advisory Service)

Activity Leaders: W. G. Klussmann, and David Harrington, Department of Agricultural Extension Service

During the second year of operation, the Sea Grant Advisory Program conducted by the Cooperative Extension Service of Texas A & M University was arbitrarily divided into two segments; the Mariculture Segment and the Extension and Advisory Segment. This report covers the latter segment only with the former being covered in a separate report.

The basic purpose of the Extension and Advisory Segment was to increase, on an ecologically sound basis, the economic opportunity of marine resource users. Efforts focused upon the development of an extension education and assistance program for the marine fishing industry and conduction of training sessions and the development of an education materials for commercial fisherman, coastal landowners and the field staff of the Extension Service.

Historically, there has been little effort to extend and interpret accumulated research information to the commercial fishing industry. Thus, specific emphasis was given to the initiation and development of an extension information program designed to extend maritime informational services to the people who stand to benefit from its application.

Project Description and Report of Work and Accomplishments

Marine Fisheries: The general approach of this work has been to seek out the problem areas within the fishing industry and to assist in their solution. Thus, the basic objective is to improve this situation of the fisherman by attempting to make his work easier and more profitable. All field work in this segment is conducted by the Area Marine Fisheries Specialist.

Specific activities included the development and testing of improved machinery, gear and fishing methods; assistance to individuals and groups of fishermen on the preparation and use of improved gear and methods; and the development of communication and collaboration between marine machinery manufacturers, the fishing industry and Texas A & M University.

Several product and gear development evaluations were made and meetings held between members of the fishing and marine products industries. These resulted in changes in proposed equipment designs and features which were extremely favorable to the fishing industry. Cruises were also made to assist vessel owners in gear experimentation. One operation resulted in significant improvements in the electrode array arrangement of electric trawls.

The electric trawl evaluation was made in cooperation with the Newman-Osborne Company which provided the vessel and equipment. A side scan radar system for detecting shrimp populations was also tested during these cruises. Sea trials of a new trawl door design were conducted with the assistance of the Twin-Disc Company and individual fishermen. Results of the study and evaluation of the electric trawl are being published in a semi-technical publication series and will be distributed to the fishing industry. Several demonstrations on the use of new fishing gear were conducted by the Extension Fisheries Specialist during short cruises with individual fishermen.

Educational efforts included general meetings on marine fisheries in Brazoria, Chambers, Galveston and Matagorda counties, a seminar at the Bureau of Commercial Fisheries in Galveston, and programs for youth at the Santa Fe Elementary School.

Significant time was devoted to the development of an effective communication link between the Extension marine fisheries personnel and personnel of the Bay & Gulf Fisherman Association, the Texas Shrimp Association, the Shrimp Association of the Americas and the Bureau of Commercial Fisheries. The Area Marine Fisheries Specialist met with local leaders of these organizations at all Texas ports in effort to determine problems and to introduce the Extension program. Local County Agricultural Agents assisted in scheduling these initial contacts with industry personnel.

General Educational Segment: The Coastal Land Resources Advisory Committee, organized during the previous year, met several times to formulate a set of priorities for the Extension and Advisory Program. The officers and executive committee are: Mr. Joe Lagow, County Commissioner of Chambers County, President and Mr. James McFaddin of Jefferson County, Vice-Chairman, Other members of the Executive Committee are Mr. Paul Hopkins, County Commissioner of Galveston County; Mr. John Gayle, County Commissioner of Brazoria County; and Mr. O. P. Little of Aransas County.

The Committee adopted a basic purpose of the existence of their Committee which was recorded as: "To provide assistance toward the development of a sound program which economically benefits marine resource users and which provides for long-term utilization of marine resources primarily by avoiding short-sighted, over exploitation."

The Committee formulated its previous discussions into the following recommendations:

1. Continue the present work in mariculture at the Brazoria County site and expand into a total marsh utilization program.
2. Initiate a program to provide information on the biological effects of land development to local decision making bodies.
3. Work toward better communication among agencies involved in coastal land use decisions.

4. Promote recreational enterprises which would adhere to multiple or long-term utilization concept of marsh areas.

5. Encourage waterfowl management and utilization in coastal marshes.

6. Provide greater information to all public on the effects of pesticides.

7. Study the effects of bait shrimping as related to the food shrimp fisheries.

8. Study shrimping laws to facilitate simplification and understanding.

9. Provide more information on the effects of shell dredging.

A Coastal Land Resource Conference was held in Galveston on June 16-17, 1970. The conference addressed itself to a "state of the art" conference as related to land use, particularly mariculture, shrimp and catfish farming in brackish coastal waters, waterfowl and recreation management on the Texas coast, coastal water quality, pollution and plans by the state for a coastal study.

A conference on the current thinking of Texas coastal recreation development was conducted by personnel of the Recreation and Parks Department of Texas A & M University at Corpus Christi, Texas, on January 22-23, 1970.

Personnel of the Agricultural Extension Service participated in the hearing of the Legislative Committee for Texas Parks and Wildlife held in Galveston on February 17, 1970. Representatives of the Texas Agricultural Extension Service are working closely with the Governor's Office of Planning Coordination at Austin, Texas, and their personnel performing the Texas Coastal Plan, a study financed by $200,000 appropriation from the Texas Legislature. Mr. James Goodwin, Mr. Bill Stoll, and Mr. Joe Moseley of the Governor's Office are our liason contacts.

The hearings on oceanography held by the Texas Legislative Interim Study Committee at Galveston, Corpus Christi, and Dallas were represented by Sea Grant personnel of the Texas Agricultural Extension Service.

A general meeting on marine resource multiples was conducted for 60 community leaders in Rockport, Texas. In addition, the session served to acquaint citizens with the activities of the Agricultural Extension Service and the Sea Grant Office at Texas A & M University.

A 35 mm color slide set relative to coastal activities such as national wildlife refuges, national parks, wildlife foundations, mineral production, private recreation, industrial plants, coastal water and air pollution and port activities was developed. These slides are now listed as a resource of the Sea Grant Office. A script was prepared and submitted which was to be used by persons utilizing the slide set for educational purposes.

Galveston Marine Laboratory (Education)

Activity Leader: Sammy M. Ray, Department of Biology and Oceanography

The Marine Laboratory's Sea Grant Program is primarily concerned with instruction, both undergraduate and graduate, and student research in areas related to exploitation and utilization of marine biological resources. Initially, the major objective of this project is expansion of the graduate instructional and research program so that students may complete in Galveston all or most course work and thesis research required for the Master of Science Degree in marine-oriented biological sciences such as marine biology, marine fisheries and biological oceanography. Courses and research programs will emphasize development and application of scientific information that may lead to more efficient utilization, as well as artificial cultivation, of commercially important marine organisms. Moreover, the laboratory's instructional and research programs will become more involved in coastal zone problems such as estuarine ecology and pollution biology.

The research program of the Marine Laboratory has been greatly strengthened by sizeable grants from the Moody Foundation of Galveston. These funds provide stipends for postdoctoral and graduate fellowships in marine-related areas as well as undergraduate scholorships for summer study at the Marine Laboratory. Some of the Moody fellows are working on Sea Grant projects such as aquaculture of marine organisms.

The Marine Laboratory is also providing offices, classrooms, and laboratories for other Sea Grant projects at Texas A & M UNiversity. These projects include: (1) Aquaculture Program of the Wildlife Science Department; (2) Marine Advisory Services. In the near future, other academic entities of Texas A & M University such as the College of Veterinary Medicine and the Division of Environmental Engineering plan to utilize this seaside facility and its personnel in some phases of their Sea Grant projects. Presently both state and out-of-state educational institutions use the Marine Laboratory as a base for field trips to the coast and for short-term studies. It is anticipated that such use by students and investigators from other institutions will greatly increase with the expansion of space and facilities projected for September 1, 1971.

Project Description and Report of Work and Accomplishments

Educational Activities - Fall Semester 1969: Twelve graduate students and one undergraduate student enrolled for courses in oceanography and wildlife science at the Marine Laboratory. Nine students enrolled in Oceanography 624 (Marine Phytoplankton) which was taught by W. B. Wilson and S. El-Sayed, In addition, most of the students also enrolled for problems and thesis report. Student credit hours for the fall semester were:

1.	Undergraduate	4
2.	Masters	94
3.	Doctoral	35

Spring Semester 1970: Twelve graduate students enrolled for courses in biology, oceanography and wildlife science at the Marine Laboratory. Nine of these students registered for Wildlife Science 611 (Estuarine Ecology) which is a new course that was designed especially for offering in Galveston. This course was developed and taught by D. V. Aldrich. Most of the students also enrolled for problems and thesis research. Student credit hours for the spring semester were:

1. Masters 86
2. Doctoral 32

Summer Sessions 1970: The summer sessions for 1970 showed the largest enrollment that the laboratory has experienced since the initiation of the resident teaching program in 1964. Sixty-one students enrolled for the first six-week session and fifty-eight registered for the second one. Seven females attended the first session and four attended the second one. The distribution of the students according to classification is presented below:

	Undergrads TAMU	Undergrads Non-TAMU	Masters TAMU	Masters Non-TAMU	Doctorate TAMU	Doctorate Non-TAMU
1st Session	27	7	16	2	9	0
2nd Session	29	3	14	1	11	0

Although the summer students were predominatly from Texas A & M University, there were students in attendance from other colleges and universities including Kenyon College, Ohio; Central State College, Oklahoma; Earlham College, Indiana; Stephen F. Austin University; Lamar State College; and Galveston College.

Student credit hours for the summer (total for both sessions) were:

1. Undergraduate 426
2. Masters 142
3. Doctorate 69

Courses offered during the summer session included:

a. Marine Invertebrate Zoology (Biology 435) - Enrollment 9

b. Marine Biology (Biology 440) - Enrollment 8

c. Marine Botony (Biology 637) - Enrollment 7

d. Biology of the Crustacea (Biology 663) - Enrollment 14

e. Marine Invertebrate Zoology (Biology 665) - Enrollment 3

f. Problems in Marine Biology (Biology 485) - Enrollment 9

g. Problems in Marine Biology (Biology 685) - Enrollment 8

h. Research (Biology 691) - Enrollment 9

i. Statistical Methods (Statistics 406) - Enrollment 27

j. Research (Oceanography 691) - Enrollment 4

k. Marine Ichthyology (Wildlife Science 312) - Enrollment 31

l. Fisheries Survey (Wildlife Science 400) -Enrollment 20

m. Animal Population Dynamics (Wildlife Science 418) - Enrollment 25

n. Problems in Marine Fisheries (Wildlife Science 485) - Enrollment 3

o. Problems in Marine Fisheries (Wildlife Science 685) - Enrollment 6

p. Research (Wildlife Science 691) - Enrollment 16

New Course Development: Two new graduate courses, "Mariculture" (Wildlife Science 615) and "Diseases of Marine Invertebrates" (Veterinary Microbiology 660), were developed for offering at the Marine Laboratory. Diseases of Marine Invertebrates was developed by Dr. Albert K. Sparks (Director of B. C. F. Laboratory, Galveston), who will teach the course for the first time during the fall semester of 1970. The Mariculture course was developed by Dr. D. V. Aldrich and will be offered for the first time during the spring semester of 1971 with D. V. Aldrich and S. M. Ray as instructors.

Student Support: During the period covered by this report, two undergraduate, two masters and three doctoral students were supported at least part of the year by working on the Wildlife Science Department's Aquaculture Project. Students were also supported by a Moody Foundation grant. These funds supported two masters and one doctoral student, as well as nine undergraduates for six weeks of summer study. The Moody Foundation grant also provides stipends for a postdoctoral fellowship program, which will be initiated on September 1, 1970.

Services Provided to Other Sea Grant Projects by the Marine Laboratory and Its Personnel

Marine Advisory Services: Until his departure in the summer of 1970, David L. Harrington, Area Marine Fisheries Specialist, maintained an office at the Marine Laboratory. The facilities and support personnel of the Marine Laboratory were available to Mr. Harrington. It is anticipated that Mr. Harrington's replacement will utilize office space and facilities at the Marine Laboratory.

Aquaculture Project of the Wildlife Science Department: Much of the Aquaculture Project, which is under the direction of Dr. Kirk Strawn, is conducted at the Marine Laboratory. Dr. David Aldrich of our resident staff devoted a quarter of his time to this project. A large space (2200 sq. ft.) in the basement has been converted to an aquarium room for this project.

Specimen Collection and Public Relations: On June 1, 1970, William Wardle, Research Associate, was employed to provide specimens for various Sea Grant projects and to assist the Director of the Marine Laboratory with public relations activities. Mr. Wardle is also responsible for conducting tours of the Marine Laboratory as well as organizing field trips for classes and groups from various educational institutions, including both state and out-of-state organizations.

Miscellaneous Sea Grant Activities

The Marine Laboratory's resident staff and the Director in particular have engaged in frequent conferences with College Station staff members who are either conducting or are planning to conduct Sea Grant projects. Our familiarity with marine and fisheries activities in the Galveston area has been useful in providing contact between personnel on the main campus and state, federal, industrial, and commercial fisheries organizations.

The staff of the Marine Laboratory conducted tours and gave short lectures to several high school and college groups who wished to become acquainted with our program and to learn something of the career possibilities in marine sciences. Groups from Kansas College, Iowa State University and University of Illinois used the laboratory as a base for week-end field trips. We are receiving an increasing number of requests from high schools and institutions of higher learning from inland areas to provide tours and lectures in the general area of marine science. Such activities are vital in stimulating an interest and awareness of importance of our marine resources.

The Director serves on a number of committees including: Oceanography, Education and Pollution Committees of the Galveston Chamber of Commerce; Moody Foundation Scholarship Selection Committee; and the Governor's Advisory Panel on the Safe Use of Agricultural Chemicals. Through such committee service by the Director, the Marine Laboratory maintains contact with educational, industrial, state, federal and philanthropic institutions in the Galveston area. The Director also served on the planning committee as well as Chairman for one of the sessions of a "Conference on the Sanitary Quality and Microbial Safety of Fishery Products" sponsored by the U. S. Public Health Service. The Conference was held in Mayaguez, Puerto Rico, September 8, 9, and 10, 1970. Other activities of the Director, including serving as Section Chairman for molluscs of "A Symposium of the American Fisheries Society on Diseases of Fishes and Shellfish" published by the American Fisheries Society, Washington, D. C., 1970 (526 pp.).

The Director conducted negotiations with the Atlantic-Richfield Company for use of offshore platforms in the High Island, Texas, area for pilot studies on the feasibility of using offshore platforms for hanging culture of oysters. All arrangements have been made to permit the initiation of such atudies during the fall of 1970.

Studies on the Labyrinthulae of Marine Molluscs and Plants (Research)

Activity Leader: J. G. Mackin, Department of Biology

A highly lethal disease of oysters was discovered in about 1949, and the parasite described in 1950 by Mackin, Owen and Collier. Mackin and Ray (1966) placed this parasite in the Labyrinthulales, a primitive fungal order. Andrews, using a diagnostic technique devised by Ray (1954), demonstrated that other bivalve molluscs carried the same or a similar parasite. Ray demonstrated that two of the molluscs parasitized by members of the group (genus Labyrinthomyxa) carried species which could not be the same as Labyrinthomyxa marina, and it was suspected that others were also different.

Mackin has recently demonstrated that the oyster itself has several species of parasites other than L. Marina and that these may or may not be detected by Ray's diagnostic method. These new oyster parasites have produced devastating destruction of oyster beds.

Project Description and Report of Work and Accomplishments

Realizing the commercial importance of the Labyrinthulae, studies concerning molluscan mortality were continued. New species of parasites, found in oysters from the Atlantic and Gulf coasts, were noted. Developmental cycles, pathogenicity, and physical parameters constituted major areas of concern.

Further work, centered around Labyrinthulae of marine plants, was conducted. As a result of developmental studies, striking similarities were noted between the genera found in molluscan and plant hosts. These developmental sequences indicate that the plant associated species, whether saprophytic or parasitic, are closely related to the molluscan parasites.

PUBLICATIONS AND DOCUMENTATION

Work carried out under the Marine Fisheries Program has been presented in several forms. The following listing includes technical and general reports, professional journal publications, and conference presentations which have resulted from the 1969-70 program.

Technical and General Reports

Cobb, Bryant F. III *"Texas Marine Resources, The Fisheries View."* Texas A & M University Sea Grant publication. College Station, Texas TAMU-SG-70-115. August 1970.

Cox, Bruce A. "A study of Labyrinthula spp., isolated from the marine gastropod, Thias haemostoma," (Thesis), Texas A & M University. College Station, Texas. 1970.

Glover, James D. *Biochemical Changes in Speckled Trout (Cynoscion Neculosus) Preserved with Ice.* Thesis. 1970.

Mahmudul, Karim and David V. Aldrich. *Influence of Diet on the Feeding Behavior, Growth and Thermal Resistance of Postlarval Penaeus azteeus and P. setiferus.* Texas A & M University Sea Grant Program. College Station, Texas. TAMU-SG-70-226. September 1970. 80 pp.

Parker, J. C., D. Moore, and B. J. Gallaway. *Key to the Estuarine and Marine Fishes of Texas.* A laboratory manual for marine ichthyology. Texas A & M University-Agricultural Extension Service Press. College Station, Texas. 1970. PP. 1-107.

Ragan, James G. "Infection of brown shrimp, Penaeus aztecus (Ives) by Prochristianella penaei (Cestoda: Trypanorhyncha) in Southern Louisiana," (Dissertation), Texas A & M University. College Station, Texas. 1970.

Ray, James P. "Developmental cycle of a marine chytrid from the Gulf of Mexico," (Thesis). Texas A & M University. College Station, Texas. 1970.

Rogers, Bill G. *A Laboratory Study of the Effects of Temperature and Salinity on the Sand Dollar, Mellita quinquiesperforata.* Texas A & M University--Marine Laboratory. College Station, Texas. May 1970.

Wardle, William J. "Contributions to the biology of Tagelus plebeius (Bivalvia, Tellinacea) in Galveston Bay," (Thesis). Texas A & M University. College Station, Texas. 1970.

Vanderzant, G. and R. Nickelson, "Comparison of Extract-Release Volume, pH, and Agar Plate Count of Shrimp," Technical Article of the Texas Agricultural Experiment Station. Texas A&M University. College Station, Texas. 1969.

Professional Journals and Periodicals

Ellender, R. D., Jr., and B. J. Camp "Analysis of ammonia-N in artificial sea water." J. Fish. Res. Bd. Can. 1970.

Klontz, G. W. "Medical care of newly captured killer whales." Sw. Vet. Vol. 23(4) 1970. pp. 267-270.

Lewis, D. H. "Summary of methods, media and other materials used in identifying bacteria associated with fish and shellfish." 1970.

Lewis, D. H. "Bacterial microflora of marine fish--Its sanitary implications." Texas J. Publishing Hea. 1970. pp. 53-58.

Lewis, D. H. and T. Allison "An immunofluorescent technique for detecting Aeromonas liquefaciens in fish utilized in lunar exposure studies." 1970.

Lewis, D. H., L. C. Grumbles, S. McConnell, and A. I. Flowers "Pastueurella-like bacteria from an epizootic in menhaden and mullet in Galveston Bay." J. Wildlife Dis. 1970. pp. 160-162.

Lewis, D. H., S. McConnell, G. W. Klontz, and L. C. Grumbles "Bibliography on infectious diseases and host response of marine fish (Partially Annotated)." 1970.

Parker, J. C. "Distribution of juvenile brown shrimp (Penaeus aztecus Ives) in Galveston Bay, Texas as related to certain hydrographic features and salinity." Texas A & M University. College Station, Texas. 1970. Vol. 15: pp. 1-22.

Parker, J. C. "Shrimp Farming--Texas Style." Proceedings of the Coastal Land Resource Conference. Texas A & M University. College Station, Texas. 1970. pp. 1-8.

Parker, J. C., H. W. Holcomb, and J. C. McNeill, IV. "Distribution of aquatic macro-fauna in a marsh on West Galveston Bay, Texas." Texas A & M University. College Station, Texas. April 1970. pp. 1-21.

Ray, Sammy M. "Current Status of Paralytic Shellfish Poisoning" Texas A & M University. College Station, Texas. August 1970.

Vanderzant, C., E. Mroz, and R. Nickelson. "Microbial flora of Gulf of Mexico and pond shrimp." *Journal Milk and Food Technology* 1970. Vol. 33. Pp. 346-350.

Vanderzant, C., and R. Nickelson. "Isolation of Vibrio parahaemolyticus from Gulf Coast shrimp." *Journal of Milk and Food Technoloyg* 1970. Vol. 33. pps. 161-162.

Vanderzant, C., and R. Nickelson. "Comparison of Extract-Release Volume, pH, and agar plate count of shrimp." Texas A & M University. College Station, Texas. 1970.

Vanderzant, C.,R. Nickelson, and J. C. Parker. "Isolation of Vibrio parahemolyticus from Gulf coast shrimp." *Journal of Milk and Food Technoloyg.* 1970. Vol 33. pp. 161-162.

Conference Reports Presented

Holland, John. "Thermal acclimation of Cyprinodon variegatus." Texas A & M University. College Station, Texas. 1970.

Klontz, G. W. "Fish as a laboratory tool." Annual Meeting, Texas Branch, American Association for Laboratory Animal Science. College Station, Texas. March 1970.

Klontz, G. W. "Parasites of fishes transmissable to man." 20th Annual Southwestern Conference on Diseases in Nature Transmissible to Man. Austin, Texas. May 1970.

Klontz, G. W. "A new area of veterinary service: Aquatic medicine." Presented at the 23rd Annual Texas Conference for Veterinarians. College Station, Texas June 1970.

Klontz, G. W. "Texas A & M University Sea Grant Program and Gulf Fisheries." 11th Annual Fish Disease Conference. Seattle, Washington. July 1970.

Klontz, G. W. "Fisheries medicine." Proceedings of the First Annual Workshop. World Marculture Society held in Baton Rouge, La. Feb. 1970.

Klontz, G. W. "Fish culture and disease." Proceedings of the 19th Western Poultry Disease Conference held in Davis, California. March 1970.

Klontz, G. W. "Use of fish as biomedical models." Proceedings of the American College of Laboratory Animal Medicine meeting held in Las Vasas, Nevada. June 1970.

Klontz, G. W. "Fish medicine" Sea Grant Seminar Series. Texas A & M University. College Station, Texas. Nov. 1969.

Klontz, G. W. "Harvesting fish and shrimp." Gulf Coast Regional Meeting of the Texas Public Health ASsociation. College Station, Texas. Dec. 1969.

Lewis, D. H. "Bacterial flora of fishes of the Texas Gulf Coast." Gulf Coast Regional Meeting of the Texas Public Health Association. College Station, Texas. Dec. 1969.

Lewis, D. H. and S. McConnell. Panel members for "Present and future role of veterinarians in marine research and the seafood industry." 45th Annual Meeting of the Texas Public Health Association. Austin, Texas. Feb. 1970.

Lewis, D. H., T. Allison and Z. Zein-Eldin. "Preliminary report on quantitative and qualitative studies on microflora of shrimp prior to exposure to lunar materials." Proceedings Texas Branch Am. Soc. Micro. meeting. Houston, Texas. 1970.

Trieff, N. M., John J. Spikes, S. M. Ray, and J. B. Nash. "Isolation of Gymnodinium breve toxin." Presented at the Second International Symposium on Animal and Plant Toxins. Tel-Aviv, Israel. Feb. 1970.

MARINE SCIENCES

Seven projects were centered on aspects of marine science during 1969-70. Most of these are research based projects. Some rely heavily on industrial support. Others contain elements of education and advisory services.

Electrical Logging in Aquatic Environments (Research)

Activity Leaders: William E. Sweet, Jr., Research Associate, Department of Oceanography.
Arnold H. Bouma, Professor, Department of Oceanography

This project is designed to (a) develop quantitative in situ and laboratory electrical logging hardware and techniques, (b) define the relationship between the eletrical properties and the chemical, physical and engineering properties of recent sediments, and (c) result in computer models capable of reducing the electrical measurements to a variety of desired parameters. These techniques will provide a quick, accurate and inexpensive means of making sediment distribution and sediment property maps useful in research, pollution control work, offshore foundation work, and offshore mining. The costly and time-consuming coring programs now used for such work can be vastly augmented and, in many cases, replaced by electrical logging.

The primary objectives of this project are to develop and construct instruments to measure the electrical resistivity of sediments both in situ and in the laboratory, and to determine empirical relationships between the electrical resistivities of these sediments and their different properties. These instruments and the developed quantitative relationships between the electrical and the physical, chemical, and engineering properties of sediments will provide research and industry with a more rapid and economical means of determining these properties.

Project Description and Report of Work and Accomplishments

The year ending August 31, 1970 has seen the successful development and construction of two instruments which do in fact measure the electrical resistivities of sediments. These instruments, along with other types of logging devices on loan from industry and research groups, were tested during a cruise in the Gulf of Mexico from September 11 to 25. At the present time the data gathered on this cruise is still being evaluated, and will form the subject for an interim report at a later date. At this time it can only be stated that both instruments worked with a mixed

measure of success.

Construction of our resistivity logging devices bagan late in the summer after aquisition of the full time services of an experienced machinist, Mr. Frank O'Hara. The equipment was completed in time for the cruise, but not in time for prior testing. The basic instrument consists of an in situ probing device which is introduced into the sediment via a free fall of a few meters. The probe is lowered on a cable to the desired free-fall height off the bottom and then allowed to plunge into the bottom. A separate multiconductor cable provides power to the sensing electrodes and carries the signal back to the recording instrument on board the ship. The probe consists of a six electrode sensing head mounted on the end of a 12-foot long, 1 3/4-inch diameter heavy walled, stainless steel tubing. A set of large stainless steel fins are welded to the upper end of the probe to insure free-fall stability. The lowering cable is fastened to a bail welded to the top of the fins.

The probe is equipped with an indexing device to indicate the degree of penetration into the sediment, and also to give an indication of the rate of pull out of the probe from the sediment. This device consists essentially of two basic parts. The inner part consists of 12 magnetic proximity switches strung inside the probe at one foot intervals. The outer part consists of 18 electro magnets mounted in the hub of a wheel-like device which fits loosely around the barrel of the probe. Spokes radiating from the hub are welded to an outer rim approximately 18 inches in diameter. When the probe plunges into the sediment the wheel remains essentially on the surface closing each magnetic switch in turn as it passes through the magnetic field. Each closing is recorded as a kick on the continuous recording device. The number of kicks indicate the depth of penetration. As the probe is withdrawn these same switches are closed in reverse, and the rate of pull out can be determined. Although the current to the probe is continuously on while it is in the water, actual sediment logging is done during withdrawal, as the pen recorder cannot keep up with the speed of penetration.

The laboratory core logging device consists of two steel traveling bars mounted in a rigid frame which is in turn bolted to a sturdy base. A small box-shaped carriage, to which the sensing electrodes are attached by adjustable holders, is driven along the bars by an electric motor. Also mounted upon the carriage is a Selsen motor which is electronically linked to the paper drive mechanism of our recording device, a four-pen Westronix recorder. The speed of the paper chart drive is controlled by the speed of the carriage.

The basic electronic unit is a control panel containing a current source and an amplifier system which provides a controlled current to the sensing electrodes and amplifies the return of the recorder.

The system can be operated in two modes. A guard electrode mode whereby an extra set of electrodes causes the current to be focused deep into the sediment insuring the measurement of resistivity away from the distrubed zone next to the probe. In the second or shunt mode, the guard electrodes are bypassed, and a point resistivity is made.

The equipment is all mounted in a renovated, surplus Air Force helicopter power van. The entire system is therefore transported to and from the ship as a single unit.

Industrial Participation: During the past year the program has been received with great interest both by individuals and groups in industry as well as by people in the academic world. The project is primarily matched by Electrofilm Inc. of North Hollywood, California. Well Reconnaissance of Dallas, Texas has loaned us a gamma-ray logging tool, a caliper logging tool, and all of the electronic control devices necessary to operate these two tools. U.S. Steel donated 250 feet of seven-conductor armored steel cable for use on a special Eh logging device loaned by Dr. Pirson of the University of Texas.

Dresser-Atlas of Houston donated a special adapter connection to connect the cable to the instrument, and sent a skilled technician from Houston to College Station to attach the connector to the cable. The activity leaders have had several conferences with Sun Oil Company in Dallas who are also interested in the project. They have provided us with the results of a horizontal resistivity survey which they conducted in the Gulf some years ago, as well as all of the technical information which they possessed concerning the operation. Dr. Christopher Crowe, a research geophysicist for Sun Oil Company, participated in the first half of the cruise on which this equipment was tested.

We have had several conferences both in Austin and in College Station with Dr. Pirson who was mentioned previously. Dr. Pirson is considered one of the foremost authorities on electrical logging. He loaned us two specially designed Eh measuring devices which we used on the cruise. The larger of the two devices was towed, and the smaller lowered vertically while stopped on station. Dr. George Huebner of Texas A&M University has designed and built all of our electronic equipment, and is still in consultation as to improvement of equipment as well as the designing of new equipment. We are in close contact with other members of the Department of Oceanography, particularly the chemical section. Dr. William R. Bryant has cooperated closely, and we have had consultations with members of the Department of Geophysics.

We have been in contact with Dr. Kermabon, formerly head of the SACLANT group in Italy, now in private industry in France. Dr. Kermabon directed the group which successfully built and tested a resistivity probe. He has offered to collaborate in design of our device.

We have been in contact with Dr. van Batenburg, Director of the SACLANT laboratory, and he has sent us the complete blueprints for their probe. It must be added that although this device worked, it was too large and cumbersome for our purposes, and we proceeded with a much simpler and smaller device.

The University of Rhode Island provided four men for cooperative work on our cruise, two men for the first week, and two for the second. The Navy Defense Laboratory located in Rhode Island works in conjunction with the University of Rhode Island, so they are at least indirectly involved in cooperation with our project.

The U.S.G.S. located at Woods Hole has expressed interest in using our logging equipment on their Red Sea project. The U.S.G.S. in Corpus Christi has expressed interest in using our equipment, and ONR has commented favorably upon applying the logging techniques to portions of their projects.

On October 14-15, 1970, the Geological section of the Department of Oceanography at Texas A&M is sponsoring a seminar for interested members of industry to familiarize them with the activities and personnel of the section. A presentation of the goals, instruments and results of this Sea Grant project will form a part of the seminar.

Development and Implementation of SCUBA Diving Training Program for Scientists and Technicians in Academic Institutions, State and Federal Agencies (Education and Advisory Services)

Activity Leader: William P. Fife, Ph.D., Professor, Biology.

Soon after the Sea Grant Program was initiated at this University it became apparent that the use of scientist-divers was essential to the successful conduct of a number of sophisticated projects being undertaken under the auspices of this University and the Sea Grant Program Office. It was also quickly realized that the qualified and trainable divers who presently are members of this University constitute a major Marine Resource of this institution.

The experienced divers on the faculty and staff realized that the great increase in University-sponsored marine diving presented an increased hazard which, if not regulated and supervised, could cause embarrassment or even litigation to the University. They also realized, however, that this program offered an opportunity to train technician- and scientist-divers who could better conduct their research.

It, thus, was determined to develop a program which had two major immediate goals:

a. To establish a Diving Safety Program which would assure the Institution that adequate precautions and controls are being exercised in its behalf and to assure the safety of the individual.

b. To conduct training and actual diving programs to test our safety procedures and to develop the most effective way to supervise diving under a variety of conditions.

Project Description and Report of Work and Accomplishments

Although this program was not begun until February 1, 1970 it has realized six significant accomplishments as follows:

1. Preparation of the University Guide for Diving Safety.

   This document establishes physical prerequisites and standards for students who wish to enroll in SCUBA diving training. It also sets up medical standards and provides guidance for physicians who are asked to certify as to the health of diver

students. In addition, this Guide recommends the various committees, boards and officers needed, and outlines their responsibility and authority. These recommendations can serve as a basis for appointments by the University administration.

This Guide brings together for the first time guides, regulations, and policies from a number of educational institutions who have had experience in this field. It probably represents the best such document in this country to date.

This Guide was published as a Sea Grant Publication and already is being used by a number of institutions and instructors in their own diving training programs.

2. In an effort to gain additional experience in all aspects of scientific marine diving this program supported two diving scientists who participated in the TEKTITE II underwater living program in the Virgin Islands. These divers were provided equipment and certain funds from this program.

3. Several members of the SCUBA diving group supported by this program took part in the State of Texas-sponsored search for sunken Spanish galleons. Indeed, one of our group was the first to dive on one of the newly discovered wrecks. This provided considerable experience in underwater search techniques.

4. In order to obtain experience in multidisciplinary diving this program supported a special cruise to the Gulf Flower Gardens, a tropical reef located about 100 miles from Galveston, Texas. Divers supported by this program carried out 2 recoveries of a penetrometer dropped in conjunction with the Sandia Corporation. They also placed on the bottom two special racks, designed to study the effects of reef water on a number of different metals, plastics, wood, etc. This was a 4-day cruise which included the conduct of diving operations during moderately heavy weather.

5. As a part of this program an effort was made to consolidate diving equipment throughout the University and set up maintenance and inspection schedules to assure that all equipment (even personal gear) used on a University-sponsored dive is in excellent condition. This has resulted in a much expanded diving locker which now is able to serve the needs of the entire University for the foreseeable future.

6. As a basic part of this project a 100-hour Marine Diving Training Program was developed. This program makes it possible to take graduates of the University-sponsored basic diving program or its equivalent and provide sufficient additional training in the ocean environment to make him an effective and safe worker underwater.

Maritime Geology (Education)

Activity Leader: George F. Carter, Distinguished Professor, Geography.

This project grew out of a request for the preparation of a syllabus

for a course in Geography of the Ocean. The syllabus prepared ran to 300 pages, and the assembled materials (mostly in Xerox) was sufficient to fill a file drawer. It was a natural foundation for a book on the geography of the sea. Support for secretarial assistance was requested to aid in this book.

Project Description and Report of Work and Accomplishments

A section on the physical geography of the sea was prepared by dictating on tapes, using the syllabus as a guide. This produced a terse, abbreviated, manuscript lacking the fullness and fluidness desired.

The preparation was then shifted to the more laborious method of writing either in long hand or in typing work from the assembled documentation. This test was carried out on the fisheries section. The result was much more satisfactory. The text is richer and more readable. A large (ca 200 page) manuscript resulted. Work was then begun on the shipping section.

Unfortunately, excessive commitments brought the writing to a halt at that stage, and it will not be feasible to resume work before the summer of 1971.

The material assembled has been used to teach a course, Geography 315, The Geography of the Ocean. This was taught in experimental form for four students in 1969, attracted 10 in 1970, and will apparently draw still more in 1971.

The assembled material has also formed a basis for several columns written for Twin Circle Publications on the general theme of food and resources. See bibliography.

Because of this work, and particularly because of participation in the Law of the Sea Conference at Rhode Island in 1969 the project leader has been selected to serve on the Committee on Oceanography of the Association of American Geographers.

Shear Strength Determination of Marine Sediments Means of Wave Energy Ratios

Activity Leaders: William R. Bryant, Associate Professor, Oceanography.
Andre P. DelFlache, Professor of Civil Engineering, Lamar State College of Technology.

Today's rapidly expanding offshore industry necessitates a more complete knowledge of the mechanical behavior of marine sediments.

The design of adequate foundations for offshore structures and underwater installations requires the determination of the bearing capacity of the sea floor. The effectiveness of certain anchorage systems depends entirely upon the holding capacity of sediments. Potential danger areas susceptible to mass movements such as slumping can be located through the analysis of the stability of submarine slopes. The mechanical response of sediments to loading is usually analyzed for two conditions, generally considered independently. First, under the effect of loading, the sediments should not break or fail along surfaces of rupture: this is a condition related to sediment shear strength. Second, the sediments should not

deform excessively: this is related to sediment compressibility. The most important engineering properties for the calculation of the mechanical behavior of sediments are the unit weight, the compressibility parameters (cohesion index, coefficient of compressibility, preconsolidation pressure, coefficient of consolidation) and the shear strength parameters (cohesion and angle of internal friction).

These engineering properties are determined by laboratory tests performed on core samples. Sediment investigations in shallow water depths rely on current technology, as developed by Soil Engineers onshore, and coring penetration depths can be of several hundred feet when necessary. Sediment investigations in deep water is presently limited by the shallow penetration depths from which core samples can be obtained.

The problem is, therefore, to establish a method by which the pertinent mechanical parameters of marine sediments can be determined sufficiently accurately and at sufficient depths below mudline over large water-covered areas. The method should also be economically feasible.

Offshore seismic surveys produce a continuous graphic profile of acoustic signals which reveal the geometry or at least the topology of subsurface horizons and geological structures beneath the sea floor. Since these surveys are economical in terms of area coverage, the objective of this research project is the development of a seismic system which will allow the determination of the most important engineering properties for the calculation of the mechanical behavior (bearing capacity, holding capacity and slope stability) of marine sediments.

The use of such a system over the oceans could contribute toward the establishment of detailed geotechnical charts.

Project description and Report of Work and Accomplishments

The apparatus built during the first year (Sept. '69 - August '70) aimed at the evaluation of the "degree of solidity" or the "state of consistency" of sediments.

Since sediments are not perfect liquids nor perfect solids, their state of semi-solidity lies in a transition zone between the liquid state (where only compressional elastic waves can exist) and the solid state (where both shear and compressional waves can propagate).

The immediate objective was the establishment of an empirical relationship between compressibility, shear strength and wave energy ratio in marine sediments of identical environment.

The wave energy ratio of a sediment is hereby defined as the ratio of vibrational energy transported by shear waves to that transported by compressional waves (attenuation), and the compressibility and shear strength of the sediments being traversed. The instrumentation was designed to generate and receive compressional and shear waves in a sample of sediment placed in a cylindrical aluminum container.

According to the Mohr's Circle theory, a square element of sediment subjected to equal and opposite principal stresses should be in pure shear at 45° from the principal directions. By analogy with the wave guide theory, it was assumed that the desired oscillating stress field could be generated by establishing resonance or a standing wave pattern of the

$T_{2,1,1}$ mode in the cylindrical sample.

For a wave velocity of approximately 5000 ft/sec., the optimum conditions were computed to occur at a frequency of 30,000 H. in a cylindrical sediment-filled 5.25-in. diameter cavity, 2.5 in. deep.

To generate the compressional waves, four transmitting transducers were placed at the N, S, E and W positions around the cavity. These transducers are 1/16-in. diameter steel rods inserted into the resonant ring and hence into the sediment. At the end are small steel spheres for introducing a spherical wave. The initial experiments were conducted with 1/8-in. steel balls, they proved to be too small. They were replaced by 1/4-in. steel balls: the signal was improved. The new assembly, uses 1/2-in. steel balls.

The 2.5-in. long steel rods are maintained in the container's wall through a system of small "0" rings which also provides the necessary acoustical insulation. The steel rods were first excited by a system of two coils: A.C. current in a small coil built around the end of the rod, D. C. current in a larger coil acting as an electromagnet. This system cannot generate enough energy without becoming quite bulky.

A system of convertible drivers (Electro-Voice, Model 188C) to generate vibrational energy in the steel rods proved to be very satisfactory. Two stereo power amplifiers (DYNACO Model 120 A) capable of 60 watt output, driven by a variable frequency oscillator (202 C Hewlett Packard 12.5 MHZ Electronic Counter) is used to monitor the exciting frequency.

To monitor the energy received at 45°, four receiving transducers (sphere-rod systems similar to those used for transmitters) were placed at the NW, SW, SE and NE positions around the cavity. A stereo-magnetic pick-up (888 Series Empire Cartridge) in contact with the end of the steel rod monitors the energy received by the sphere located in the sample. This mechanical energy changed into an equivalent electrical energy is amplified by two stereo pre-amplifiers (Dynaco PAT-4 Solid State), and monitored by a Tektronix Oscilloscope (Type 561 A).

A Polaroid camera mounted on the CRT records the final data.

Preliminary results indicated that there was no relationship between the compressibility and the rigidity in marine sediments. The reasons for this lack of correlation are probably two-fold:

(1) the consolidation theory developed in soil mechanics does not always apply to marine sediments, and

(2) the static shear strength as determined by soil mechanics laboratory techniques is not proportional to the dynamic rigidity as determined by elastic wave propagation.

Consolidation tests performed on a large number of marine sediments obtained by the *R/V Alaminos*, Texas A&M Oceanographic Research Vessel, in the Gulf of Mexico indicated that high-void ratio marine clay sediments exhibit a linear void ratio-pressure relation in contrast to the non-linear relation ordinarily observed in clay soils.

The use of this linear relationship provides a more accurate evaluation of the preconsolidation pressure and a more precise determination of the "compressibility" of the upper five meters of marine sediments.

It then became important to relate this newly determined "compressibility" with the compressional wave velocity. This was accomplished with a velocimeter connected to a consolidation apparatus. The analysis of laboratory measurements made of the coefficient of compressibility, compressional-wave velocity, density and void-ratio of marine sediments indicates that there is a relationship between the coefficient of compressibility and the velocity of compressional waves.

It is different from the suspension equation in which the bulk compressibility is the result of two components: the particle and the water compressibilities. The difference lies in an additional component of the bulk compressibility: the "frame compressibility" which was found to be related to the coefficient of compressibility. It is concluded that the determination of the compressibility characteristics of marine sediments can be made by in-situ measurements of the compressional wave velocity.

Marine Geochemical Analysis (Research)

Activity Leader: William M. Sackett, Associate Professor, Oceanography.

Project Description and Report of Work and Accomplishments

The expertise developed in several programs in chemical oceanography at Texas A&M University has valuable implications concerning the present emphasis on environmental awareness. Early in 1970, a change in the directions of our effort was initiated to take practical advantage of our capability. These new directions are as follows:

1. Dissolved light hydrocarbon distributions--Rather than finding natural seeps, our expertise is useful in determining the extent of light hydrocarbon pollution of offshore waters. There is some information available that indicates the dissolved light hydrocarbons which are somewhat soluble in water have deleterious effects upon marine life.

2. Dissolved organic carbon (DOC)--A recent paper and thesis of ours shows that this parameter is a sensitive indicator of industrial and sewage pollution of natural water. For example, about one half of the DOC being added to the Gulf by the Brazos River is due to man's activities. Also two separate studies a year and a half apart indicate over a 100% increase in DOC in the Houston Ship Channel during this period. A program of continual monitoring of Gulf Coast waters for this parameter has been initiated by us.

3. Radiocarbon and tritium--Little attention has been paid to radioactive pollution along the Gulf Coast. With the proliferation of nuclear power plants in the wide area of the U.S. whose rainfall, with its nuclear power plant produced C^{14} and H^3 contaminants, runs into the Gulf of Mexico; this problem should be immediately considered. A baseline study with an annual brief survey of coastal water and organisms is proposed.

4. Crude oil fingerprinting--The carbon isotope composition (capability only in the oceanography department of TAMU) has been shown to be

the best correlation indicator of many methods studies over the years. A program of routine analysis of the oil spill source and beach, organism and other occurrences is being initiated.

Coastal Zone Problems Institute for Elementary and Junior High Teachers (Advisory Services and Education)

Activity Leader: Earl Jones, Professor of Curriculum and Instruction, Sociology.

This project was designed as the initial step in the development of a program for elementary and junior high educators. A pilot summer institute was outlined, centering on the incorporation of audio-visual aids and special coastal zone problems into science and social science curricula. The summer work included working with elementary and junior high personnel to identify areas of study and the collection of materials suitable for audio-visual teaching aids. Contacts with educational facilities were established to aid in the development in the summer program of 1971.

Project Description and Report of Work and Accomplishments

With the assistance of the Education Service Center - Region II in Corpus Christi, initial planning was made for the pilot program in the summer of 1971. Using the Texas A&M Agricultural Experiment Station at Beeville as a headquarters, the program has been outlined as a six week summer session which will offer six graduate credits. Organizational meetings, under the direction of Dr. Earl Jones, were held through the summer to outline the program. Mr. Fred Smith of Geology, Dr. Delmar Janke of Curriculum and Instruction, and two graduate assistants will serve as the staff working under Dr. Jones.

The coastal zone was photographed with 35 mm slide cameras and 16 mm movie cameras to begin the assemblage of suitable film units. These materials will supplement existing visual aids in the creation of audio-visual teaching units. Trips along the Gulf Coast, as well as the filming of hurricane Celia, are included in the summer work.

Contacts with educational facilities along the Texas Coast, as well as many Sea Grant affiliates were established. A review of similar existing programs in elementary and secondary education was commenced. Newspapers, television and radio media were contacted in order to include special resource and reference material in the program.

Pertinent literature was collected. This included lists of books dealing with the marine environment, the environmental crises, socio-economic status of the Texas Coast, etc. Besides educational facilities, state and federal government offices were contacted as to these subject areas. A reference library of these materials, along with texts and reprints was established.

Review of all these matters pointed to the urgent need for a program of this nature. Both the University and the Sea Grant realize the importance of better preparing educators to meet the needs of the people.

Marine Geochemical Analysis of Deep Ocean Core Samples (Research)

Activity Leader: Dr. R. E. Wainerdi, Associate Dean, Engineering College

This project has been directed toward the following objectives:

(a) Determine if trace element analysis can be utilized to substantiate the concept of metallogenisis

(b) Develop methodology for large-scale mineral exploration, both terrestrial and marine.

(c) Analyze deep sea core samples from the JOIDES Deep Sea Drilling Project.

Neutron activation analysis procedures have been used to determine the major elements present in core samples from Legs 1 through 6 of the National Science Foundation's Deep Sea Drilling project. Core samples from each Leg of the expedition were obtained from Scripps Institution of Oceanography and analyzed for Si, Al, Fe and O using 14-MeV neutron activation analysis methods developed at Texas A&M University during the first year of this project. This project has provided the only source of elemental analyses for inclusion in the initial core descriptions which are being published by the NSF subsequent to each Leg. In addition to major element analyses, attention has been focused on the use of reactor neutron activation analysis for trace element determinations in deep sea core samples and on the development of efficient and accurate data handling methods.

Project Description and Report of Work and Accomplishments

This project continued the use of 14-MeV neutron activation analysis for determination of the major chemical elements composing deep sea sediment samples as well as the development of new methodology for improving the data quality and measurement efficiency. This method was chosen because of its ability to provide rapid, non-destructive analyses of a relatively large number of samples. The elements of interest were: oxygen, silicon, aluminum, magnesium and iron.

During the year ending August 31, 1970, a total of 231 deep sea sediment samples from the Drilling Ship Glomar Challenger were received as indicated below:

Leg	Quantity Received
V	79
VI	15
VII	55
VIII	82
Total	231

Results on Leg V and VI samples have been submitted to Scripps. The details of the 14-MeV neutron activation procedures have been reported in the literature and will not be repeated here.

Reactor neutron activation analysis offers additional analytical possibilities for minor and trace constituents of sediment and rock materials, provided that methods are available to resolve identify and quantify the many components present in the gamma-ray spectra. Special-

ized computer procedures are being developed to handle the very complicated spectra which are obtained from the high-resolution spectrometer. One of the more significant programs developed under this project is the computer program KRIS-II, designed to be used for the quantitative or qualitative and quantitative analysis of gamma-ray spectra. The user can specify a particular set of standard gamma-ray spectra to be employed in the weighted least-squares quantitation, or optionally the qualitative choice can be left to the program in cases where the activities are unknown, or at best uncertain.

The processing of gamma-ray spectral data from lithium-drifted germanium, Ge(Li), detectors generally involves the handling of large numbers of channels of information, typically 1024-4096 channels, and since many standard spectra must be stored for frequent retrieval, a direct-access disk storage must be utilized to provide the necessary bulk storage, and to provide the rapid access. The standard spectra stored, and the sample spectra processed are digital representations of an analog intensity-versus-energy response curve, and resulting from instabilities in the instrumentation, are subject to changes in gain and base line calibration, the gain and base line being analogous to the slope and intercept, respectively, of a straight line. As it is imperative that all standards and samples processed have the same gain and base line calibration, a gain shifting routine will be required in the program.

For a given sample count, a large number of the channels are found to represent counts observed in the Compton continuum regions, these regions resulting from partial energy depositions of the gamma rays in the detector, and another sizeable portion of the channels may contain very small numbers of counts (approximately background), particularly in the high energy region of the spectrum.

The first area mentioned, the Compton continuum, appears as almost a straight line when successive channel intensities are considered. Thus, there appears to be little "unique" information in this area. A computer program which would probably not be hurt by this omission of data; and indeed, the omission may enhance the performance of the least-squares method.

The variance of the data in each channel of information used in the fit must be estimated from the sample spectral data to construct the weighting matrix. The variance estimates obtained when the number of counts in each channel is small tend to be poor estimates of the true variances, so that exclusion of these "difficult" estimates would likely present a problem more liable to a concise mathematical description.

The least-squares method is also sensitive to the correct specification of the linear model to be used. That is, the correct set of standards should be specified. If an incorrect set of standards is specified, or a deliberate omission is made because some standard is not available, it would be desirable to inhibit from consideration the area of the spectrum containing the primary interference from the unaccounted activity, the primary interference being the photopeaks.

As a possible solution to the three problems mentioned above, the program will select a set of channels for the analysis, based on the library information concerning the standards actually specified. In

instances where the set of standards is not specified, a qualitative analysis routine, in conjunction with a photopeak location and evaluation routine, will determine the required set of standards. Peaks located, but determined not to be members of the library reference data will be excluded from the least-squares fit.

The testing of KRIS-II was performed by preparing a small library of standard spectra, and then subsequently using the separate standards as samples to be analyzed by the program. The standards library consists of the activation products of the elements Arsenic, Cadmium, Copper, Dysprosium, Erbium, Manganese, Potassium, Silver, and Sodium, plus a six-hour background spectrum.

The data, in general, are quite encouraging, through leaving room for improvement in some instances. The components determined in the aluminum spectrum, though at low levels, illustrate the need for knowing the correct model, and the necessity of having a complete library of standards. The same problem is noticed for the spectra of cadmium and dysprosium, though not as dramatic, and would in many cases be acceptable.

Future tests of KRIS-II will involve the compilation of a much more extensive library of standards, and the subsequent analysis of real samples, such as the U.S.G.S. standard rocks G-2, BCR-1, and GSP-1. During these tests the qualitative analysis routine will be explored in detail to evaluate its utility for selecting the proper model to present to KRIS-II for a least-squares solution, as well as masking out channels of information which cannot be explained by information in the Library Reference Data Set.

Parallel with the development of the KRIS-II program, selected JOIDES samples from Leg III were subjected to instrumental reactor neutron activation analysis as an initial step toward assessing relationship between trace element concentrations and the theory of metallogenic provinces. A total of 31 samples from 4 different drilling sites near the mid-atlantic ridge were analyzed for Sc, Ce, Co and Br. Since conventional peak area methods were used in this series of analyses, the number of samples and elements sought was limited. By using more advanced techniques included in the KRIS-II comcept, it appears feasible to obtain results on larger numbers of samples for many more elements than can be accomplished with present approaches. With larger numbers of samples and elements, it will then be possible to determine if trace element patterns in the ocean floor are correlated with other geological factors associated with ocean floor spreading or with the formation of metallogenic provinces.

PUBLICATIONS AND DOCUMENTATION

Work conducted through the Marine Sciences program has been published in general and technical reports, professional journals and periodicals, and has been presented at conferences and seminars.

Technical and General Reports

Hoffman, B. W. "KRIS-II, A Computer Program for the Least-Squares Resolution of Gamma-Ray Spectra, Using Selected Data Channels," *Internal Report*, January, 1970.

Kuykendall, W. E., Jr., B. W. Hoffman, and R. E. Wainerdi "Major Element Composition of Selected JOIDES Core Samples from Leg B," *Initial Reports of the Deep Sea Drilling Project, Vol. 3* (in press)

Kuykendall, W. E., Jr., B. W. Hoffman, R. E. Wainerdi, "Major Element Composition of Selected JOIDES Core Samples from Leg VI," *Initial Reports of the Deep Sea Drilling Project, Vol. 4.* (in press)

Schroeder, William W. and William P. Fife. *University Guide for Diving Safety*. Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-602. May 1970. 28 pp.

Professional Journals and Periodicals

Chmelik, Frank B. and Arnold H. Bouma. "New Logging Technique will Speed Ocean Bottom Surveys." *Ocean Industry*. Houston, Texas: Gulf Publishing Company. Vol. 5, No. 5. May 1970. pp. 56-59.

Hoffman, B. W. and R. E. Wainerdi, "KRIS--A Computer Program for the Least Squares Resolution of Gamma Ray Spectra by Half-Life and Gamma Ray Energy" *J. Radioanalytical Chem. 4.* (1970), pp 375-382.

Sackett, W. M., J. M. Brooks, and A.D. Fredericks. Evaluation of Organic Carbon as an Indication of Pollution in the Brazos River Basin, Texas. *Environmental Science and Technology.*

Sackett, W. M., D. J. Frank, R. Hall, and A. D. Fredericks. "Methane, Ethane and Propane Concentrations in the Gulf of Mexico." *Journal of the American Association of Petroleum Geologists.* October 1970. (This paper was accepted for presentation at Interocean '70 in competition with many others from the U.S.A.)

Conference Papers Presented

Chmelik, F. B. and A. H. Bouma. "Electrical Logging in Recent Sediments." Dallas, Texas: Offshore Technology Conference. Paper Number OTC 1147. 1970. 8 pages.

DelFlache, Andre P. and William R. Bryant. "Compressional Behavior of High-Void Ratio Marine Sediments," Offshore Technology Conference OTC 1148, April 1970.

Kuykendall, W. E., Jr., B. W. Hoffman, and R. E. Wainerdi. "Analysis of Oceanographic Samples by 14-MeV Neutron Activation," *Proc. Second Oak Ridge Conference on the Use of Small Accelerators for Teaching and Research*, Conf-700322 (1970), pp 221-230.

Kuykendall, W. E., Jr., B. W. Hoffman, and R. E. Wainerdi, "Analysis of Oceanographic Samples from the SLOMAR CHALLENGER Voyage," *Proc. NATO Adv. Study Inst - Activation Analysis in Geochem. and Cosmochem.* (in press).

MARINE ENGINEERING AND TECHNOLOGY

Sea Grant projects in the Marine Engineering and Technology program cover a wide variety of areas. Included are research and education projects in coastal and ocean engineering, instrumentation and hardware, fouling and corrosion, testing and evaluation, and supporting technology. Eleven projects are reported here for 1969-70.

Development of an Automatic Marine Corer (Research)

Activity Leader: E.I. Bailey, Coastal Engineering Division, Mechanical Engineering

The tools and techniques used today in ocean mining and exploration for obtaining undisturbed samples of the seafloor leave something to be desired. They require either logistic support from divers on the bottom or must be operated from large surface ships with multipoint anchoring. Upon request of several Ocean-Geological concerns, a program was initiated to design a self-contained automatic seafloor setting corer which could:

1) extract up to fifty feet of continuous undisturbed core by the fixed piston method.
2) operate in depths of up to 1,000 feet of water.
3) core in hard as well as soft material.
4) be as compact as possible to facilitate shipboard handling.

This project was partially funded by Oceanonics, Inc., Houston, Texas.

The benefits of this program to the Sea Grant Program and to other geoscience concerns is that a much needed research tool would be designed. It was intended that this program would lead to a construction program the following year.

Project Description and Report of Work and Accomplishments

This project was initiated on February 2, 1970. The purpose was to design an automatic marine corer with the aforementioned characteristics Dr. E.I. Bailey was the project leader. Dr. H.J. Sweet of the Mechanical Engineering Department at Texas A&M University and Dr. W.R. Bryant of the Oceanography Department assisted with advice and information. Dr. J.L. Harding, Vice President of Oceanonics, Inc., Houston, Texas, and Mr. B.R. Bowen, a Consulting Marine Engineering in Houston, Texas, offered considerable assistance in the design of the coring device. Mr. G.L. Davis, a Graduate Student, had taken the design project as a thesis topic and therefore did a large amount of the work on the project. He was assisted by Mr. H.O. Henderson who was also a Graduate Student. There were several undergraduate students who helped on the project.

The first months of the project were spent trying to separate and evaluate the parameters for designing the coring device. Much time was spent with Mr. Bowen since he has had extensive experience in marine machinery. Communications with the Oceanography Department and with Dr. W.R. Bryant helped in determining the mechanical characteristics of the various types of cores to be taken. Following the parameter study, a search was conducted to find the best equipment to use in the coring device since it was desirable to use off-the-shelf items as much as possible. The basic design was completed in about five months and the work of putting this into the form of machine drawings began.

In May 1970, a letter was received by Dr. Bryant from Mr. M.C. Hironaka of the Naval Civil Engineering Laboratory, Port Hueneme, California. This letter enclosed a drawing of a coring unit that the Navy was considering building and asked if there might be any local interest. A letter was returned stating that a unit was already under consideration locally. Mr. Hironaka called and a lengthy conversation resulted. He is interested in the Sea Grant Corer but has advanced too far in his own corer design to drop it.

In August 1970, Mr. R.D. O'Brien sent a letter to Dr. E.I. Bailey stating that he was interested in the Sea Grant Corer. Mr. O'Brien is Research Supervisor for the Marine Minerals Technology Center, Bureau of Mines, Department of the Interior. He requested that he be allowed to visit Texas A&M University to look over the design of the corer. After spending a full day going over the design and the considerations, Mr. O'Brien seemed to be very pleased with the results and is interested in funding the construction of the corer pending a sufficient budget.

Coastal Engineering (Research)

Activity Leader: Robert M. Sorensen, Civil Engineering

Safe and economical design of pile supported structure in the marine environment is of major importance to the development of marine resources. The hydrodynamic forces acting on a pile will generally increase as the surface roughness increases (e.g. due to the growth of the marine organisms, natural roughness of the pile). The largest and most significant forces acting on a pile are those unsteady drag and inertia forces caused by surface waves.

The overall objective of this project is to experimentally study the forces that act on a circular cylindrical pile subjected to monochromatic waves and having a surface that is smooth and then has varying degrees of roughness. During the first year of the study a literature search was completed; a model pile (3.74 in. dia. and 36 in. long) was designed and constructed; and this pile was installed in the wave tank, verified and calibrated.

The objectives of the second year of this study were to measure wave forces and moments on the pile caused by waves having a variety of lengths and amplitudes for a range of pile surface roughnesses; to develop a computer program to reduce these data measurements; to reduce the data; and to present the final results.

Project Description and Report of Work and Accomplishments

The model test pile and strain gage sections were machined from aluminum to very close tolerances. The pile surface was polished in preparation for the smooth surface tests. After these tests, selected sand grains having three different size ranges were alternately glued to the pile surface and the tests run with the smooth pile were duplicated for each surface roughness. The sand grain diameter ranges used were 0.023 - 0.033 in., 0.065 - 0.079 in., and 0.132 - 0.157 in. The ratios of average grain diameter to pile diameter were 0.0075, 0.0186, and 0.0361. The last corresponds to a marine growth of 1.7 in. in a 4.0 ft. diameter pile.

During each test run the wave caused force and moment on the pile and the water-surface time-history at the pile and 7 ft. ahead of the pile were measured continuously for at least 20 waves. This was done for 22 different combinations of wave height and period; the same combinations being used for each surface condition for a total of 88 test runs. The wave period varied from 0.82 to 1.67 seconds and the wave height varied from 1.83 to 9.78 in.

Each force and wave characteristics record from each of the 20 waves from each of the 88 tests runs had to be analyzed; a process that required several man-months of effort. The maximum force on the pile and maximum wave amplitude; the force and wave amplitude at the wave crest and one-quarter of a wave period past the crest; the wave period; and the time interval between the appearance of a wave crest at the pile and at the wave gage ahead of the pile had to be taken from the recorder printouts for all 1760-plus waves. Linear wave theory was used to calculate the wave kinematics (particle horizontal velocity, local acceleration, and orbital diameter) for each wave at 12 different locations along the submerged portion of the pile.

Certain problems such as the slight different in speed of the recorder charts when set for the same speed and the oscillation of the pile at its natural frequency (0.2 cycles/second) in response to certain waves had to be overcome as data reduction proceeded. All calculations were carried out by the TAMU IBM 360-65 computer through a program developed for this study.

Average values for each wave and force record were used to calculate the Coefficients of Drag (C_D) and Mass (C_m); the Reynolds number (pile diameter x root-mean-square horizontal particle velocity $\div$ fluid kinematic viscosity); Keulegan-Carpenter parameter (wave period x root-means square horizontal particle velocity $\div$ pile diameter); Acceleration Modulus (root-mean-square horizontal local acceleration x pile diameter $\div$ root-mean-square horizontal particle velocity squared); maximum force corrected for increase in pile diameter due to surface roughness size; and Total Resistance Coefficient ($C_D + C_m \pi/2$ x Acceleration Modulus).

The most common approach to the presentation of wave-forces-on-pile data is to plot Coefficients of Drag and Mass (C_D) and (C_m) as a function

of Reynolds number. These plots for the four different surface conditions showed the usual scatter but, no indication of effects of surface roughness. The same was found for plots of C_D and C_m as a function of the Acceleration Modulus and the Keulegan-Carpenter parameter, and for a plot of the Total Resistance Coefficient as a function of the Acceleration Modulus. Thus, no specific conclusion could be drawn as to whether an increase in the surface roughness of a pile effects the drag or the inertial component of force in any specific way.

However, when the maximum force excerted on the pile was plotted as a function of Reynolds number a definite increase in force was found as the surface roughness increases. It is this maximum force that will do the most damage. This maximum force also generally increased as the Reynolds number increased indicating an even greater effect on prototype size piles. For the roughest pile and highest Reynolds number, the increase in maximum force was 23 percent.

It is of interest that the common approach of evaluating C_D and C_m did not indicate an increase in force that consistently occurred. This is due partially to the camouflaging effect of the scatter typical in C_D and C_m versus Reynolds number plots.

Acoustic Communication (Research)

Activity Leader: Stephen Riter, Electrical Engineering

Underwater acoustic communications has the potential of providing the oceanographer, fisherman, and others interested in the development of marine resources with new dimensions in the area of data collection. In this study it is proposed to survey the present and future communications requirement of those engaged in ocean science, industry, and technology in order to specifically gauge the need for acoustic communications systems. Modulation, multiplexing, and signal processing techniques to satisfy these needs would then be studied. From these studies, designs of practical systems would be developed. Cost effectiveness and tradeoff studies between competing designs would be conducted. Finally, prototypes of the most attractive systems would be built and tested.

Project Description and Report of Work and Accomplishments

Work during the 1969-70 academic year consisted of general studies of representative acoustic communications techniques, specific theoretical studies of communications problems peculiar to the underwater channel, design of a PPM acoustic transmitter, and discussions with other organizations working in the area.

The purpose of the general studies was to develop basic design considerations for practical acoustic communications systems. These considerations were then applied to three representative modulation schemes: pulse position modulation (PPM), frequency modulation (FM) and frequency shift keying (FSK). These modulation techniques when used in an underwater telemetry system were then compared on the basis of system complexity, performance and reliability.

It was shown that PPM was the least complex of the methods investigated; however, PPM systems are particularly susceptible to interference and multipath. In general, PPM is a useful tool when simplicity but not absolute realiability is a design criterion.

FM is a slightly more difficult technique to instrument but one which can give a concomitant increase in accuracy and reliability. In addition, FM provides some immunity to Rayleigh fading and interference.

For applications where one is willing to pay a comparatively high price for reliability, FSK seems the obvious choice. One can, with a FSK system, use various combinations of diversity, coding and equalization to obtain as low a probability of error as desired.

A number of unresolved communications theory questions which have special significance to the underwater channel were investigated. These include studies of PPM telemetry systems, and of digital FSK telemetry systems. As a result of the PPM studies, techniques were developed for calculating the required transmitter power, pulse repetition, rate, and pulse width to communicate over some specified geometry in the presence of background sea noise, multipath, and time dispersion.

Digital signals transmitted through the underwater channel are subjected to time dispersion and reverberation. Studies with other Electrical Engineering Department members were conducted to develop a linear systems model for a general reverberation system. The results of this work cast new light on this phenomena. Although the procedures developed for eliminating reverberation do not appear to be easily realized in an acoustic communications system, they are directly applicable to the closely related problem of marine seismic signal enhancement.

Another important problem associated with digital transmission is to find practical realizations for theoretically optimum systems. Problems studied included the selection of filter bandwidths for Rayleigh fading signals, the effects of limiting, and the improvement to be gained by using various forms of diversity. Work in this area will be continued through the 1970-71 academic year.

To test some of the theoretical concepts developed, a working PPM underwater acoustic transmitter has been designed and built. A receiver is presently being designed. The transmitter can serve a number of purposes. It can, of course, be used to telemeter measurements from remote locations, and to verify the design criteria developed from the theoretical studies. Because of built-in flexibilities, it can also be used to measure the characteristics of the underwater channel. It is planned to test this device at sea in October 1970.

In addition to the work described above many contacts with government and commercial users and designers of underwater communications equipment have been made. As a result of these contacts, considerable

insight into commercial uses of underwater acoustics have been gained. In some cases results of our studies shed new light on practical current problems. In other situations, discussion of problems encountered in the field have helped guide our investigations.

The Measurement of Structural Properties with Nonlinear Acoustic Interactions (Research)

Activity Leader: Jerald W. Caruthers, Assistant Professor, Oceanography

The feasibility of determining the properties of sediments by nonlinear acoustics is presently under investigation. If the workability of this technique can be demonstrated, a probe with which an in situ survey of the nonlinear properties may be conducted will be developed.

Viscoelastic properties--to which we hope to relate the nonlinear properties--of the sediments are of great importance in ocean technology. For example, the oil industry needs this information in both the exploration for oil and the design of drilling platforms and pipelines.

Project Description and Report of Work and Accomplishments

In this first year's activities, investigators have been designing and building the hardware and electronic components needed to carry out this project. Presently most of the electronics is complete. The major task that remains is the fabrication of the transducers. This work is now in progress.

Industry has not yet been approached with the technique since it is still a theoretical development. After it is demonstrated that the phenomenon exists in nature, petroleum companies will be contacted to seek industrial interest in the application of these methods.

Development of a Course in Underwater Acoustics (Education)

Activity Leader: Jerald W. Caruthers, Assistant Professor, Oceanography

A three hour graduate course in Marine Acoustics was developed. This course stresses practical aspects of generation, transmission, and reception of underwater sound. The course is designed to acquaint those who have interests in ocean-related technology to marine acoustic technology.

Project Description and Report of Work and Accomplishments

This course was taught in the Spring of 1970. There was an enrollment of ten graduate students--2 electrical engineers, 1 geophysicist, 1 statistician, and 6 oceanographers. Ronald C. Thompson, a student in the course

and a graduate student in physical oceanography, helped gather resource materials. In the course of this work, a set of lecture notes was developed. These notes have been filed with the Sea Grant Program Office.

In addition to this actual course, travel funds allocated to this project made it possible for two of the students to actually participate in acoustic experiments at sea aboard the *R/V Alaminos* and aboard the Goodyear Blump *America*. The former acoustic exercise resulted in a paper that has been submitted for publication.

Ocean Engineering (Education)

Activity Leader: Dr. J.B. Herbich, Professor, Civil Engineering

One of the significant and important objectives of the National Sea Grant Program is training of qualified manpower. The manpower is essential if we are to accelerate development of marine resources. There is a shortage of qualified coastal and ocean engineers. This fact is based on:

(a) Many contacts with Industry
(b) Requests from Industry for names of graduate students in coastal and ocean engineering program
(c) Inquiries regarding the availability of undergraduate training in coastal and ocean engineering both from Industry and from prospective students
(d) Salary scales offered to M.S., M.Eng. and Ph.D. graduates which are on the average of about $3,000 per year above those who graduate in other branches of engineering and as much as $5,000 above the average in one particular case.

The purpose of the ocean engineering project has been to strengthen the curriculum in coastal and ocean engineering and to develop new graduate courses in this field.

The objective of the second year's program was to continue development of three new courses:

(1) CE 682 Coastal Sediment Processes
(2) CE 683 Estuary Hydrodynamics, and
(3) CE 684 Shallow and Deep Ocean Dredging

All three new courses were offered during the 1969-70 Academic Year. As an additional objective the following courses were strengthened:

(4) CE 675 Coastal Engineering I
(5) CE 677 Coastal Engineering II
(6) CE 676 Ocean Engineering
(7) CE 686 Design and Analysis of Offshore and Coastal Structures
(8) CE 687 Marine Foundation Engineering

Courses CE 682, CE 683, CE 684, CE 686 and CE 687 have now been approved by the Academic Council and will appear in the next issue of the Catalog. Several graduate students conducted thesis research in coastal and ocean engineering as part of this program.

Project Description and Report of Work and Accomplishments

A major effort was directed to further development of a curriculum in coastal and ocean engineering. A graduate program was firmly established with as many as eight educators of professional rank teaching at least one course in the program. A brochure describing the program was modified and reprinted and sent to all engineering schools. Brochures (Appendix A) were also made available at major meeting such as the Offshore Technology Conference, American Society for Engineering Education, Civil Engineering in the Oceans II, etc.

Other activities included presentation of technical papers in ocean engineering by several staff members and students, arranging from seminars held on the A&M Campus, speaking to local chapters of various technical and non-technical organizations and conducting tours for high school students through the Hydromechanics Laboratories.

New, qualified students were attracted to the program from different parts of the United States and from abroad. The graduate student enrollment reached 24 students during the Academic Year of 1969-70.

Four Master of Science degrees, one Master of Engineering degree, three Ph.D.'s were awarded to students majoring in ocean engineering during the 1969-70 Academic Year.

Course Development. The courses under development were as follows:

CE 682 Coastal Sediment Processes
CE 683 Estuary Hydrodynamics
CE 684 Deep-Ocean and Continental Shelf Dredging
CE 675 Coastal Engineering I
CE 676 Ocean Engineering
CE 677 Coastal Engineering II
CE 686 Design and Analysis of Offshore and Coastal Structures
CE 687 Marine Foundation Engineering

The three new courses developed under this program were taught by Dr. R.L. Irvine (CE 683), Dr. R.M. Sorensen (CE 683) and Dr. Herbich (CE 684).

The other courses were taught by Dr. Herbich (CE 675, CE 677), Dr. Sorensen (CE 676), Dr. Coyle (CE 687) and Dr. Lowery (CE 686).

Course Description, Estuary Hydrodynamics. A three-credit hour graduate level course entitled "Estuary Hydromechanics" was taught by Dr. Irvine during the Spring Semester of 1970. In view of Dr. Irvine's background in environmental engineering, the course content varied somewhat from the course presented during the first year of the project, with more emphasis on the environmental problems in estuaries.

Four students took the course during the spring semester of 1970. Course notes have been developed and are in process of being duplicated.

Course Description, Continental Shelf and Deep Ocean Dredging: A three-credit hour graduate level course was taught by Dr. Herbich during the spring semester 1970. Five graduate students took the course.

A final draft of course notes is in the process of being typed.

Course Description, Coastal Sediment Processes. This course was given (as CE 685) during the Spring Semester, 1970. Twelve graduate students including three from the Department of Oceanography took the course which essentially followed the enclosed outline. Each student prepared and orally presented a paper on a topic of their choice pertinent to the course material.

Also, a field trip was taken to the mouth of the Colorado River near Matagorda, Texas. Profiles were measured at several beach sections and sand samples were taken along the beach and in the inlet. These were analyzed for size distribution by the Visual Accumulation Tube in the Hydrodynamics laboratories.

The course paper and the field trip lead to the M.S. thesis topic for M. Ward. His thesis dealt with the use of fluorescent dye to trace sand movement at the mouth of the Colorado River and was completed by September, 1970.

In April 1970 this course received final approval by the Academic Council and is listed as CE 682 Coastal Sediment Processes. The course will be given in the Spring of alternate years or on demand.

Coastal Engineering Laboratory. Planning of the Coastal Engineering Laboratory continued during the report period. A brochure describing the proposed Laboratory in the Annex is being prepared. The Laboratory will include a large wave tank, a large towing tank and scale models of eight Texas Gulf Coast estuaries.

Computer Programs. Several computer programs have been developed or adapted to IBM 360-65 computer, the programs were all assembled as part of the ocean engineering program in the Civil Engineering Department. Listing of the computer program follows:

(1) Stokes' Third Order Wave Theory
(2) Cnoidal Wave Theory
(3) Wave Forces and Moments on Circular Cylindrical Piles by Small Amplitude Wave Theory.
(4) Combined Effect of Refraction and Diffraction of Water Waves
(5) Wave Forces on Submerged Structures
(6) Dynamic Response of Offshore Piling

Seminars. Six seminars in ocean engineering were organized during the year. These included:

"Design and Construction of Marine Pipelines" by A.B. Crossman of Brown & Root, Inc; "Dynamic Response of Ocean Structures" by Dr. B. Edge; "Numerical Model for Predicting Motion of Mooring Systems" by Dr. R. Dominguez.

An Analytical Solution for the Dynamic Response of a Laterally Loaded Pile (Research)

Activity Leader: Harry M. Coyle, Associate Professor, C. E. Dept.

In the past ten years there has been a steady increase in the use of offshore structures for petroleum exploration and production. Many of these structures are supported on piles driven into the ocean bottom. Frequently, the critical factor in the design of these structures is lateral loads from wind and waves. These loads are time-dependent and in most instances impulsive in nature. Very little consideration has been given to the dynamic effects of these time-varying forces on these structures.

During the first year of this research project (1968-69), the objective was to develop a mathematical model which would represent, within reasonable limits, the dynamic characteristics of the interaction between individual piles and their soil and water environment. It became apparent that validation of the mathematical model required experimental data with which to compare results. Therefore, the objective of the second year of this project was to obtain experimental data in the clay soil.

Project Description and Report of Work and Accomplishments.

To obtain the experimental data needed, semi-prototype pile tests were conducted in the field in a relatively homogeneous clay stratum.

Preliminary tests were made early in the year for the following reasons:

1. to provide experimental data from which a rudimentary check of the model could be made;
2. to test the feasibility of such tests; and
3. to aid in the establishment of a meaningful and worthwhile test program.

The preliminary test piles were instrumented with only one accelerometer at the top of the pile. The limited results of these tests, however, did show that the mathematical model was giving reasonable results and that such tests were indeed feasible. They also showed that more instrumentation was needed to better determine the response along the length of the pile.

For the final test program, three piles of standard steel pipe with nominal diameters of 1.25 inches, 2.0 inches, and 3.0 inches were used. Each pile was instrumented with 4 bridges of strain gages and 2 accelerometers. The final test program consisted of 7 tests. The basic description of the configuration for each test is given in Table 1. Since most of the piles supporting offshore structures are driven into place, the test piles were also driven with a drop hammer in order to more closely simulate conditions experienced in the field. Each pile was given an initial displacement, then released and allowed to vibrate freely. Accelerations and bending moments were measured at instrumented points along the piles during the vibration period. Several parameters were varied in order to determine their effects on the test results. These parameters were pile diameter, depth of embedment, and frequency of vibration. One test was conducted with water surrounding the pile. Vibration tests were repeated on the 1.25 inch and 3.0 inch piles after approximately a two week period to determine the effects of soil setup.

The experimental data obtained has been reduced and analyzed. The computer program developed during the first year has been modified to output moment-time relationships as well as the acceleration-time relationship. As a consequence, the computer results can be compared directly to the experimental data obtained from the model field tests. If necessary, modifications to the mathematical model will be made in order to obtain better agreement between the experimental and computed data.

The third year of this project will be used to study the same test piles loaded in sand. Essentially the same 7 tests will be conducted with modifications made as deemed necessary to obtain valid experimental data.

Scour of Gulf Coast Beaches Due to Wave Action in Front of Sea Walls and Dune Barriers (Research)

Activity Leader: R. E. Schiller, Jr., Associate Professor, Civil Engineering

Little is known about the mechanics of scour and the distribution of scour patterns caused by wave action in front of beaches fronted by sea-walls or other barriers. Earlier studies indicate that the ultimate depth of scour is a linear function of wave length. It is possible that the depth of scour would depend on beach sand size, the slope of the bottom in front of the beach, the inclination of the barrier, and magnitude of wave reflections from the barrier.

Objectives during the first year of study included:

(1) Literature review
(2) Survey of Texas beach sand size distributions
(3) Preliminary small wave channel tests
(4) Tests in large glass sided wave tank
(5) Procurement and setting up of visual accumulation tube and ultrasonic distance meter.

Project Description and Report of Work and Accomplishments

A visual accumulation tube was purchased and received in early September, 1969. This device was installed and used to determine grain size distributions of a large number of sand samples secured from Texas Coast beach locations ranging from Sabine Pass on the east to Mansfield Cut on the southwest.

Analysis of these samples indicated only a small variation of median grain size of sand (mean median size about 0.10 to 0.17 mm). It was then decided that one size of sand would be sufficient for laboratory studies and approximately 20 cubic yards of sand was secured from the beach near the mouth of the Colorado River below Matagorda, Texas.

Preliminary studies were started in the small 8" wide by 40' long wave channel during July, 1970, to determine scour patterns in front of natural beaches. Wave heights and periods were varied to determine equilibrium scour patterns which generally occured after 24 to 48 hours of operation of the wave tank. It is expected that these studies will continue during the 1970-71 period.

Instrumentation, in the form of an ultrasonic distance meter, was not received until August, 1970, so it was not possible to initiate tests in the 2' x 3' x 120' glass sided wave channel. The dual channel ultrasonic distance meter is capable of measuring water depths and bottom elevation

Simultaneously to an accuracy of 0.02 ft and recording these values on a strip chart for later analysis. The meter was checked out and found to be quite sensitive in that it would record small ripples (approximately .02 ft high) on top of waves approximately 6 inches high.

Mr. Charles Chesnutt has been employed as a graduate research assistant on the project only since the start of the 1970 Spring semester but has made considerable progress in setting up laboratory wave tank testing procedures.

Coastal Engineering (Research)

Activity Leader: Dr. J. B. Herbich, Professor, Civil Engineering

Many activities along the coast in the estuaries require either repeated or continuous dredging. Such activities involve dredging of new ship channels, maintenance of existing channels, burying oil and gas pipelines, beach replenishment, etc. Other activities include offshore mining; it is generally agreed that the most economical methods of mineral recovery offshore will be by suction dredging.

The purpose of this project is to improve the cavitation performance of dredge pumps.

The first year of the project was devoted to construction of the testing facility, the construction continued through the first part of the second year and was completed by December 1969. This was a major effort, delayed to some extent by construction of the new wing of the Hydromechanics Laboratories.

Project Description and Report of Work and Accomplishment

The test stand consists of three major components: (1) Vacuum tank, (2) Pump and drive unit, (3) Instrumentation.

The vacuum tank is 11 feet in diameter and 15 feet tall with a maximum volume of 800 cubic feet. It was designed to withstand a vacuum pressure of 29 inches of mercury. A Beach-Russ, Type RP-Model 50, Rotary Piston Vacuum Pump has been installed to pull the vacuum on the tank. The pump has a displacement of 80 C.F.M. and is equipped with a vapor purge system to remove water vapor from the air pumped. The tank pressure is measured by a 40-in. absolute pressure mercury manometer, which also reads barometric pressure when the tank is open to the atmosphere.

The drive unit consists of a constant speed electric motor and a variable speed coupling. The motor is a 200-HP, 400 V, 1775 RPM Continental Electric Motor. The variable speed coupling is a Dynamic 200-HP, 50-1750 RPM, constant torque, eddy current coupling. A Morris Machine Works, Type 6-JC-14, slurry pump is presently being studied. The pump is rated at 1180 RPM with a capacity of 1300 GPM and a head of 94 feet of water.

The instrumentation for the system includes:

1) Suction side pressure by manometer and pressure transducer
2) Discharge side pressure by gauge and pressure transducer
3) Discharge by a Fischer & Porter 6" magnetic flowmeter
4) Temperature and density of the fluid flowing
5) Shaft horsepower to the pump by use of an in-line torgue sensor

6) Shaft speed by magnetic-pickup
7) Plexiglas suction side cover to be used when high speed movies are taken.

The first study was conducted on the Morris Pump. The performance curves (head, brake H.P., and efficiency vs. capacity) have been determined for clear water. Also, the cavitation characteristics (net positive suction head, NPSH) have been determined for several speeds. The solid-water mixtures investigated were several concentrations of uniformly graded sands. Both the performance curves and cavitation characteristics were determined as in the case of the clear water. The effects of these fluids on the characteristics of the pump were correlated and a method for the prediction of the effects of these fluids on other pumps is being investigated.

High-speed movies will be used to study incipient cavitation as well as other stages of cavitation of clear water. An attempt will be made to take high-speed movies of the other fluids, but it is doubtful that any useful information can be obtained since the water-sand mixture will scratch the plexiglas and the water-clay mixture will be too opaque to see through. To date, it seems that a filming speed of 4,000 frames per second gives the best results with the lighting arrangement presently being used.

Cavitation Characteristics.

Cavitation refers to conditions within the pump where, owing to a local pressure reduction due to dynamic action, cavities filled with water vapor are formed. Cavitation can be expressed in terms of the net positive suction head and defined as

$$NPSH' = (H_{atm} - H_{vp} + H_s)/S_m + \frac{V_s^2}{2g} \quad \text{.....(11)}$$

where:

NPSH' = net positive suction head, in feet of liquid,
H_{atm} = atmospheric pressure, in feet of water, and
H_{vp} = vapor pressure of the fluid, in feet of water.

A dimensionless form of the NPSH is called the cavitation index and expressed by

$$o = \frac{NPSH'}{H'} \quad \text{.....(12)}$$

where:

o = cavitation index.

A critical NPSH can be determined experimentally from tests performed at constant shaft speed, head, and capacity while the suction pressure is varied. The critical NPSH for each capacity at a constant shaft speed is the NPSH at which the total head breaks away from the initial trend to remain constant. Cavitation characteristics can be expressed as curves of critical NPSH or critical cavitation index versus capacity.

An expression for the suction conditions of a pump with respect to cavitation is called the suction specific speed (16) and defined as

$$S = \frac{N(Q)^{0.5}}{(NPSH_c)^{0.75}} \quad \text{.....(13)}$$

where:

S = suction specific speed, and
$NPSH_c$ = critical net positive suction head, in feet of liquid.

Suction specific speed is based on the use of the affinity laws at conditions approaching cavitation.

Effect of Solid-Water Mixtures. Several studies on the effects of various fluids on the pump characteristic curves have been performed. However, these studies dealt with high temperature water, butane, oils and several petroleum derivatives. The results of these studies are of little value when applied to solid-water mixtures. The above fluids have well established thermodynamic properties which can be used to describe their effect on the clear water pump characteristics. Solid-water mixtures are classified as either a homogeneous or heterogeneous mixture depending upon the grain size. Mixtures whose solid particles are smaller than 0.050 mm are considered homogeneous fluids. It has been found that these mixtures exhibit properties similar to the non-Newtonian fluid referred to as a Bingham plastic. Mixtures whose solid particles are greater than 0.050 mm are classified as a heterogeneous mixture or suspension.

A solid-water mixture can be described by its specific gravity, or as a percentage concentration of the total volume or weight. Specific gravity is related to the concentration by volume by

$$C_v = \frac{S_m - S_w}{S_s - S_w} \quad \text{.....(14)}$$

where:

C_v = concentration by volume,
S_s = specific gravity of the solids, and
S_w = specific gravity of liquid (1.00 for clear water).

Concentration by weight is related to the mixture specific gravity by

$$C_w = \frac{S_s(S_m - 1)}{S_m(S_s - 1)} \approx \frac{C_v S_s}{S_m} \quad \text{.....(15)}$$

where:

C_w = concentration by weight.

Fairbank found that at a given capacity the total head developed by a centrifugal pump handling solids in suspension is less than that developed for water alone and varies not only as the concentration but also as the particle size of the solids. The power input to the pump was found to vary directly with the apparent specific gravity of the suspension. The best efficiency capacity remained the same over the range of concentrations and particle sizes studied. The affinity laws (i.e., dimensionless representation of performance characteristics) were found to be valid within small ranges of speed when pumping solid-water mixtures. Stepanoff derived from several sources that at the b.e.p. the shaft horsepower increases as the ratio of the specific gravity and the head reduction ratio is the same as the efficiency reduction ratio.

Cavitation studies of solid-water mixtures are very limited. Stepanoff found that the NPSH requirements established for clear water apply to solid-liquid mixtures when the NPSH of the solid-liquid mixture is expressed in feet of liquid. Mariani and Herbich found that a silt-clay-water mixture cavitated at the same dimensionless specific speed as that of clear water.

Conclusions and Recommendations. It was found that the clear water pump performance characteristics are the same as the fine sand-water characteristics when these are presented in dimensionless form. The best efficiency point remains unchanged over the range of mixture concentrations studies. At the best efficiency point, the power does not increase in the ratio of the specific gravity increase, but is less at specific gravities below 1.30 and greater above this value. The head, in feet of liquid, and efficiency were unaffected by the sand-water mixture at the best efficiency point for the particular grain size distribution studies.

Critical net positive suction head remained the same for clear water and each mixture concentration studies when expressed in units of feet of liquid mixture. Cavitation with the sand-water mixture occurred at the same dimensionless specific speed and dimensionless head as the clear water.

Further research should be done in the area of solid-water mixture effect on pump characteristics. Uniformly graded sands with a median grain size diameter larger than the sand studies; silts and clays should be used. Since mixtures pumped in actual dredging operations are usually combinations of the above materials, studies with various combinations of the materials need to be undertaken. Also it is suggested that in the future a prototype dredge be instrumented. Valuable information could be obtained under actual dredging conditions which cannot be reproduced in a laboratory.

Underwater Welding (Education)

Activity Leader: J. E. Tompkins, James Connally Technical Institute

Due to the critical need for qualified personnel in the underwater welding field, a comprehensive training program was instituted at Texas State Technical Institute in September of 1969. The underwater welding program will furnish quality welder divers for entry into the area of underwater maintenance and research. The objectives of the underwater program are as follows:

1) Develop the necessary skills for carrying on the underwater welding process
2) To develop diving skills
3) To develop skills in rigging and underwater maintenance
4) To emphasize the safety and psychological aspects of underwater activities
5) To develop through experience, a more efficient method in the training of welder divers

Project Description and Report of Work and Accomplishments

After reviewing the methods and techniques used during the first training session, several changes were instituted in the attempt to place the students in a more realistic atmosphere. The students spent minimal time in the swimming pool and were moved to the thirty foot tank earlier in the training than the previous class. It was found that the students progressed

at a greater rate by exposing them to the deep tank operation at an earlier date.

During the early stages of the training period, safety was emphasized above all other things. After the students became fully acquainted with the Hooker type diving equipment, they were then assigned underwater type assembly projects. During this period, they used screwed pipe and various elbows, trees, nipples and other common type pipe fittings. The second part of the familiarization project was the building of an underwater box, formed by measuring, squaring, sawing and nailing underwater. Larger pipes, flanges and fittings were then used by the students to develop skills in cutting and assembling.

The deep sea hard hat gear was introduced at this time. A great deal of emphasis was placed on the assembly and disassembly and the relationship, name and purpose of each individual part. The students became fully familiar with hard hat gear and the safety aspects associated with it and began making practice dives until reaching the depth of eleven feet. The most important part of this particular aspect of the training was the safety and development of student skills in stabilizing his position underwater. Familiarization and useage of scuba diving gear was introduced to the students at this time. After approximately three weeks of diving, the students then began to develop skills in welding. The progression from simple flat position welding to horizontal welding was done. At this time, the students moved from the swimming pool to the thirty foot diving tank and began using the Hooker type equipment.

The welding students in the diving tank progressed from the simple vertical beads then to V-welds, T-welds, lap-welds and butt-welds, in all positions. This was followed by several pipe weldings.

The training site was then moved to Lake Whitney for a period of one week. During this time, the students used both scuba and Hooker type equipment and had diving exercises which took them to a depth of ninety feet. The final week of training was carried on from the Harlingen Campus of Texas State Technical Institute, where the students carried on diving exercises in the Gulf of Mexico, and they went to a depth of 150 feet. Plans at this time are being made to increase the depth of exercises in the future to approximately 200 feet.

In conjunction with the laboratory experiments and the proceedures that have been described, approximately one hour of classroom theory was held in conjunction with each two hours of laboratory.

During the underwater welding exercises, it was noted that there were some very different operational characteristics and appearances in the welding rods being used. Even though the rods had the same classification numbers, it appeared that there were some differences in the quality of the welds due to the differences in the rods of different brand names. A continued study will be made of this particular aspect and a report will be made available to the manufacturer of this particular type of rod.

At the present time planning is taking place for the development of a dry habitat device to be used for experimental work under water. Some of the proceedures used with the dry chamber will include MIG and TIG welding. In conjunction with the dry habitat plans, four viewing windows, 18" in diameter are to be mounted in the wall of the diving tank for the purposes of

viewing and monitoring the welding operations in the diving training period.

Certain changes in the present curriculum for training underwater welder personnel are being studied at this time by the Welding Department, Industrial Advancement Committee and other industrial officials. Any changes that are felt to be of significant value will be carried out during the next training session.

Ocean Technician Training (Education)

Activity Leader: Henry A. Rowe, Chairman, Department of Marine Technology

The technician training program is conducted by Galveston College through a contractual agreement with Texas A&M University and with the cooperation of Texas A&M University Marine Laboratory, Texas Maritime Academy, and the Department of Oceanography of Texas A&M University. Curricula included both theory and practice necessary to equip graduates to perform useful work aboard the increasing numbers of oceanographic vessels and fishing boats.

Training is conducted under Oceanographic Instrument Technology. These students are basically marine oriented electronic instrument technicians.

Technicians are trained to be useful in ship operations, and electronics equipment, and in assisting scientists and engineers in operating instruments and in recording and reporting meaningful data.

Project description and report of work and accomplishments

Summary of Work Performed. During the period of this report, Galveston College continued the training of ocean instrument technicians started on 1 June 1969. The Fall 1969 semester started with 17 students in the ocean instrument technology curriculum. The training, both in the classroom and aboard T/V MARINER was conducted in accordance with the approved curriculum. Of these 17 students in training during the fall semester, only five returned for the spring semester. The loss of twelve trainees in the program breaks down as follows:

Enlisted in Navy	1
Transferred to 4 year college	1
Transferred to other programs at Galveston College	4
Transferred to hometown Junior Colleges	2
Went to work	4

The underlying reasons for these changes are not always clear. An analysis of non-returning students indicated that for some, the curriculum was too difficult, (particularly in fundamental and elementary mathematics); the scarcity of 6 weeks summer marine employment was also offered as a fundamental reason for leaving. Compassionate reasons also took their toll.

Curricula Development. Top level representatives of the major industrial employers of oceanographic technicians in the area were formed into an active Ocean Technician Advisory Committee to make our program responsive to the real

needs and requirements of ocean related industries in the western Gulf of Mexico. Specifically, this committee represented the following:

Teledyne	Geophysical Exploration
United Geophysical	Geophysical Exploration
Shell	Petroleum Exploration and Production
Esso	Petroleum Exploration and Production
Divcon	Underwater Construction and Mining
Decca	Precision Navigation and Survey
Kelso Marine	Shell, Sand, Ship Construction and Operations
Manned Spacecraft Center	Oceanography
Marine Systems Engineering	Diving
Commercial Engineering Corporation	Specialized Deck Equipment

Little participation was experienced from the Advisory Committee due to cut backs in oil allowance and funding for Federal Research to private industry.

Recruitment. A study of the problem revealed three primary prospective sources of students: 1) Military Separation Centers; 2) Area High Schools; 3) Transferees from Other Colleges.

Recruitment methods included:

1) Press releases to trade journals and newspapers.
2) Talks at business and other clubs.
3) Personal rapport with high school counselors.
4) Visits to separation centers.

Accomplishments. The first class consisted of fourteen students; ten recent high school graduates and four transferees from other schools. Twelve enrolled in Ocean Instrument Technology and two in the Deck and Fisheries Technology.

The first summer session was devoted to Introduction to Oceanography, Seamanship, and Navigation, Scuba Diving, Drafting and Water Safety.

At registration for the fall semester, eight of the original students were still in the program; however, ten new students were enrolled.

The six students lost at the end of the first summer broke down as follows:

Transferred to four year colleges	4
Enlisted in Navy	1
Bought a shrimp boat and went to work	1

The six week summer session emphasized practical at sea work and included at least eight day cruises for each student.

Liaison. In addition to a close working relationship with other departments of Galveston College and Texas A&M University, contact is maintained with industry, the U. S. Coast Guard, and the Bureau of Commercial Fisheries on a local level, and similar training programs on a national level. As an example, five of our students had a one week cruise on a U. S. Coast Guard buoy tender. This program was a continuing one, and it was planned to have every student make at least one Coast Guard cruise.

Exchange of information on curricula, recruiting, and training aids was established with then other institutions engaged in Ocean Technician Training.

Problem. The newness of Oceanography makes it difficult to attract students, especially when the average counselor knows little about the subject, and only counselors in the immediate area know that such a program is available at Galveston College.

Due to a lack of student interest, and available jobs, the program was terminated at the end of the spring semester, 1970, until such time as the economic conditions pick up and additional personnel are required.

PUBLICATIONS AND DOCUMENTATION

Technical and General Reports

Burton, W. J., and Robert M. Sorensen. *The Effects of Surface Roughness on the Wave Forces on a Circular Cylindrical Pile.* Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-211. March 1970. 137 pp.

Davis, G. L., "Design of an Automatic Marine Corer", Masters Thesis, Texas A&M University, College Station, Texas, 1970.

Ford, Robert F., Jr. and Bob M. Gallaway, "Galvanic Corrosion of Structural Aluminum Coupled with Mild Steel in a Dilute Sodium Dichromate Electrolyte," COE Report No. 119, Sea Grant Publication No. 206, January 1970.

Garrison, C. J. and R. H. Snider, "Wave Forces on Large Submerged Tanks," COE Report No. 117, Sea Grant Publication No. 210, January 1970.

McNair, E. C. Jr., "Some Characteristics of Waves Broken by a Longshore Bar", May 1970. (Thesis).

Machemehl, Jerry L. and John B. Herbich. *Effects of Slope Roughness on Wave Run-up on Composite Slopes.* Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-222. August 1970. 243 pp.

Newbolt, Lawrence and John B. Herbich. *Hydrology of Coastal Waters.* Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-225. August 1970. 91 pp.

Ross, Hayes E., Jr., *Dynamic Response of Laterally Loaded Offshore Piling.* Texas A&M University Sea Grant Program. College Station, Texas TAMU-SG-70-224. August 1970. 111 pp.

Shank, G. Edward and John B. Herbich, "Forces Due to Waves on Submerged Structures," TAMU-SG-70-212, COE Report No. 123, May 1970.

Spencer, Edmund B. and Robert M. Sorensen. *Set-up of Oil on Water by Wind.* Texas A&M University Sea Grant Program. College Station, Texas. TAMU-SG-70-220. August 1970. 145 pp.

Wells, Donald R. and Robert M. Sorensen, *"Scour Around a Circular Pile Due to Oscillatory Wave Motion,"* Sea Grant Publication No. 208, COE Report No. 113, January 1970.

Worthington, Henry W. and John B. Herbich, *"A Computer Program to Estimate the Combined Effect of Refraction and Diffraction of Water Waves,"* TAMU-SG-70-219, COE Report No. 127, August 1970.

Professional Journals and Periodicals

Caruthers, J. W., R. C. Thompson, J. C. Novarini, G. A. Franceschini, *"The Response of Deep Scattering Layers of the Gulf of Mexico to a Total Solar Eclipse,"* Submitted for publication, 1970.

Riter, S., Boatright, P.A., and M. T. Shay, *"Design Considerations for a PPM Underwater Acoustic Communications System"*, IEEE Trans. on Audio and Acoustics, to be published March 1971.

Riter, S., *"Threshold Performance of Sub-Optimum PPM Receivers"*, IEEE Trans. - on A.E.S., vol AES-6 No. 2, March 1970, pp 257-259.

Schell, J. A., Riter, S., and R. K. Cavin, *"Dereverberation by Linear Systems Techniques"* accepted for publication by IEEE Trans. on Geoscience Electronics.

Sorensen, R. M. and Burton, W. J., *"Effect of Pile Surface Roughness on Wave Forces on Piles"*, Proceedings, Civil Engineering in the Oceans II Conference, Miami, December, 1969.

Sorensen, R. M., *"Waves Generated by a Model Ship Hull"*, Proceedings, Waterways and Harbors Division, A.S.C.E., November, 1969.

Conference Papers Presented

Garrison, C. J., V. Seetharama Rao, and R.H. Snider, *"Wave Interaction with Large Submerged Objects,"*Offshore Technology Conference, Paper Number OTC 2178, 1970.

Herbich, J. B., *"Continental Shelf and Deep Ocean Dredging"*, ASEE National Meeting, University Park, Pennsylvania, June 1969.

Herbich, J. B., *"Deep Ocean Mining"*, Civil Engineering in the Oceans II, A.S.C.E. Specialty Conference.

Herbich, John B. and George E. Shank, *"Forces Due to Waves on Submerged Structures Theory and Experiment."* Dallas, Texas: Offshore Technology Conference, Paper Number OTC 1245, 1970.

Herbich, J. B.,*"Ocean Engineering - Present Status and Future Development"*, ASEE National Annual Meeting, Ohio State University, June, 1970.

Orr, Terry E. and John B. Herbich, *"Numerical Calculation of Wave Refraction from Shorelines by Digital Computer."* Offshore Technology Conference, Paper Number OTC 1279, 1970.

Riter, S., *"Applications and Limitations of Underwater Acoustic Telemetry,"* 80th Annual Meeting Acoustic Society of America, Houston, Texas, November 1970

Riter, S., and P.A. Boatright, *"PPM Underwater Acoustic Telemetry"*, IEEE International Conference on Engineering in an Ocean Environment, Panama City, Florida, September 1970.

Riter, S., *"Pulse Position Modulation Communications via the Underwater Acoustic Communications Channel,"* 1970 SWIEECO Record, Dallas, Texas, April 1970, pp 453-457.

Riter, S., *Underwater Acoustic Telemetry"*, Paper No. 1124, 1970 Offshore Technology Conference, Houston, Texas, April 1970.

Sorensen, R. M., *"Wave Forces on Piles: Effects of Surface Roughness"*, Texas Section, ASCE Meeting, Galveston, Texas, May 2, 1970.

Sorensen, R. M.,*"Wave Set-Up of Oil Slicks"*, A.S.C.E. Transportation Engineering Conference, Boston, Mass., July 13, 1970.