UNIVERSITY OF NORTH CAROLINA

SEA GRANT PROGRAM

ANNUAL REPORT

JULY 1971 THROUGH DECEMBER 1972

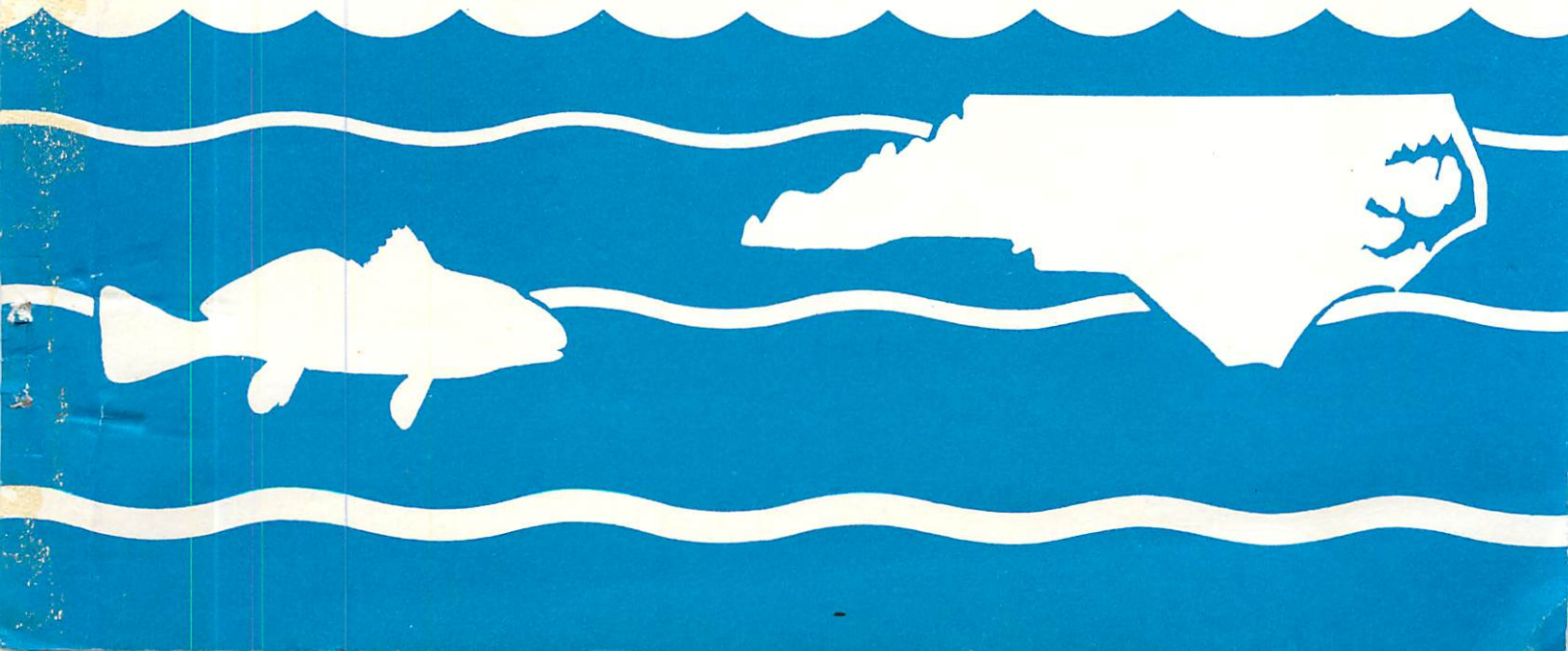
JOHN LYMAN

WILLIAM L. RICKARDS

SEA GRANT PUBLICATION

UNC – SG – 73 – 13

JUNE, 1973



UNIVERSITY OF NORTH CAROLINA SEA GRANT PROGRAM

ANNUAL REPORT

July, 1971 through December,

by
John Lyman and William L. Rickards
Sea Grant Program
School of Public Health
University of North Carolina
Chapel Hill, N. C. 27514

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A Report to Office of Sea Grant, NOAA, U.S. Department of Commerce in Partial Fulfillment of Grant No. 2-35178.

SEA GRANT PUBLICATION UNC-SG-73-13 June, 1973

Sea Grant Program, 1235 Burlington Laboratories, North Carolina State University, Raleigh, North Carolina 27607

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NOAA FORM 90-2 (5-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED.
DECEMBER 31, 1972
OMB NO. 41-R2600

SEA GRANT PROJECT SUMMARY

(Limit all information to this page)

PROJECT NO.	PROJECT TITLE	DATE INITIATED, IF CONTINUING
MD/A-1	Program Administration and Development	July 1970
GRANT NO. (OFFICE)	OLD TITLE (If different)	DATE OF THIS FORM
2-35178		May 1973
INSTITUTION		ESTIMATED COMPLETION DATE
UNC		continuing

☐ NEW ☒ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
John Lyman, Envir. Sci. & Eng., UNC-CH	50	William L. Rickards	100

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS *(By numbers)*
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 86,842	$ 43,415	$ 59,713	$ 29,862	$	$	all

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Program Administration & Development	Program Administration

OBJECTIVES:

1. To coordinate program and project activities within the North Carolina Sea Grant Program.

2. To function as liaison between and among project investigators, administrators of participating institutions, the Office of Sea Grant in Washington, and agencies of the State of North Carolina which provides matching funds for the entire program.

3. To oversee budgetary matters, with the exception of actual accounting, for the program.

4. To oversee and undertake the final steps in the preparation and review of proposals which are to be presented to the Office of Sea Grant and the State of North Carolina.

HOW INFORMATION WILL BE APPLIED *(Be specific)*:

ACCOMPLISHMENTS DURING PAST TWELVE MONTHS *(Not more than one sentence per accomplishment)*:

1. A system of program and project review by persons outside of the North Carolina Sea Grant Program has been instituted and utilized for the preparation of proposals for calendar year 1973.
2. A series of North Carolina Sea Grant Program Publications was established; to date, fifteen publications have appeared with the Sea Grant publication designation. Other program publications have appeared elsewhere in scientific literature.
3. Program activities have been coordinated, reviewed, and developed to the satisfaction of the State agencies involved with such Sea Grant matters.

(Do not use more space.)

Project No.: MD/A-1

Project Title: Program Administration and Development

Principal Investigators: John Lyman, Coordinator; William L. Rickards, Assistant Coordinator

Program Objectives

The University of North Carolina Sea Grant program is primarily directed at providing solutions in two major problem areas of concern to the State of North Carolina and its citizens. The first of these areas is associated with the necessity for raising the level of economic development in the eastern part of North Carolina. Since this region is also the coastal part of the state, marine resource development is a prime target for economic growth, and it has been so recognized by the Coastal Plains Regional Commission and the State of North Carolina Marine Science Council.

The second of these great problem areas, which is not unrelated to the first, concerns the necessity to preserve the environment of North Carolina. Pollution of the air, addition of domestic, agricultural and industrial wastes to the waterways, disposal of solid wastes, the possibility of erosion and storm damage to the shoreline, and the danger of overharvesting or damaging the renewable marine resources or of adversely modifying their nursery grounds, all require attention. Under the Sea Grant program, concentrated study of the marine environment is being undertaken as well as training of scientists, administrators, and technicians in the special problems of coastal North Carolina, assisting fishermen and fish processors in improving their procedures, and studying the legal regime of the state for the purpose of clarifying and, if necessary, modifying the jurisdictions of various authorities concerned with the coastal zone.

During its second grant period, July 1971 through December 1972, the program received a total of $710,000 Sea Grant funds and $355,000 matching funds from the State of North Carolina Department of Administration. Distribution of these funds according to Sea Grant Activity Categories is shown in Table 1.

Program Organization and Coordination:

Overall coordination and direction of the program are assigned to the Sea Grant Program Coordinator, Dr. John Lyman, and his assistant, Dr. William L. Rickards. The program offices have been located in the Department of Environmental Sciences and Engineering, School of Public Health, University of North Carolina at Chapel Hill.

Effective 1 July 1973, the program offices will be located at 1235 Burlington Laboratories, North Carolina State University, Raleigh, N. C. 27607.

The research and extension activities of the program are under the direction of investigators and personnel from four campuses of the University of North Carolina: North Carolina State University, Raleigh; University of North Carolina

TABLE I.

BUDGET BY SEA GRANT ACTIVITY
July, 1971 through December, 1972

	OSG Funds	Matching Funds
I. Marine Resources Development		
Aquaculture	$ 50,370	$ 25,184
Living Resources Other Than Aquaculture	27,924	13,962
Mineral Resources	77,832	38,915
Marine Law	19,910	9,955
II. Marine Technology Research & Development		
Ocean Engineering	21,171	10,585
Resource Recovery & Utilization	37,421	18,710
III. Marine Environmental Research		
Research in Support of Coastal Zone Management Decisions	84,698	42,348
Pollution Studies	151,342	75,671
Environmental Models	46,569	23,284
IV. Advisory Services		
Extension Programs	122,550	61,274
Other Advisory Services	10,500	5,250
V. Program Management and Development	59,713	29,862
	$ 710,000	355,000

at Chapel Hill; East Carolina University, Greenville; and University of North Carolina at Wilmington.

Within the program, coordination of activities was improved during the past year through the establishment of five project groups and group coordinators. Establishment of the groups has improved communication between the investigators as well as making possible more immediate program responses to user inquiries and needs. Project groups and coordinators are as follows: Estuarine Studies, Dr. B. J. Copeland; Aquaculture and Fisheries, Dr. William L. Rickards; Ocean Engineering, Dr. C. C. Tung; Ocean and Coastal Law, Prof. Seymour W. Wurfel; Education and Advisory Services, Dr. John R. Canada. Each coordinator has been responsible for proposal preparation and review, information exchange between investigators, coordination of effort, etc. for those projects in his group. Of the projects funded during the period of this report, 9 were in Estuarine Studies, 2 in Aquaculture and Fisheries, 1 in Ocean Engineering, 1 in Ocean Law, and 5 in Education and Advisory Services. The project progress reports contained in the remainder of this report may, in some cases, apply directly to one or more of the project groupings other than the one to which it has been assigned. This is to be expected in any attempt to classify such an assemblage of inter-related projects into exclusive groupings.

Project Group Summaries

A. Aquaculture and Fisheries

The two projects in this group are largely unrelated and have few detailed objectives in common. However, both are aimed at developing technology which may be used to increase the yield of seafood products in North Carolina.

Investigations into the feasibility of culturing dolphin as a food product are being conducted at Hatteras, North Carolina. The project, "Propagation of the dolphin, Coryphaena hippurus in North Carolina", has obtained promising results with regards to maintaining dolphin year-round and is now looking into the development of spawning and rearing techniques.

The second project, "Studies on reproduction and fungal parasites affecting reproduction in the blue crab, Callinectes sapidus, in North Carolina waters," has its more immediate application in the management of the State's blue crab fishery, but it will prove beneficial to crustacean aquaculture in general, as is being found in the case of fungal diseases in shrimp culture. One part of the study is devoted to determining the reproductive cycle of the blue crab, and the remainder of the effort is being applied to studies of the fungi infecting crab ova and the effects of the fungi on crab reproduction.

B. Estuarine Studies

North Carolina has over 300 miles of coastline and nearly 3 million acres of coastal waters and lowlands. These resources support multimillion dollar fishing and tourism industries, both critical components to the state's economy.

Jeopardizing this important coastal complex are the activities of man and the forces of nature. We must understand these effects and learn to manage the North Carolina coastal resources for optimal utilization. Research efforts seem to be the only means whereby this understanding and management can be achieved.

This grouping includes research in two general areas of North Carolina coastal problems, coastal management and estuarine dynamics.

North Carolina is faced with a serious problem of dune destruction and stabilization and the disposition of dredge spoil in relation to development of the coastal islands and marshlands. One project, "Coastal Dune and Dredge Spoil Stabilization", has established a reliable method of stabilizing coastal dunes with vegetation. Efforts are also underway to determine additional details for dunes and study the stabilization problems with dredge spoil. Another project, "Community Succession on Dredge Islands", is a study of the successional stages on existing dredge spoil islands. This important study will be useful in determining the natural forces at work stabilizing dredge spoil. Supporting these is another project, "Investigation of Insects Affecting Vegetation Used in Coastal Dune and Dredge Spoil Stabilization", designed to determine and control the insects affecting the stabilization vegetation. This is an important area of research since insects are one of the forces working against the use of vegetation in dune and dredge spoil stabilization.

Another important area for coastal management in North Carolina is the utilization of the coastal zone for tourism. Important here is the management of insect pests in relation to tourism usage. A research project, "Insect Pest Management in Coastal and Estuarine Areas", is designed to survey the populations of biting flies and mosquitos in the North Carolina coastal zone and to determine means of controlling them.

In order to evaluate and manage the complex estuarine system of North Carolina, research is being conducted to determine the dynamics of flow and cause-and-effect relationships of sediment transport and input of materials into the estuarine areas. The coastal estuarine system of North Carolina ranges from river mouth to the large and polyhaline Pamlico Sound. At the present time the North Carolina coastal zone is in relatively good shape, but danger signs are upon the horizon. With the emphasis on development and utilization of the coastal zone, we are jeopardizing the future of these fragile ecosystems unless we have proper knowledge in order to manage them for optimal utilization.

One research project, "Dynamics of Flow in Estuarine Waters", is designed to determine the flow through inlets and dispersion of water from rivers and the ocean through the complex Pamlico Sound system. This project is necessary to develop abilities for predicting dispersion of materials and organisms in the coastal zone. Related to this project, and dependent on it, is the "Erosion and Deposition in the Sounds and Estuaries of the N. C. Coast". This project is designed to determine the transport of bottom materials in relation to flow through inlets and the transport of water from rivers, and to predict future changes. These findings are of practical importance in the maintenance of harbors and channels, in the construction of any facility in or near the water, and in determining the types of organisms that might be able to live in a given area. Also related is another project, "Recent Sediments of Northeastern North Carolina Estuaries and their Relations to Plio-Pleistocene Mineral Deposits", which is designed to yield a basic understanding of the existing physical environment and the controls producing it in the northern portion of the Pamlico Sound and eastern Albemarle Sound. These three research projects, together, are producing information necessary for the management of deposition and transport problems.

Another important problem in the North Carolina coastal zone is the transport and effect of nutrients and sewage in estuarine waters. Increased fertilization

in agricultural practices on the North Carolina coastal plain has resulted in transport of nutrient materials downstream to the coastal zone. A research project, "Source, Fate and Effects of Nutrients added to North Carolina Estuaries", is designed to study the transport and effects of these nutrient materials in Albemarle Sound, Pamlico River Estuary and Neuse River Estuary. This study, with the results of "Dynamics of flow", will be combined to determine nutrient budgets and their fate in the estuaries. Another research project, "Optimum Ecological Designs for Estuarine Systems", is designed to study the effects of sewage on estuarine waters and possible beneficial uses. Considerable information has already been obtained dealing with the ecosystem response to treated sewage and emphasis is now being placed on the utilization of these findings for beneficial uses such as aquaculture.

C. Ocean Law

The single project in this area, "Marine Resources Legal Research", is a continuing study of problems associated with two geographically distinct but legally related areas, i.e. offshore waters with their international access and fisheries issues and the inshore and coastal zone lands and waters with a multitude of complex legal issues.

In addition to surveying existing laws pertaining to marine resources in North Carolina, this program is aiding in developing new legislation for the management of the resources as well as providing legal advice for other Sea Grant projects in the State.

D. Ocean Engineering

The single project in this area, "Reliability analysis and optimum design of marine structures", is a continuing study analyzing 1) the current building codes and practices in North Carolina and 2) the effectiveness of these practices in producing properly designed and safe coastal structures. Emphasis is being placed upon analyses of the effects of wave and current forces upon structural elements and the development of optimum designs for such structural systems.

E. Education and Advisory Services

The advisory services portion of the program is mainly designed to improve the economic status of the seafood industry of North Carolina through direct cooperation with all aspects of the industry from fisherman to consumer via field work, research, and information transfer.

Of the five projects in this group, all of which are continuing, three are closely related phases of an overall plan for developing marine industries harvesting and processing systems. These projects are titled "Seafood Science and Technology - Applied Research", "Seafood Science and Technology - Advisory Services", and "Engineering Advisory Services". The overall goal of these projects is to improve existing seafood production techniques, including catching the product, transporting it to the processor, processing, distribution, and marketing, as well as developing new products and methods for producing them.

These three related projects are engaged in a wide variety of activities concerning seafood harvesting and processing including the following: processing methods for scallops; sanitation tests and procedures for in-plant use; development of cominuted products; freezing and pasteurization of crab meat; waste

reclamation; publication of an advisory newsletter; development and testing of new or improved fishing gear for use in North Carolina; fishing vessel insulation; conducting a conference for the industry; assistance to processing plants on expansion planning, sanitation, pollution control, and product quality control; seafood cooking demonstrations.

Whereas the three projects described above have functioned largely in the region around Morehead City, the education program for fishermen involves advisory personnel in the Albemarle Sound region. The program has functioned to inform the fishermen concerning financial assistance programs, new or improved gear, regulations, marketing, etc. A marketing cooperative with over 200 members has been formed, and instruction in cooperative marketing and basic economics was provided on a small group and individual basis.

The final project in the advisory group is a publication which will present updated information concerning the fisheries of North Carolina including species descriptions, fishery statistics, physical descriptions of the region, fishing equipment and gear, and biology of both commercial and non-commercial organisms of interest to the public. The "Updated Survey of Marine Fisheries" will be intended for use by fishermen, dealers, seafood processors, legislation, administrators, and the general public.

Outside Participation and Assistance

In addition to the participation of university personnel as principal investigators for the projects discussed above, the program has received cooperation and/or assistance from a wide variety of State, Federal, and local agencies, academic institutions, and industrial organizations. Participation by these agencies, as listed in Table 2, is hereby gratefully acknowledged.

Publications

In addition to the duties of general program administration, the Coordinator's office initiated a series of Sea Grant publications during 1972. The 15 publications issued under Sea Grant funding during the year are listed below.

UNC-SG-72-01. Lyman, J. and W. Rickards. University of North Carolina Sea Grant Program, Annual Report, 1 July 1970 - 30 June 1971.

UNC-SG-72-02. Wurfel, S. W., ed. Attitudes regarding a law of the sea convention to establish an international seabed regime.

UNC-SG-72-03. Upchurch, J. B. Sedimentary phosphorus in the Pamlico estuary of North Carolina.

UNC-SG-72-04. Chleborowicz, A. G. Direct oil fired heat exchanger for a scallop shucking machine.

UNC-SG-72-05. Angel, N. B. Insulation of ice bunkers and fish holds in older fishing vessels.

UNC-SG-72-06. Edzwald, J. K. Coagulation in estuaries.

TABLE II.

Agencies and Organizations Involved in Planning or Implementing the University of North Carolina Sea Grant Program

A. State Agencies:
- N. C. Department of Administration
  - Board of Health
    - Division of Sanitary Engineering
      - Victor and Rodent Control Section
  - Department of Public Instruction
  - Department of Community Colleges
  - Department of Natural and Economic Resources
    - Division of Commercial and Sports Fisheries
  - Board of Science and Technology
  - Highway Commission
  - Attorney General Department

B. Federal Agencies:
- U. S. Department of Defense
  - Department of the Army
    - Corps of Engineers
      - Coastal Engineering Research Center
      - Wilmington District
- U. S. Department of the Interior
  - National Park Service
    - Cape Hatteras National Seashore
  - Bureau of Sports Fisheries & Wildlife
- U. S. Department of Agriculture
  - Soil Conservation Service
- U. S. Department of Commerce
  - National Oceanic and Atmospheric Agency
    - National Marine Fisheries Service
- National Science Foundation

C. Local Agencies:
- Carteret County School System

D. Academic Institutions
- The University of North Carolina - Chapel Hill
- North Carolina State University
- University of North Carolina - Wilmington
- East Carolina University
- Carteret Technical Institute
- Pamlico Technical Institute
- College of the Albemarle
- American Museum of Natural History, Lerner Laboratory
- Cape Fear Technical Institute

E. Industrial Organizations:
- Coastal Zone Resources Corporation, Wilmington, N. C.
- Marine Chemurgics, Morehead City, North Carolina
- Sound Packing Company, Whortenville, North Carolina
- Willis Bros. Seafoods, Williston, North Carolina
- C. A. Davis Fish Company, Beaufort, North Carolina
- Blanchard Box & Crate Company, Englehard, North Carolina
- Pamlico Packing Company, Vandermere, North Carolina
- Captain Nelson Lee, Trawler Edna Fay, Hobuken, N. C.
- Sewage Treatment Plant, Morehead City, N. C.

UNC-SG-72-07. University of North Carolina. Proposal for institutional Sea Grant support.

UNC-SG-72-08. Schwartz, F. J. and J. Tyler. Marine fishes common to North Carolina.

UNC-SG-72-09. Porter, H. J. and J. Tyler. Sea shells common to North Carolina.

UNC-SG-72-10. Woodhouse, W. W., E. D. Seneca, and S. W. Broome. Marsh building with dredge spoil in North Carolina.

UNC-SG-72-11. Copeland, B. J. Nutrients in Neuse River and Albemarle Sound estuaries, North Carolina: survey. (in preparation).

UNC-SG-72-12. Whitehurst, J. H. The menhaden fishing industry of North Carolina.

UNC-SG-72-13. Schoenbaum, T. J. Public rights and coastal zone management.

UNC-SG-72-14. Tung, C. C. and N. E. Huang. Some statistical properties of wave-current force on objects.

UNC-SG-72-15. Tung, C. C. and N. E. Huang. Wave-current force spectra.

Copies of these publications are available from the Sea Grant Program, Room 1235, Burlington Laboratories, North Carolina State University, Raleigh, N. C. 27607.

Program Development - New Project Initiation

Early in 1972, the Coordinator's office was requested to fund a short-term project concerning sediment movement in Tubbs Inlet, N. C. As a result of sand transport and deposition in the vicinity of the inlet, navigation had been impaired and the North Carolina Office of Water and Air Resources had expressed interest in obtaining information which could be used in stabilizing the inlet.

Program development funds were alloted for such a study, and a progress report from the investigation is presented on the following four pages as part of the Program Administration and Development report.

NOAA FORM 90-2 (5-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SEA GRANT PROJECT SUMMARY
(Limit all information to the 1 page)

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 41-R2600

PROJECT NO.	PROJECT TITLE [ ] NEW [ ] CONTINUING [ ] CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
none	Sediment Movement in Tubbs Inlet, N.C.	June 1972
GRANT NO. (Prior)	OLD TITLE (If different)	DATE OF THIS FORM
2-35178		May 1973
INSTITUTION		ESTIMATED COMPLETION DATE
UNC		June 1973

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
V.V. Cavaroc, Dept. of Geosciences, NCSU	5	Robert P. Masterson	50

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (Re numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	R/ES-9 R/ES-7, R/ES-8,
$ 1900	$ 900	$ 1900	$ 900	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Program Administration & Development	included under Program Administration

OBJECTIVES: (1) To gain insight into the processes active in an inlet environment by combining and correlating more classical geological parameters (i.e. bedforms and sedimentary structures) and oceanographic parameters (i.e. tidal flow characteristics and waves) to form an hypothesis of sand transport and distribution patterns; (2) To test the hypothesis of sediment transport by using fluorescent tracer sand and to test the validity of the tracer technique in an inlet environment; (3) To contribute data on Tubbs Inlet which will be useful in curbing migration of the inlet and increasing its navigability.

HOW INFORMATION WILL BE APPLIED: The sediment movement pattern, sediment movement rates, water distribution, and tidal current data gathered during this project were applied by engineers to design a stabilization plan consisting of groins and training structures. The plan was submitted to the Office of Water and Air Resources of the State. The presence of inlets in a barrier beach affects beach and dune stability by providing a means by which beach sand is lost to the estuary. The reintroduction of the sediment from the estuary back into the alongshore transport system through the inlet is dependent upon the flushing ability and stability of the inlet. This study has provided data which should be applied to further studies of natural bypassing and downdrift beach nourishment.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS: (1)Formulation of sediment movement pattern through the inlet; (2)Determined the current regime in the inlet system; (3)Determined transport velocities for a "sand mass" marked by concentrations of tracers moving into the estuary and for individual tracer grains moved by different means (i.e. suspended or bedload); (4)Improved and refined techniques for using tracer sand and demonstrated the tracer technique to be a valid method of monitoring sediment movement in the inlet environment; (5) Data resulting from the study were used in the design of a stabilization plan which has been submitted to the North Carolina Office of Water and Air Resources.

Project No.: None (included under Program Administration)

Title: Sediment Movement in Tubbs Inlet, North Carolina

Principal Investigators: V. V. Cavaroc and Robert P. Masterson
Dept. of Geosciences, North Carolina State University

Introduction

Tubbs Inlet, approximately 3.5 miles from the North Carolina-South Carolina line, separates Sunset Beach to the west and Ocean Isle Beach to the east. The inlet drains approximately 2.5 square miles of marshland and the Atlantic Intracoastal Waterway via three estuarine channels which converge near the inlet. Fresh water input is negligible. A rather large flood-tidal delta and an intertidal flat have formed as a result of the transport of sand into the estuary through the inlet. Filling of the inlet and estuary is decreasing the flushing ability of the estuarine channels.

The major objectives of the study were: 1) to gain insight into the processes active in an inlet environment by combining and correlating more classical geological parameters (bedforms and sedimentary structures) and oceanographic parameters (tidal flow characteristics and waves) to form an hypothesis of sediment transport and distribution patterns; 2) to test the hypothesis of sediment transport by using fluorescent tracer sand and to test the validity of the tracer technique in an inlet environment; and 3) to contribute data on Tubbs Inlet which will be useful in curbing migration of this inlet and increasing its navigability.

The Inlet's history was studied and trends were established using aerial photography and surveys. The inlet migrated rapidly westward prior to 1969-1970 at which time it was artificially relocated approximately 3800 feet to the east. The trend subsequent to 1970 has been for the inlet gorge to remain relatively stationary and the inlet width (high-water limits) to increase.

Bedforms and sedimentary structures on the intertidal sand bodies were analyzed and mapped. Bedforms on the channel bottoms were surveyed using a precision fathometer. To determine a flow pattern and water distribution, tidal-current velocity and direction measurements were taken at selected stations in the inlet and estuarine channels as shown in Figure 1. From these data a generalized hypothesis of sediment movement was formed.

Separate ebb- and flood-flow movement tests were conducted using fluorescent tracer sand to monitor sediment transport. Two thousand pounds of tracer, equally divided between five colors, were introduced into the inlet system by either water-soluble bags placed in subtidal channels or by raking into the intertidal beach or flat. Surface and subsurface samples were collected for four days after introduction. Analysis of the tracer dispersion was based upon relative concentration of each color tracer detected primarily by the coring method of sampling.

Results of Research

The research performed during this project has expanded the data base concerning processes active in a tidal inlet environment and demonstrated the use of fluorescent tracer to be a valid method of study of sediment distribution in this

high energy environment.

The generalized sediment movement pattern for Tubbs Inlet is shown in Figure 1. Sediment is moved into the estuary across the intertidal flat, particularly on the eastern side. Flood-tidal currents were the dominant agent of transport. Breaking waves refracted into the inlet placed much of the sediment into suspension for transport by tidal currents. Estuarine movement of sediment in the inlet gorge occurred as suspended load. The ebb-oriented bedforms in the main channel, reflective of the dominant ebb current, were not observed to become flood oriented during a tidal cycle. Seaward transport was restricted primarily to the main channel and a small intertidal channel on the eastern flat; however, some sediment did exit across the western beach and flat.

Tracer which moved along the recurved spit on the eastern intertidal flat was detected as zones of high concentration which showed a net estuarine movement with time. Based on distance traveled and elapsed time, an average net movement rate along the spit corresponding to mid-to-high water was 0.58 cm/sec (1.14 ft/min). This rate of net movement for the "sand mass" is in marked contrast with the average movement rates of individual tracer grains of 10 cm/sec (20 ft/min). The movement rate of individual grains was determined using maximum distance between source and detected tracer and elapsed time between introduction and detection.

Tracer was detected in the inlet system four weeks after introduction, particularly in low energy environments such as intertidal point-bars formed primarily by flood-tidal currents. Isolated tracer grains were also detected in areas of higher energy. This tendency for tracer to ramain in the system for several weeks would necessitate the use of tracers of different colors if repeated tests were performed.

The results of this research have been applied by engineers in stabilization plans for the inlet. It was beneficial to know the sand movement pattern, water distribution, and tidal current characteristics for the design and proposed placement of groins and training structures which were submitted to the Office of Water and Air Resources, Department of Natural and Economic Resources, State of North Carolina

The Federal and State governments will spend vast amounts of money for beach and dune stabilization in Brunswick County in the future. The data gathered during this project will be useful in planning the effects of inlets on beach stabilization and nourishment. The net loss of sand from the beach to the estuary is better understood and data are provided concerning the redistribution of sand from the estuary to the beach via the inlet gorge and downdrift side of the inlet.

As can be seen from Figure 1, sediment is transported alongshore bypassing the inlet as part of the ebb-tidal delta. Sediment is also introduced into the bypassing transport system through the main inlet channel. The data base established by this project should be further applied in the study of the natural bypassing of an inlet and the overall effects upon the littoral drift system and downdrift beach nourishment.

The adaptability of the tracer technique to the inlet environment has been demonstrated. Technique improvements and refinements in the use of tracer in this environment of variable depth and changing energy conditions will be beneficial to further studies.

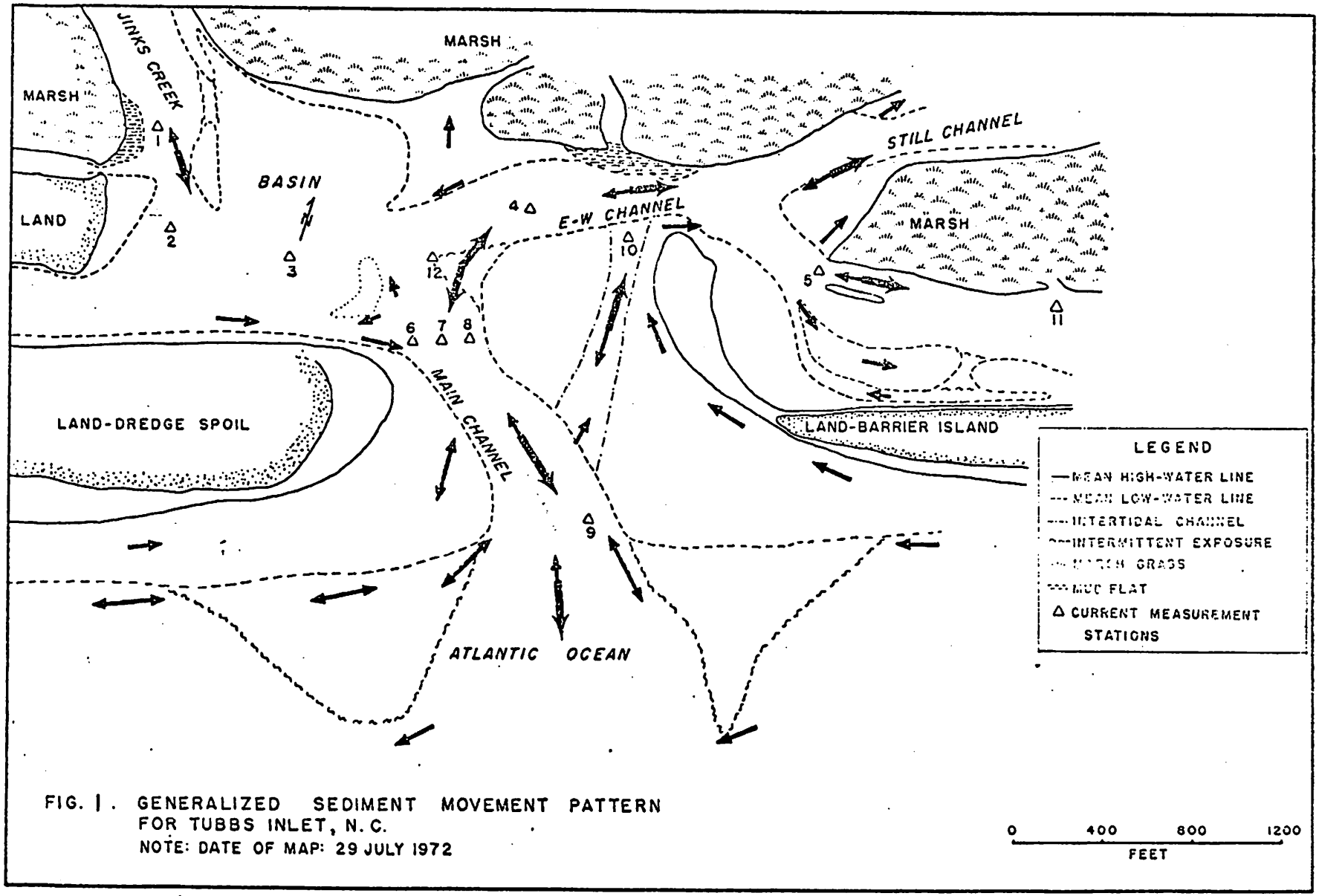

FIG. 1. GENERALIZED SEDIMENT MOVEMENT PATTERN FOR TUBBS INLET, N. C.
NOTE: DATE OF MAP: 29 JULY 1972

Program Evolution

During the 1970-71 and 1971-72 grant periods, the program has undergone rigorous changes with regards to project funding and project direction. The evolution of the program during these two grant periods is depicted by Table 3. This table indicates project re-direction (R), termination (T), initiation (N), and continuation (C). Detailed progress reports for the 19 projects indicated as on-going during Grant No. 2-35178 in Table 3 are presented in the remainder of this report.

TABLE III.

PROGRAM SUMMARY

Project Group	Grant #GH-103 Year '70-'71	Grant #2-35178 Year '71-'72
I. Program Operations		
Administration & Development, Lyman	C	C
II. Aquaculture & Fisheries		
Propagation of Dolphin, Hassler	N	C-R
Nutritional Requirements of Fishes, O'Rear	N-T	
Aquaculture Technique Development, Porter	N-T	
Reproduction & Fungal Parasites, Ryan & Bland	N	C
III. Estuarine Studies		
Benthic Estuarine Ecology, Bellis	N-T	
Community Structure - Smith Island, McCormick	N-T	
Alternative Development Patterns, Hufschmidt	N-T	
Resource Capability - Smith Island, Parnell	N-T	
Dune & Dredge Spoil Stabilization, Woodhouse	N	C
Insects Affecting Vegetation, Campbell	N	C-R
Dredge Island Succession, Parnell & Soots		N
Insect Pest Management, Axtell	N	C-R
Erosion & Deposition, Ingram	N	C
Sediments & Mineral Deposits, Riggs & O'Connor	N	C
Flow in Estuaries, Amein & Knowles	N	C
Nutrients in Estuaries, Copeland & Hobbie	N	C
Estuarine System Design, Kuenzler & Chestnut	C	T
Microbial Hydrocarbon Degredation, Perry	N-T	
Fate of Pollutants, O'Melia	N-T	
Phosphate in Blue-green algae, Schlichting	N-T	
IV. Ocean Law		
Marine Resources Legal Research, Wurfel	N	C
V. Ocean Engineering		
Design of Structures, Tung & Huang	N	C-R
VI. Education & Advisory Services		
Curriculum Development, Thornton	N-T	
Seafood Applied Research, Webb	N	C
Seafood Advisory Services, Thomas	N	C
Engineering Advisory Services, Angel	N	C
Education for Fishermen, McGee	N	C
Updated Fisheries, Chestnut	N	C

NOAA FORM 90-2 (5-71) | U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION | FORM APPROVED DECEMBER 31, 1972 OMB NO. 41-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT TYPE	PROJECT TITLE (X NEW / CONTINUING / CHECK IF SEPARATE PROJECT GRANT)	DATE INITIATED, IF CONTINUING
R/AF-1	Propagation of the dolphin, Coryphaena hippurus, in North Carolina	July, 1970
GRANT NO. (OFFICE USE) 2-35178	SUB-TITLE (If different)	DATE OF THIS FORM May, 1973
INSTITUTION UNC		ESTIMATED COMPLETION DATE December, 1975

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
William W. Hassler - Dept. of Zoology, NCSU	30%		

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (Gr. numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 71,304	$ 35,651	$ 50,370	$ 25,184	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Aquaculture & Fisheries	Aquaculture/Finfish

OBJECTIVES:

OBJECTIVES:

1. To conduct aquaculture studies on the dolphin, Coryphaena hippurus, and to determine the feasibility of commercial propagation of this very fast-growing and palatable species.
2. To investigate methods of incubation of dolphin eggs.
3. To investigate methods of rearing dolphin larvae.
4. To investigate methods of transporting dolphin eggs.
5. To investigate methods of obtaining and preserving milt from dolphin.
6. To maintain a stock of dolphin throughout the year at Hatteras, N. C.
7. To investigate methods of artificial spawning techniques for the dolphin by the use of human chorionic hormones.
8. To observe behavior of captive dolphin.
9. To investigate ecological requirements of captive dolphin.

HOW INFORMATION WILL BE APPLIED:

1. This information will be used to encourage the development of commercial aquaculture operations in N. C. estuaries. It is also applicable to other Atlantic and Gulf Coast areas of the U. S.
2. This information would also be of considerable benefit in aquaculture developments in the U.S. Virgin Islands and Puerto Rico. These areas have marginal commercial fisheries, high rates of unemployment, high demand for choice fish for the tourist industry, and year-round seasons for aquaculture.
3. This information also has worldwide application to all countries which have need of supplies of nutritious and palatable fish at reasonable costs for their people.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

1. Improvements have been made in techniques of obtaining and transporting wild dolphin. The development of a doughnut-type tank has facilitated transport of this species.
2. Twenty-one dolphin were reared from juveniles to adult size for retention as brood stock. These fish were lost when a gale destroyed the pens.
3. Captive dolphin utilized both natural and artificial foods.
4. Fast growth rates were observed in captive dolphin. In 1971, five dolphin gained an average of 1.13 lbs./week. The food conversion for these fish was 3.45. In 1972, 21 dolphin gained an average of 0.86 lbs./week, and individual gains for these fish ranged from 0.31 to 1.29 lbs./week.
5. Dolphin eggs and larvae were collected from late May to August off of the N.C. Coast. These eggs were incubated and maintained for periods up to 9 days.
6. Behavioral and ecological onservations were made on captive dolphin.
7. A concrete recirculating tank of 10,000 gallon capacity was constructed at Hatteras to hold dolphin throughout the year.

Project No.: R/AF-1

Title: Propagation of the Dolphin, Coryphaena hippurus, in North Carolina

Principal Investigator: William W. Hassler, Dept. of Zoology, North Carolina State University

Creel Census Data:

Creel census studies have been conducted at Oregon Inlet and Hatteras, N. C. primarily to determine the stage of maturation and spawning in male and female dolphin. A state-owned boat is not available for this project and charter funds are limited. Consequently, the creel census provides the opportunity to inspect large numbers of dolphin at negligible cost. Ripe male dolphin have not been observed in any of these landings. Only immature and spent males have been found. Other creel census information such as dolphin catch and effort are readily available when the maturation and spawning data are acquired. Samples were also taken of the size range and sex ratio of dolphin throughout the fishing season.

The dolphin catch and effort data for Hatteras, N. C. are tabulated in Table 1 for 1970-1972. These data show that the dolphin catch per unit effort was greater in 1971 and 1972 than in 1970. Data for Hatteras indicate that the dolphin catch-per-trip increased approximately 50 percent during the 1971 season. Although the number of charters decreased from 862 offshore trips in 1970 to 581 offshore trips in 1971, the total number of dolphin caught increased slightly. Consequently, the catch-per-trip showed a sizeable increase. The decline in the number of charter trips in 1971 resulted from increased charter rates which were necessitated by increased costs. In 1972 the dolphin catch-per-trip was only slightly lower than 1971. However, a considerably larger number of dolphin were caught since more charter trips were involved. The increased trips at Hatteras in 1972 were largely the result of additional boats at this port during the 1972 season.

The dolphin catch at Oregon Inlet, N. C. is tabulated in Table 2. These data show that the catch per unit effort increased 167 percent in 1971 and decreased approximately 30 percent in 1972. The effort at Oregon Inlet decreased in 1971 because of economic factors. Another decrease in effort occurred in 1972, and this decline was attributed to bad weather. In 1972 approximately one-third of the fishing days were too rough to allow fishing.

The combined dolphin catch records indicate that dolphin were more abundant at Oregon Inlet and Hatteras, N. C. in 1971 than 1970. Evidently 1971 was a better spawning year for this species since the increased abundance was represented in the catch by small dolphin. Most of the dolphin in the catch were in the 0+ and 1+ age group. The number of charter trips decreased in 1971, and this is generally believed the result of increased charter rates. The 1972 catch declined because of the high incidence of bad weather. The Hatteras boats were able to make trips in bad weather because of the proximity of fishing grounds to port. The Oregon Inlet boats had a longer distance to go to the fishing grounds, and consequently, did not venture out in bad weather.

Table 1

Dolphin Catch and Effort Data, Hatteras, N. C.
1970 - 1972

Year	No. Trips	No. Dolphin Caught	Catch per Unit Effort
1970	862	8,387	9.73
1971	581	8,742	15.05
1972	819	12,038	14.70

Table 2

Dolphin Catch and Effort Data, Oregon Inlet, N. C.
1970 - 1972

Year	No. Trips	No. Dolphin Caught	Catch per Unit Effort
1970	1,814	11,320	6.24
1971	1,412	23,558	16.68
1972	1,261	14,920	11.83

Catch per trip data, compiled from 1961 to 1972, show the effects of poor spawning years, and a poor spawning year is immediately reflected in the low catch of small dolphin.

Sex Ratio Data:

Sex ratio data were obtained from a total of 19,211 dolphin during 1970, 1971, and 1972 at Hatteras and Oregon Inlet, N. C. The combined samples for these three years indicate that female dolphin are statistically more abundant in the catch than males. Also, no ripe male dolphin were observed in the 5,552 male specimens which were sampled.

The sex ratio for dolphin was compiled by size groups and months for 1970, 1971, and 1972. Examination of the data showed that female dolphin are significantly more abundant in size groups up to 10 pounds. Male and female dolphin from 10 to 15 pounds in weight are present in approximately the same abundance. Males are significantly more abundant in size groups exceeding 15 pounds. It is believed that greater longevity and differential metabolism are prime factors in the greater abundance of males in the large size groups.

These sex ratio data indicate that the growth and survival of the sexes should be considered in the aquaculture studies. It may be more efficient to harvest females at smaller sizes if the males have greater longevity and growth potential after 10-15 pounds. The sex ratio data for dolphin at Hatteras and Oregon Inlet, N. C. for 1970-1972 are presented in Table 3.

Capture and Transport of Dolphin off Hatteras, N. C.:

Hatteras, N. C. is the closest port in North Carolina to the Gulf Stream which runs along the Continental Shelf. However, even at Hatteras it is necessary to go on the average about 20 miles to reach the Gulf Stream. Consequently, the capture and transport of dolphin from the Gulf Stream to the laboratory in small local boats originally presented some difficulties since local boats required 3 to 3 1/2 hours to get to port after a supply of dolphin had been obtained. In 1972 it was necessary to go 25 to 30 miles to obtain dolphin.

Tanks - The first tank used for transporting fish was rectangular, and this caused some problems. Dolphin swim continuously and pass water over the gill filaments by swimming with the mouth agape. A dolphin would cease swimming and suffocate when its head was poked into a corner. The tanks were altered by placing curved pieces of plywood in the corners. This installation improved the survival of dolphin but the additions to the tank were difficult to maintain. Eventually, a round fiberglass tank of approximately 300 gallon capacity was obtained. Survival was considered to be fair in this tank, but considerable abrasions occurred on the dolphin in this tank since they tended to rub the sides. In 1972 a fiberglass tank having an oblong, doughnut-like shape was designed and this tank was the most successful type used in transporting dolphin.

Gear - The capture of dolphin was facilitated by the use of heavier fishing gear than is normally used to catch this species. The dolphin are caught and landed quickly to

Table 3

Sex Ratio Data for Dolphin
at Hatteras and Oregon Inlet, N. C.
1970 - 1972

Year	Male	Female	X^2
1970	1,519	3,429	725 **
1971	2,144	5,761	1,655 **
1972	1,889	4,469	1,047 **
Total	5,552	13,659	3,420 **

Table 4

Growth and Food Conversion of Dolphin, Coryphaena hippurus
at Hatteras, N. C., 1971

Initial Weight (lbs.)	No. Days Held	No. Weeks Held	Final Weight (lbs.)	Gain in Weight (lbs.)	Average Gain/Week (lbs.)	Food Fed (lbs.)	Food Conversion
3.5	18	2.6	7.25	3.75	1.44	8.50	2.27
4.5	42	6.0	11.75	7.25	1.21	23.75	3.28
4.5	42	6.0	11.75	7.25	1.20	25.44	3.51
5.0	48	6.9	11.50	6.50	.94	24.75	3.81
5.0	48	6.9	12.25	7.25	1.05	27.81	3.84
Total	198	28.3		32.00	1.13	110.25	3.45

avoid exhaustion of the fish. Fish which are brought in slowly generally die shortly after capture. Barbless hooks were also used to minimize handling of the fish. The fish were usually placed directly in the tank and were disengaged from the hook without handling. Generally, a barbless hook will fall out if the tension is released from the line. Any fish which had abrasions or showed evidence of bleeding was not retained. Our experience indicated that these specimens invariably died.

Temperature - Transportation of dolphin from the Gulf Stream to estuarine waters was difficult when water temperature differences occurred between these areas. At the beginning of the season considerable mortality occurred after the dolphin had been transported to inshore waters. Another difficulty encountered in transporting dolphin occurred when cold areas of water were found between the Gulf Stream and shore. Often considerable temperature differentials existed, and passage through these currents caused some loss because of the rapid change in water temperature.

In the fall the temperature inshore at Hatteras would drop considerably and again complicate the transport of fish since we had little control of temperature, and this imposed some stress on the captive dolphin.

During 1972 dolphin were maintained in pens in Pamlico Sound. These fish endured water temperatures as low as 59°F.

Pens - In 1972 new fish pens were constructed in Pamlico Sound near Hatteras, N. C. Six-inch diameter pilings, approximately 20 feet long, were pumped 4 to 5 feet into the bottom. Stainless steel cyclone fence was attached to the piling for the first six feet (Water depth was approximately 5 feet). Plastic-coated wire was used above the cyclone fence for the next six feet. An inner pen was formed which was approximately 30' x 30'. A portion of this pen was subdivided into five holding pens approximately 6' x 10'. This left a large inner pen approximately 20' x 30'. This pen contained 20 to 25 dolphin satisfactorily under normal conditions. However, storm waves imposed some maneuvering difficulties to the fish, so the original pen was enlarged by installing additional piling and plastic-coated wire approximately 10 feet around its perimeter. This created a race-track type of enclosure of which the original pen as the infield. It also created considerable swimming space for the dolphin and allowed the fish to swim to the lee side during storms. The pens were damaged during a severe storm in late October, 1972.

Growth and Feeding of Dolphin:

Life history data and growth statistics indicate that dolphin are a very fast growing species with a short life span, both of which are desirable attributes for aquaculture purposes. However, no bonafide fish cultural experiments have been attempted on dolphin even though observations have been made on several fish.

If dolphin could be artificially propagated and achieve rapid growth, these fish could provide regular supplies of excellent food at economical prices. This species has a potential that far exceeds that of other species now being tested for aquacultural purposes. Although pompano have a high market value, their growth is relatively quite slow. Many crops of large dolphin could be raised during the time it would require to raise pompano to marketable size. Also, the market price of dolphin would be within the range of people who could not conceivably purchase pompano.

Feeding and growth investigations were conducted on dolphin during midsummer and fall in 1971 and 1972. In both years dolphin showed an excellent rate of growth. These data are tabulated in Tables 4 and 5.

During the summer of 1971 a feeding trial was conducted on five dolphin ranging from 3.5 to 5.0 pounds in weight. In Table 4 it can be seen that all of the fish doubled their weight in periods ranging from 18 to 48 days. Percent gains of 107, 161, 161, 130, and 145 were made in 18, 42, 42, 48, and 48 days respectively. The food conversion ratio for these fish ranged from 2.27 to 3.84. The average conversion ratio was 3.45 pounds of fish fed to every pound gained. However, it should be stressed that additional food might have been obtained from the numerous small fish which swam freely in and out of the pen.

In 1972 we maintained 21 dolphin in a holding pen in Pamlico Sound. Our objectives were to hold these dolphin for brood stock for the next year. The fish would be held in the estuarine pen until mid-fall and then be transferred to a large, heated tank until next spring. Unfortunately, a severe storm resulted in the death of these dolphin before the transfer could be made. However, these fish were weighed during late summer and growth data are available in Table 5 for these specimens.

A resume of the growth attained by dolphin, Coryphaena hippurus, is tabulated in Table 6.

The dolphin were fed as much as they could consume. Initially, feeding was tried 3 times a day, but when the dolphin refused food at noon, then twice-a-day feeding was followed.

Many types of fish were consumed by the dolphin. The species fed include spot, pinfish, bluefish, mullet, bonito, amberjack, king mackerel, spanish mackerel, blackfin tuna, croaker, wahoo, and sailfish. Also, shrimp and squid were readily ingested. The food was obtained locally from sport and commercial fishermen. An abundance of fish is readily obtained without charge at Hatteras. Commercial fishermen dump non-salable fish into the estuary, and sport fishermen leave excess fish on the docks.

The dolphin respond readily to feeding and will generally accept food in 12 to 24 hours after capture. It was noted that fresh fish was preferred to previously frozen fish.

In 1972 artificial foods were fed to dolphin, and the experimental fish consumed artificial food only in the absence of fresh fish. It was also necessary to withhold food for some time before the dolphin would ingest the floating pellets.

It should be stressed also that this is the first time that dolphin have been raised outside a commercial aquarium. The only successful accounts of growing dolphin are one fish at the Miami Seaquarium and two dolphin at Marineland. These aquaria are both multi-million dollar establishments. Furthermore, the dolphin were reared in these tanks some years ago under conditions which may not be available today.

Dolphin Holding Tank - In 1972 we constructed a 10,000 gallon holding tank for dolphin adjacent to the main laboratory building at Hatteras, N. C. The external measurements

Table 5

Growth of Dolphin, Coryphaena hippurus at Hatteras, N. C.
1972

Tag No.	Sex	Initial Weight in lbs.	Time in days	Subsequent Weight in lbs.	Weight Gain in lbs.
1700	F	2.75	73	10.5	7.75
1702	F	2.25	67	7.5	5.25
1712-13	M	3.5	45	10.5	7.00
1706	F	2.75	45	10.25	7.50
1704	M	3.00	45	9.00	6.00
-	M	2.00	38	6.38	4.38
1707	F	1.50	38	5.50	4.00
1714-15	M	1.75	34	7.00	6.25
1696	F	1.00	34	2.50	1.50
1709	F	2.50	34	8.50	6.00
1717	F	2.25	34	8.00	5.75
1710	F	2.25	34	7.00	4.75
-	F	1.50	34	5.50	4.00
1697	F	2.50	31	4.50	2.00
1705	F	1.50	22	5.50	4.00
1699	F	2.00	22	4.50	2.50
1711	F	1.50	22	3.12	1.62
1703	F	1.50	22	3.25	1.75
1701	F	1.50	22	4.50	3.00
1698	F	2.00	22	4.50	2.50
1708	F	1.50	22	4.50	3.00

Table 6

Growth of Dolphin, Coryphaena hippurus
at Hatteras, N. C., 1970-1972

Year	Number of Specimens	Average Weight in pounds per week	Range in Growth Pounds per week
1970	4	0.59	0.50 - 0.69
1971	5	1.13	0.94 - 1.44
1972	21	0.86	0.31 - 1.29

on this tank are approximately 10 feet wide x 20 ft. long x 8 ft. high. The walls are of reinforced concrete and are approximately 8 inches thick. The salt water in the tank is circulated through a gravel filter by a corrosion-proof electric pump at a rate of 20gpm. The filter is located on the top of the tank and is approximately 16 feet long, 2 1/2 feet wide, and 21 feet in depth. The filter is filled with gravel of varying size and the tank water is sprayed over this gravel. The filtered water returns by gravity to the holding tank. The holding tank is also aerated by an automatic air compressor which discharges compressed air through airstones at the bottom of the tank.

Originally the temperature of the tank was to be maintained during the winter season by means of a salt water swimming pool heater but funds were insufficient to install this heater. Temperatures were maintained at less than desired levels by means of infra-red lamps. In addition the tank was insulated externally with styrofoam insulation.

Dolphin Culture in Other Areas:

In 1971 we attempted to locate more suitable areas to cultivate dolphin. One location which was tried was Bimini, B.W.I. However, local water conditions were not suitable for dolphin and these efforts were terminated.

A survey was also made for suitable sites in the Florida keys, but no satisfactory site could be located.

Dolphin Spawning off Hatteras, N. C., 1972:

During 1972 we made a series of plankton tows for dolphin eggs offshore of Hatteras, N. C. Sample tows were made while enroute from Hatteras Inlet to the Gulf Stream, and egg tows were only made in those areas where previous sampling had indicated dolphin eggs. A total of 111 plankton tows were made, and dolphin eggs were generally taken 20 to 30 miles offshore of Hatteras Inlet. Few eggs were collected inshore of this distance. Meter nets of 0.505 mm mesh and 0.706 mm mesh were used for the egg collections. The plankton samples were separated immediately after collection, and the dolphin eggs (and similar eggs) were removed from the plankton sample and placed in separate containers. These containers were covered with plankton netting, placed in large plastic barrels and aerated with oxygen. The eggs were placed in various types of incubation devices after transportation to the laboratory. Considerable difficulty was encountered with the weather in 1972, and boat charters were not always available when we wished to make offshore collections. Dolphin eggs were first collected on May 21,1972, and these eggs were available irregularly until August 18, 1972.

The plankton tows were generally short in duration since the buckets and nets were filled with organisms rather quickly. Tows of 10-minute duration were considered most suitable.

Incubation of Dolphin Eggs:

The egg collections which were made in the Gulf Stream adjacent to Hatteras, N.C. were transported to the laboratory for observation. The dolphin eggs were separated from the eggs of other species. Also, care was exercised to select viable dolphin eggs. These eggs were incubated by various methods involving both filtered and

artificial sea water. The various methods which were employed are listed as follows:

1. Eight-inch culture dishes. The lowest survival of eggs and larvae occurred in this method. The longest survival time was approximately 54 hours. (aeration only).

2. Modified 8-inch culture dishes. Both aeration and rotary circulation were employed in this method to keep the eggs and larvae off of the bottom. Survival time was extended approximately 5 or 6 hours.

3. Three-gallon Battery Jars. These containers were considered an improvement over the culture dishes since the dolphin eggs and larvae remained in flotation with only gentle aeration. However, survival time was only extended 5 or 6 hours and this technique was also considered unsuitable.

4. Thirty-gallon plastic containers. The survival of dolphin eggs and larvae was extended approximately 30 hours in this technique. However, we encountered difficulties in observing and feeding the larvae and, consequently, abandoned this method.

5. Thirty-gallon aquaria. These tanks were prepared for dolphin culture by promoting the growth of blue-green algae on the glass sides of the aquarium. In addition cultures of Chlorella sp. were added to the filtered sea water. Survival of dolphin larvae was increased considerably over previous techniques by this method. However, it was difficult to maintain a sufficient supply of plankton for the dolphin larvae in a tank of this capacity. The use of a smaller aquarium was indicated.

6. Ten-gallon aquaria. These tanks were previously prepared by allowing blue-green algae to cover the sides of the aquarium and by adding a quantity of Chlorella to the tank. Food organisms of suitable size were added to the aquarium just prior to the eyed stage. Larval dolphin survived to approximately 9 days.

A resume of the maximum survival times of dolphin incubated by various methods is presented in Table 7.

Observations on Dolphin Behavior:

During the 1972 season we noted that feeding competition stimulated the appearance of dark, vertical bands on the dorsolateral surface of the dolphin. These bands varied from individual to individual but the coloration appeared to be most prominent in the dominant members of the school. Also, the intensity of the bands appeared to be greatest during the initial phases of feeding. As individual fish became satiated, they gradually displayed a lesser degree of banding and eventually returned to normal coloration. On several occasions photographic documentation of this behavior was obtained.

Another type of dolphin behavior which was observed for the first time in 1972 was the reaction of these fish to a floating paddle. The introduction of such an object to the pen was immediately followed by lateral swimming movements of male dolphin under

Table 7

Maximum Survival Time of Dolphin, Coryphaena hippurus, Eggs and Larvae Reared in Laboratory at Hatteras, N. C., 1972

Hatching Device	Approximate Time in days
8 inch culture dishes	2 1/4
8 inch modified culture dishes	2 1/2
3 gallon battery jars	3
30 gallon plastic containers	4 1/2
30 gallon aquaria	7
10 gallon aquaria	9

the object. These individuals repeatedly circled the object and then rolled on their sides as they passed underneath. Convulsive flutterings occurred frequently. Initially, the larger males dominated this activity. Eventually, the smaller males and large females participated in this behavior. Photographic documentation of this behavior was also obtained.

Presentation of dolphin research progress:

1. Sport Fishing Short Course, Hatteras, N. C..
2. Coastal Plains Workshop on Aquaculture, Jekyll Island, Georgia.

NOAA FORM 90-2 (8-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SEA GRANT PROJECT SUMMARY
(Limit all information to the spaces provided)

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 41-R2600

PROJECT NO.	PROJECT TITLE	DATE INITIATED (If continuing)
R/AF-3	Studies on reproduction and fungal parasites affecting reproduction in the lobster, Homarus americanus, and the blue crab, Callinectes sapidus, in North Carolina waters.	July 1970
GRANT NO. (Previous) 2-35178	(If different)	DATE OF THIS FORM May 1973
INSTITUTION UNC	☐ NEW ☒ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT	ESTIMATED COMPLETION DATE December 1975

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
Edward P. Ryan, Dept. of Biology, ECU	16%	Charles E. Bland	16%

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (By numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 41,672	$ 20,836	$ 27,924	$ 13,962	$	$	R/ES-10

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Aquaculture & Fisheries	Commercial Fisheries-Biology

OBJECTIVES:

OBJECTIVES:

The objectives of this project are: 1) to examine extensively the reproductive cycles and seasons of the blue crab, Callinectes sapidus, and the lobster, Homarus americanus; 2) to examine the effect of certain fungal parasites on the reproductive capabilities of the species in question. In so doing, a further goal will be to provide information pertinent to the future selective harvesting and possible aquaculture of these important marine species.

HOW INFORMATION WILL BE APPLIED:

The information obtained will allow an assessment of the reproductive potential of the species, the seasons in which areas could be utilized for fishing and/or set aside as spawning sanctuaries and of techniques to be utilized in aquaculture. Knowledge about the fungal parasites will be applied in aquaculture operations where organisms are raised in confined areas and diseases such as fungi spread easily.

HOW INFORMATION WILL BE APPLIED (By specific)

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

Progress:

1. Histological and physical evidence were obtained of a fourth spawning in female crabs and circumstantial evidence of a possible fifth.
2. Geographical distribution in N.C. waters of the fungal parasite of blue crab ova, Lagenidium callinectes, has been determined.
3. Complete developmental cycle for the fungus, L. callincetes has been studied with light and electron microscopy.
4. Controlled infection experiments to determine the destructive potential of L. callinectes on the blue crab have been initiated.
5. A fungal pathogen of shrimp (similar to the one occurring on crabs) has been isolated and is under investigation.

Accomplishments:

1. Information concerning fungal parasites is being applied in tests for effective fungicides and other means of controlling the disease.

Project No.: R/AF-3

Title: Studies on reproduction and fungal parasites affecting reproduction in the blue crab, Callinectes sapidus, and the lobster, Homarus americanus, in North Carolina waters.

Principal Investigators: Edward P. Ryan and Charles E. Bland,
Department of Biology, East Carolina University.

Crustacean Reproduction--Field collections and laboratory rearings of blue crabs concerned spawning cycles during the two summer spawning seasons. Female crabs were usually caught in crab pots, brought to the laboratory, tagged, and maintained in concrete holding tanks. The tanks were provided through the cooperation of the National Marine Fisheries Service, Center for Menhaden Research, Beaufort. Procedures for maintenance of the females were those that had been developed in the previous spawning season of this study (1970). Despite extreme care and twice daily observations, mortality rates were high; only approximately 30% of the females survived from one spawning to the next.

During the time period 453 were maintained during parts of their spawning cycles. The mean time interval between ovulations for these crabs was 21.1 days which approximates the time interval reported for another crab species, Libinia emarginata, by Hinsch (Biol Bull. 143:358-366, 1972).

Crabs ovulating in the holding tanks also provided source material for studies dealing with ovulation behavior and ova attachment. All crabs which ovulated in the tanks attached the two million or so eggs in a normal manner. Except in a few instances, ovulation occurred late at night and attachment of the ova to setae of the abdominal appendages did not involve formation of a special cementing layer. A paper dealing with the ovulation cycle and the process of ova attachment is in preparation.

Gonadal tissues from these crabs have been fixed and embedded for examination by light and electron microscopy. Some of this material is being utilized in a master's thesis, now in preparation, by Mr. Samuel Bryan on changes in the fine structure of crab oocytes during oogenesis. Electron micrographs were obtained of eggs in the earliest stages of fertilization, e.g. up to two hours but without success in determining nuclear involvement. The fertilization process is relatively unknown for decapod crustaceans and probably requires several hours.

During collections, crabs of other species (Family Xanthidae, Panopeus herbstii and Eurypanopeus depressus) were collected near Oregon Inlet and Wanchese that were infected with a sacculinid parasite. Infected specimens of these species were also collected at Beaufort. It could not be determined if this parasitic barnacle was Loxothylacus texanus Boschma which is known to cause parasitic castration in blue crabs in the Gulf of Mexico.

As proposed, the research was to have included studies on reproduction in the lobster, Homarus americanus, beginning with the third year. Limited access to the spawning grounds allowed us to obtain specimens for gonadal examination at the beginning of the winter spawning season, 1972-73. These tissues have been processed for light and electron microscopy.

Fungal Parasites Affecting Reproduction--During the period 6-1-71 to 8-1-71 a survey of over 2000 ovigerous crabs was made for fungal parasites of the ova. Collections were made via "crab pots" that were placed at random locations throughout Bogue and Core Sounds, N. C., with a majority of the samples being taken from the Newport Estuary.

Crabs were sorted according to age of the sponge and the ova examined microscopically for the presence of fungi. Ova that were obviously infected with fungi as well as random samples of non-infected ova were placed on the agar medium of Fuller et al. (1964) or on crab egg agar. Fungi present on the eggs grew out into the agar and were isolated for later study.

Two fungi, Lagenidium callinectes, and Thraustochytrium sp. and a filamentous bacterium, Chlamydobacterium sp., were present in many of the collections. However, severe, naturally occurring fungal infections of ova were observed in only six samples (see below). In each of these samples, the dominant fungus present was Lagenidium callinectes. This organism was isolated from the ova and brought into pure agar culture on PYG agar (Difco) that was made up with sea water. This material has been used subsequently for a thorough study of the life cycle, structure, and development of L. callinectes. Manuscripts covering portions of the study have been submitted for publication (Bland and Amerson, 1973a&b; Amerson and Bland, 1973). Portions of this study were included also in a thesis by Mr. H. V. Amerson entitled, "Structure and Development in Lagenidium callinectes." (see appendix for abstracts of papers and thesis).

Studies into the destructive potential of L. callinectes were begun as soon as the fungus was brought into culture. Preliminary results indicate that under crowded laboratory conditions L. callinectes may spread from sponge to sponge with great rapidity. However, these studies were just begun when the spawning season of the crabs came to an end. Subsequent studies with crab eggs that were autoclaved in sea water show that L. callinectes may infect an entire non-living sponge. Whether or not this could occur with living eggs under crowded conditions and where there are numerous fungal propagules has not been determined.

During the period May 1, 1972, to August 1, 1972, extensive collections for fungal parasites of crabs were made from Bogue, Core, Pamlico, and Albemarle sounds and from offshore. Assistance in collecting was provided by Dr. C. Johnson of the Duke University Marine Laboratory who is now engaged in a study of protozoan parasites of the blue crab . As of June 1, 1972, the sponges of 174 crabs had been examined with a resulting infection rate with L. callinectes of over 95%. In most instances, 1/3 to 1/2 of the eggs in a given sponge were destroyed by the disease with the future of the remaining eggs questionable. By August 1, 1972, 676 sponges had been examined with a cumulative infection rate of approximately 30%. For reasons which cannot be explained, no infected crabs were collected after July 9, 1972. From these collections, 25 strains of L. callinectes were brought into pure culture and are now under study. In addition,

studies involving disease transmission when crabs are maintained under crowded conditions indicated that L. callinectes may spread very rapidly under such conditions. Also, under confined conditions, eggs of Libinia, Menippe, and Panopeus became infected with L. callinectes. A paper describing the results of this portion of the study is now in preparation.

With the aid of a graduate student, Mr. D. Ruch, studies into possible control methods for fungal parasites of the blue crab have been initiated. Mr. Ruch's research involves testing the effectiveness of various fungicides in stopping growth of L. callinectes. The fungicides being tested are as follows: Benlate, Manzate 200, Dithane M-45, Difolatan, Dyrene, Captan, Tribasic Copper-Sulfate, Chlorinated Anthroquinone. The results of these tests will be used in a subsequent study concerning the effect of workable fungicides on growth and development of shrimp larvae. In this connection, a cooperative program of study involving a species of Lagenidium parasitic on penaeid shrimp has been established with Dr. B. Hysmith (Dow Chemical Co., Freeport, Texas) and Dr. D. Lightner (NMFS, Galveston, Texas).

Publications and Papers Presented

Publications:

Amerson, H. V. and C. E. Bland, 1973. The occurrence of polycomplexes in encysting spores of Lagenidium callinectes. Mycologia (in press).

Bland, C. E. and H. V. Amerson. 1973a. Observations on Lagenidium callinectes. isolation and sporangial development. Mycologia, 65 (in press).

Bland, C. E. and H. V. Amerson. 1973b. Zoosporogenesis and zoospore structure in Lagenidium callinectes. Archiv fur Mikrobiol. (submitted for publication).

Papers Presented:

Amerson, H. V. and C. E. Bland. Fine structure of spore development in Lagenidium callinectes Couch--Presented to Spring, 1972, meeting of Association of Southeastern Biologists.

Amerson, H. V. and C. E. Bland. Occurrence and distribution of Lagenidium callinectes Couch in North Carolina waters--presented to spring, 1972 meeting of North Carolina Academy of Science.

Bland, C. E. and H. V. Amerson. Observations on Lagenidium callinectes Couch: isolation and sporangial development--Presented to Spring, 1972, meeting of Association of Southeastern Biologists.

APPENDIX I

Observations on Lagenidium callinectes Couch: Isolation and Sporangial Development (Oomycetes, Lagenidiales)*

Charles E. Bland and Henry V. Amerson, East Carolina University

A strain of Lagenidium callinectes Couch, isolated from the ova of crabs collected in the Newport Estuary, North Carolina, was brough into agar culture, and studied with regard to growth and sporogenesis. The vegetative thallus consists of both intramatrical hyphae, which may completely fill infected ova, and extramatrical hyphae, which may grow from egg to egg or function in the discharge of cytoplasm prior to spore formation. In sporogenesis, the cytoplasm from a given septum delineated portion of the thallus migrates through a specialized, non-branched, extramatrical hypha into a gelatinous vesicle that forms at the hyphal tip. The cytoplasm does not flow as one large mass, but rather as individual cytoplasmic units that are connected in sequence by a cytoplasmic thread. Cleavage of the cytoplasm occurs inside the vesicle with subsequent spore discharge through a break at the distal end of the vesicle. Once released, the spores swim away immediately.

*Abstract of paper accepted for publication in "Mycologia", Vol. 56.

APPENDIX II

Fine Structure of Spore Development in Lagenidium callinectes Couch (Oomycetes, Lagenidiales)*

Henry V. Amerson and Charles E. Bland
East Carolina University

Lagenidium callinectes Couch occurs as a peripheral parasite of the egg mass of the blue crab, Callinectes sapidus Rathbun. Fine structural observations on sporagenesis in this organism have shown that cleavage of cytoplasm is initiated by the coalescence of many small vacuoles, "cleavage vesicles." Cleavage continues until mononucleate zoospores are delimited. The structure of free swimming spores resembles that described by other investigators for related organisms. Spore encystment is preceded by the accumulation of numerous fibrous bodies within the quiescent spore. Lamellate nuclear inclusions that resemble compound synaptenemal complexes are also obvious at this stage. An interesting feature of spore germination is the accumulation of mitochondria and fibrous bodies in the germ tube. Results presented in this study are compared with those obtained by other investigators for related organisms.

*Abstract of paper presented to Spring 1972 meeting of Association of Southeastern Biologists.

APPENDIX III

Zoosporogenesis and Zoospore Structure in the Marine Phycomycete, Lagenidium callinectes, Couch*

Charles E. Bland and H. V. Amerson
East Carolina University

Summary:

1. Zoosporogenesis and zoospore structure of Lagenidium callinectes, parasitic on ova of the blue crab, Callinectes sapidus, are studied by electron microscopy.

2. The cytoplasmic thread connecting discharging cytoplasmic units appears as a simple constricted area of cytoplasm, containing much membranous material, and bound by only the plasma membrane.

3. Cleavage of discharged cytoplasm may be grouped into four stages and occurs by the coalescence of cleavage vacuoles.

4. During cleavage, microtubules contained within packets formed from the endoplasmic reticulum attach extracellularly to the anterior flagellum.

5. The zoospores are rather "unspecialized" with the two flagella arising from a raised area of the diagonal groove.

6. Rootlets interconnect the basal bodies and project anteriorly and posteriorly along the plasma membrane of the spore.

7. Microtubules project away from the basal bodies and appear to ensheath the beaked nucleus.

*Summary of paper submitted for publication in Archiv für Mikrobiologie.

APPENDIX IV

Henry Van Amerson. THE STRUCTURE AND DEVELOPMENT OF LAGENIDIUM CALLINECTES COUCH.* (Under the direction of Dr. Charles E. Bland) Department of Biology, August, 1972.

Co-ordinated light and electron microscope observations were made, tentatively establishing the life cycle of Lagenidium callinectes. Each stage of this life cycle was studied in detail. The zoospores are typical for an oomycete, oval and biflagellate. Spore encystment involves flagellar retraction or detachment and the formation of a cyst wall from fibrous and wall vesicles. Structures resembling polysynaptonemal complexes are present in the nucleus of encysting spores and are indicative of meiosis at this stage. Germination of the encysted spores is generally monopolar with the cytoplasm moving into the germ tube leaving the cyst empty. Wall formation in the germ tube and hyphae is accomplished by small wall vesicles. Spore development in L. callinectes occurs in a gelatinous cleavage vesicle formed at the tip of an unbranched hypha. Cytoplasm discharges from this hypha into the vesicle where a process of vacuolar fusion results in the cleavage of the sporogenic cytoplasm into zoospores. The spores are released when the vesicle ruptures.

*Abstract of thesis submitted for Master of Arts in Biology, August, 1972.

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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 11-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT TYPE	PROJECT TITLE	☐ NEW ☒ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED IF CONTINUING
R/ES-1	Community Succession on Dredge Islands		July, 1971
GRANT NO. (OFFICE) 2-35178	SUB TITLE (If different)		DATE OF THIS FORM May, 1973
INSTITUTION UNC			ESTIMATED COMPLETION DATE December, 1974

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
James F. Parnell, Dept. of Biology, UNC-W	50	Robert F. Soots	50

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (By numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	R/ES-2, R/ES-3 R/ES-4
$ 22,040	$ 11,020	$ 22,040	$ 11,020	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Estuarine Studies	Coastal Zone Mgmnt./Natural Sciences

OBJECTIVES:

OBJECTIVES:

The objectives of this study are: 1) to analyze the invasion and succession of vascular plants and vertebrates on known-age islands created by dredging operations along the southeastern coast of North Carolina, 2) to relate our findings to studies on dredge island stabilization, and 3) to develop management techniques which may be employed to provide habitat for wildlife species.

HOW INFORMATION WILL BE APPLIED:

The information from this research will be applied in increasing the effectiveness of the management of estuaries. By knowing the patterns of plant and vertebrate succession on the dredge islands in relation to their age, location, and configuration, management procedures can be established to provide habitat for desirable wildlife species (for example, maintenance of the proper stage of plant development to provide nesting areas for colonial shorebirds). The U. S. Army Corps of Engineers, the N. C. Department of Natural and Economic Resources, the National Marine Fisheries Service and others have indicated a strong interest in such possibilities. (By species)

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

A survey was made of the plants and vertebrates on dredge islands located north of the South Carolina line to Roanoke Sound. Two years of plant data have been obtained from selected islands in southeastern North Carolina. An extensive trapping program for small mammals was accomplished during the fall and winter of 1971-72. The breeding birds associated with dredge islands in southern North Carolina were studied intensively during 1971-72 and some work has been done as far north as Roanoke Sound. Chemical analysis has been made on 116 soil samples and particle size analysis of additional samples was initiated. Regular land and waterbird surveys were conducted along a transect. Negotiations with the appropriate agencies were initiated to obtain permits to use herbicides in habitat manipulations.

(Do not exceed this space)

Project No.: R/ES-1

Title: Community Succession on Dredge Islands

Principle Investigator: James F. Parnell, Professor, Biology Department University of North Carolina, Wilmington, North Carolina.

Associate Investigator: Robert F. Soots, Jr., Assistant Professor, Biology Department, Campbell College, Buie's Creek, North Carolina.

Field studies were begun during the summer of 1971 by making a general inspection of the dredge islands along the North Carolina coast. Special consideration was given to the islands located in southeastern North Carolina. From these a series of islands were selected for intensive analysis of vascular plant and vertebrate succession following deposition of dredge spoil. These islands were located between New River Inlet and the South Carolina line. The deposits comprising them ranged from fresh material to deposits over 30 years old. Ages of the depositions were determined by consultation with the Wilmington District Corps of Engineers and by examination of annual rings on various species of trees.

Field work, in addition to establishing the study areas, has consisted of mapping of islands, vegetation analysis, soils analysis, and study of vertebrate utilization of the islands.

Mapping

Most of the field measurements of the islands to be mapped have been made. Data from ground measurements of elevations and aerial photographs has been collected from which maps are being constructed.

Vegetation Analysis

Permanent vegetation transects were established on 12 islands of known age. These islands were selected to represent the range of different ages available and to show as little other physical variation as possible.

Transects were established by placing treated stakes and nylon cord across the center of the island perpendicular to the Intracoastal Waterway. In some cases an additional transect was established across the center of the island running parallel to the Waterway. The lengths of transects depended on the size of the island, the shortest being 31 meters and the longest 391 meters. The average transect length was 151 meters. The width of the transect depended on the type of vegetation being sampled. A one-meter wide transect was utilized in grass-herbaceous vegetation and a four meter wide transect in shrub-tree vegetation. Samples were tabulated from $1M^2$ and $4M^2$ plots along the transect depending on the type of vegetation present. For example, on islands up to

about 6 years of age meter wide transects were sampled across the whole island because shrub zones were not well developed. On older islands contiguous $1M^2$ quadrats were utilized in the bordering grass-herbaceous zone and $4M^2$ quadrats in the shrub and/or tree zones. Within the $4M^2$ quadrats a $1M^2$ subsample was taken of the herbaceous vegetation.

The phytosociological studies were initiated during the summer of 1971 and continued through the summer of 1972. Also, periodic checks were made at other seasons to observe the condition of the vegetation and to note physical changes on the islands.

Quadrats of $1M^2$ size were delimited by use of a portable wooden frame subdivided into quarters. The following data was recorded from each $1M^2$ sample: Species composition, density, total aerial coverage, coverage by species, range of height and average height for each species, and condition of the plants.

The $4M^2$ quadrats were established by placing permanent, pressure-treated stakes at each corner. The boundary of the quadrat was marked by attaching #18 nylon cord between the stakes. The following data was recorded from the $4M^2$ plots: Species present, height, aerial coverage, diameter at breast height (DBH), and diameter at the base of each shrub or tree.

Samples of all species of plants found on the islands to date have been collected and identified. A specimen of each species will be placed in the herbaria at The University of North Carolina at Wilmington and Campbell College.

Analysis of the plant data has not been completed, but preliminary observations indicate a definite pattern of succession does occur and we anticipate being able to make predictions concerning the development of vegetation on dredge islands.

The following factors were found to be the most important affecting plant succession on dredge islands: Age of island, seed source, elevation, prevailing wind, degree of protection from wind, erosion (wind and water), tide level, and nesting of colonial birds. Human usage was also found to be important on some of the islands.

Approximately 130 species of plants representing 43 families have been recorded within the transects sampled. The dominant plants found in the various stages and zones included 16 herbaceous species, 10 sedge and grass species, 6 shrub species, and 2 tree species.

Tables are being made of the plant data and statistical analysis is in progress.

Soils Analysis

A total of 183 soil samples have been collected. Samples were taken from each

island on which a vegetation transect was located. A sample was collected from each vegetation zone and from transitions between zones. Most of the samples were collected from the top six inches of the deposit but some were also taken from the surface of the fresh water table found on the islands. Of the samples collected, 116 have been analyzed for the following: pH in water, buffer pH, phosphorus, calcium, magnesium, potassium, manganese, organic matter, nitrate, acidity (@pH 6.6, ME/100cc). The Soil Testing Division of the North Carolina Department of Agriculture conducted the soils analysis. Particle size is being carried out on the remaining 67 samples.

Vertebrate Utilization of the Dredge Islands

A study of small mammal populations on dredge islands was begun in the fall of 1971 and continued into the spring of 1972. This study yielded information on population levels and habitat associations of these mammals in relation to the island's age and associated vegetative structures. The only common small mammals found on the islands studied were the House Mouse, Mus musculus and the Marsh Rice Rat, Oryzomys palustris. Larger mammals found on the islands included the Marsh Rabbit (abundant on some islands), Sylvilagus palustris; the Eastern Cottontail Rabbit, Sylvilagus floridanus; Raccoon, Procyon lotor; Mink, Mustela vision, and White-tail Deer, Odocoileus virginianus. All of the larger mammals with the exception of the rabbits appeared to have been transients.

Additional observations on mammals will be made during 1973 with special attention being given to their role as predators on ground nesting birds.

Cold-blooded vertebrates are very rare on the dredge islands in southeastern North Carolina. The Squirrel Tree Frog, Hyla squirella, was the only species of amphibian observed and it was rare. The only reptile that is commonly found on the dredge islands is the Diamond-backed Terrapin, Terrapin centrata. These turtles frequently utilize the islands as egg laying sites during their nesting season. The only other repitles observed on the islands were the Rough Green Snake, Opheodrys aestivus, and the Eastern Glass Lizard, Ophisourus ventralis. Occasionally, an American Alligator, Alligator mississipiensis, has been observed laying on the edge of dredge islands in the lower Cape Fear River.

By far the greatest usage of the dredge islands is by birds and a great deal of time has been devoted to a study of them. Two field exercises have been employed in our study of birds. Regular land and waterbird surveys have been made to establish seasonal population levels in an 11 mile transect extending along the Intracoastal Waterway from Snows Cut in the vicinity of Carolina Beach to the U. S. 74 bridge near Wrightsville Beach. Also, lists of numbers and

kinds of birds observed were recorded periodically when traveling to and from dredge islands lying outside the survey transect.

Approximately 130 species of birds have been recorded along the study transect. Seventy-five species are those that would be classified as waterbirds or shorebirds. Seasonal population levels and changes in social structure of the bird populations have been recorded.

Table 1 lists the number of species according to resident status.

Table 1. Number of species of birds by resident status recorded in the study area.

Resident status	Number of species
Winter	36
Summer	22
Permanent	35
Transient	37
Total	130

Of the 57 species of summer and permanent residents recorded 35 are known to nest on the dredge islands. The species known to nest on dredge islands are listed in Table 2. The degree of utilization and comparison to other habitats utilized for nesting is given. The symbols utilized in the table are: A = Abundant, C = Common, U = Uncommon, R = Rare.

As can be seen in Table 2, nineteen species perform most or all of their nesting activity on dredge islands. Therefore, proper management of the islands would be of great importance since there is wide variation in nesting habitat preference among the species. The two most important criteria in nest site selection are the location of the dredge island and the density and structure of the vegetation. Assuming that the necessary stage of vegetation is present the more isolated islands will be selected over the less isolated. The stage(s) of vegetation preferred by the 19 species mentioned above is shown in Table 3. Other criteria found to be important in nest site selection are: Presence of predators, slope of terrain, composition of the substrate, and presence of other nesting birds.

Extensive descriptions have been made on the nesting sites of all of the above species and a more detailed analysis will be given in future reports and publications. Descriptions have been made on location, substrate, vegetation (coverage,

Table 2. Species of birds known to nest on dredge islands along the North Carolina coast.

Species	Island Utilization	More important than other sites
Brown Pelican	R*	Yes ?
Green Heron	C	No
Little Blue Heron	C	Yes +
Cattle Egret	A	Yes +
Common Egret	C	Yes +
Snowy Egret	A	Yes +
Louisiana Heron	A	Yes +
Black-crowned Night Heron	U	?
Glossy Ibis	U	Yes +
White Ibis	C	Yes +
Gadwall	R	No
Osprey	R**	No
Clapper Rail	C	No
American Oystercatcher	A	Yes +
Wilson's Plover	C	?
Willet	A	Yes +
Great Black-backed Gull	R	? +
Herring Gull	U	Yes +
Laughing Gull	A	Yes +
Gull-billed Tern	C	Yes +
Forester's Tern	R	No
Common Tern	A	Yes +
Least Tern	A	Yes +
Royal Tern	A	Yes +
Sandwich Tern	U	Yes +
Caspian Tern	R	? +
Black Skimmer	A	Yes +
Common Night Hawk	C	?
Carolina Wren	R	No
Long-billed Marsh Wren	U	?
Mockingbird	U	No
Yellow Breasted Chat	R	No
Redwinged Blackbird	A	?
Boat-tailed Grackle	A	Yes
Seaside Sparrow	C	?

*Only one nesting colony observed on North Carolina Coast (3 miles north of Portsmouth Island)
**Nesting sites for Ospreys are not generally available on the islands.
+Species that carry out all or the majority of their nesting in North Carolina on dredge islands.

Table 3. Preferred nesting habitat of 19 species of birds that depend heavily on North Carolina dredge islands for nesting sites.

Species	Preferred Nesting sites
Little-blue Heron	Medium shrubs
Cattle Egret	Medium shrubs
Common Egret	Low trees
Snowy Egret	Medium to tall shrubs
Louisiana Heron	Low shrubs
Glossy Ibis	Low to medium shrubs
White Ibis	Tall shrubs to low trees
American Oystercatcher	Sparsely vegetated open domes
Willet	Medium coverage of low grasses ajacent to sparsely vegetated openings.
Great Black-backed Gull	Unknown
Herring Gull	Island bordered by dense grass leading up to open domes with large scattered clumps of plants.
Laughing Gull	Dense grass and herbaceous plants, flat terrain.
Gull-billed Tern	Medium dense grass and low-scattered shrubs
Common Tern	Sparse to medium grasses and herbaceous plants - flat terrain
Least Tern	Slopes and ridges of shelly, bare to sparsely vegetated islands
Royal Tern	Bare islands surrounded by large expanses of open water
Sandwich Tern	Always adjacent to Royal Tern colonies
Caspian Tern	Sparsely vegetated domes
Black Skimmer	Bare to medium, low grasses and herbaceous plants

density, height, species, etc.), nest contents, nest structure, distance between nests, distance from water, slope direction, and mortality. In addition, several hundred photographs have been taken of the nesting habitat and nests. When possible all nests in a colony were counted. Sometimes this was not practical because of the number of nests present. For example, one Royal Tern colony in the lower Cape Fear River contained over 4500 nests. Since there were approximately 6 nests per square meter it was time consuming to get an accurate count. If the adults had been kept from the nests too long egg mortality would have occurred.

With the exception of two species, the American Oystercatcher and Willet, all of the birds listed in Table 3 are colonial nesters. This fact has practical value in that a relatively small number of islands could be managed and yet a large number of young could potentially be produced.

Nesting mortality on dredge islands varied between the 1971 and 1972 nesting seasons and among the species. For example, nesting success for most species was higher in 1971 than 1972. The primary reason for the difference was due to more adverse weather during the 1972 nesting season. As a matter of fact, inclement weather was found to be the primary cause of nesting mortality.

The effect of inclement weather on nesting success was quite variable among the species. Although nesting was attempted several times by Least Terns during the summer of 1972 very few eggs or young survived. At the same time the weather appeared to have very little effect on Royal Terns. The latter species had a very successful nesting season along the North Carolina coast. Most of the other species fell somewhere between the above two as far as the effect of weather is concerned.

The number of nesting colonies or rookeries studied which included the common nesting species are shown in Table 4. The increase in the number of colonies and rookeries observed in 1972 compared to 1971 was primarily a result of an increase in effort devoted to that phase of the project. But, there was also a real increase in the number of nesting colonies in some species. The Common Tern showed such an increase.

Although the American Oystercatcher and the Willet are not colonial nesters, surveys were done to determine the extent of nesting by them on dredge islands. Observations were made on 47 Oystercatcher nests. This species nests along the entire North Carolina coast and was found nesting on 35 different islands. A total of 133 observations of Willet nests were made. These nests were found on 33 different islands. Most nesting by the Willet was found to occur on dredge islands along the southern half of the North Carolina coast.

Table 4. Number of colonies (nests on ground) or rookeries (nests in shrubs or trees) in which the major nesting species were studied. *

Species	Number of Colonies		Number of Rookeries	
	1971	1972	1971	1972
Little Blue Heron	0	0	2	5
Cattle Egret	0	0	2	3
Common Egret	0	0	3	6
Snowy Egret	0	0	3	4
Louisiana Heron	0	0	3	5
Glossy Ibis	0	0	2	4
White Ibis	0	0	1	1
American Oystercatcher**	0	0	0	0
Willet**	0	0	0	0
Great Black-backed Gull	0	1	0	0
Herring Gull	0	6	0	0
Laughing Gull	2	8	0	0
Gull-billed Tern	4	13	0	0
Common Tern	7	19	0	0
Least Tern	18	22	0	0
Royal Tern	5	9	0	0
Sandwich Tern	0	4	0	0
Caspian Tern	0	2	0	0
Black Skimmer	11	16	0	0

*Most of the colonies and rookeries were comprised of mixed species populations.

**Do not nest in colonies or rookeries.

Comparative studies were made on usage of sites other than dredge islands. Transects were set up on relatively undisturbed (Masonboro Island) and frequently disturbed barried islands. Observations made along these transects and other places showed that dredge islands were used for breeding sites much more extensively by many species (See Table 2.). Of the 35 species listed in Table 2 seventeen were not found nesting anywhere except on dredge islands within the general study areas. Surveys of nearby beaches will be expanded during 1973 in order to make a more accurate comparison.

Observations were also made on the behavior of those species of birds that utilize the islands heavily as breeding sites. Special note was made of those behavioral patterns that were thought to be important in nest site selection.

Associated Projects

Observations were also made on Sea Grant stabilization projects conducted by Drs. Seneca and Woodhouse of North Carolina State University. Comparisons will be made of vegetation and vertebrate utilization at some of their project sites.

Seminars and Presentations

Seminars and/or presentations on the project have been given at the following places:

Annual meeting of the Carolina Bird Club
Zoology Seminar, North Carolina State University
Biology Seminar, The University of North Carolina at Wilmington
Biology Club, Campbell College

A paper will be presented at the annual meeting of the Wilson Ornithological Society in May 1973.

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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 41-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT NO.	PROJECT TITLE [ ] NEW [X] CONTINUING [ ] CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
R/ES-2	Coastal Dune and Dredge Spoil Stabilization	July, 1970
GRANT NO. (previous)	(if different)	DATE OF THIS FORM
2-35178		May, 1973
INSTITUTION		ESTIMATED COMPLETION DATE
UNC		Dec., 1977

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
W. W. Woodhouse, Jr.; Dept. of Soil Science, NCSU	30%	E. D. Seneca	25%

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (Re numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 40,470	$ 20,235	$ 27,602	$ 13,801	$	$	R/ES-1, R/ES-3, R/ES-4

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Estuarine Studies	Coastal Zone Mgmnt./Natural Sciences

OBJECTIVES:

Dunes - To develop superior techniques for building and stabilizing coastal barrier dunes, with particular emphasis on long-term solutions through (1) improvement of sea oats, Uniola paniculata; (2) developing propagation procedures and planting-stock supplies of Panicum amarum; (3) establishment of large-scale mixed-species planting experiments involving all the major foredune grasses.

Spoil - To devise procedures for the stabilization, through conversion to salt marsh, of materials lying in the intertidal zone, with major attention focused on dredge spoil. Initial efforts will be centered on Spartina alterniflora but not to the exclusion of other important species such as Spartina patens and Juncus roemerianus. Work will encompass: (1) site requirements for establishment and growth, the most important of these being elevation, tide range and regime, salinity, circulation, erosion, accretion, and nature of substrate materials, including nutrient supply; (2) develop propagation methods, including seed harvest, processing and storage, nursery production of planting stock, mechanical harvest of planting stock, and seeding-transplanting methods; (3) evaluate some of the effects of such plantings on the spoil and the estuary, to include accumulation of sediments, uptake of nutrients, and invasion by marsh plants and animals.

HOW INFORMATION WILL BE APPLIED:

Findings will be useful in preserving and protecting the coastal zone, both developed and undeveloped, along the Atlantic and Gulf Coasts. Useage will be by local, state, and Federal agencies (zoning boards, state parks, fisheries, natural resources departments, Corps of Engineers, National Park Service), and by the private sector, from individual homeowners to large developments. Will help provide a basis for promulgating coastal zone protection regulations as well as lending guidance to the stabilization and protection process. The spoil phase should eventually contribute to the replacement of some of the productive marsh lost during the last 50 years.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

Dunes - (1) Isolated and identified the organism (Marasmius sp.) causing extensive losses of American beachgrass; (2) sea oats, Panicum amarum and Coastal bermudagrass have been successfully established on diseased areas of American beachgrass dunes; (3) established Panicum amarum nursery, plants to be used in mixed-species dune experiments; (4) supplied two nurserymen with Panicum amarum for 1973 increase; (5) held in-service training school for County Extension Agents and Shoreline Protection Officers.

Spoil - (1) Established Spartina alterniflora by a large-scale, mechanized, seeding; (2) followed a Spartina planting into a fully developed marsh in 24 months; (3) succeeded in producing S. alterniflora planting stock under upland conditions; (4) established that S. alterniflora in this area is limited by N & P, indicating salt marsh deters buildup of N & P in estuaries; (5) provided guidance for restoration of marshes destroyed by dredging spills.

Project No.: R/ES-2

Title: Coastal Dune and Dredge Spoil Stabilization

Principal Investigator: W. W. Woodhouse, Jr., Dept. of Soil Science, North Carolina State University, Raleigh, N. C.

Dunes

The organism causing extensive die-out of American beachgrass (Ammophila breviligulata) over the southern extensions of its range (Virginia, North and South Carolina) has been isolated and identified. (See two papers on Marasmius Blight in List of Publications and Reports.)

The revegetation of die-out areas has been accomplished through the transplanting of sea oats, Panicum amarum, and Coastal bermudagrass, and Panicum amaralum by seeds. P. amarum appears particularly promising either alone or as a companion plant for sea oats, Uniola paniculata. The latter is very slow in developing but seems to eventually take over, particularly on the more exposed sites. Coastal bermuda establishes quite rapidly but appears to have promise only for rather specilized situations. It requires frequent fertilization in order to maintain vigor under dune conditions but does have the advantage of being able to withstand traffic, a hazard the regular dune species cannot tolerate. P. amaralum has the advantage of establishment by direct seeding, and for this reason appears to warrant further effort, although results so far are only mildly encouraging.

We have not been able to define or reproduce the specific set of environmental conditions that initiates the flowering sequence in sea oats. The study designed to do this has yielded useful information on the reaction of this species to controlled environmental conditions (phytotron), time of initiation of flower primordia in nature (May in North Carolina), and flower sequence along the coast. The main objective of learning to control flowering at will still eludes us.

It seems quite evident, at leat to us, that mixed-species plantings are a much sounder approach to dune building and stabilization than the use of single species that predominated in the past. A mixed-species dune building experiment was initiated on Ocracoke in the spring of 1971 but was essentially destroyed by Hurricane Ginger that fall. We did get some useful experience from it, particularly in handling P. amarum.

Building on the above, planting stocks have been built up, a site selected, and the first steps taken to establish another mixed-species experiment under field conditions. The area selected, between Old and New Drum Inlets, is slightly higher and more protected than the site of the Ocracoke trail. Therefore, the chances of it coming through the first 12 months, the critical period, without serious damage should be good. The planting will be about 3,000 feet in length and will involve P. amarum, sea oats and three selections of American beachgrass in two and three-way mixtures.

It is becoming increasingly evident that P. amarum has a great deal more potential for use on dunes than we and others had assumed earlier. Recent

observations on Padre Island, Texas indicate this is the most palatable of the dune grasses. Therefore, it is highly probably that is was largely grazed out early in the game. This, coupled with the absence of seeds in this species, could account for its relative scarcity throughout most of its range. Experience gained during the last 4 or 5 years on the North Carolina, Florida, and Texas coasts indicates to us that it could play a major role in the same general areas in which sea oats are used. It is much easier to propagate and grows off much faster than sea oats.

We started increasing two selections of P. amarum in 1972, one from Ocracoke and the other from near Buxton, North Carolina. Practical nursery procedures have been developed and an estimated 20,000 plants produced during the 1972 growing season. Based on this experience we have arranged to supply two North Carolina nurserymen with planting stock of this grass for 1973 increase. We have also provided guidance in the establishment of a two-acre nursery of P. amarum on Amelia Island, Florida, using a robust selection from that locality, plus 2 acres of sea oats from local stock at the same site.

Spoil

Emphasis in this phase has remained on smooth cordgrass, Spartina alterniflora, up to this point with minor attention to S. patens and Panicum amaralum. Activity has continued on developing techniques of establishment with emphasis, during 1972, on scaling-up seeding. We are also beginning to look at marsh development and its effect upon the spoil site.

Seeding

Establishment of S. alterniflora by seed has been successful at 4 sites -- Oregon Inlet, Drum Inlet, Beaufort, and Snow's Cut. Successful field-scale seeding was done for the first time in April 1972, near Beaufort, North Carolina. Seeds were broadcast by hand and covered by tillage tools mounted on a farm-type tractor equipped with high flotation tires. This resulted in a dense cover on about the upper 1/3 of the tide range with dry matter production, aboveground, reaching about 65% of that of the average long-established marsh in that area. It is evident that direct seeding of this species is feasible on some sites, that it is an economical method, and that it can provide rapid coverage. It is subject to hazards as evidenced by several seeding failures that were encountered in 1972. Two spoil islands in Pamlico Sound, behind Drum Inlet, were seeded in early May, and seedlings had emerged prior to the sub-tropical cyclone that hit this area in late May, at which time they were completely destroyed by erosion.

This was an unusual storm for this season of the year and if it had not occurred, the chances of survival of these seedlings would have improved considerably by the advent of the hurricane season.

A large-scale seeding near Hatteras Inlet, made immediately after the Beaufort planting, was destroyed by drifting sand moved by this storm. The Beaufort site would have suffered the same fate except that a sand fence was erected between the planted area and the higher part of the spoil pile. It appears to us that sand drifting onto the intertidal zone is a major deterrent to natural invasion of fresh spoil by S. alterniflora seedlings.

Another satisfactory seed harvest of S. alterniflora has been obtained, using the same harvesting equipment devised in 1971 but with the further refinement of threshing the seedheads. This was necessary in order to reduce the bulk for storage. It was accomplished by storing the harvested heads, without drying for 3 or 4 weeks in burlap sheets, and then putting them through an experimental small grain thresher. This left most of the seeds in the glumes but removed the bulky plant parts and cut storage.

Plans are to use part of these seed on a fresh spoil island resulting from redredging of the sound channel behind Drum Inlet. Also the National Park Service is planning an extensive filling operation on the sound side of Hatteras Island in the vicinity of Sandy Bay. This is designed to widen a very narrow section of the island by developing new marsh on the fill. If this materializes in time, a substantial part of the 1972 seed harvest will be used here as this would represent our first large scale opportunity to test marshbuilding as a means of protecting sound shores.

Fertilizer Response

Quite marked fertilizer response on the part of S. alterniflora was measured at four sites in 1972 -- Beaufort on young seedlings, at Drum Inlet on fresh transplants, at Hatteras Inlet on a young (2-3 years) natural stand in an accreting site, and at Oak Island on old established marsh. Response was primarily due to the application of nitrogen with some effect from phosphorus. This suggests that N, and to some degree P, may be rather generally limiting the growth of S. alterniflora in the sounds and estuaries of this state and in line with the findings of Copeland & Hobbie that N is the principal nutrient limiting the growth of algae in many of these waters. This raises the possibility that one important contribution of S. alterniflora marsh may be to help maintain the concentration of these nutrients in the estuary at a tolerable level.

Marsh Development

More effort has gone into follow-up of planted areas as the opportunity for this increases. For example, areas transplanted at Snow's Cut in April 1971 have, in less than 24 months, by all appearances developed into fully functioning salt marches. Stands and productivity are equal to the more productive established marshes of the area. Some 17 other species of plants have appeared as secondary invaders and around 0.5 feet of sediments have been trapped compared with a slight loss from adjacent unplanted areas. Although not designed for this purpose, the latter observations give some positive indication of the stabilizing effects of the plantings.

Several of these plantings are being sampled periodically by a graduate student in marine ecology to study the development of marine invertebrate populations as these stands mature.

Publications and Reports

1. Lucas L. T., T. B. Warren, W. W. Woodhouse, Jr., and E. D. Seneca. 1971. Marasmius Blight, a New Disease of American Brachgrass. Plant Disease Reporter. Vol. 55(7):582-585.

2. Seneca, E. D. and S. W. Broome. 1972. Seedling Response to Photoperiod and Temperature by Smooth Cordgrass, Spartina alterniflora from Oregon Inlet, N. C. Chesapeake Sci. 13:212-215.

3. Woodhouse, W. W. Jr. 1972. Report on Dredge Spoil Phase (20 minutes, on slides) before North Carolina Marine Science Council.

4. Broome, S. W. 1972. Stabilizing Dredge Spoil by Creating New Salt Marshes with Spartina alterniflora. Proc. Soil Sci. Soc. of N. C.

5. Woodhouse, W. W., Jr., E. D. Seneca, and S. W. Broome. 1972. Marsh Building with Dredge Spoil in N. C. N. C. Agri. Expt. Sta. Bul 445 (28 p, 22 plates).

6. _____. Establishing Salt Marsh on Dredge Spoil - to be published in Proceedings of WODCON V, the 5th World Dredging Conference (June 1973).

7. Blake, C. T., and W. W. Woodhouse, Jr. 1972. Vegetative Dune Stabilization in North Carolina. Agron. Inf. Leaflet B & DS Series No. 1, N. C. Agri. Extension Service.

8. Seneca, E. D. In press. Stabilization of Coastal Dredge Spoil with Spartina alterniflora. In R. J. Reimold and W. H. Queen (ed.) Ecology of Halophytes: Their Interactions in Wetlands and on Saline Soils. Academic Press Inc., N. Y.

9. Warren, Tyler B. and L. T. Lucas. 1973. Histopathology of Marasmius Blight of American Beachgrass. Phytopathology 63. (In press).

NOAA Form 90-2 (8-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB No. 41-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT TYPE	PROJECT TITLE ☐ NEW ☒ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
R/ES-3	Investigation of Insects Affecting Vegetation Used in Coastal Dune and Dredge Spoil Stabilization	July, 1970
GRANT NO. (Leave blank) 2-35178	SHORT TITLE (If different)	DATE OF THIS FORM May, 1973
INSTITUTION UNC		ESTIMATED COMPLETION DATE Dec. 1976

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
W. V. Campbell, Department of Entomology, NCSU	10%		

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (R/ numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	R/ES-1, R/ES-2, R/ES-4
$ 16,865	$ 8433	$ 11,156	$ 5,578	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Estuarine Studies	Coastal Zone Mgmnt./Natural Sciences

OBJECTIVES:

OBJECTIVES:

American beach grass Ammophila breviligulata, sea oats Uniola paniculata, and marsh grass Spartina alterniflora used to stabilize coastal dune and dredge spoil are attacked by a complex of destructive insects.

The objectives are to identify the destructive insects as well as any beneficial predators and parasites, to determine the damage, general distribution and abundance, and to assess their importance as a limiting factor in the establishment and persistence of grasses used for stabilization. The primary concern in any pest management program will be prevention of environmental contamination.

HOW INFORMATION WILL BE APPLIED:

Information will be disseminated to coastal county agents, National Park Service, and National Marine Fisheries Service for their use in managing insect pests.

Research information will be useful in the cooperative program on dredge spoil and dune building.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

The scale insect Eriococcus carolinae was found on American beach grass for the first time south of Cape Hatteras in three isolated infestations at Wrightsville Beach, Atlantic Beach, and Fort Macon.

Six predators and three parasites were identified associated with E. carolinae and parasitism of the scale insect ranged from 44% to 90% in the heavily infested areas.

Marsh grass Spartina alterniflora was infested with fly maggots Oscinella (Chloropidae) that may cause reduction in seed set.

A potentially destructive beetle (Mordellidae) feeds on the flowers of Spartina as an adult and 72% of the stems were infested and tunneled by the larvae at Drum Inlet, N. C.

Project No.: R/ES-3

Title: Investigation of insects affecting vegetation used in coastal dune and dredge spoil stabilization.

Principal Investigator: William V. Campbell, Dept. of Entomology, North Carolina State University, Raleigh.

Research on the biology, distribution, damage and control of the destructive scale insect Eriococcus carolinae Williams was conducted in the laboratory and on the North Carolina Outer Banks, principally Pea Island National Wildlife Refuge, during 1972.

Survey for the distribution of E. carolinae revealed American beach grass was infested with scale from 13.5 mile post on Pea Island north to New Jersey where the survey was terminated. Three new scale infestations were found in a survey conducted in 1972. Fort Macon and Atlantic Beach in Carteret County and Wrightsville Beach in New Hanover County were found heavily infested with scale. The survey was discontinued at the North Carolina-South Carolina line.

Laboratory studies indicate the scale is capable of surviving the winter far north of New Jersey. Two weeks exposure to 0°F did not affect egg hatch, five weeks exposure to 0°F resulted in approximately a 50% reduction, and a few scales survived eight weeks exposure (Table 1).

While two generations of scale per year occur on Pea Island, low temperature may limit the scale to one generation in its northern habitat. Scale crawlers (larvae) failed to complete development when held at 55°F or below (Table 2). Scales held at 80°F completed sac formation in four weeks.

It has been observed that foredune beach grass has fewer scale insects than beach grass growing in a protected site. An experiment conducted during 1972 clearly showed that the foredune was a hostile habitat for overwintering scales while scales developing interdunal thrived. Poor survival is due to the accummulation of sand on the plants and probably the abrassive force of wind driven sand. Scale insects on the foredune (8 total observed) spread only 2 ft. downwind while scales in the interdunal habitat (224 total observed)spread 32 ft. in one generation (Table 3).

Eriococcus carolinae eggs are capable of surviving floatation or submersion in sea water for periods in excess of four weeks. Scale insect eggs submerged in 45°F sea water survived better than when submerged in 80°F sea water (Table 4). Similar results were obtained with summer generation and overwintering eggs. These data suggest the possibility of distant dispersal of the scale during storms in the winter and spring and a more limited dispersal during summer and fall storms. Continuous aeration of 80°F sea water increased the hatch of submerged eggs only during the first week of submersion.

Scale insects may be controlled by chemicals or by cultural method of control. Dimethoate (Cygon 267) applied at the rate of 1 lb. active ingredient per acre gave 100% control. Scalecide, a 60-second superior

oil, applied at 1 gal. per acre resulted in 47% control. The use of dimethoate at 1/4 lb. active ingredient per acre plus 1/2 gal. Scalecide resulted in scale control equivalent to 1/2 lb. dimethoate alone. The scale may be controlled on beach grass without insecticide by burning the grass during the dormant season. A small insecticide sprayer was modified into a flame thrower using Varsol as a fuel. Grass was burned on March 1 prior to spring growth and prior to scale egg hatch. Thorough burning of the grass will destroy overwintering scale eggs. This method of cultural control resulted in 91% reduction in scales (Table 5). The effectiveness of this method of control is governed by the thoroughness of burning.

The application of dimethoate by helicopter at 1 lb. active ingredient per acre resulted in excellent control of E. carolinae and good control was evident in the treated plots one year post treatment. (Table 6). The scale was nearly eradicated with dimethoate applied on May 20. The August 1 application date was less effective.

A study of the beneficial insects associated with E. carolinae revealed six predators and three parasites. The most important predators were Nemia seriata and Collops nigriceps while Aphycus clauseni was the most important parasite (Table 7). Collops feeds on scale ovisacs containing eggs while Nemia eat young scales prior to sac formation. The parasites feed on eggs in the ovisac.

Parasitism of first generation sacs is low but was higher on Assateague Island, Virginia than on Pea Island, N. C. Parasitism of second generation sacs was 9.7% at Wrightsville Beach, 44% at Pea Island, and 90% at Duck. The scale infestation at Wrightsville Beach is the southernmost infestation, it is isolated and probably represents a relatively new infestation (Table 8).

Most sacs are parasitized by one parasite since 68% of the parasitized sacs had only one parasite exit hole. Twenty-seven per cent of the parasitized sacs had two exit holes. Less than 1% of the sacs had three or more exit holes (Table 9).

Dimethoate applied by helicopter to control the scale caused some reduction in parasitism (Table 10). This apparent reduction in parasitism may be partially due to the very low number of scale in the treated area compounded by the fact that the parasite is a weak flier and had to search for the sparce host.

Smooth cordgrass Spartina alterniflora used experimentally to stabilize dredge spoil was found heavily infested with a beetle complex of the family Mordellidae. Adults feed on the flowers and the larvae tunnel the stems. The larvae are capable of surviving tidal innundation. Mordellid larvae tunneled 72% of the Spartina stems on dredge spoil at Drum Inlet on Core Bank, North Carolina. Information on the biology, distribution, importance, and control is lacking.

A Chloropidae (Diptera) of the genus Oscinella was found infesting the heads of Spartina. These fly maggots may cause significant losses in seed set. Additional information on the importance of this pest needs to be ascertained.

Table 1. Effect of low temperature on scale egg hatch. 1972.

weeks exposure 0°F	Avg. no. scales emerging/20 ovisacs
1	196
2	195
5	105
8	2
Check	236

Table 2. Effect low temperature on larval scale survival and development. 1972.

	Avg. no. surviving/200	
Temperature	4 weeks	8 weeks
55°F	94	16[b/]
45°F	54	20[b/]
35°F	58	0
Check	153[a/]	153[a/]

[a/] Completed development and formed sac by 4th week.

[b/] No sac formation.

Table 3. Effect of habitat on scale dispersal and survival. 1972.

No. ft. from release site	Avg. no. scales/15 leaves	
	Interdunal	Foredune[a/]
0	136	5
1	49	2
2	16	1
4	14	0
8	5	0
16	3	0
32	1	0
64	0	0
Total scales	224	8

[a/] All scales recovered downwind.

Table 4. Effect sea water and temperature on scale egg hatch. 1972.

Weeks exposed °F	Avg. no. scales emerging/20 ovisacs		
	Floating	Submerged	Aerated
45°F			
1 wk.	384	237	-
2 wk.	528	240	-
3 wk.	537	601	-
4 wk.	263	197	-
Check	1,144	860	-
80°F			
1 wk.	89	39	206
2 wk.	17	5	24
3 wk.	13	0	-
4 wk.	11	1	-
Check	369	891	426

Table 5. Comparison of methods for scale control. 1972.

Treatment	AI/acre	Avg. % scale control
Insecticide		
Dimethoate	1/4 lb.	92
Dimethoate	1/2 lb.	97
Dimethoate	1 lb.	100
Oil		
Scalecide	1 gal.	47
Insecticide+oil		
Dimeth.+oil	1/4 lb.	98
Dimeth.+oil	1/2 lb.	98
Cultural		
Burning	-	91

Table 6. Longevity of control of the scale insect following aerial application of dimethoate. 1972.

Date applied	Avg. no scales/25 leaves	
	May 17	August 8
May 20, 1971	1.1	0.1
July 31, 1971	8.4	14.7
Check	459.7	417.2

Table 7. Predators and parasites of Eriococcus carolinae. 1972.

Predators	Parasites
Coccinellidae	Chalcidoidea
Nemia seriata*	Aphycus clauseni*
Hippodamia convergens	Cheiloneurus sp.
Coleomegilla maculata	Chrysophagus americanus
Cycloneda sanguinea	
Melyridae	
Collops nigriceps*	
Tenebrionidae	
unidentified	

* Most important

Table 8. Parasitism of Eriococcus carolinae.

Scale Generation	Location	% Parasitism
1st	Assateague Island, Va.	14.7
1st	Pea Island, N. C.	8.4
2nd	Pea Island, N. C.	44.0
2nd	Duck, N. C.	90.0
2nd	Wrightsville Beach, N. C.	9.7

Table 9. Parasitism of second generation Eriococcus carolinae ovisacs. Pea Island, N. C. 1972.

Parasitized sacs		Parasite exit holes	
No.	%	No. holes	%
372	44	-	-
		1	68.2
		2	27.3
		3	0.5
		4^{+}	0.2

Table 10. Effect of dimethoate on parasites of the scale insect. Pea Island, N. C. 1972.

	%	%
Treatment category	Non-parasitized	Parasitized
Untreated check	58.0	42.0
Drift area	73.2	26.8
Treated area	83.5	16.5

Publications

Campbell, W. V. and E. A. Fuzy. 1972. Survey of the scale insect effect on American beach grass. Shore and Beach 40: 18-19.

Meetings

Participated in a two day tour and discussion of insect problems on grasses used in coastal dune stabilization. Meeting was planned for county agents and district agents in the coastal counties.

Reports

Progress reports submitted to the U. S. Fish and Wildlife Service, Pea Island Wildlife Refuge and to the National Park Service, Cape Hatteras National Seashore.

NOAA FORM 90-2 (5-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 41-R2600

PROJECT TYPE	PROJECT TITLE ☐ NEW ☒ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED (IF CONTINUING)
R/ES-4	Insect Pest Management in Coastal and Estuarine Areas	July 1970
GRANT NO. (ASSIGNED) 2-35178	(SHORT TITLE (If different))	DATE OF THIS FORM May 1973
INSTITUTION UNC		ESTIMATED COMPLETION DATE Dec. 1975

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
R. C. Axtell, Entomology Department, NCSU	30	K. L. Knight	10

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (If numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	R/ES-1, R/ES-2, R/ES-3
$ 36,062	$ 18,030	$ 23,900	$ 11,949	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Estuarine Studies	Coastal Zone Management/Natural Sciences

OBJECTIVES:

OBJECTIVES:

The objective of this project is to develop programs, based on ecologically sound principles of pest management, for the control of biting flies and mosquitoes developing in the coastal marshes of North Carolina. These pest management programs will integrate cultural, chemical and biological methods of control. Indiscriminant alteration or pesticide pollution of the coastal and estuarine habitats will be prevented by developing and disseminating recommendations prior to the initiation of control measures. Insect pest management programs are needed for the optimal economic development of the region, especially by the tourist and recreation industry, but must be compatible with preservation of the marsh ecosystem. Sound management of the estuarine systems and promotion of the tourist and recreation industry are both major objectives in the long-range plan for the development and conservation of marine resources which was adopted by the North Carolina Marine Science Council.

HOW INFORMATION WILL BE APPLIED:

Recommendations will be disseminated for the best use of insecticides and cultural measures (ditching and impoundment of marshes) for the control of economically important insects. This will be done by semi-technical publications and advisory personnel involving the N.C. Agricultural Extension Service, Sea Grant Advisory Services, N.C. Board of Health and N.C. Water Resources Research Institute. This information will be applied by resort owners, real estate developments as well as State and local governmental agencies.

ACCOMPLISHMENTS DURING THE PAST EIGHTEEN MONTHS:

The principal pest species of biting flies (Tabanidae), biting gnats (Ceratopogonidae) and mosquitoes (Culicidae) have been determined. Seasonal population levels have been determined for Carteret County for biting flies and gnats. The breeding habitats (sites of larval development) have been located and described. By means of a public opinion survey, the economic importance of the various pest species has been measured. Over 80% of the respondents desired better insect control and a majority felt this would enhance the value of their property. Techniques and plans have been developed for the implementation of a monitoring and integrated control program for demonstration and gathering operational data.

Project No.: R/ES-4

Title: Insect Pest Management in Coastal and Estuarine Areas.

Principal Investigator: R. C. Axtell, Professor, Department of Entomology, North Carolina State University.

Associate Investigator: K. L. Knight

The objective of this project is to develop data for the implementation of programs, based on ecologically sound principles of pest management, for the control of biting flies (including mosquitoes) which develop in the coastal marshes of North Carolina. Most of the research has been conducted in Carteret County (Fig. 1).

Emphasis in this reporting period has been on determination of the species which are pests and their seasonal abundance, the sources (habitats for the immature stages) of these species, preliminary behavioral studies, economic importance, and ditching as a method of mosquito control. A summary of the findings follows.

a. Adult Insect Populations: Collections of adult Tabanidae (deerflies and greenheads) indicate the following to be most abundant and of probable economic importance: Chrysops atlanticus, Chrysops fuliginosus, Tabanus nigrovittatus, Tabanus quinquefasciatus and Tabanus lineola. There are about 40 other species of Tabanidae which in particular times and places may become serious pests. The major species of Tabanidae occur at different times of the year (Figs. 2,3) so that the composition of the pest population is a changing problem. For example, C. fuliginosus appears in mid-May and is a problem for about 3 weeks in Carteret County. It is followed by the "yellow fly", C. atlanticus, which occurs for the entire summer but with 2 periods of particular abundance. T. nigrovittatus is present throughout the season but is most abundant from mid-May to the first of July. It is followed by increasing numbers of T. lineola and T. quinquevittatus.

Biting gnats (Culicoides, Family Ceratopogonidae) are major pests in many areas. The major species are Culicoides furens, C. hollensis and C. melleus. C. furens occur throughout the season beginning about the first of May with peaks of abundance in late May, mid-June and late August. C. hollensis appears earliest (mid-March) and has two distinct seasonal peaks, mid-April and early October (Fig. 4) C. melleus appear in mid-April and occur until October with several population peaks during the season; (early May, mid-June to early July, late September). These data on seasonal abundance were obtained in 1972 and further data will be collected in

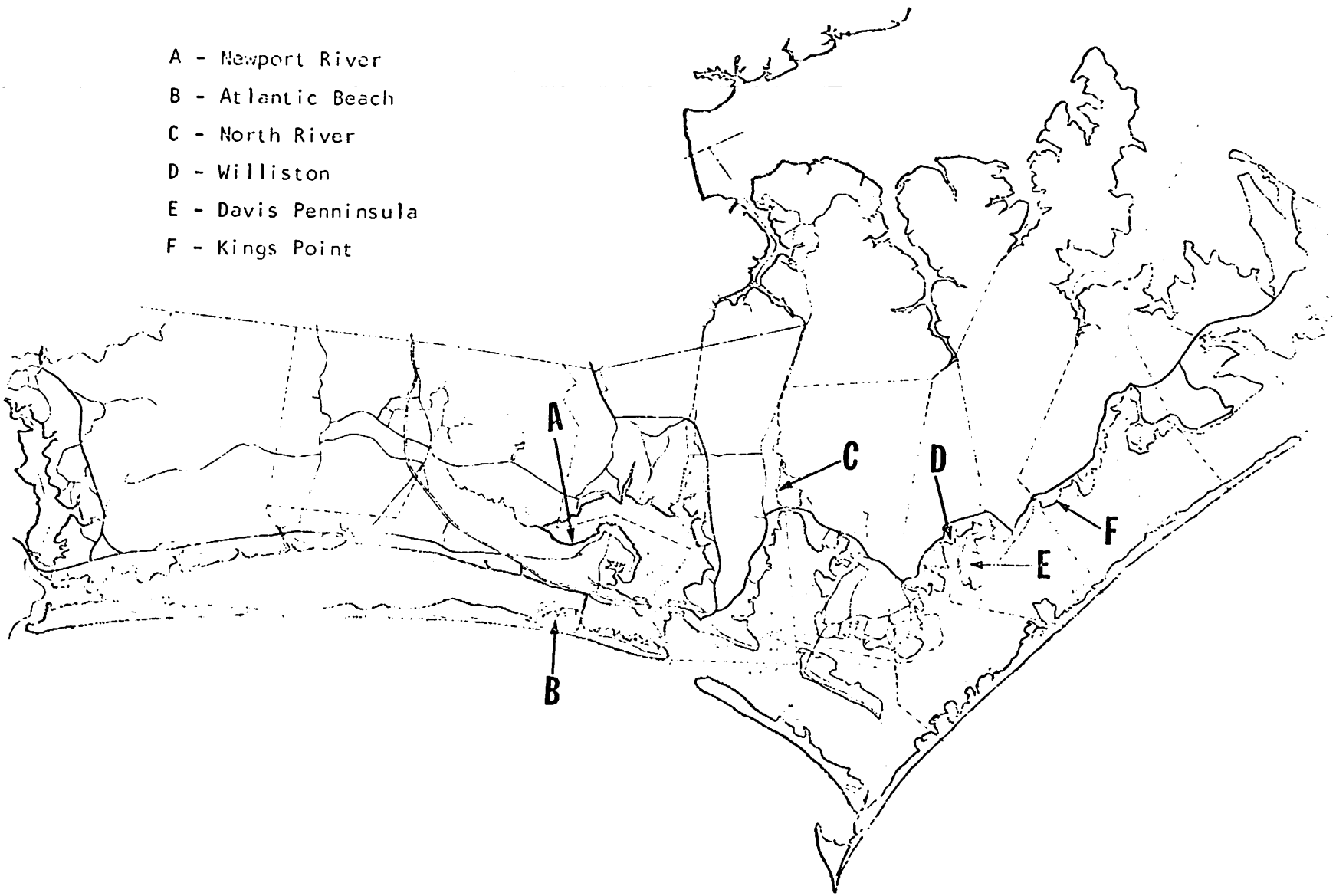

Fig. 1 - Map of Carteret County, North Carolina, showing locations of experimental sites.

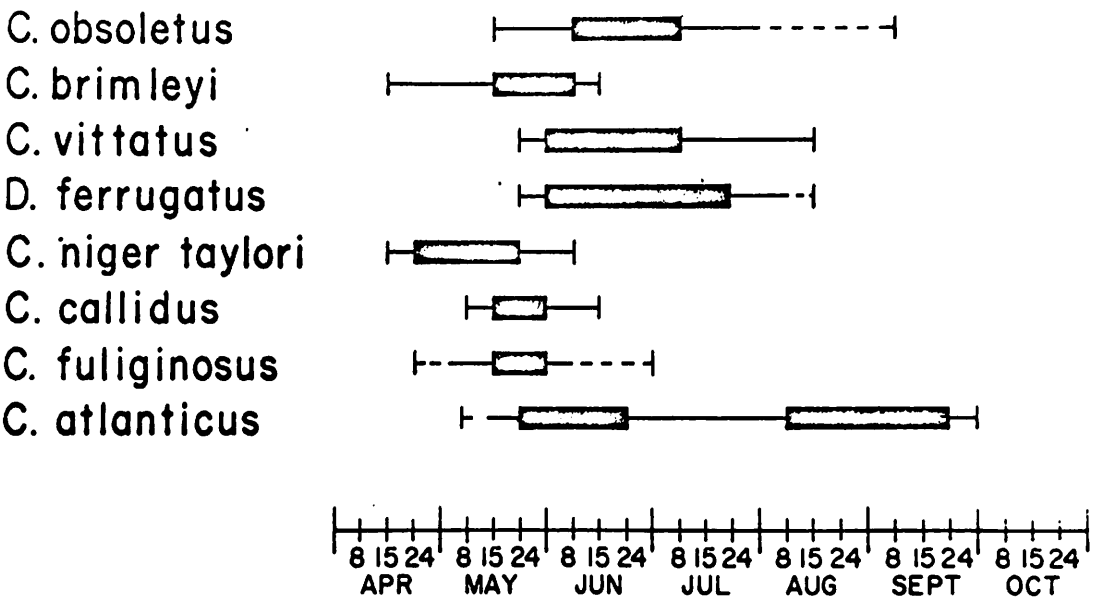

Fig. 2 Seasonal abundance of major pest species of "deerflies" (Chrysopinae) in coastal North Carolina. Width of line shows relative abundance.

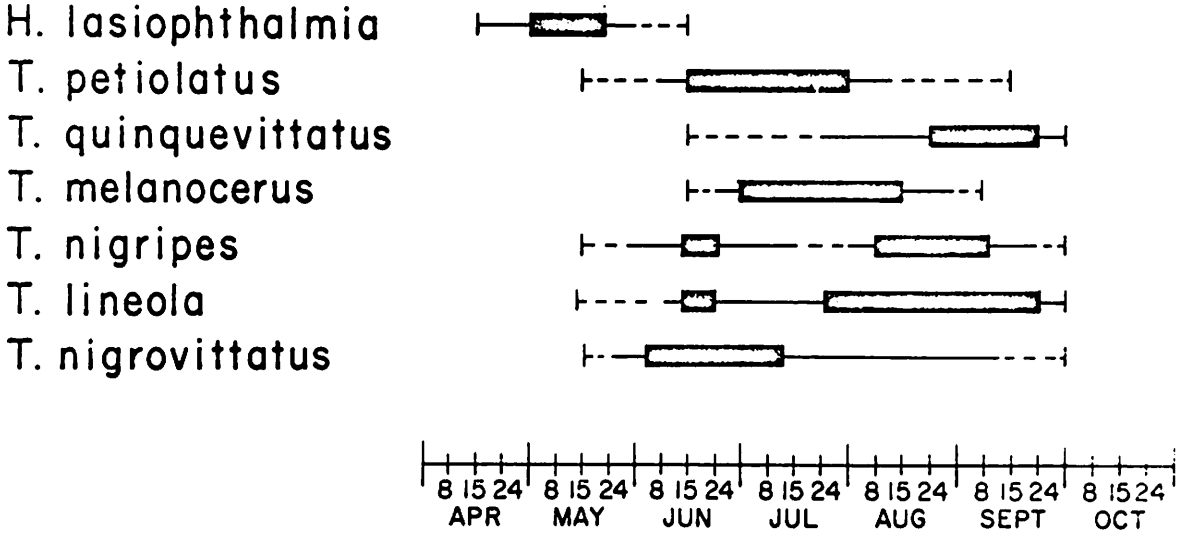

Fig. 3 Seasonal abundance of major pest species of "greenhead flies" (Tabanidae) in coastal North Carolina. Width of line shows relative abundance.

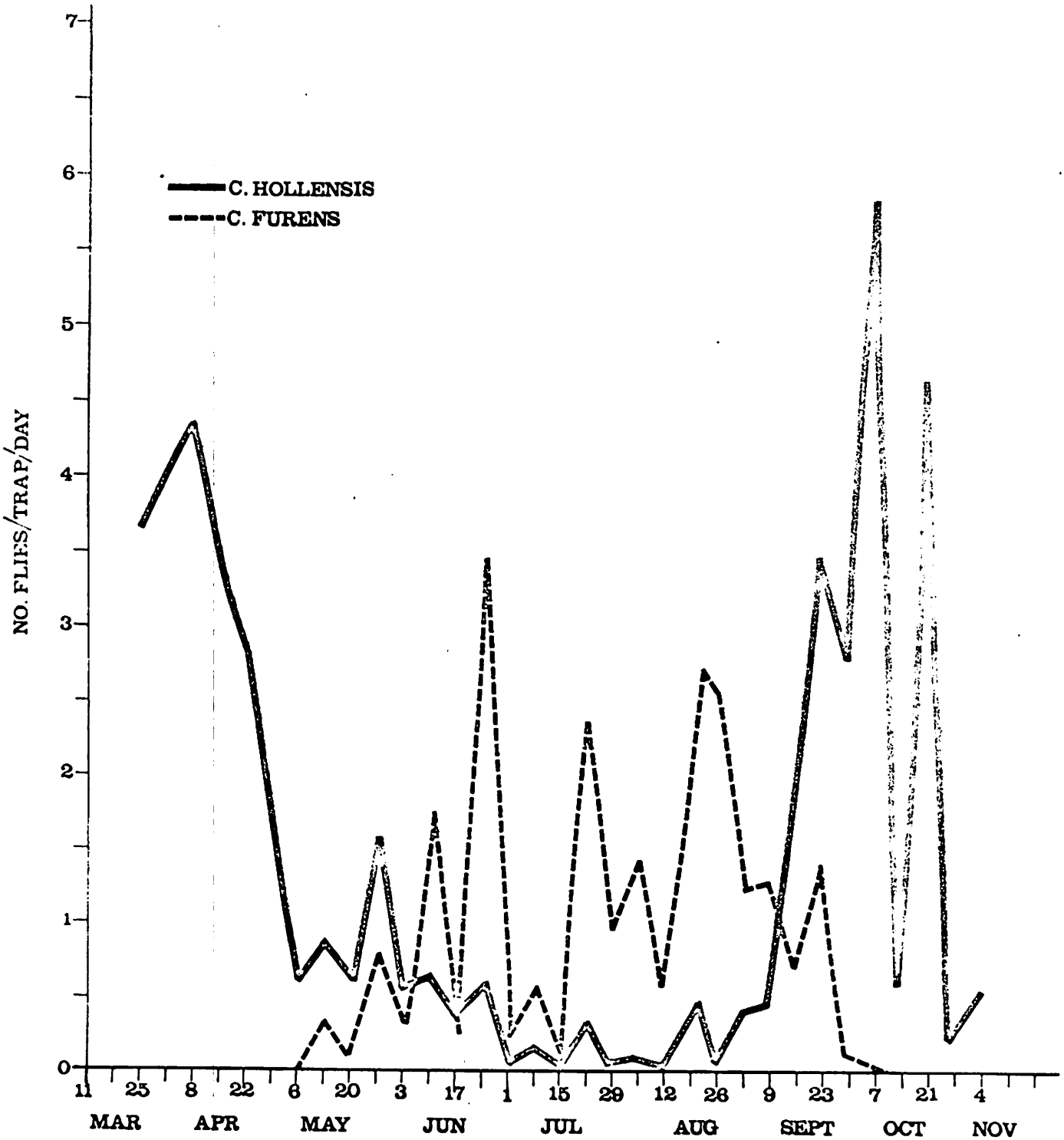

Fig. 4 Seasonal abundance of 2 species of biting gnats (Culicoides) in Carteret County, N.C. 1972.

1973 in order to correlate more precisely the abundance levels with environmental conditions (mainly temperature).

Adult mosquitoes most commonly encountered in the coastal areas are: Aedes sollicitans, Aedes taeniorhynchus, Anopheles bradleyi, Anopheles atropos, Culex salinarius, and Psorophora confinnis. About 6 other species may be important in particular times and places. Seasonal population levels of the adults of most of the above species are dependent upon the periods of exceptional high tides flooding the marsh breeding habitats. The Aedes are dependent upon cycles of flooding and drying of the depressions in the high Juncus marsh since the eggs must experience a critical sequence of drying ("conditioning") and wetting in order to hatch. Thus, there are successive "broods" correlated with tide level fluctuations. The other species develop throughout the marsh in standing water or in water accumulations upland and are less critically tied to the tide fluctuations, provided there is a continuing minimum level of water. Seasonal abundance data for the adults of these mosquitoes are less extensive than our data on the adults of Tabanidae and Ceratopogonidae because it has been more meaningful to sample the mosquito larvae.

Data to be collected in 1973 on the seasonal abundance levels of the tabanid flies, biting gnats and mosquitoes will, together with our data collected in previous years, provide good baselines for predicting population outbreaks in Carteret County. Continuation of this pest-level monitoring program is planned because the predictive value of the data increases the more years are included. Also, the continuing monitoring program will provide a direct measure of the effectiveness of future attempts to control the pest population in the area.

An important contribution of the above adult population investigations is the development and refinement of sampling methods. We will be able to recommend the simplest method of monitoring the pest populations for defining the problem in an area and for evaluating the progress of any control measure that may be instituted. In cooperation with other States (New Jersey, Delaware, South Carolina) we tested 5 types of Tabanidae traps in hopes of adopting a standard sampling device. These tests will be repeated in 1973.

b. Breeding Sources: The habitats producing the above pest species have been investigated and research is continuing. The major pest species develop in the marshes. It should be emphasized, however, that other species develop in the upland area and would have to be considered in a pest management program in those localities where they are abundant enough to create a problem.

Extensive sampling of the soil (and washing through screens) from the marshes and other habitats has been done to locate the larvae of the Tabanidae and Culicoides. Emergence traps placed over the soil and designed to retain the adult insects have been used. The sources of mosquitoes have been located by taking water samples with a dipper and examining for larvae.

From our investigations in Carteret County it is possible to generalize on the nature of the breeding habitats for many of the major pest

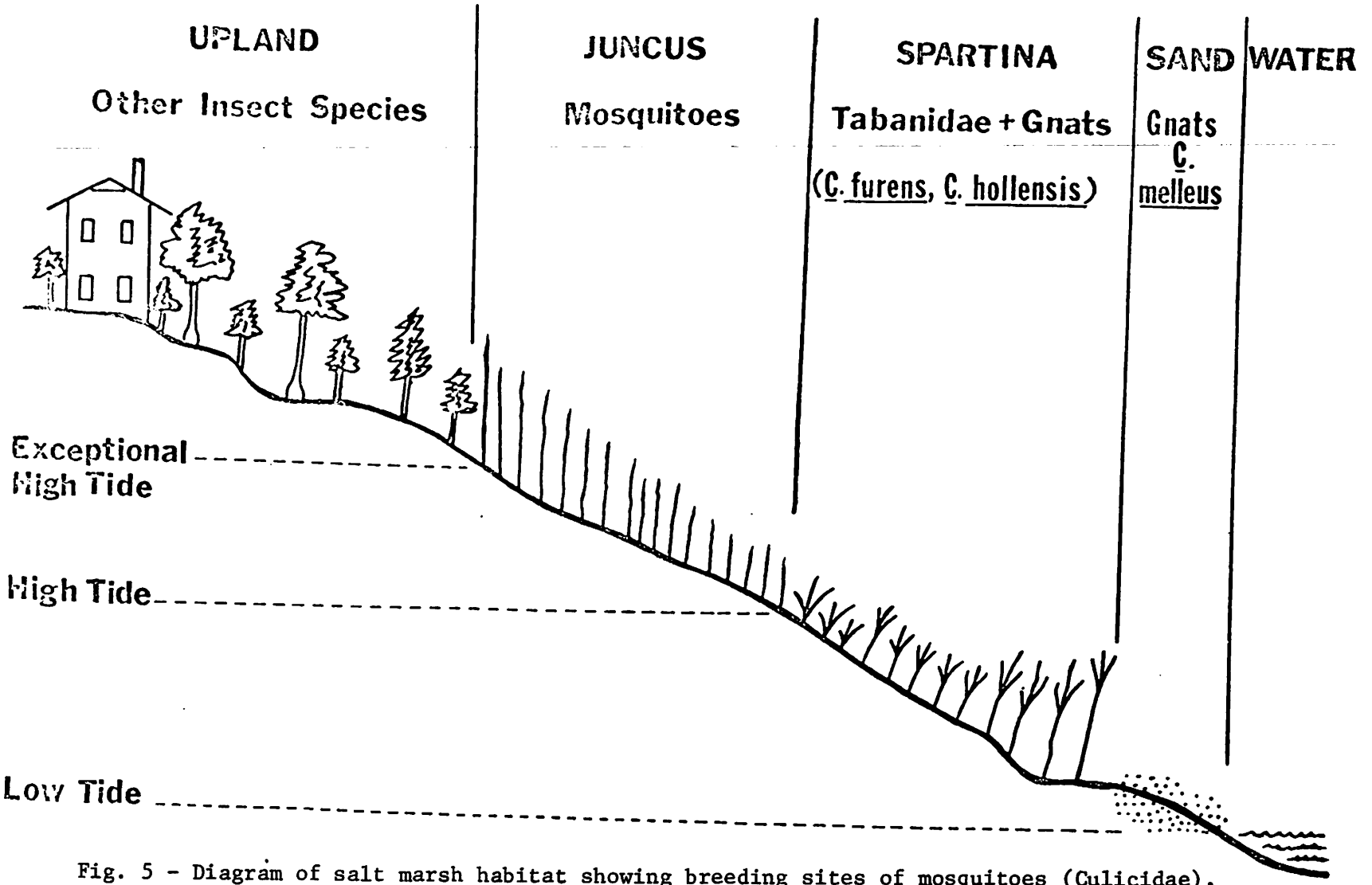

Fig. 5 - Diagram of salt marsh habitat showing breeding sites of mosquitoes (Culicidae), deerflies and greenhead flies (Tabanidae) and biting gnats (Culicoides, Ceratopogonidae) in relation to dominant marsh vegetation and tide levels. This is generalised and the vertical scale is highly exaggerated.

species (Fig. 5). The major pest species of Tabanidae lay their eggs in vegetation in the marshes where the larvae and pupae develop in the soil. Most of this occurs in regularly flooded (twice daily) marshes with Spartina alterniflora (cordgrass) the dominant vegetation. Pure stands of S. alterniflora produced the greatest numbers of T. nigrovittatus and C. fuliginosus (Table 1). At higher levels of the marsh, above mean high tide, fewer tabanid larvae were found and this was correlated with decreasing abundance of S. alterniflora and increasing abundance of other plant species. The same was true for the biting gnats Culicoides furens and C. hollensis; it was not true for C. melleus. C. melleus larvae were found in very sandy soil along the ocean beach or along the sandy interface between Spartina marsh and the open water.

The irregularly flooded high marsh, characterized by Juncus roemerianus (needle rush) vegetation, produces very few tabanid flies and biting gnats. In this type of marsh, Aedes mosquito larvae (A. sollicitans and A. taeniorhynchus) were commonly collected. Their distribution was aggregate and restricted to slight depressions having the proper slope where the tidal fluctuations provide the requisite drying-wetting cycle for the eggs to successfully hatch. The larvae of these salt marsh mosquito species were most abundant in depressions in the portion of the marsh immediately adjacent to the upland. These areas were characterized by a high proportion of Juncus roemerianus and Spartina patens vegetation. Other mosquito species (especially Anopheles atropos and Culex salinarius) were found breeding in the shallow water in large areas throughout the Juncus marsh.

The other important pest tabanid, Chrysops atlanticus, requires further investigation. Only a very few larvae were found in all of the sampling of marsh soil. One larva was found in a freshwater pond. Unfortunately, there are not sufficient data to characterize the larval habitat of this species, although it is a major pest along most of the Atlantic Coast.

As summarized above, the coastal salt marshes provide an extensive breeding habitat for biting flies, gnats and mosquitoes but these insects have specific site-criteria and are actually restricted to particular types of marshes and to only certain portions of those marshes. Other species develop in upland situations and fresh water habitats and in a particular locality may assume sufficient importance to necessitate control measures.

c. Behavior: A species only becomes a pest when the adult moves from the marsh breeding habitat into the upland and into contact with people (or livestock and pets). An understanding of this dispersal behavior is a prerequisite to designing control measures against the adult insects.

Our investigations have been on the movement of the Tabanidae (T. nigrovittatus and C. fuliginosus) and the biting gnats (Culicoides hollensis and C. furens) from the Spartina marsh into the upland. Both readily move from the open marsh to the protection of vegetation (shrubs and trees) in

Table 1. Recovery of tabanid larvae from soil in various plant associations in 4 salt marshes in Carteret Co., N.C. 1972.

Vegetation	Samples		Larvae		Species & No. Identified.
	Total No.	% With Larvae	Total No.	Avg./ Sample	
Newport River					
Spartina alterniflora	179	77.1	521	2.95	82 C. fuliginosus 4 C. atlanticus 24 T. nigrovittatus
Distichlis spicata	27	25.9	12	0.44	7 C. fuliginosus 1 T. nigrovittatus
Juncus roemerianus	47	26.1	29	.62	1 T. nigrovittatus 6 C. fuliginosus
S. cynosuroides	13	53.8	17	1.31	1 C. fuliginosus 3 T. nigrovittatus
S. alt. + D. spic.	15	46.7	14	.93	1 C. atlanticus 1 C. fuliginosus
J. roem. + D. spic.	5	40.0	7	1.40	4 C. fuliginosus
Hoop Hole Creek					
Spartina alterniflora	11	36.4	6	.54	3 C. fuliginosus
Juncus roemerianus	14	7.1	1	.07	
S. alt. + D. spic.	5	40.0	3	.60	2 T. nigrovittatus
S. alt. + J. roem.	5	40.0	3	.60	2 C. fuliginosus
S. alt. + D. spic. + J. roem.	5	40.0	2	.40	
None	3	0.0	0	0.0	
North River					
Juncus roemerianus	16	50.0	14	0.87	11 C. fuliginosus
S. alt. + J. roem.	4	50.0	6	1.50	3 C. fuliginosus
Davis Peninsula					
Spartina alterniflora	10	40.0	5	0.50	1 C. atlanticus 2 C. fuliginosus
Distichlis spicata	6	16.7	1	0.17	

Table 1. Recovery of tabanid larvae from soil in various plant associations in 4 salt marshes in Carteret Co., N.C. 1972.

Vegetation	Samples		Larvae		Species & No. Identified
	Total No.	% With Larvae	Total No.	Avg./ Sample	
	Davis Peninsula contd.				
Juncus roemerianus	37	16.0	7	0.19	3 T. nigrovittatus
S. alt. + D. spic.	4	0.0	0	0.0	2 T. nigrovittatus
S. alt. + J. roem.	2	50.0	1	0.50	
J. roem. + D. spic.	14	28.6	7	0.50	3 T. nigrovittatus
S. alt. + D. spic. + J. roem.	4	25.0	1	0.25	
None	16	0.0	0	0.0	

the upland. Traps located on the marsh, but near the edge of the upland, are more effective in catching these insects than traps placed in other locations; this may possibly be utilized in a control program.

Shrubs and small trees on the edge of the upland facing the marsh act as a natural trap for some of the insect species and discourage their further movement upland into areas inhabited by people; the possibility of using a buffer zone of vegetation as a control measure is promising.

Apparently some of these species of Tabanidae, and perhaps the Culicoides, lay their first batch of eggs without having a blood meal (a phenomenon called "autogeny"). Research by others on T. nigrovittatus, C. fuliginosus, C. atlanticus and Culicoides melleus in other geographic locations have shown this. Consequently, those adults moving upland to seek a blood meal have already deposited a batch of eggs on the marsh vegetation. This suggests that depletion of the upland adult population by control measures will have little effect on the size of the next generation of insects produced from the marshes. Although this appears to reduce the value of adult control measures, there actually is an advantage to this situation. Since the adult control measures should not reduce significently the insect larvae in the marsh, those larvae will continue to be available as components of the natural marsh food chain. The role of the insect larvae in the marsh ecology is not understood and in this state of ignorance it is best to avoid depletion of that component of the environment.

Correlation of the activity of these pests with environmental conditions (light, temperature, wind, relative humidity) is being attempted in order to be able to predict under what conditions the flies and gnats will be flying and attacking man. This will be important to the proper timing of any chemicals for adult insect control. These investigations are concentrating on C. fuliginosus, C. atlanticus and the 3 species of Culicoides. Additional data will be collected in 1973.

d. Economic Importance: In cooperation with other agencies (Animal Health Division, ARS, USA and the N.C. Dept. of Agriculture), we demonstrated that Tabanus lineola and T. quinquevittatus can transmit hog cholera virus and incriminated 3 other species of Tabanus. This has resulted in the addition of insect control practices in the federal-state cooperative program of hog cholera eradication. This disease has been a significant handicap to development of the swine industry in certain coastal counties of North Carolina.

To measure public opinion on the economic importance of biting flies and mosquitoes in the coastal areas, we distributed a questionnaire in the counties of Carteret, Pamlico, and Pender. A detailed report on that study is in print. This type of survey reveals useful information for planning research and extension activities and can be a mechanism for establishing a base of public support for initiation of a pest management program in an area. A summary of results for Carteret County is as

follows (based on 2,688 questionnaires with 35.3% return which was 9.5% of all the households in the county): (1) 4 out of 5 respondents are bothered often by biting insects; (2) Mosquitoes are the most widespread and annoying pests followed in order by yellow flies (deer flies), biting gnats and greenheads; (3) A large majority (84.2%) felt that there was a need for more community effort devoted to the control of biting insects; (4) 81.4% of the respondents indicated that they would be willing to pay some amount of money to support this community effort; (5) Most property owners thought that their property would increase in value if there was a better control of biting insects.

A cost-benefit analysis of coastal insect control was initiated in late 1972 with cooperating economists (Mr. Don deBord and Dr. G. Carleson). Since little data are available for North Carolina, analysis of several coastal mosquito control districts in other east coast States will be conducted to provide information that will be useful to North Carolina planners. By analysis of the expenditures and mosquito population levels in those districts over the past 10-15 years it is hoped to accomplish the following objectives: (1) Determine the underlying relationships be-
degree of mosquito control and control costs; (2) Determine the relationship between size of control area and average control costs; (3) Estimate the relative impact of tax and social-economic factors on the level of mosquito abatement expenditures; (4) Indicate future data needed for benefit calculations of mosquito control.

e. Control Methods: Cultural: Ditching and impounding marshes for mosquito control has been practiced for many years. These techniques have been used in North Carolina. A study of the effectiveness of these methods is in progress (under the supervision of K. L. Knight with support from the N. C. Water Resources Research Institute). The data on a comparison of mosquito production from ditched versus unditched Juncus marshes are complete and a final report is in preparation. From this study, methods of evaluating the mosquito-breeding potential of a marsh will be available. We plan to further evaluate and refine those methods so that a reasonably simple, effective method will be available for determining whether or not a particular area of marsh is likely to be a major source of mosquitoes. Thus the chances of ditching marsh that is low in mosquito production would be reduced. Further, the study will suggest methods for placing only a minimum amount of ditches in an area. It should be emphasized that there are many environmental factors to consider before permission is given to install mosquito-control ditches in a Juncus marsh. If a decision is reached by the concerned and responsible agencies to proceed with ditching, then the above study (and further refinements) will aid in the accomplishment of that ditching in the most effective manner with the least possible damage to the habitat. Research data of this type has not been available in the past.

Chemical: Research on control measures against adult biting flies, gnats and mosquitoes is planned for 1973. Emphasis will be on evaluation of ULV (ultra low volume) applications of short residual life insecticides by ground equipment in the areas occupied by people, such as golf courses,

camp-grounds and residential areas. It is planned to conduct these tests in cooperation with the County Commissioners and the N.C. State Board of Health in areas of Carteret County. It should be emphasized that these adult control measures are viewed as an approach to temporary suppressions of pest outbreaks and not as a routine procedure. Properly used only when and where needed, this method would be economical and of little risk to the estuarine habitat.

Reports, Publications and Papers Presented:

Published:

Tidwell, Mac A., W. D. Dean, M. A. Tidwell, G. P. Combs D. W. Anderson, W. O. Cowart and R. C. Axtell. 1972. Transmission of hog cholera virus by horseflies (Tabanidae: Diptera). Amer. J. Vet. Res. 33(3): 615-622.

In Press:

Gerhardt, R., J. Dukes, J. Falter, and R. C. Axtell. Public Opinion on insect pest management in coastal North Carolina. N.C. Agric. Ext. Misc. Publ. 97, N.C. Sea Grant Prog. Publ. UNC-SG-73-03.

Knight, K. L. and R. LaSalle. The effects of ditching for mosquito control on irregularly flooded salt marsh in Carteret County, North Carolina. N.C. Water Resources Research Institute Report.

In Manuscript:

Dukes, J. C., T. D. Edwards, and R. C. Axtell. Associations of Tabanidae (Diptera) larvae with plant species in salt marshes, Carteret County, North Carolina. J. Environmental Entomology.

Edwards, T. D., J. C. Dukes, and R. C. Axtell. Soil-washing apparatus for recovery of insect larvae and other invertebrates. J. Environmental Entomology.

Dukes, J. C., T. D. Edwards, and R. C. Axtell. Distribution of Tabanidae (Diptera) larvae in a Spartina alterniflora salt marsh. J. Medical Entomology.

Papers Presented:

LaSalle, R., and K. L. Knight. The biology of Anopheles atropos D. & K. in North Carolina. 1972 Annual Meeting, Entomological Society of America, Montreal.

Axtell, R. C. Seasonal occurrence of biting flies (Tabanidae) in coastal North Carolina. 1972 Annual Meeting, American Mosquito Control Association, Miami.

NOAA FORM 90-2

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED

SEA GRANT PROJECT SUMMARY

R/ES-5	Source, Fate and Effects of Nutrients Added to N. C. Estuaries (☒ CONTINUING)	DATE INITIATED, IF CONTINUING: Sept. 1970
2-35178		DATE OF THIS FORM: May 1973
UNC		ESTIMATED COMPLETION DATE: Dec., 1975

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
B. J. Copeland, Zoology Dept., NCSU	10	John E. Hobbie	10

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 71,022	$ 35,511	$ 46,342	$ 23,171	$	$	R/ES-8, R/ES-9

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Estuarine Studies	Pollution Studies/Nutrients

OBJECTIVES:

1. Continue surveying the nutrients (phosphorus and nitrogen compounds), hydrography and flows in Albemarle Sound and Neuse River Estuaries of N.C.;

2. Determine biological communities and species diversity in relation to nutrient and hydrographic parameters;

3. Measure the community metabolism in relation to biological, nutrient and hydrographic parameters; and

4. Conduct laboratory experiments to determine phytoplankton uptake of nutrients under varying experimental conditions and the fate of nutrients in relation to sediments.

The determination of nutrient budgets for N. C. estuaries is already being used to set water quality criteria. Ecological response to nutrient inputs will be used to manage and preserve the N. C. estuarine ecology. Predictive modeling can be developed, using the findings of this project, for predictive capabilities.

Data and techniques from this project will be available for use in planning in the coastal zone; e.g., placement of housing developments, navigation and transportation planning, industrial siting, sewage treatment needs, etc.

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Nutrient budgets for Albemarle Sound and Neuse River Estuaries have been established. Nutrient inputs and concentrations in the Neuse River Estuary are comparable to those in the Pamlico River Estuary and significantly higher than in Albemarle Sound. Results of this study were used by the N. C. Office of Water and Air Resources to evaluate and regulate nutrient inputs into the Chowan River and Albemarle Sound in response to a large algal bloom in the Chowan during 1972. Our techniques and analyses were provided to the Currituck County study of Currituck Sound in relation to impending development of Currituck Banks. We continually provide data to various state agencies in their quest to regulate and assess eutrophication of N. C. coastal waters.

Project No.: R/ES-5

Title: Source, fate, and effects of nutrients added to North Carolina estuaries.

Principal Investigators: B. J. Copeland and John E. Hobbie, Dept. of Zoology, North Carolina State University.

Introduction

This project was initiated in 1970 to determine, through flow and concentration measurements, budgets for nitrogen and phosphorus compounds entering Albemarle Sound and Neuse River Estuaries. The initial survey of these nutrients was necessary to provide the baseline data against which to measure any long-term changes in the estuaries and to provide data for subsequent measurement of response by the ecological systems. Study of these two large, complex estuaries will also provide information to enable realistic comparison with the Pamlico River Estuary, which has been intensively studied. Eventually, we hope to utilize data from all three estuaries to develop ecological models useful for predictions and management of North Carolina's valuable estuarine resources.

Approach

Albemarle Sound and Neuse River Estuaries, along with Pamlico River Estuary, are major arms of the Pamlico Sound system (Figure 1). These estuaries serve as the major nursery grounds for the large and economically important commercial and recreational fishery of Pamlico Sound.

Nutrient concentrations, along with concomittant hydrographic parameters, have been sampled monthly since September 1970. Water samples are taken from selected stations (Figures 2 and 3), immediately frozen in a deep freeze aboard ship, and returned to the Pamlico Marine Lab for subsequent analysis. Salinity and temperature are determined *in situ* with a Beckman RS-5 electrodeless salinometer. Dissolved oxygen and chlorophyll samples are fixed on ship and later analyzed.

Reactive (ortho) phosphate, filtered (dissolved) total phosphorus, total phosphorus, nitrite nitrogen, ammonia nitrogen, nitrate nitrogen, total filtered (dissolved) nitrogen, and total nitrogen are determined at the laboratory with standard spectrophotometric techniques. For example, persulfate oxidation is used for the phosphorus analysis, a cadmium reduction column for nitrate analysis, and an ultraviolet oxidation followed by nitrate analysis for the total nitrogen.

Nekton samples have been taken monthly at all stations since June 1972. Samples are taken by pulling an eleven-foot otter trawl behind a boat for ten minutes at two knots. Nekton are preserved in 10% formalin and taken to the laboratory for identification, enumeration and weighing.

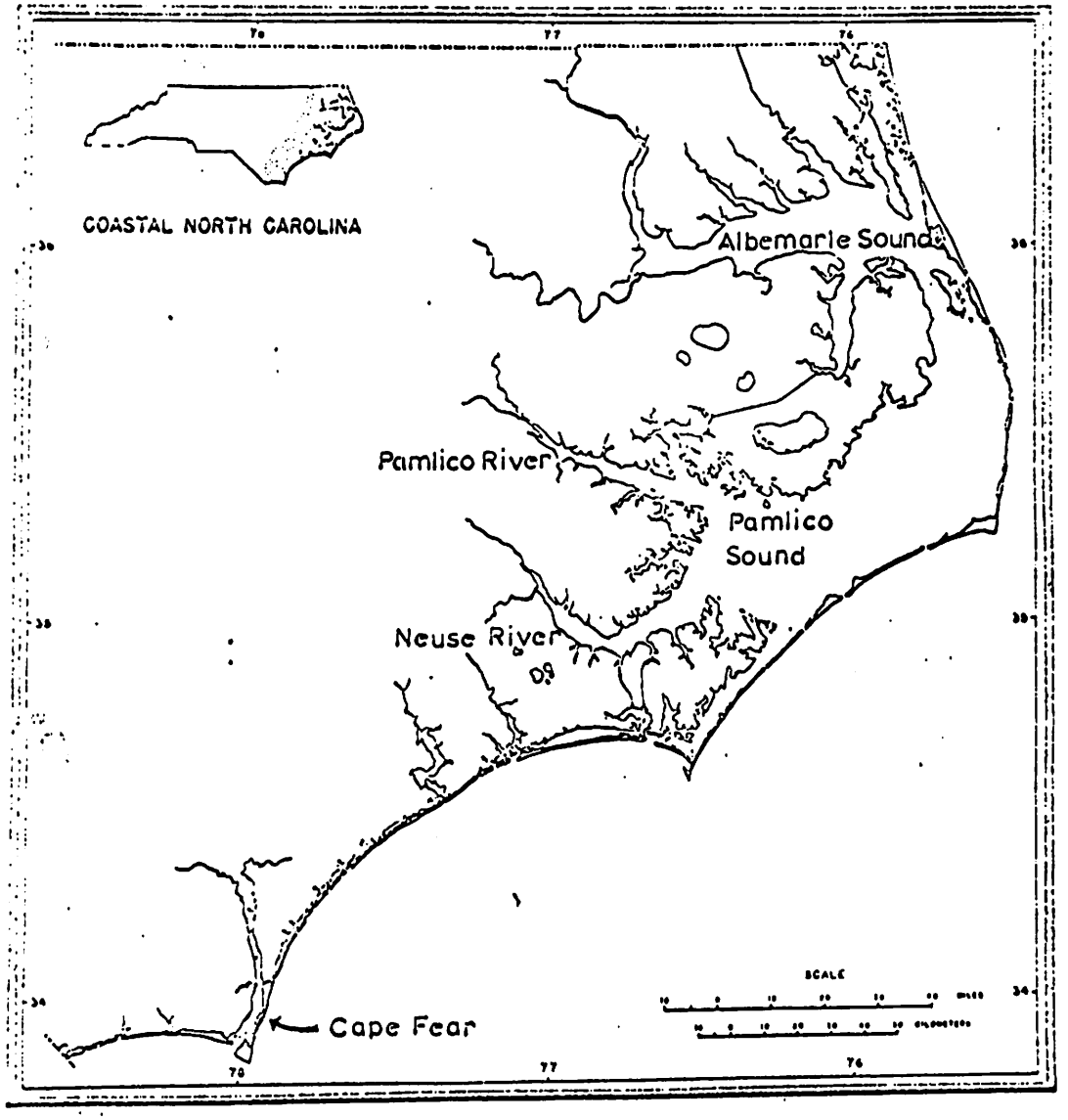


Figure 1. Map of Pamlico Sound and adjacent waters.

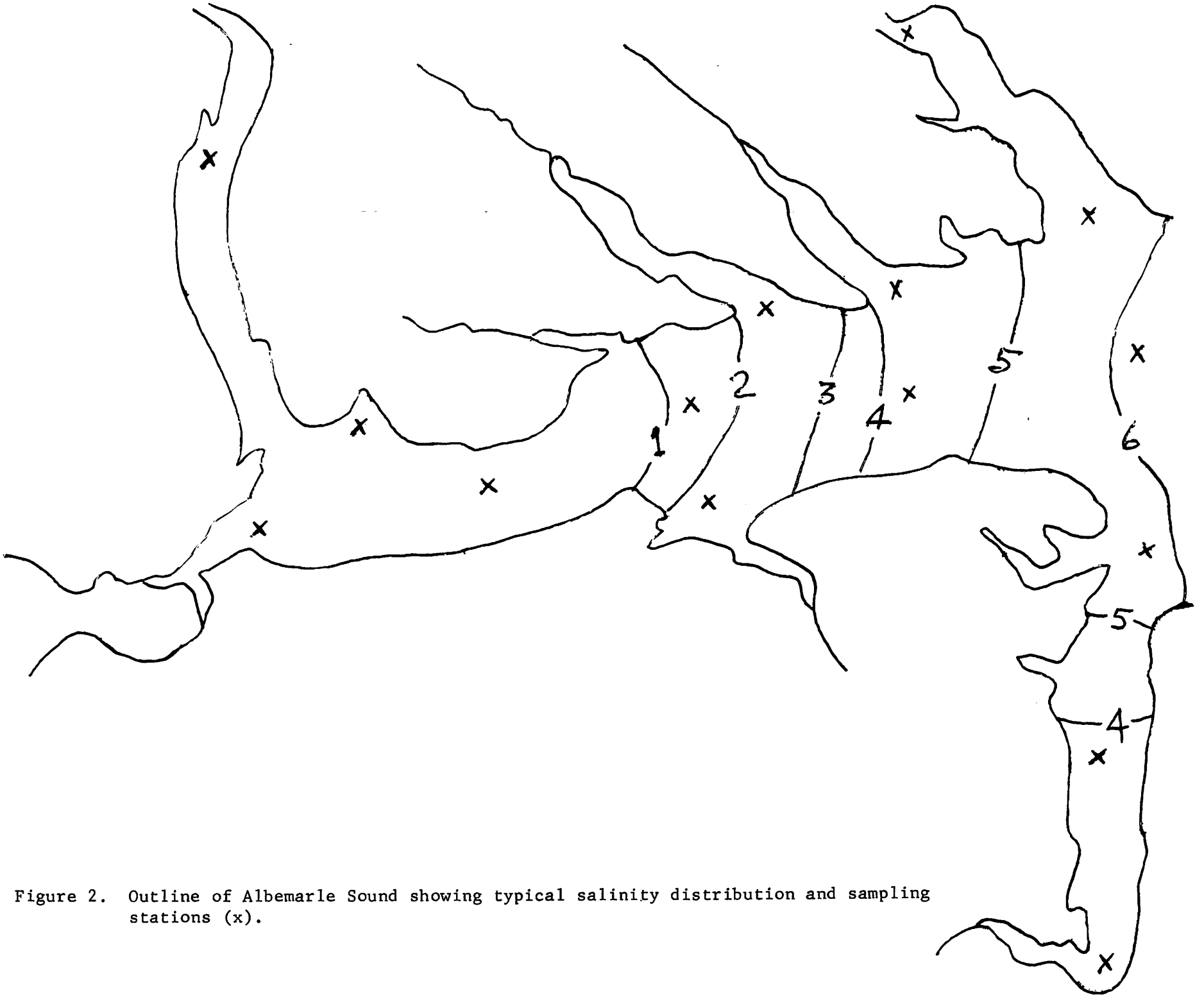


Figure 2. Outline of Albemarle Sound showing typical salinity distribution and sampling stations (x).

Figure 3. Outline of the Neuse River Estuary showing typical salinity distribution and sampling stations (x).

Albemarle Sound Estuary

Albemarle Sound Estuary extends from just west of Edenton, N. C., to its connection with Pamlico Sound through Roanoke and Croatan Sounds near Manteo, N. C. The estuary has an average depth of about five feet and an area of 500 square miles. The Outer Banks have a damping effect on the lunar tide, but wind tides can be significant. The large freshwater input to the estuary, which is important for mixing and nutrient supply, keeps the salinity at a low level throughout; ranging from near zero to no more than 7 or 8 ppt at the lower end of the estuary (Figure 2).

The phytoplankton and zooplankton of Albemarle Sound have not been studied; there is, however, evidence that small diversity of both groups occurs in this oligohaline system. No substantial algal blooms have been observed in Albemarle Sound, although a large blue-green algae bloom was in the lower Chowan River (a major tributary on the west end) during most of the summer of 1972. Albemarle Sound fish populations are dominated by a mixture of estuarine and freshwater species. Throughout a good portion of the estuary, croaker and anchovies are the dominant species. White perch are dominant seasonally throughout and continually at the upper end of the estuary.

Nutrient concentrations are relatively low in Albemarle Sound Estuary (compared to Neuse and Pamlico River Estuaries). Reactive phosphorus concentrations ranged between about 0.1 and 1.2 ug-at P/l, with average values of less than 0.4 ug-at P/l (Figure 4). Very little difference was observed between tributary concentrations and estuary concentrations, indicating little dilution of tributary phosphorus by low-nutrient sea water. Reactive phosphorus peaks occurred during September 1971 and February 1972, possibly from heavy rainfall runoff from the watershed. Concentrations are typically low (about 0.2-0.3 ug-at P/l) during the summer.

Total phosphorus averaged between 1 and 4.5 ug-at P/l, with typical values around 2 ug-at P/l (Figure 5). Concentrations, as with reactives phosphorus, was relatively high in September 1971 and during late winter 1972. Again, the estuary concentrations were not significantly different from tributary concentrations. Total phosphorus was not significantly higher than dissolved (filtered) total phosphorus, indicating very little suspended matter present in Albemarle Sound.

Ammonia nitrogen and nitrate nitrogen peaked during the wintertime, a possible reflection of input from waterlogged soil drainage (Figures 6 and 7). Ammonia nitrogen averaged more than 5 ug-at N/l all year, with a high of 14 ug-at N/l during February 1972 (Figure 6). Nitrate nitrogen was low during summer, averaging around 1 to 4 ug-at N/l (Figure 7), but peaked at 30 to 37 ug-at N/l during winter. There was no significant difference in mean tributary and estuary concentrations.

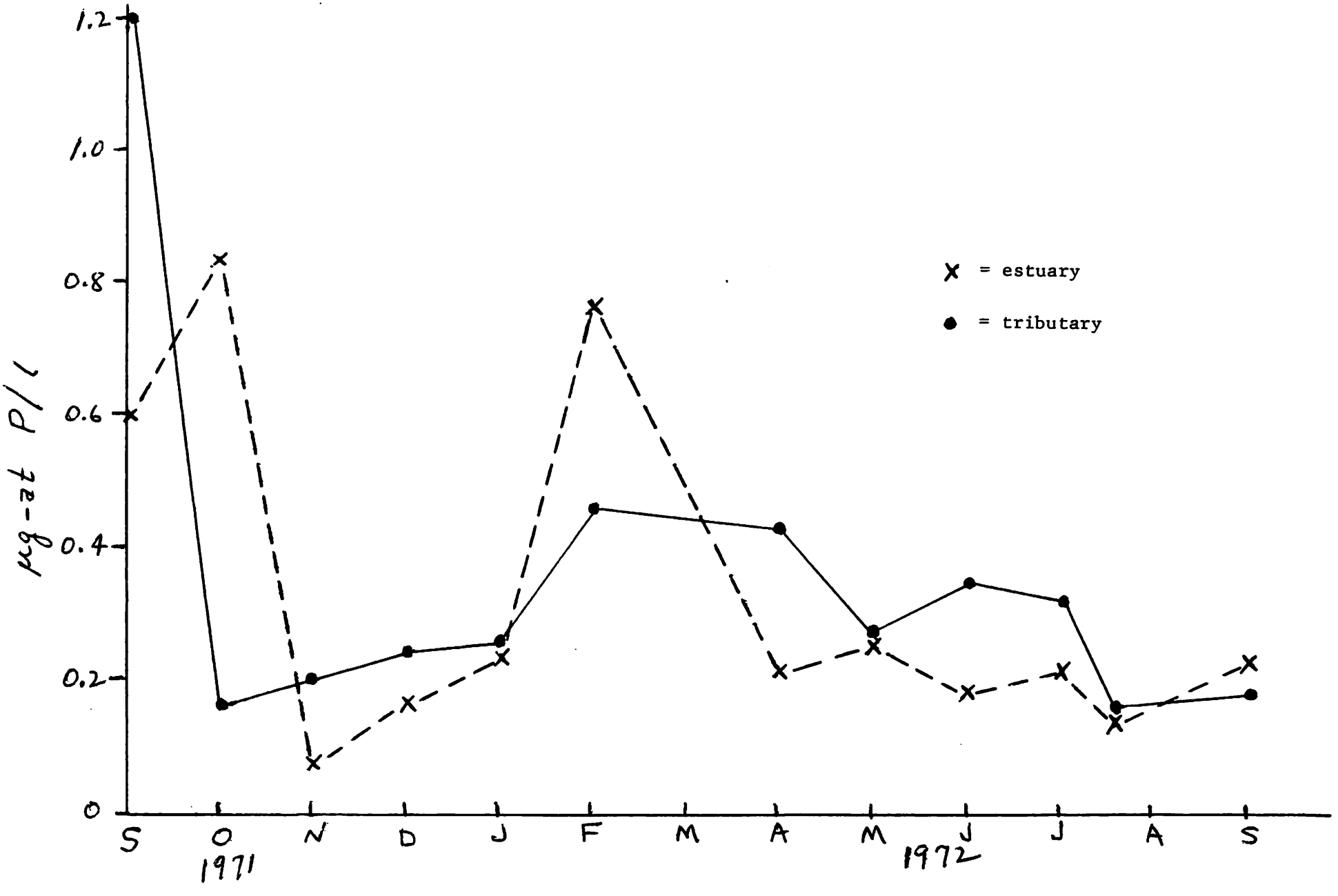


Figure 4. Mean reactive phosphorus (ortho) in ug-at P/1 in Albemarle Sound, 1971-1972. Tributary data is a mean of 7 stations and estuary data a mean of 8 stations.

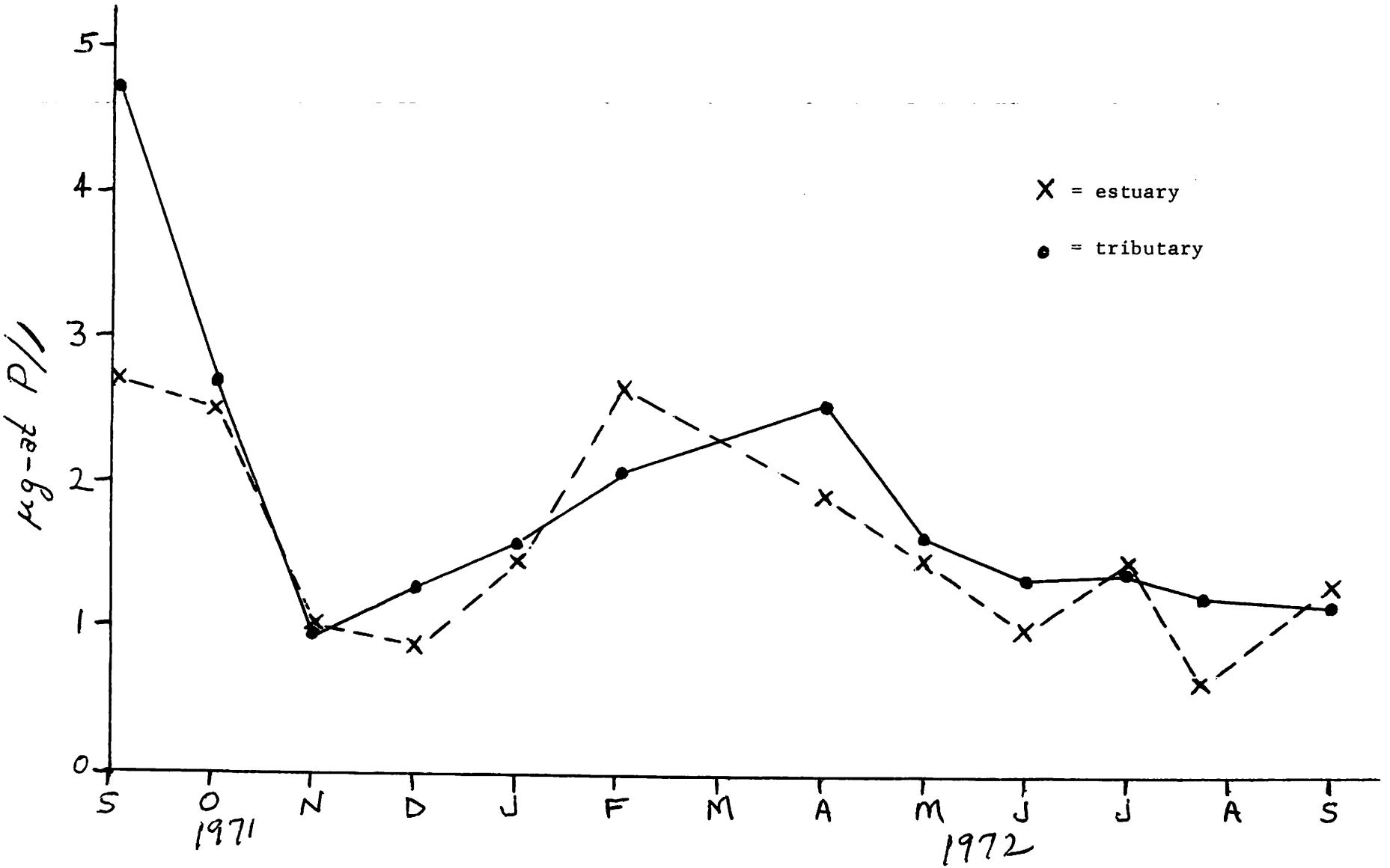


Figure 5. Mean total phosphorus in ug-at P/l in Albemarle Sound, 1971-1972.

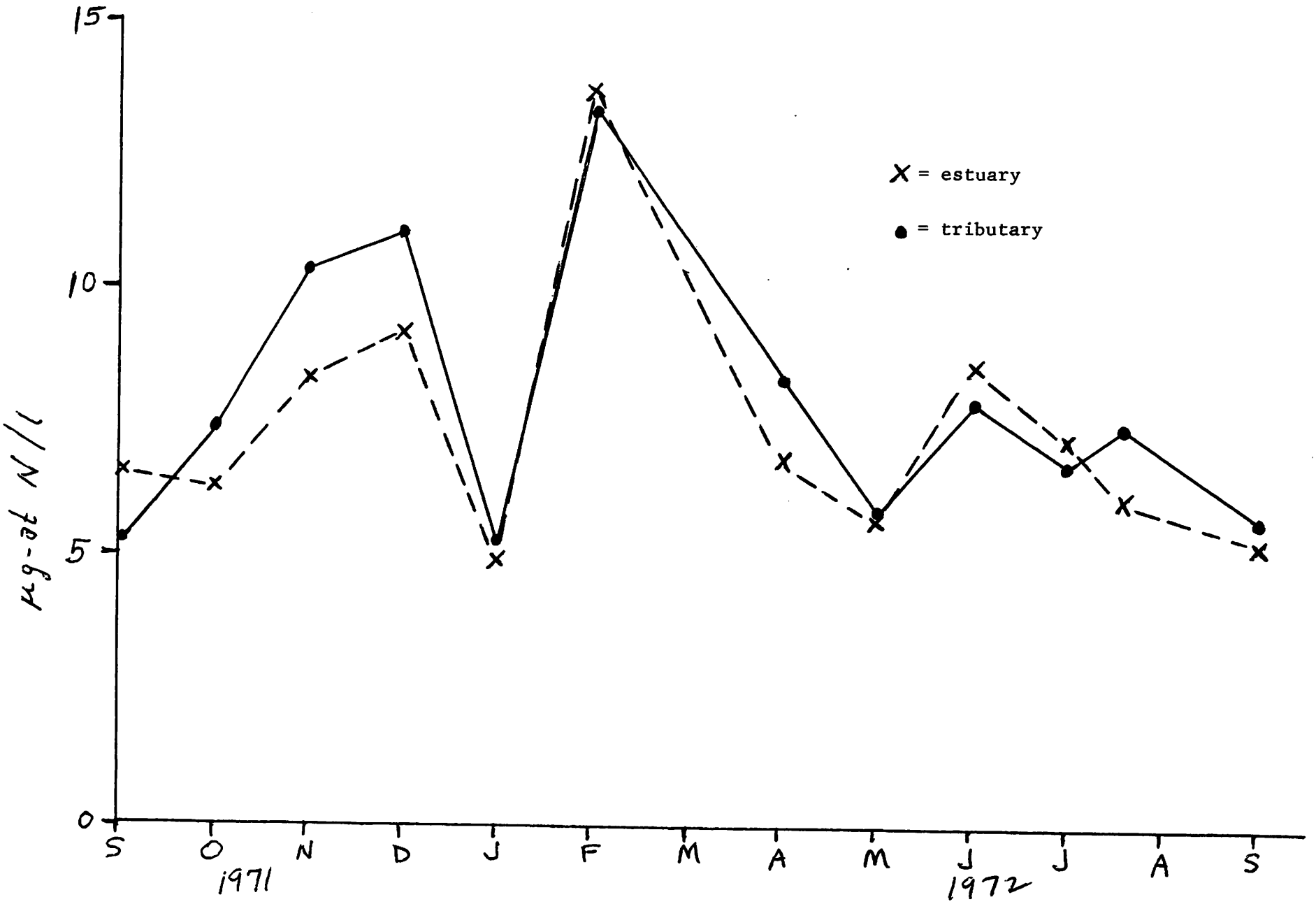


Figure 6. Mean ammonia nitrogen in ug-at N/l in Albemarle Sound, 1971-1972.

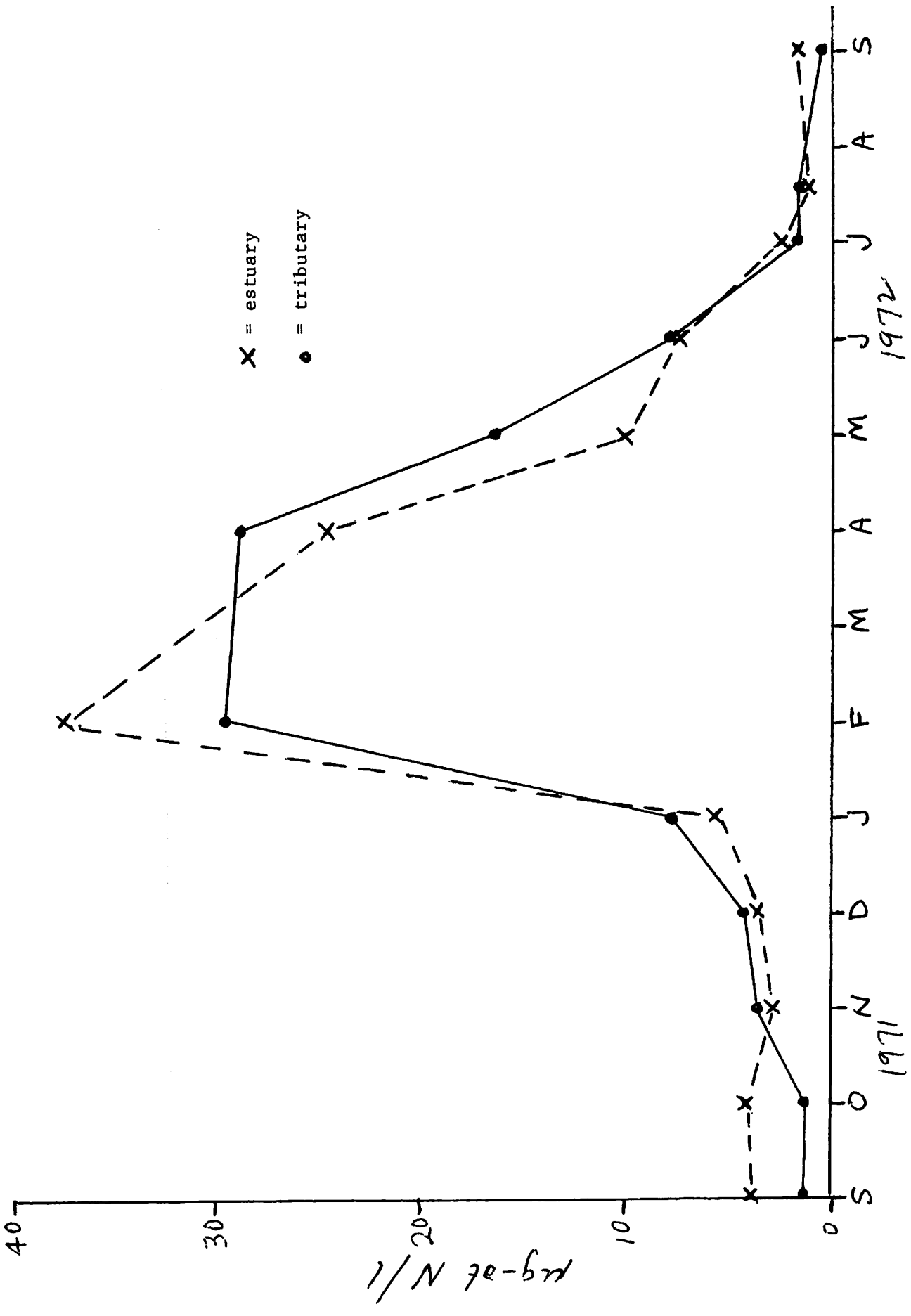


Figure 7. Mean nitrate nitrogen in ug-at N/l in Albemarle Sound, 1971-1972.

Chlorophyll a concentration, an indication of phytoplankton activity, is relatively low in Albemarle Sound, with values usually averaging around 5 mg/m^3 (Figure 8). The relatively low nutrient input into the estuary probably is responsible for the low algal activity, since the water in the estuary is relatively clear. Phosphorus may be the controlling nutrient during the wintertime, especially since the nitrate/reactive phosphorus molecular ratio is greater than 20. An unusually high peak (for Albemarle Sound) occurred during the summer 1972, possibly a result of a large algal bloom situation in the Chowan River.

Neuse River Estuary

The Neuse River Estuary extends from just west of New Bern, N. C., to where it enters Pamlico Sound near Pamlico, N. C. The estuary has an average depth of about 10 feet and an area of over 140 square miles. Lunar tides are small (less than one foot), but wind tides are up to three feet. The main freshwater input is from the Neuse and Trent Rivers near New Bern, with several small tributaries around the periphery. Salinity ranges from almost zero at New Bern to about 20 ppt at the junction with Pamlico Sound (Figure 3).

The phytoplankton is dominated by a large algal bloom that reaches red tide proportions during the winter. The dominant species in the algal bloom in Peridinium triquetrum, similar to the algal bloom situation found in the Pamlico River Estuary. Zooplankton is dominated by the common estuarine copepod, Acartia tonsa. The fish are typical estuarine species with some freshwater forms occurring near river mouths. Several species of fish, including hickory shad, glut herring, American shad, gizzard shad, striped bass and common sturgeon, migrate through the estuary during certain seasons of the year.

In contrast to Albemarle Sound, nutrient concentrations in the Neuse River Estuary are relatively high (more like those in the Pamlico River Estuary). There is a significantly larger average concentration in the tributaries than in the estuary, particularly for reactive phosphorus and nitrate nitrogen (Figures 9, 10, 11 and 12). Phosphorus concentrations are usually higher during the summer and fall than during spring and winter (Figures 9 and 10) and about an order of magnitude higher than in Albemarle Sound. Ammonia nitrogen remains at about 7 or 8 ug-at N/l throughout the year, with tributary concentrations only slightly higher than estuary concentrations (Figure 11). Nitrate nitrogen exhibits a very strong seasonal pulse (Figure 12), with extremely high values during winter reaching 60 ug-at N/l. Nitrate concentrations during summer are around 1 ug-at N/l undoubtedly limiting phytoplankton activity. Tributary concentrations are significantly higher than estuary concentrations, indicating considerable dilution and/or physical loss.

Chlorophyll a during the past year averaged around 10 mg/m^3, without the wintertime bloom conditions usually found in the Neuse River Estuary in previous years (Figure 13).

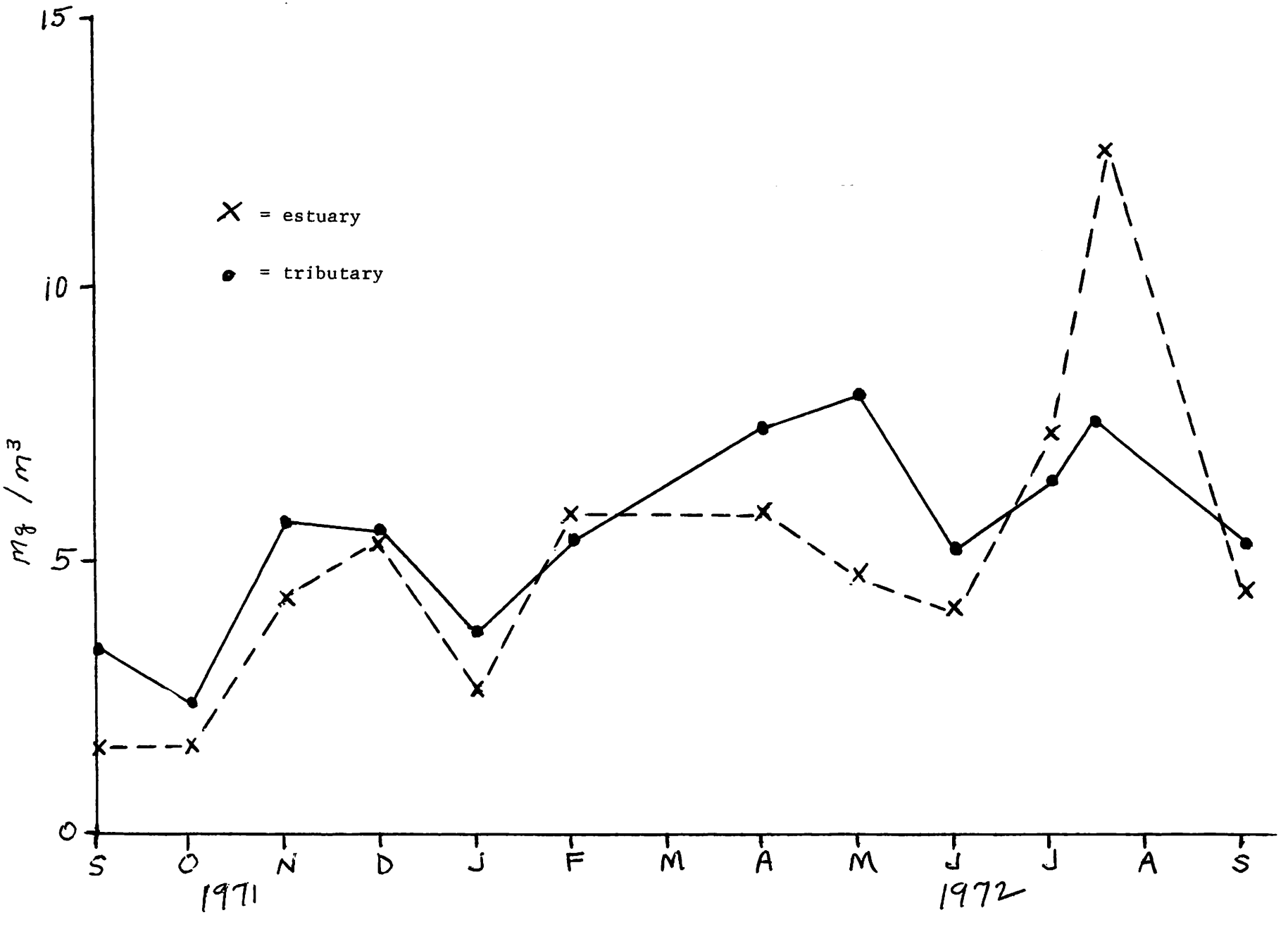


Figure 8. Mean chlorophyll a in mg/m^3 in Albemarle Sound, 1971-1972.

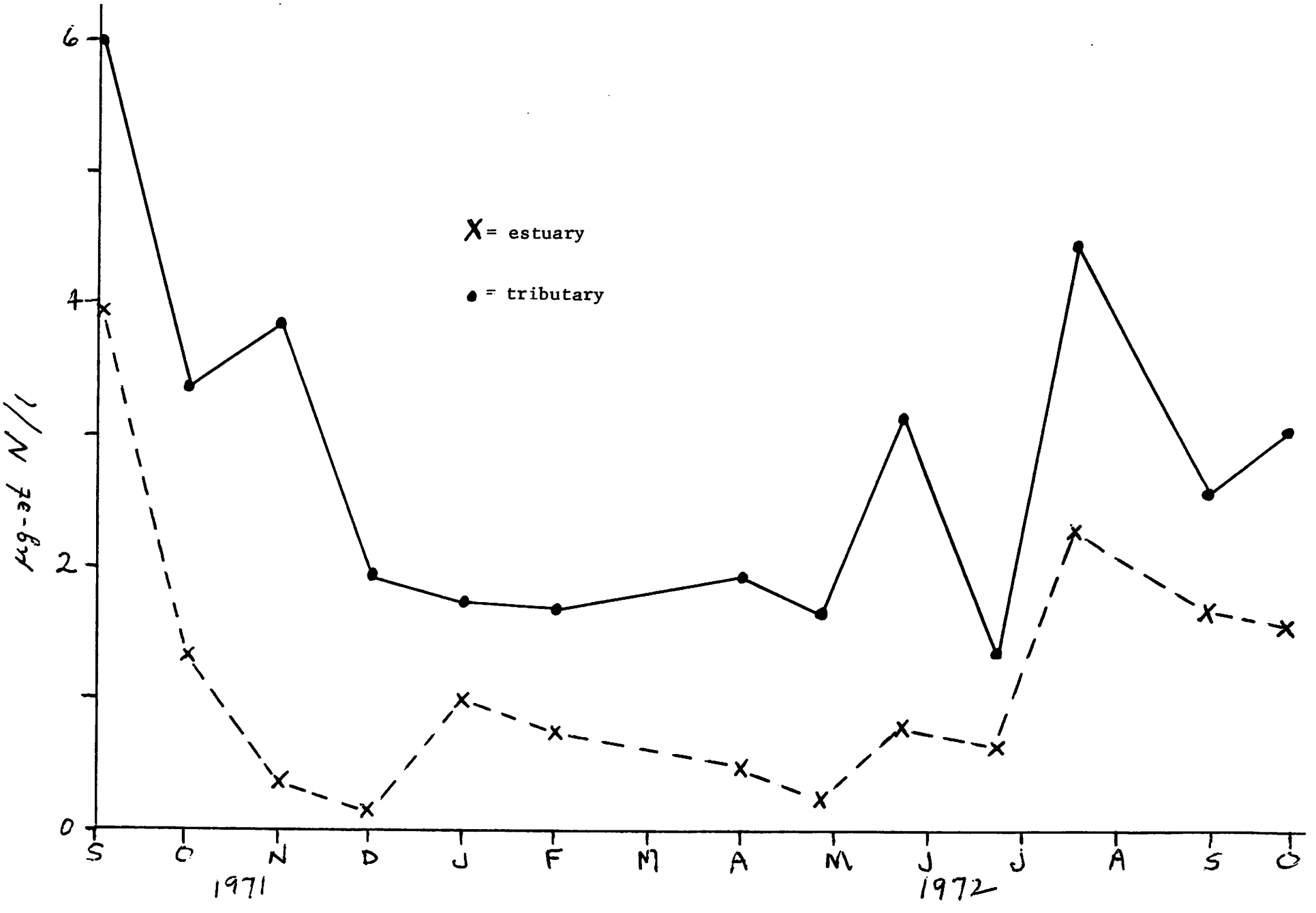


Figure 9. Mean reactive phosphorus (ortho) in ug-at P/1 in Neuse River Estuary, 1971-1972. Tributary data is a mean of 9 stations and estuary data a mean of 8 stations.

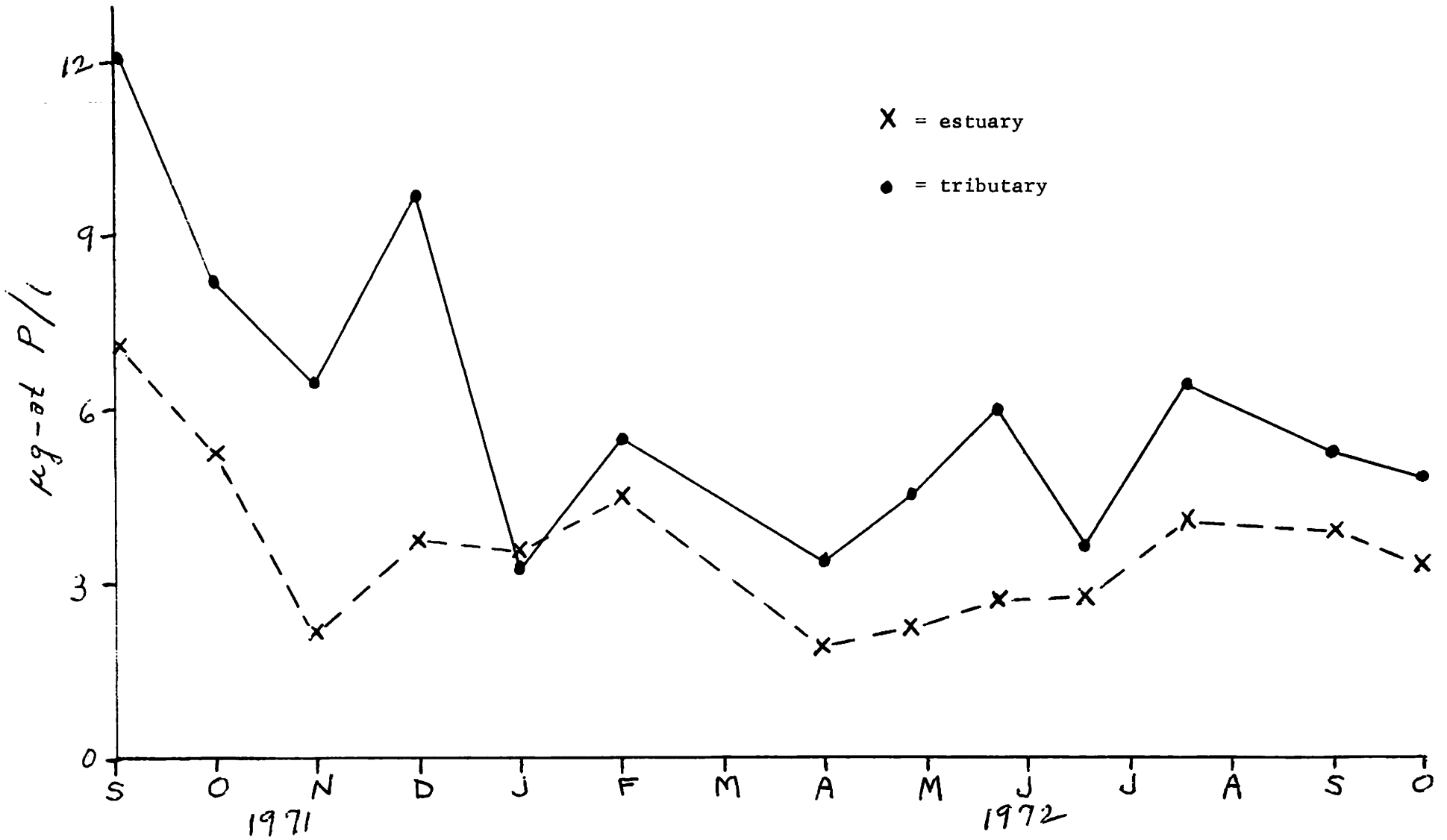


Figure 10. Mean total phosphorus in ug-at P/1 in Neuse River Estuary, 1971-1972.

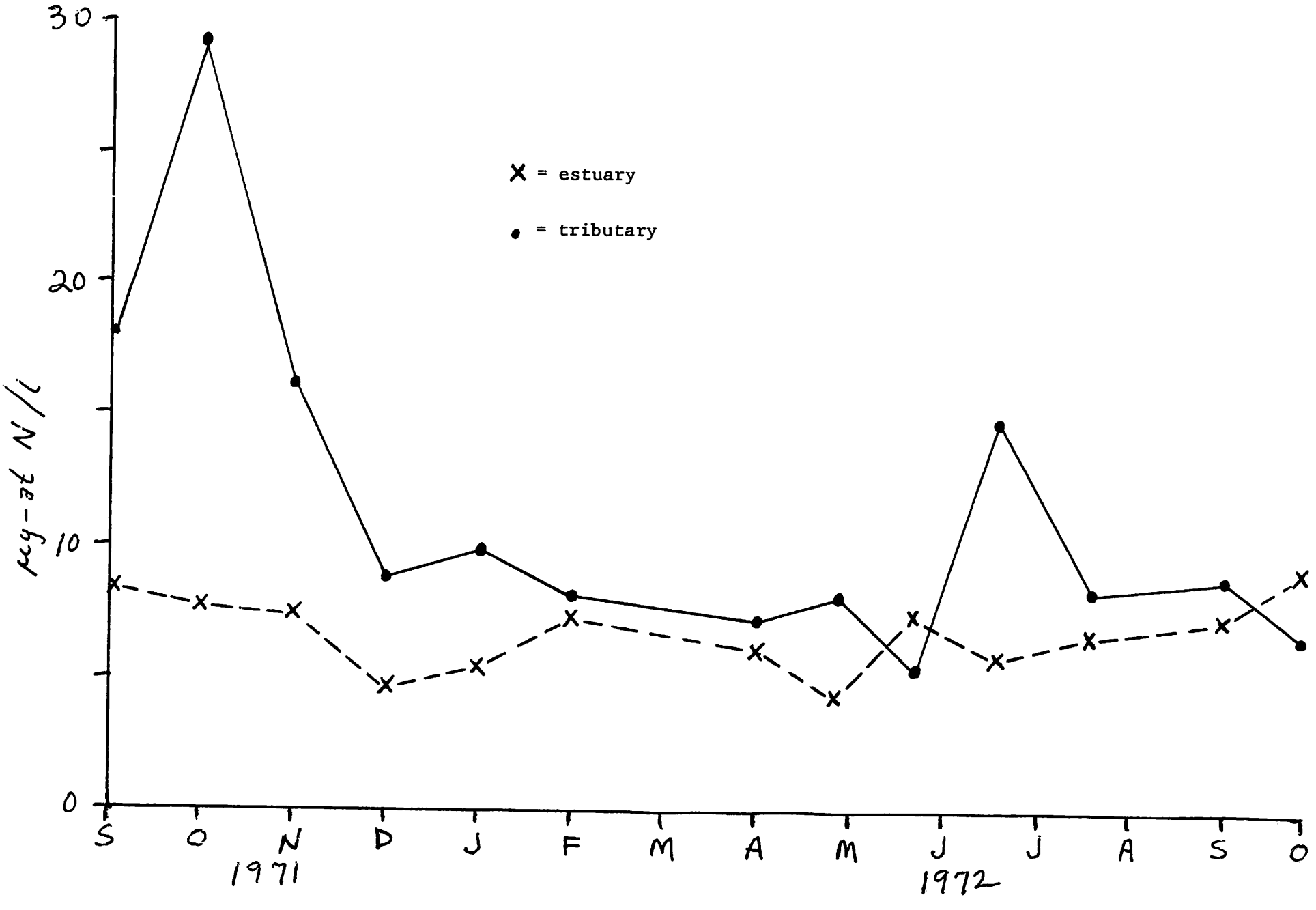
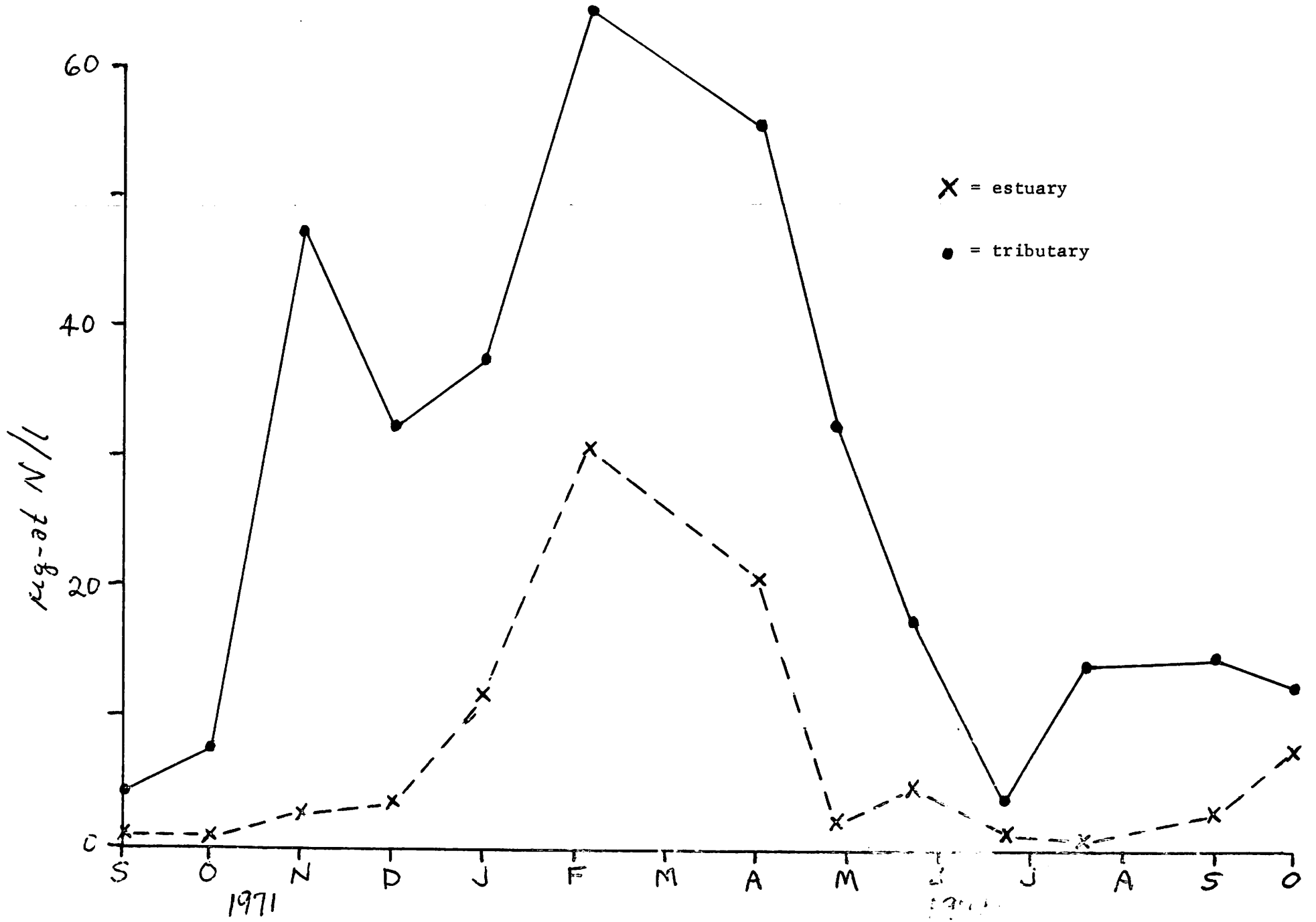


Figure 11. Mean annonia nitrogen in ug-at N/l in Neuse River Estuary, 1971-1972.



F . 12 Mean nitrate nitrogen in ug-at N/l in Neuse River Estuary, 1971-19..

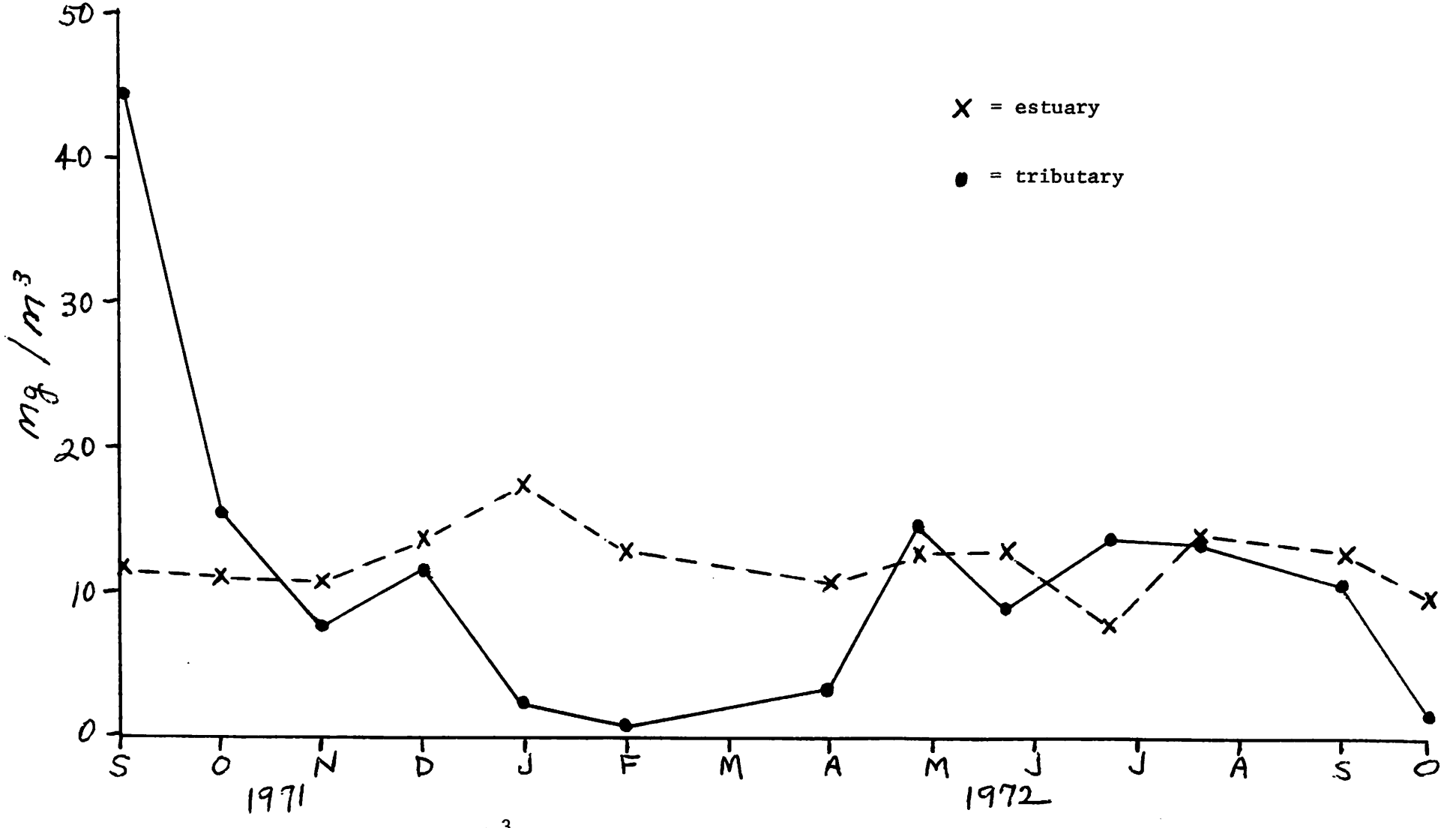


Figure 13. Mean chlorophyll a in mg/m^3 in Neuse River Estuary, 1971-1972.

The Chowan River Algal Bloom

During the summer 1972 a large and extensive algal bloom occurred in the lower Chowan River. Dominant algae in the bloom were 3 species of blue-green algae. This bloom created considerable interest on the part of local users of the river and state agencies.

One of our sampling stations for Albemarle Sound was located near the downstream end of the bloom. We were able to provide some baseline data for consideration of the state agency in its control and assessment activity. Nitrate nitrogen was determined to be the major causative factor and some data are presented in Figure 14. Nitrate concentration during the summer 1972 was significantly higher than during the previous summer.

Reports, Presentations and Seminars

1. Presentation of results to the N. C. Marine Science Council.

2. Presentation of results to the N. C. Board of Water and Air Resources (2 occasions).

3. Seminars including results of this study were presented to the following: N. C. State University Marine Sciences Faculty and Graduate Students, University of South Carolina Marine Sciences Faculty and Graduate Students.

4. Copeland, B. J. 1972. Nutrients in Albemarle Sound and Neuse River Estuaries, 1970-1972 - A Survey. N. C. Sea Grant Publication, UNC-SG-72-11.

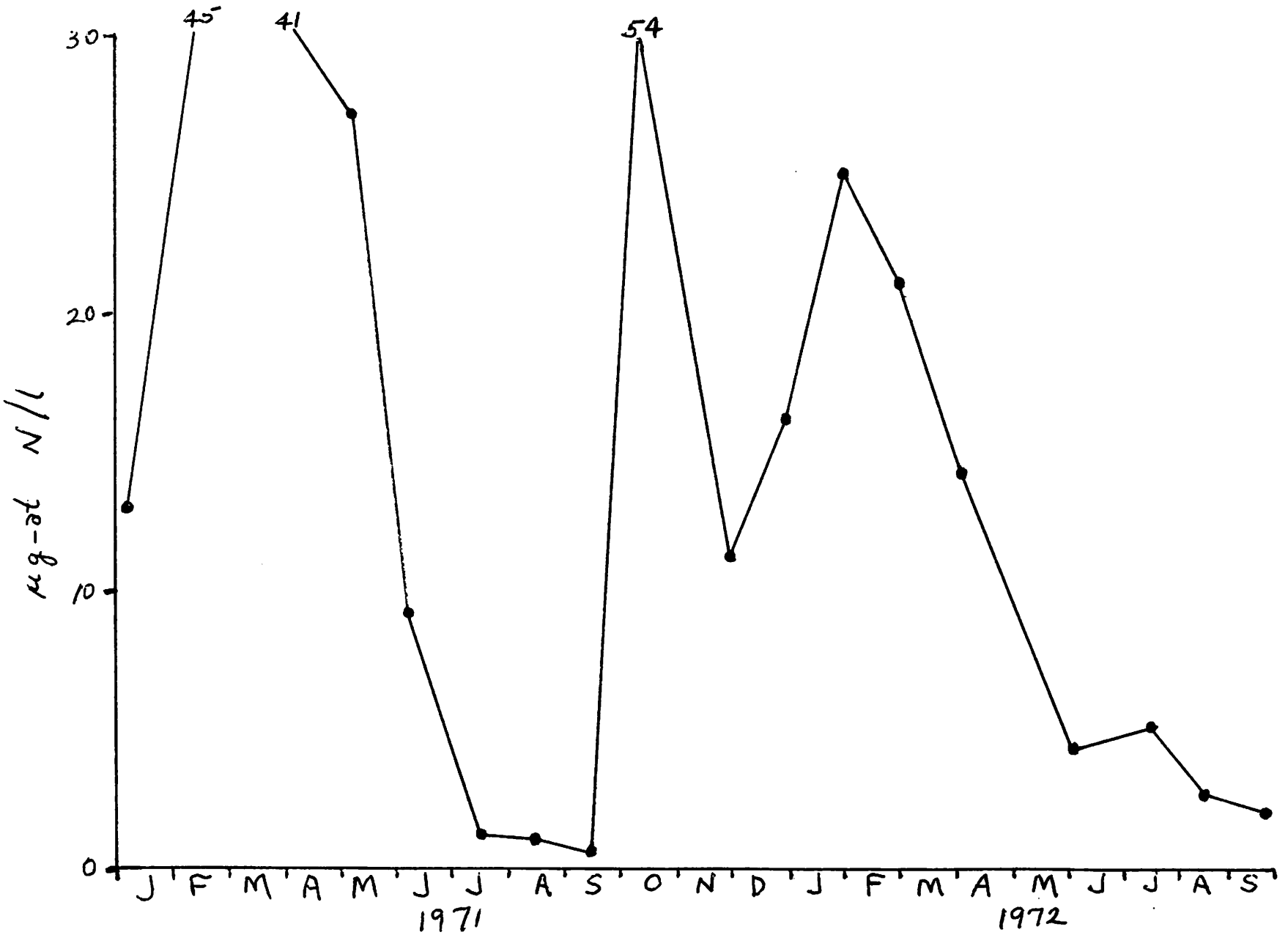


Figure 14. Nitrate nitrogen in ug-at N/l in the lower Chowan River, 1971-1972.

NOAA Form 90-2 (5-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 41-R2000

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT NO.	PROJECT TITLE ☐ NEW ☐ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
R/ES-6	Optimal ecological designs for estuarine systems	1968
GRANT NO. (if any)	OLD TITLE (if different)	DATE OF THIS FORM
2-35178		May, 1973
INSTITUTION		ESTIMATED COMPLETION DATE
UNC		Terminated 3/31/73

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
E. J. Kuenzler, Envir. Sci. & Eng., UNC-CH		A. F. Chestnut C. M. Weiss	

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (R/ numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 262,529	$ 131,265	$ 115,000	$ 57,500	$	$	R/ES-5, R/ES-10

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Estuarine Studies	Pollution Studies/Domestic Wastes

OBJECTIVES: The basic objectives were to examine the effects of sewage effluent upon brackish water ecosystems, including the effects on water chemistry; plant, animal, and bacterial populations; productivity; nutrient cycling; and potential for aquaculture. Studies were made in artificial ponds and in natural estuaries and salt marshes.

HOW INFORMATION WILL BE APPLIED: This information will be applied in the following ways: (1)through theses, dissertations, and publication in the open literature it will be available to active scientists and engineers who can extend or directly utilize the findings; (2)copies of the reports will be available to individuals in government agencies for input into the decision-making processes; (3)the investigators will contact fisheries and water-quality agencies in the State of North Carolina to provide advice based on these findings.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS: A large number of projects were continued in order to develop solid data on the long-term constancy of physical, chemical, and biotic factors in the ponds and neighboring marshes. The general pattern of recurring seasonal events was confirmed. The cut-off of sewage during part of the winter of 1971-72 resulted in a failure of the Monodus population to reach the bloom conditions of former years, presumably because of unavailability of sufficient ammonia for this alga. There is further evidence that sewage enrichment of Spartina alterniflora marshes results in larger populations of large-size Littorina irrorata. The greater density and robustness of Spartina in sewage-enriched marshes was confirmed, but there were no significant differences in densities of microarthropods (mostly insects), except for spiders and amphipods. Productivity of insects in the North Carolina marshes was only about 2.5% that of Georgia marshes, but the diversity was about 4 times higher. New data are now available concerning benthic microfauna of the ponds. Polychaete worms (Capitella capitata and Laeonereis culveri) are dominant in the sediments. A detailed study of foraminiferal populations in the ponds showed lower populations densities in the waste ponds than in the controls; this is attributable to larger ranges in oxygen content, pH, and type and availability of food supply rather than to toxicity of sewage effluent. A number of species of bacteria were identified in the pond waters. The coliform bacteria consistently declined in the sewage-treated ponds, but oysters in the ponds had bacterial counts above USPHS acceptable levels for shellfish. A ^{14}C tracer technique was devised to follow energy conversions in an aquacultural system (algae - oyster - oyster feces - shrimp). Shrimp were shown capable of excellent growth in the waste ponds if they were provided with air to prevent anoxic conditions in spring and summer. Oysters cultured in the ponds should be available over a longer period of the year than wild oysters, and the oysters are bigger and have more glycogen. Intensive studies of the phytoplankton Monodus have revealed much concerning its physiology and ecology; it may prove to be highly useful in brackish sewage lagoons because it maintains an even dispersion throughout the water column, is tolerant of wide changes in temperature and salinity, and consumes large amounts of nitrogen and phosphorus.

Project No.: R/ES-6

Title: Optimum Ecological Designs for Estuarine Ecosystems

Principal Investigators: E.J. Kuenzler, A.F. Chestnut, and C.M. Weiss, Curriculum in Marine Science, University of North Carolina, Chapel Hill, N.C.

This is a report of the accomplishments of the final 18 months of research on this grant. The original objectives of the study were to examine the ecological systems that develop when treated wastes from municipal sewage systems flow into estuarine waters. A team of faculty and students of the University of North Carolina, Chapel Hill, investigated a small, marsh-lined estuary, Calico Creek, which receives wastes which have undergone secondary sewage treatment and a set of three small artificial ponds in which estuarine water and treated sewage are mixed. Control areas in other marshes and three control ponds were also examined. A basic theme of the study was "self-design": What kind of system will result naturally if ponds are provided with a wide variety of plants and animals? Will stable systems evolve in the presence of heavy waste loads? Will any commercially important species thrive? Will effluent quality be improved? The detailed annual reports from this grant have provided answers to many aspects of these questions. Unfortunately only the briefest mention of our results during the past 21 months can be given here and the interested reader is referred to our annual report for 1971-72 (Sea Grant Pub. No. UNC-SG-73-10).

One of the most interesting phenomena which developed in the waste ponds was the recurring winter bloom of the planktonic alga Monodus guttula. This dense bloom usually crashed in May, leading to temporary anoxic water. Detailed studies of the ultrastructure of Monodus were completed and pigment extracts were chromatographed in order to determine its taxonomic position. Since this species is so abundant in the waste ponds, it dominates the process of photosynthetic energy fixation and thereby may have a marked effect upon the herbivores and higher trophic levels. A study of phytoplankton distribution in relation to oxygen levels in the ponds in summertime indicated some migration out of the oxygen-deficient water into regions of higher oxygen content. A number of species of bacteria were identified in the pond waters. The Coliform bacteria consistently declined in the sewage-treated ponds, but oysters in the ponds had bacterial counts higher than U.S.P.H.S. acceptable levels.

An intensive study of various aspects of foraminiferal ecology showed higher densities and standing crops in the control ponds than in the waste ponds, although the same species, Elphidium clacatum was the most commonly occurring species in both sets of ponds. Municipal sewage effluent was not in itself detrimental to the foraminiferans, but micro-environmental differences in oxygen, pH, and food concentration made their distribution erratic.

Sewage enrichment of Spartina marshes along Calico Creek resulted in larger populations of the snail Littorina irrorata than were found in

control marshes, and these snails were larger in size. There were, however, no significant differences in densities of microarthropods (mostly insects), although spiders and amphipods were somewhat more abundant in waste-enriched marshes. Standing crops of microarthropods were low and annual productivity appeared to be much lower than has been reported for other marshes. On the other hand species diversity was higher. A study of fiddler crab populations showed that Uca pugnax and U. minax were present in waste-receiving marshes; the total number of fiddler crabs was higher in the control marshes.

The yields of oysters, shrimps, and fishes which might be obtained from the ponds are not encouraging from the standpoint of aquaculture. It is evident that self-design under the conditions of this study is unlikely to result in a profitable venture unless yields can be markedly increased or a very high priced specialty crop can ge grown and harvested. One factor which may severly limit aquaculture in enriched ponds is the oxygen decline to near-zero levels which often occurs in spring and summer. To counteract this factor, air was bubbled through one of the waste ponds, resulting in a much higher minimum oxygen concentration (3.4 mg/l) and lower daytime pH (8.3). Penaeus setiferus stocked in the aerated waste pond survived and had growth rates greater than shrimp in a control pond and comparable to growth rates in natural populations in North Carolina. In anticipation of success in maintaining oxygenated conditions necessary for shrimp survival, an annotated bibliography on the ecological requirements and culture of penaeid shrimps in impoundments was prepared. A further step was the preliminary study of a promising, two-stage aquacultural venture. It was envisioned that cultured oysters might be grown on racks such that their feces and pseudofeces would drop down into shrimp pens. Here the shrimp could eat and assimilate this compacted organic matter. Time did not permit carrying this effort beyond the stage of development of a ^{14}C tracer technique to demonstrate the food transport pathways. Studies of the condition of oysters grown in the ponds showed that they had no marked seasonal variations in dry weight and glycogen content. Oysters cultured in ponds should be available over more of the year than wild oysters and it is possible that they can be fattened up better in enriched waters.

The effect of treated sewage effluents on the rates of N-fixation and ammonia diffusion of three estuarine ponds were determined for an 8-month period starting in June, 1971. The waste ponds fixed nearly twice as much nitrogen as did the control ponds, although the ratios of total N-fixation to total inflowing nitrogen were about the same for both pond types. Peak N-fixation rates occurred during mid-summer in water and top sediments of both types of ponds. On a diel basis, peak rates occurred at mid-day, thus suggesting the importance of phototrophic N-fixation. For the waste ponds over the entire investigation, the top sediments fixed about twice as much nitrogen as did the pond water, and the lower sediments fixed about four times as much nitrogen as did the top sediments. However, assuming that 50 per cent was subsequently denitrified, the lower sediments contributed about twice as much fixed (combined) nitrogen to the pond system than did the top sediments. For the control ponds over the entire investigation, the top sediments and pond water fixed about the same amount of nitrogen, but the lower sediments

fixed about 20 times more nitrogen than either the top sediments or pond water. The daily phototrophic contribution to N-fixation of the pond water was 54-73 per cent for the P-ponds, and 39-79 per cent for the C-ponds. For top sediments, the daily phototrophic contribution was 48-67 per cent for the P-ponds, and 34-76 per cent for the C-ponds. In general, the rate of heterotrophic N-fixation increased with the approach of winter. The total contribution through N-fixation of each pond was offset by nearly the same loss through ammonia diffusion, with peak ammonia diffusion rates occurring in mid-summer for both pond types. Temperature appeared to be the most controlling physical factor initiating the decrease in summer phytoplankton flora and the start-up of Monodus.

RELATIONSHIP OF THIS STUDY TO PROBLEMS OF ESTUARINE EUTROPHICATION

Conditions in the brackish water control ponds are quite different from a natural estuary in many regards -- total area; flushing rate; turbulence, access for migrants, or even occasional wanderers, too large or delicate to pass through the pumps; and community structure. On the other hand a viable ecosystem has developed with high productivity and rapid nutrient cycling. Viable systems also developed in the waste ponds with high primary productivities.

There are several ways in which results from our pond studies may bear on the problem of estuarine eutrophication. It is possible that relatively small, brackish oxidation ponds may help to prevent deterioration of the quality of the receiving water; organics and algal nutrients stripped out in the ponds would not cause troubles downstream. Unfortunately time did not permit the ultimate in development of a flow regime or other engineering solution to the two major problems in the waste ponds, (1) apparent unsuitability of Monodus as a prime food for oysters and (2) the unstable winter and spring conditions of pH and oxygen associated with the Monodus bloom. Furthermore it would be desirable to establish whether brackish water ponds have any real advantage over freshwater oxidation ponds in terms of effluent quality.

Secondly, larger brackish ponds might be desirable. Very large impoundments are presently being constructed in the high Juncus marshes of North Carolina for mosquito control, sport fishing, and waterfowl hunting. Addition of reasonable amounts of sewage wastes from nearby cities might not prove harmful to these other uses. Studies of yields of oysters, shrimp, crabs, and fish from these ponds are proposed in order to assess the possibility of converting the high primary productivity into a commercial product. Unfortunately, the problem of possible pathogenic virus contamination of shellfish has not been solved.

Finally, we hope that some of our results will be applicable to the problems that result when domestic wastes are dumped directly into estuaries. There is an urgent need for data on levels of nutrients that can be added without harming our traditional and highly desirable uses, as well as the trade-offs that must be made if waste removal is, for some particular estuary, an important consideration. Cost benefit analysis, preferably not limited to economics, is necessary and we trust that planners in the future will consider ecological costs and benefits in their balances.

SCIENTIFIC REPORTS RESULTING FROM THIS PROJECT

Papers Presented and Published

1. Kuenzler, E. J. 1968. Cycling of phosphorus in marine ponds. Atlantic Estuarine Research Society. Atlantic Beach, N. C. October 4.

2. Day, J. W., Jr., C. M. Weiss, and H. T. Odum. 1970. The carbon budget and total productivity of estuarine oxidation ponds receiving secondary sewage effluent. Second International Symposium of Waste Treatment Lagoons. Kansas City, Missouri. August 22-25. To be published in Proceedings; in press.

3. Kuenzler, E. J. 1970. Aspects of phosphorus cycling in brackish waters. Symposium: "Algae and Pollution, Experimental Studies of Eutrophication." A.I.B.S., University of Indiana, Bloomington. August 27.

4. Kuenzler, E. J. 1970. Aspects of phosphorus cycling in brackish waters. Symposium Honoring Dr. E. P. Odum: "Toward Relevant Ecology." University of Georgia, Athens, Georgia. October 2-3. To be published in Proceedings; in press.

5. Campbell, P. H. and E. J. Kuenzler. 1971. Phytoplankton populations of polluted brackish waters. Atlantic Estuarine Research Society. Atlantic Beach, N. C. April 16.

6. Rhyne, C. F. and W. J. Woods. 1971. Field and laboratory observations on the seaweed Ulva curvata. Atlantic Estuarine Research Society. Atlantic Beach, N. C. April 16.

7. McKellar, H. N., Jr. 1971. Phosphorus kinetics in estuarine pond ecosystems developing with treated sewage wastes. American Society of Limnology and Oceanography, University of Winnipeg, Winnipeg, Manitoba, Canada. June 16.

8. Kuenzler, E. J. 1971. Ecology of sewage-enriched brackish ponds. Lecture to the Division of Biological Sciences, University of Connecticut, Storrs. 15 November 1971.

9. Odum, H. T., E. J. Kuenzler. 1972. A study of marine pond ecosystems developing with treated sewage inflow. Thirty-fifth Annual Meeting, American Society of Limnology and Oceanography, Florida State University, Tallahassee, 19-22 March 1972.

10. McMahan, Elizabeth, R. L. Knight and A. R. Camp. 1972. A comparison of microarthropod populations in sewage-exposed and sewage-free Spartina salt marshes. Environ. Entomol., 1: 244-252.

11. McMahan, Elizabeth. 1972. Relative abundance of three marsh floor organisms in a sewage-affected and in a sewage-free marsh. J. Elisha Mitchell Sci. Soc., 88: 61-65.

12. Rickards, W. L. and A. B. Williams. Aquaculture in Brackish Water Ponds Receiving Treated Domestic Sewage: Preliminary Studies. Atlantic Estuarine Research Society, Myrtle Beach, S. C. 13-15 April 1972.

13. Odum, H. T., E. J. Kuenzler, A. B. Williams, J. Day, and W. J. Woods. 1973. A study of marine pond ecosystems developing with treated sewage inflow. In manuscript.

Theses and Dissertations

1. Beeston, M. D. 1971. Decapod crustacean and fish populations in experimental marine ponds receiving treated sewage wastes. Master of Science thesis, Curriculum in Marine Sciences, University of North Carolina, Chaple Hill, Under the direction of Dr. A. B. Williams.

2. Day, J. 1971. The Carbon Metabolism of Estuarine Ponds Receiving Treated Sewage Wastes. Ph.D. Dissertation, Curriculum in Marine Sciences, University of North Carolina, Chapel Hill, under the direction of Dr. C. M. Weiss.

3. McKellar, H. 1971. The Phosphorus System of Brackish Water Pond Ecosystems Exposed to Treated Sewage Waste. Master of Science thesis, Curriculum in Marine Sciences, University of North Carolina, Chapel Hill, under the direction of Dr. E. J. Kuenzler.

4. LeFurgey, Ann. 1972. Foraminifera in Estuarine Ponds Designed for Waste Control and Aquaculture. Master of Science thesis, Curriculum in Marine Sciences, University of North Carolina, Chapel Hill, under the direction of Dr. J. St. Jean.

5. Smith, Martha. 1972. Productivity of Marine Ponds Receiving Treated Sewage. Master of Science thesis, Department of Zoology, University of North Carolina, Chapel Hill, under the direction of Dr. H. T. Odum.

6. Muse, Barbara. 1973. The Effect of Effluent from a Secondary Sewage Treatment Plant on Oyster Condition. Master of Science thesis, Curriculum in Marine Sciences, University of North Carolina, Chapel Hill, under the Direction of Dr. A. F. Chestnut.

7. Rapps, Martin. 1973. The Effects of Treated Sewage Effluents on Nitrogen Fixation and Ammonia Diffusion. Department of Environmental Sciences and Engineering, University of North Carolina, Chapel Hill, under the direction of Dr. C. M. Weiss.

8. Rhyne, Charles F. 1973. Field and Experimental Studies on Systematics and Ecology of Ulva curvata and Ulva rotundata. Department of Botany, University of North Carolina, Chapel Hill, under the direction of Dr. M. Hommersand.

NOAA FORM 90-2 | U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION | FORM APPROVED DECEMBER 31, 1972 OMB NO. 41-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT NO.	PROJECT TITLE [ ] NEW [X] CONTINUING [ ] CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED IF CONTINUING
R/ES-7	Recent sediments of northeastern North Carolina estuaries and their relation to Plio-Pleistocene mineral deposits	July 1970
GRANT NO.		DATE OF THIS FORM
2-35178		May 1973
INSTITUTION		ESTIMATED COMPLETION DATE
UNC		December 1974

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
Stanley R. Riggs, Dept. of Geology, ECU	21	M.P. O'Connor	21

FUNDS EXPENDED TO DATE: FED.-SEA GRANT	FUNDS EXPENDED TO DATE: MATCHING	LAST YEARS FUNDING: FED.-SEA GRANT	LAST YEARS FUNDING: MATCHING	PROPOSED FUNDING: FED.-SEA GRANT	PROPOSED FUNDING: MATCHING	RELATED PROJECTS (R. numbers)
$ 47,599	$ 23,800	$ 29,747	$ 14,874	$	$	R/ES-8 R/ES-9

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Estuarine Studies	Mineral Resources/other

OBJECTIVES:

1. To develop a basic understanding of the sediment system of the area;
2. To determine the temporal, spacial, and genetic relationships of the Recent and Plio-Pleistocene sediment units:
3. To evaluate and delineate the potentially economic sediment resources of the area;
4. To develop sediment models to be used in locating potentially economic minerals in the Plio-Pleistocene sediments of coastal northeastern North Carolina and for the maximum development and preservation of North Carolina's coastal regions.
5. To disseminate the results both to the scientific community and to potential user groups.

HOW INFORMATION WILL BE APPLIED: The expected results will define the mineral resources and their future potential for regional development. A series of mineral potential maps, along with the models generated from this study, may be applied directly to the mineral exploration of the Plio-Pleistocene estuarine and shoreline deposits of North Carolina's Coastal Plain.

The information of this project will supply the following guidelines for coastal land utilization and development through scientific journals, laymen's publications, and public presentations:

1. The geologic history of the North Carolina coastal region for the last 40,000 + years will provide the essential time perspective for considering the problems of opening and closing of inlets; the erosion, deposition, and migration of the barrier islands and estuarine shorelines; and the designation of potential natural hazard zones in terms of shoreline stability.
2. A stratigraphic framework for guiding real estate and commercial land development, sanitary disposal, water supply, and recreational interests.
3. A growing understanding and appreciation of the fragile equilibrium system under which this section of the North Carolina coast exists; an understanding which must be seriously considered by all, if future environmental crises are to be circumvented in this rapidly developing area.

ACCOMPLISHMENTS DURING PAST MONTHS: The primary accomplishment of this work period is a sediment facies model for the Roanoke Island area which has been synthesized from shallow water coring (25 feet), deep land drilling (50-80 feet), seismic profiling of the sounds, sediment size and fossil analysis, and Carbon-14 dating. Initial application of this model to the objective listed above has proven successful and should improve considerably as the model is refined over the next six months. A suspended sediment analysis of the adjacent estuaries is in progress and has already provided considerabl background data for guiding environmental management policy.

Project No.: R/ES-7

Title: Recent sediments of northeastern North Carolina estuaries and their relation to Plio-Pleistocene mineral deposits.

Investigators: Stanley R. Riggs and Michael P. O'Connor, Department of Geology, East Carolina University, Greenville, N.C.

PROGRESS REPORT - JULY 1971 THROUGH DECEMBER 1972

Field work on the Sea Grant project began July 1, 1970 operating out of the E.C.U. Marine Science Center at Manteo, North Carolina. To date the program has operated for five and one-half full months in the field, two weeks in the laboratory, and one fourth time during the academic months. Since the last project report (July 1970-December 1971) we have accomplished the following:

1. 23 fifty to eighty foot 4-inch land-based core holes were contract drilled by Girdler Foundation of Lanexa, Virginia during the summer of 1972 (Fig. 1) on the Outer Banks, Roanoke Island and the adjacent mainland area. As all cores were obtained, they were logged, split, subdivided into stratigraphic units, sampled, washed, dried, and stored for subsequent analysis.

2. A binocular microscope examination and classification of all the core samples was completed with detailed lithic logs and correlation sections constructed for each hole. A detailed textural analysis has been made of 400 selected surface and subsurface samples, including a wet sieve, a mechanical dry sieve, and pipette separations. A general economic textural analysis has been completed on 250 of these samples. All of this data is presently in computer storage waiting for final evaluation. Figure 2 is an example of the type of data obtained.

3. Forty six samples containing appropriate shell and organic material, were selected, picked and cleaned in preparation for carbon-14 age date analysis for stratigraphic correlation and interpretation. Forty-two final age dates have been completed; the remaining four turned out to be unnecessary and are being replaced with more critical samples.

4. Three hundred heavy mineral analyses have been completed on 250 selected samples throughout the study area. This data is presently ready for computer analysis. Table 1 shows some of this data.

5. A total of 540 fossiliferous samples have been wet sieved and the macrofossil assemblage prepared for subsequent identification and stratigraphic correlation. The latter is presently in progress.

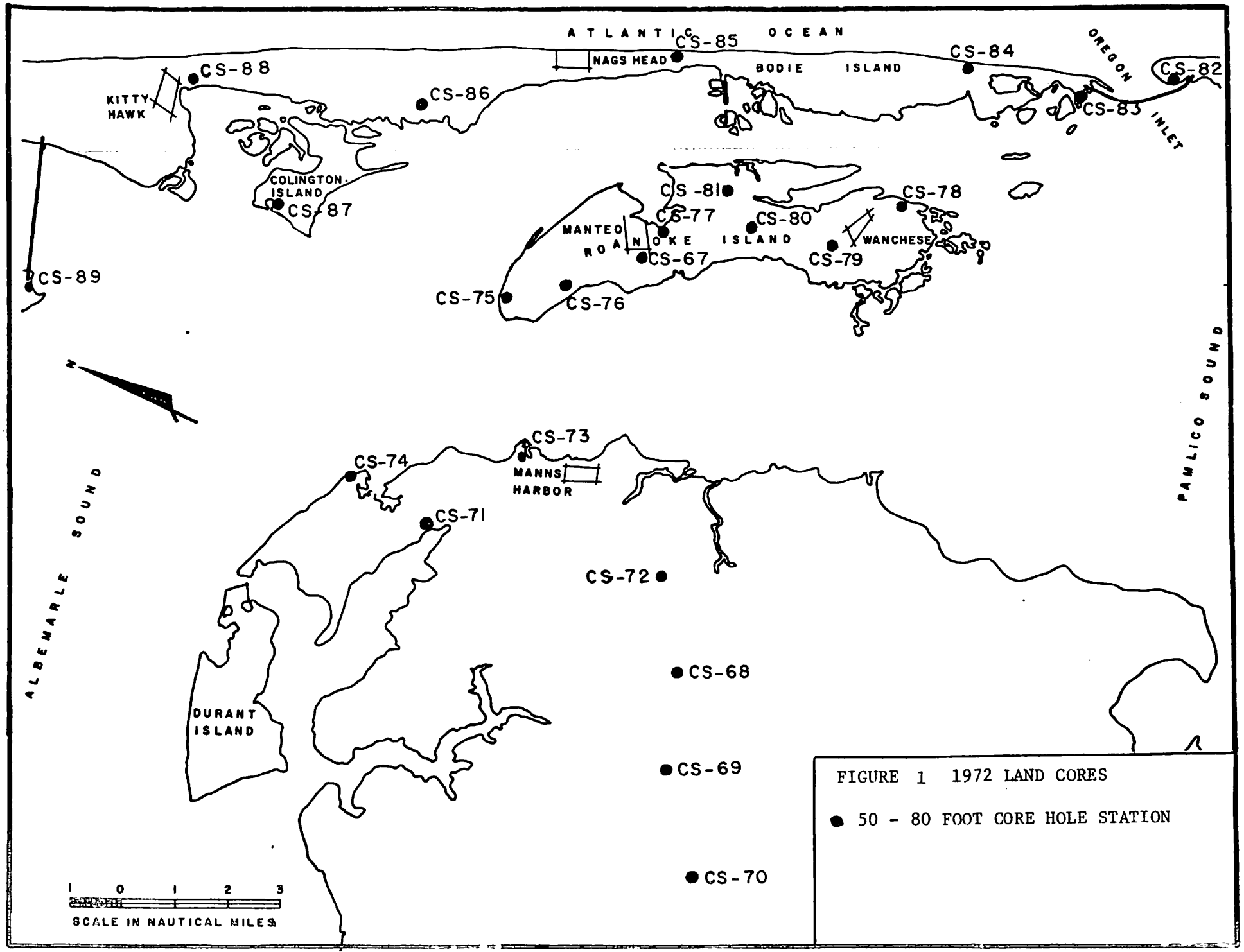


FIGURE 1 1972 LAND CORES

● 50 - 80 FOOT CORE HOLE STATION

Figure 2. Stratigraphic Distribution of Potential Economic Sediment Commodities – Drill Hole CS-69

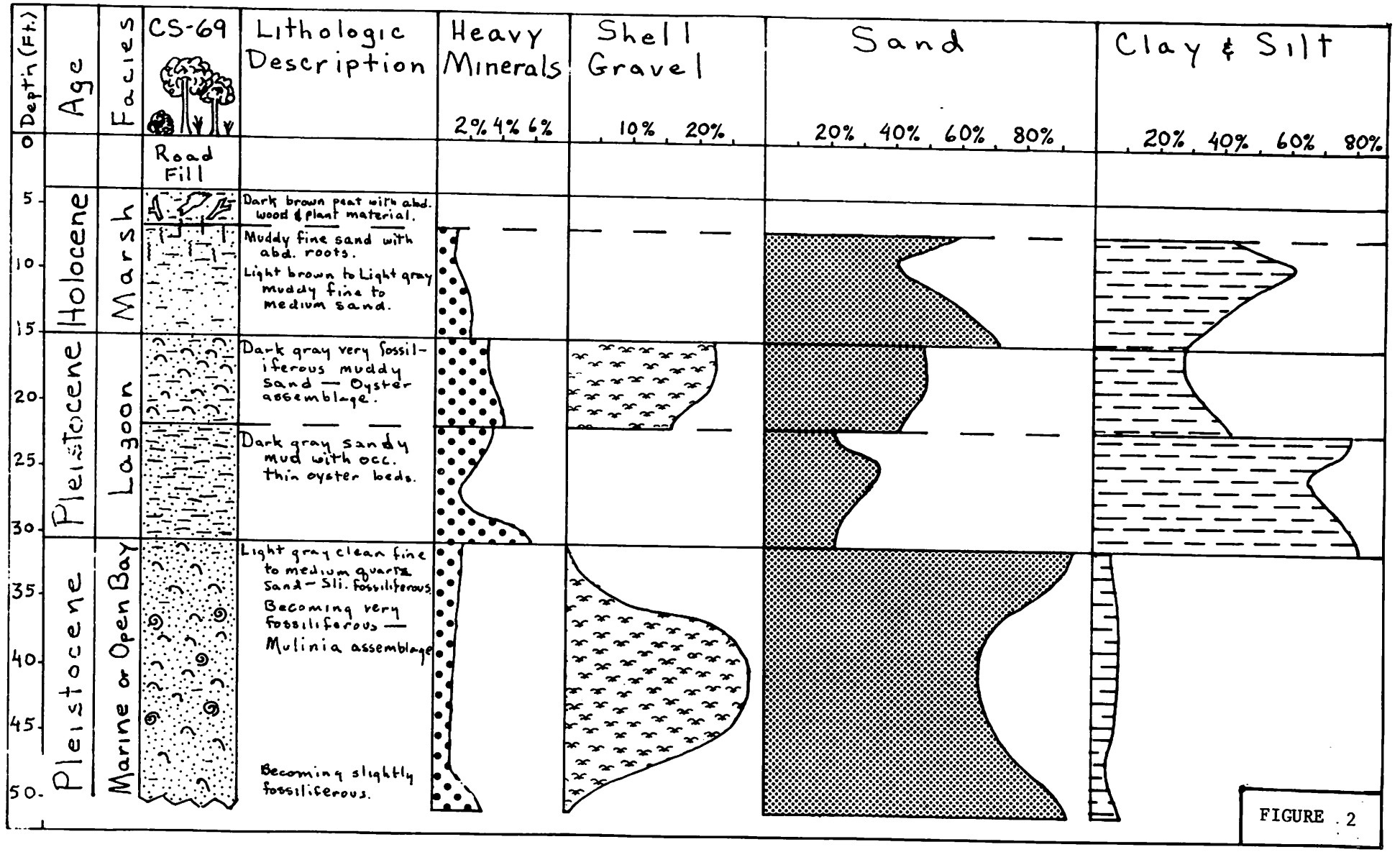
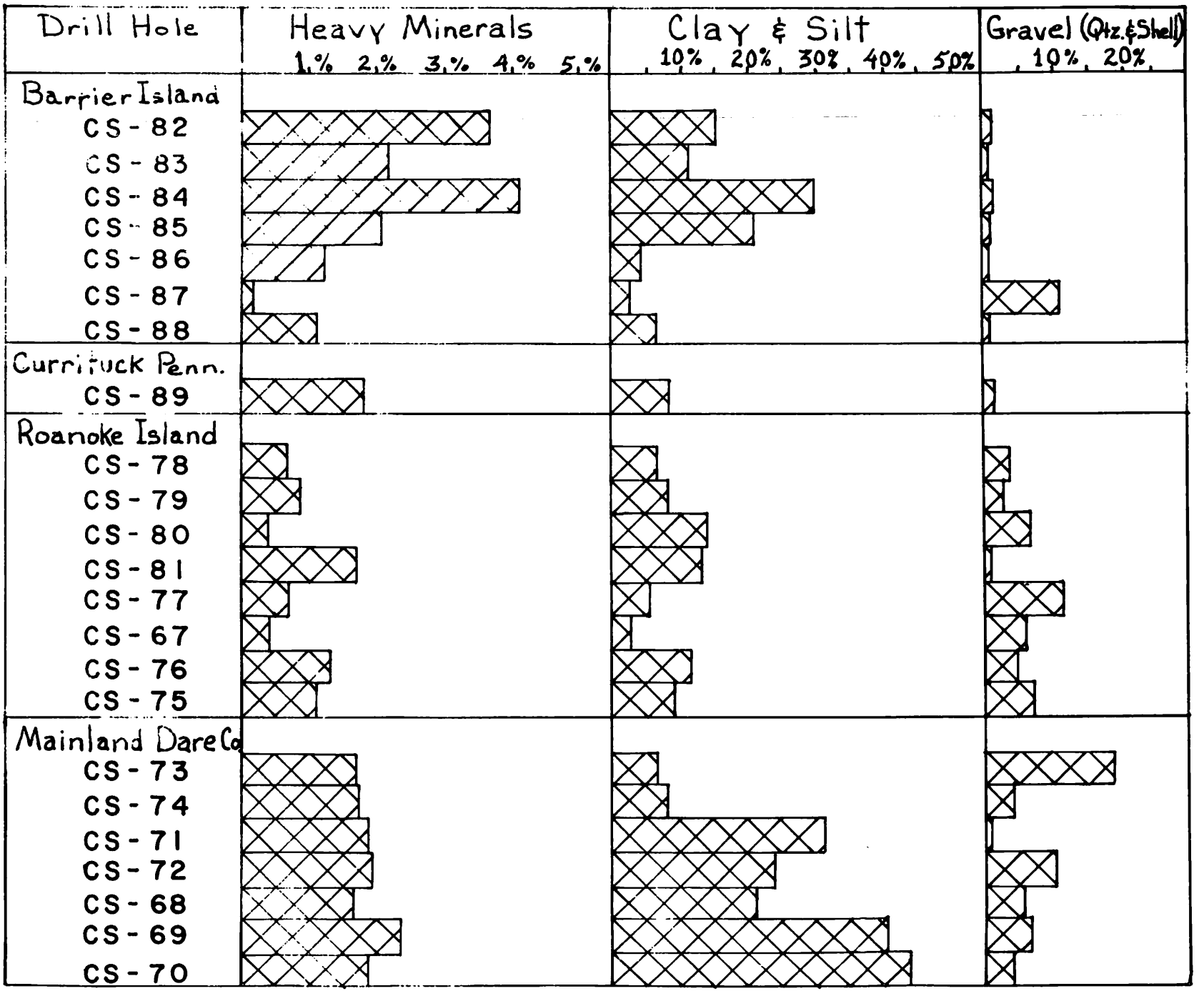


FIGURE 2

Table 1 Average % of Potential Economic Sediment Commodities



6. On the basis of the shallow coring accomplished during the summers of 1970 and 1971, the acoustic seismic profiling of the summer of 1971, the deep core drilling of the summer of 1972, and the Carbon-14 age dates obtained to date, we have put together a sediment facies model for the Roanoke Island area (Fig. 3). This model at present looks to be a promising tool for accomplishing the objectives of this project and will be refined over the next six months as the final data are analyzed.

7. The instrumentation has been set up and four months worth of water samples have been collected (in cooperation with B. J. Copeland's Sea Grant project) for the Albemarle, Pamlico, and Neuse estuaries. These samples are continously being processed for percent organic and inorganic suspended sediment, and will provide much useful background data for environmental management policy.

In addition to the above accomplishments, the co-investigators have directed the geology field quarter four times at the E.C.U. Marine Science Center at Manteo. During this program twenty seven major studies have been carried out by the students under the direct guidance of the co-investigators. All twenty seven of the research projects are within the Roanoke Island area and are related to our Sea Grant research program. Projects carried out during the 1972 fall quarter include:

1. Erosional and depositional processes of a high energy beach as related to climate conditions, Nags Head Pier, N. C. - D. Pearson.

2. Effects of the groins at the north end of Roanoke Island on the erosional-depositional processes - N. Howell.

3. Sediment transport along the NW shore of Roanoke Island as related to wind and water movement - S. Hardaway.

4. Relationship of sediment texture to depositional environments across Bodie Island, N. C. - Ed Yopp.

5. Shoreline recession at Caroon Pt., N. C. - J. Brame.

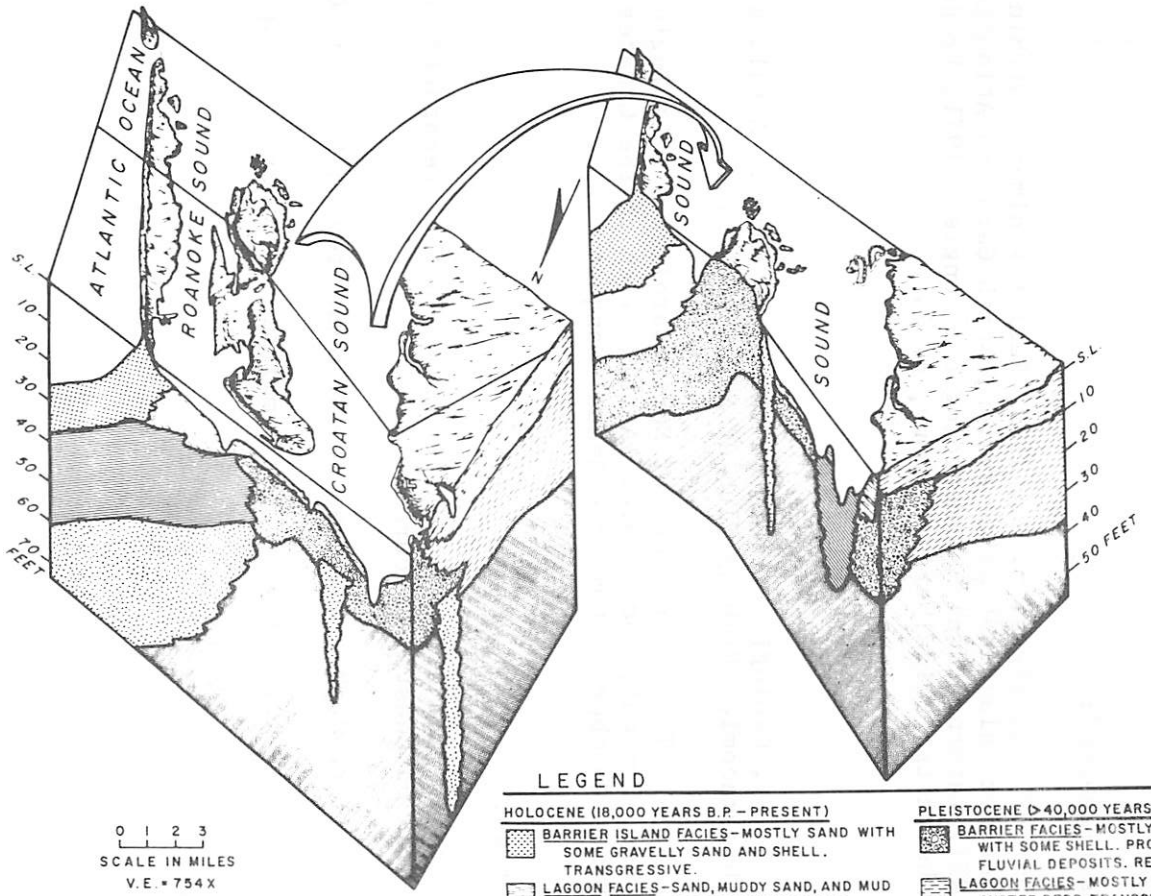
6. Salt marsh development on the basis of Indian middens, Wanchese, N. C. - J. Oliver.

7. Beach types along the Atlantic coast, Bodie Island, N. C. - B. Crew.

8. Sediment bed forms in Roanoke Sound behind Jockey's Ridge, N. C. - J. Wilson.

9. Migration of the Seven Sisters Dune, Nags Head, N. C. - B. Simpson.

SEDIMENT FACIES MODEL FOR THE ROANOKE ISLAND AREA OF NORTH CAROLINA



LEGEND

HOLOCENE (18,000 YEARS B.P. – PRESENT)

- BARRIER ISLAND FACIES – MOSTLY SAND WITH SOME GRAVELLY SAND AND SHELL. TRANSGRESSIVE.
- LAGOON FACIES – SAND, MUDDY SAND, AND MUD WITH OYSTER BEDS. TRANSGRESSIVE.
- CHANNEL FACIES – MOSTLY MUD WITH SOME SAND AND OYSTER BEDS. TRANSGRESSIVE.
- MARSH FACIES – MOSTLY PEAT WITH SOME SAND AND MUD. TRANSGRESSIVE.

PLEISTOCENE (> 40,000 YEARS B.P. – 18,000 YEARS B.P.)

- BARRIER FACIES – MOSTLY SAND AND GRAVELLY SAND WITH SOME SHELL. PROBABLY INCLUDES SOME FLUVIAL DEPOSITS. REGRESSIVE AND TRANSGRESSIVE.
- LAGOON FACIES – MOSTLY MUD AND MUDDY SAND WITH OYSTER BEDS. TRANSGRESSIVE.
- CHANNEL FACIES – SAND, GRAVELLY SAND, MUDDY SAND MUD, SHELL, AND PLANT DEBRIS OCCURRING AS SEPARATE BEDS AND MIXTURES. REGRESSIVE WITH TRANSGRESSIVE FILL.
- MARINE OR OPEN BAY FACIES – MOSTLY MUDDY SAND WITH ABUNDANT SHELL (MULINIA ASSEMBLAGE). TRANSGRESSIVE AND REGRESSIVE.

FIGURE 3

10. Vertical stratigraphic relationships as shown by dominance assemblages of Pleistocene Foraminifera - R. Koehler.

11. The sedimentary environments of the north and south side of Oregon Inlet and their changes through time - a sedimentation class project for the last four years.

Publications:

O'Connor, M. P., Riggs, S. R., Winston, D., 1972, Recent estuarine sediment history of the Roanoke Island area, North Carolina: Ed. Nelson, B. W., Estuarine Symposium: Geol. Soc. America, Memoir 133, p. 453-464.

Papers Presented:

O'Connor, M. P., Riggs, S. R., 1971, Relict sediments within a transgressive barrier island-estuarine system, North Carolina Atlantic Coast (Abs.): VIII International Sedimentological Congress 1971, Program with Abstracts, Heidelberg, Germany, p. 74.

Talks:

Riggs, S. R., Geologic History of the Outer Banks. A talk given to the Chicamacomico Fishing Club at Nags Head, N.C.

Riggs, S. R., The Outer Banks of North Carolina: A Geologic Overview, Past, Present, and Future. A talk given to the Greater Outer Banks Chamber of Commerce Annual Banquet.

Activities:

Both project directors participated in the preparation of the 1972 State Plan on Coastal Resources.

O'Connor, M. P., Chairman of the Committee on Resource Conservation.

Riggs, S. R., Member of the Committee on Mineral Resources.

NOAA Form 90-2 (5-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 41-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to the space provided)

PROJECT NO.	PROJECT TITLE	DATE INITIATED (If continuing)
R/ES-8	Erosion and Deposition in the Sounds and Estuaries of the North Carolina Coast	Jan. 1971
GRANT NO. (2-digit)	OLD TITLE (If different)	DATE OF THIS FORM
2-35178		May 1973
INSTITUTION		ESTIMATED COMPLETION DATE
UNC		December 1973

( ) NEW (X) CONTINUING ( ) CHECK IF SEPARATE PROJECT GRANT

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
Roy L. Ingram, Department of Geology, UNC-CH	80		

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (By numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 54,044	$ 27,016	$ 48,085	$ 24,041	$	$	R/ES-7, R/ES-9 R/OE-2

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Estuarine Studies	Geological Oceanography

OBJECTIVES:

To apply geological techniques to the problems of determining sites of erosion and deposition in the sounds and estuaries; to use heavy minerals and clay minerals in sediments to make estimates of the major sources of the accumulating sediments; to use sedimentary structures and grain-size analyses to indicate the current conditions at different parts of the sound-estuary complex.

HOW INFORMATION WILL BE APPLIED:

To permit prediction of the effects on erosion and deposition of the following: storms, floods, and droughts; opening and closing of inlets; shoreline construction activities.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS: (Publications)

A preliminary examination of 148 box cores and their epoxy peels and radiographs shows a good correlation between types of sedimentary structures and the current conditions existing at the times of deposition.

A preliminary examination of the plots of 140 size analyses indicates that the relative importance of traction, saltation, and suspension transportation can be determined from these analyses.

Project No.: R/ES-8

Title: Erosion and Deposition in the Sounds and Estuaries of the North Carolina Coast

Principal Investigator: Roy L. Ingram, Professor, Department of Geology, University of North Carolina, Chapel Hill, N. C.

INTRODUCTION

During 1972, work was concentrated on collecting data on the bottom topography, sedimentary structures, and grain-size characteristics along 22 transects shown on Figure 1. Work continued on the interpretation of mineralogic data previously collected.

RATES OF EROSION OF SHORELINE

Aerial photographs taken by the Coast and Geodetic Survey in the 22 transect areas from 1945 to 1968 are on order (but undelivered). These will be compared and contrasted with recent (1971) photography to ascertain changes in the shoreline and nearshore bottom topography. Fathometer tracings were obtained in these areas during the summer of 1972.

HEAVY MINERAL COMPOSITION OF SANDS

The work on this project is essentially complete and the final report is being prepared.

This project is based on the assumption that a systematic evaluation of the regional distribution of the heavy minerals should enable estimates to be made of the major sources of accumulating sands, since the heavy mineral composition of the sands is controlled by the source areas (mainland streams and ocean) and the currents.

The evaluation of the heavy mineral composition of 173 samples indeed showed that certain minerals come primarily from the rivers (i.e. red garnet, amphibole, pyroxene, tourmaline) while other minerals come primarily from the ocean (i.e. staurolite, kyanite, colorless garnet). Unfortunately, no single mineral or combination of minerals showed a uniform variation in abundance from river mouth across the sound to the sea that would enable one to calculate that X% of a sample came from river sources and Y% from the sea. The data does indicate, however, that 1) much sand-size material moves through the inlets into the sounds but does not move very far because the tidal currents die out rapidly; 2) the river transported sands are deposited primarily near the mouths of streams at the heads of the estuaries; 3) in most parts of the sounds and estuaries there is some mixing of river and ocean sands, but the picture is erratic and complicated because sands are undoubtedly being obtained by a reworking of the underlying Pleistocene deposits and by erosion of Pleistocene deposits along the shoreline.

CLAY MINERAL COMPOSITION

No new work was done on this project during 1972. The project is approximately one-half complete.

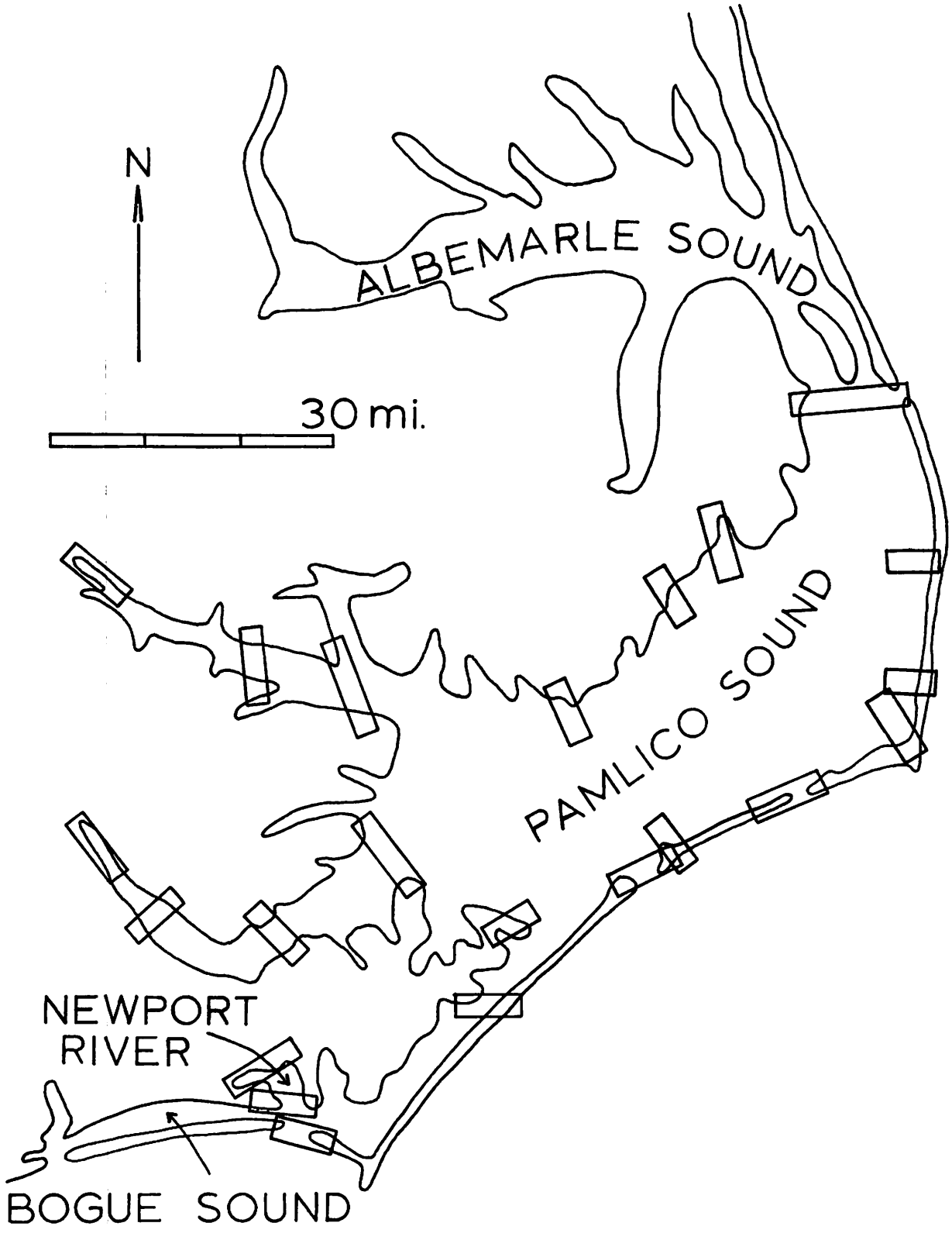


Figure 1 - Location of transects for studies of sedimentary structures, grain-size characteristics, and bottom topography.

SEDIMENTARY STRUCTURES

The 148 box cores collected in Pamlico Sound and vicinity have been processed with regard to core descriptions, epoxy peels, and X-ray radiography. The samples, peels, and radiographs are now being examined to determine the types of sedimentary structures present and their relations to the sedimentary environments. All of the structural types will be catalogued and tabulated with respect to their occurrence in the various depositional environments. The occurence of these structures will then be compared to the energy conditions and other factors acting within the environment which are responsible for their formation.

Preliminary examinations indicate the following relationships between sedimentary structures and environments. The marsh environments is a low energy environment in which abundant plant material can accumulate. The cores have a peaty appearance consisting of plant material with minor amounts of silt and fine sand. These fine-grained clastics are probably introduced during times of flooding. Cores from inlets show high angle, inclined laminations commonly showing two directions of inclination which are probably related to the change in tidal currents. The sediments consist of coarse sand, gravel, shell material, and frequently clay clasts. The estuarine channel muds commonly show mottling and bioturbation resulting from burrowing organisms. The central basin muddy sediments are very similar lithologically to the muddy sediments of the estuaries except they are more cohesive and show more bioturbation. The beach and very shallow water cores have a predominance of horizontally laminated coarse sands and shell fragments but commonly have ripple cross-lamination within the upper few centimeters. Cores collected on shoals within Pamlico Sound consist mainly of homogeneous silty sands which are commonly micaceous and contain marine grass. Ripple cross-lamination and worm burrows and mounds are the most common sedimentary structures in the shoal sediments.

The relationships which are observed between the sedimentary structures and their environments of deposition can be correlated with the energy conditions under which the structures were formed. Under high energy conditions of the inlets where high velocity tidal currents are predominant, there exist large scale structures such as steeply inclined bedding, cross-bedding, and scour and fill structures. The littoral zone is another high energy environment where waves produce ripple cross-stratification, cross-bedding, and horizontally laminated sediments. In the deeper portions of the sounds and estuaries sedimentation occurs predominately by settling from suspension. Under these low energy conditions thinly laminated sediments are sometimes preserved; but because of the great amount of bioturbation, most of these sediments show a mottled or burrowed texture.

GRAIN SIZE ANALYSES

Surface samples from the box cores or grab samples collected near the sites of the box cores are in the process of being sieved in order to determine their size frequency distributions. These analyses are about 80% complete. The data will be plotted on arithmetic probability paper in order to determine the relative importance of traction, saltation, and suspension transportation in the deposition of these sediments.

A preliminary analysis of the data indicates that 1) the sand samples of the shallow parts of the sounds were transported primarily by saltation with minor settling from suspension; 2) the sediments from the deeper waters were deposited mainly from suspension; and 3) the sediments in the tidal inlets contain a large traction population.

NOAA Form 90-2 (5-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 11-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to the space provided)

PROJECT NO.	PROJECT TITLE	DATE INITIATED (If continuing)
R/ES-9	Dynamics of Flow in Estuarine Waters	July 1970
GRANT NO. (Previous)	(If different)	DATE OF THIS FORM: May 1973
INSTITUTION: UNC		ESTIMATED COMPLETION DATE: December 1975

( ) NEW (X) CONTINUING ( ) CHECK IF SEPARATE PROJECT GRANT

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
M. Amein, Dept. of Civil Engineering, NCSU	20	C.E. Knowles, N.E.Huang	20

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (By numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	R/ES-5, R/ES-7 R/ES-8, R/OE-2
$ 74,852	$ 37,426	$ 46,569	$ 23,284	$	$	

PART OF UNIVERSITY PROGRAM: Estuarine Studies

OFFICE OF SEA GRANT CLASSIFICATION: Environmental Models/Physical Processes

OBJECTIVES:

OBJECTIVES:

The major objective of this research has been and still is to study the behavior of the waters in the North Carolina estuaries. During the period of this report, 1 July 1971 to 31 December 1972, efforts were concentrated on the Pamlico Sound area. It has been a definite goal of the research to develop and make available to other interested investigators, predictive models for estuary dynamics.

In order to accomplish this objective, it is necessary to undertake study of this estuarine area that includes the following:

(a) Freshwater flow into the Sound
(b) Tidal exchange across the inlets
(c) Wind tides and currents in the Sound and in the river estuaries
(d) Mechanics of salinity variations
(e) Variations in the concentrations of conservative and non-conservative substances in the estuaries

HOW INFORMATION WILL BE APPLIED:

The information will be given to the investigators of related projects to facilitate their studies. The results of the circulation and diffusion processes together with the information of other Sea Grant studies in the estuarine studies project group will provide data for estuarine and coastal management planning by state and federal agencies.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

Three basis numerical models have been prepared for use in Pamlico Sound: (1) flow dynamics of inlets, (2) flow dynamics of Pamlico Sound, (3) water quality and flow dynamics of one dimensional estuaries. A method of estimating current flow in an inlet from knowledge of wave length and direction has been developed analytically and is to be used in the inlets of Pamlico Sound during 1973. Vertical diffusivity in stratified shear flow has been calculated and will be applied to Pamlico Sound as field data become available. Wind tide spectra and cross-spectra calculated for Pamlico Sound confirm the importance of wind set-up in controlling water levels in the Sound. Salinity and flow data for Drum Inlet, N. C. taken in July and September, 1972 have led to a proposed means of relating specific conductance of seawater to Cox's redefinition of salinity. All these accomplishments have been or will be the subject of technical reports, theses, papers or publications.

Project No.: R/ES-9

Title: Dynamics of flow in estuarine waters.

Principal Investigators: Michael Amein, Dept. of Civil Engineering; Charles E. Knowles, Dept. of Geosciences, North Carolina State University, Raleigh, N.C.

The major objective of this research has been and still is to study the behavior of the waters in the North Carolina estuaries. During the period of this report, 1 July 1971 to 31 December 1972, efforts have been concentrated on the Pamlico Sound area. It has been a definite goal of the research to develop and make available to other interested investigators, predictive models for estuary dynamics.

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The steps taken to complete this systematic study during the period of this report are discussed below.

Dr. Michael Amein, Professor Civil Engineering, has served as the project director. His research efforts have been toward the application and testing of predictive models and delineation of deficiencies in field data. Drs. C. E. Knowles and Norden Huang of the Department of Geosciences have been co-principal investigators. Dr. Knowles has concentrated his efforts in the collection and analysis of the needed field data and Dr. Huang in the analytic and statistical analyses of wind and wave interaction and dispersion, useful also for the predictive models.

Project Activities and Results Obtained

A. Mathematical Modeling and Analysis

A one-dimensional (spatial) model is currently available for the inlets. An implicit method developed by Dr. Amein has been successfully applied to one of the inlets and a comparison with field observations has been made with excellent results, the detailed nature of which is contained in a report currently being prepared for publication. A two-dimensional (spatial) model is also available for Pamlico Sound. This type of model has been applied successfully by others to bays, harbors, lakes and estuaries. It is capable of treating complex unsteady flow conditions and contains steady state solutions as a special case. A one-dimensional diffusion model is also available and has been applied to study conservative (salt) substances. It is planned to apply a more general diffusion model to the estuaries which will also treat the movement of non-conservative materials.

A statistical analysis of tidal and wind induced oscillations of

Pamlico Sound has also been made. Five years (1963-1968) of data of water level changes at eleven stations around Pamlico Sound (Figure 1) were obtained through the North Carolina District Office of the U. S. Army Corps of Engineers at Wilmington. Out of the entire period covered by the data, the most complete whole month (June, 1965) was picked for detailed statistical analysis to obtain spectra and cross-spectra of the elevation change. Results confirm that these "wind tides" are the predominant factor affecting water level changes in Pamlico Sound. A report of this analysis is to be published in the summer 1973.

In addition to this work, a theoretical analysis of gravity wave current interaction has also been completed. It was found that the dispersion relation for gravity waves was drastically changed by coexisting currents, as shown in Figure 2. From this relationship, and a knowledge of wave frequency and wave length, a means of measuring currents through the inlets by observing the waves may be possible. These results have been presented at a conference and published as documented in the next section.

Since it is difficult to obtain wave frequency, a modification to this analytic procedure was also devised that needs only wavelength and wave direction to calculate the current in and near the inlet. This approach is currently the subject of a thesis. Using aerial photographs, an attempt will be made to calculate the currents in N. C. coastal inlets. This thesis and an accompanying report should be completed by October 1973.

The study of dispersion processes in a fully turbulent environment with density stratification and shear is a very difficult problem. The approach adopted here was to use field data as a guide to calculate the vertical dispersion coefficient K_v, and then apply dimensional analysis to get a simple rule that will govern the vertical dispersion processes. By using field data collected by Budinger et al (1964) and Duxbury et al (1966) off the Columbia River mouth, K_v was calculated and the following relationship derived:

$$K_v = w l \, Ri^{-3/2}$$

W and l are the velocity and the length scale in the vertical direction, and Ri is the Richardson number. This finding was presented at the 52nd Annual AGU Meeting. Field data presently available for Pamlico Sound are not adequate, but as field data are collected the same technique will be used there to compare with the results obtained.

B. Field data

As was mentioned in the introduction, any study of the estuary dynamics requires that adequate and accurate field data be available. Although excellent data on some characteristics of the estuarine waters

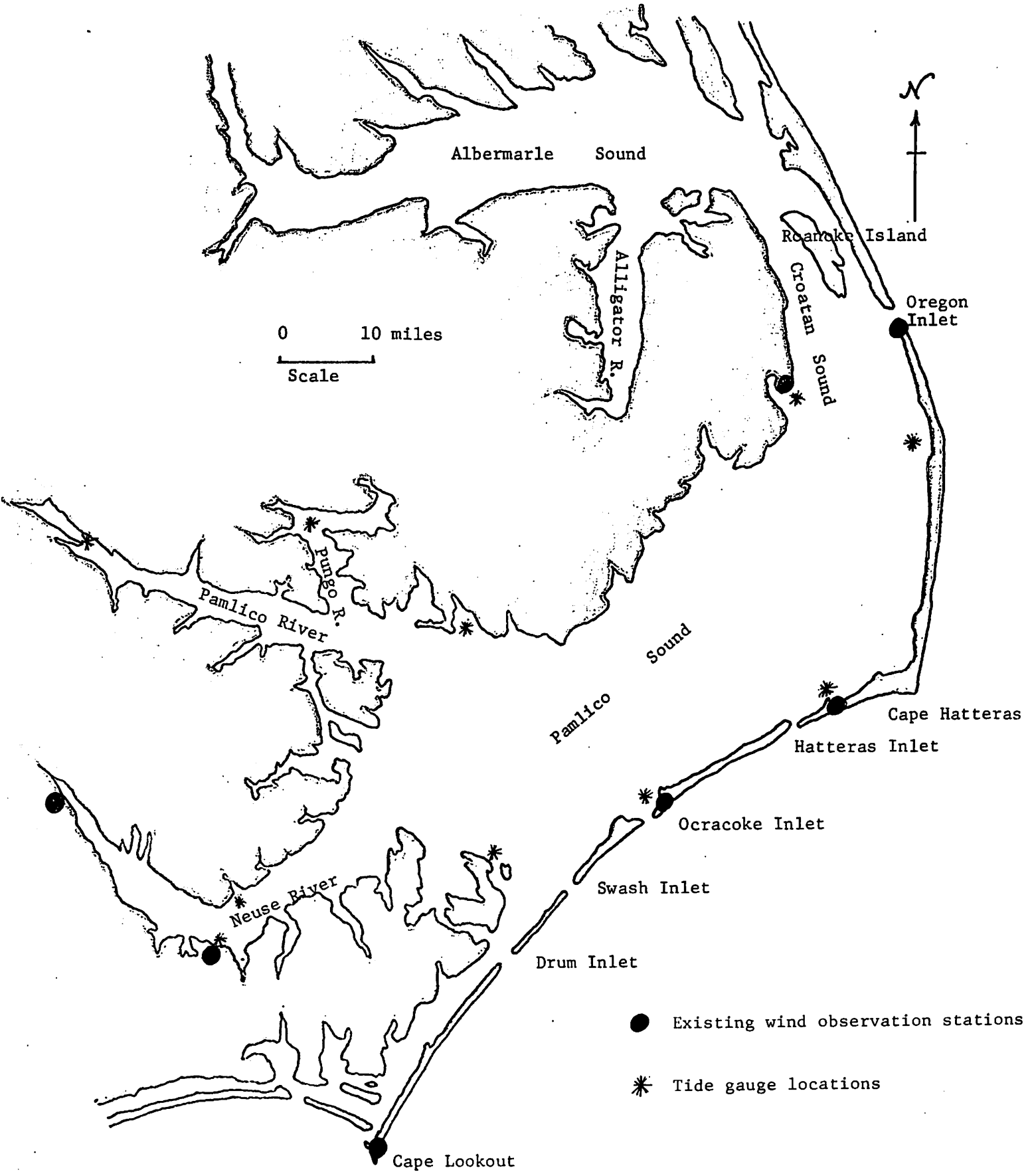

Figure 1. Existing wind observation station locations and tide gauge stations

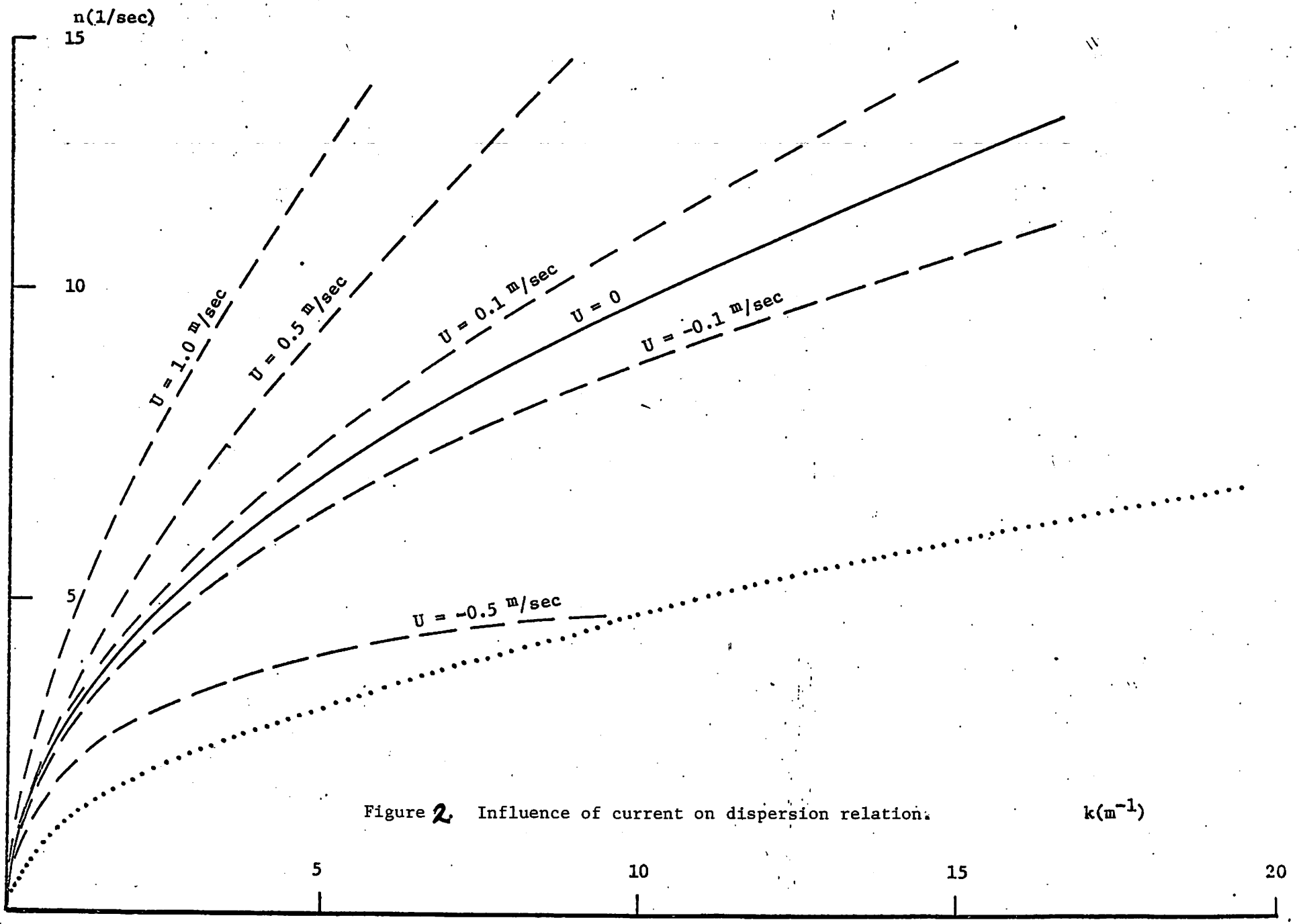

Figure 2. Influence of current on dispersion relation.

are available, vital information for others, such as flow rates and vertical profiles of salinity and temperature are lacking at most important locations. As a part of this study, existing field data has been supplemented by new field measurements. The data is being used to furnish parameters for the numerical models, to analyze the dynamic processes themselves and also to provide useful information for other involved agencies and investigators. As an example, a joint effort with Dr. Copeland was initiated in 1972 to provide needed field data for an environmental study of Currituck Sound. Adverse weather affected collection of field data in late 1972, but this project will continue during 1973. It will act as a focal point for student input and experience. Experience gained by this coordinated effort will be invaluable for further cooperation in Pamlico Sound already planned.

A long term coastal wind data collection and analysis effort was begun in January 1972 and typical seasonal wind patterns were delineated. Two additional portable wind recording stations which were not delivered in time to use in 1972 are now being established on the landward side of Pamlico Sound. The data collected at these stations will supplement those available from the permanent coastal stations (Figure 1), and will be used to supply additional wind field data needed for the numerical model of the Sound and for use by state and local government agencies. The wind data collected every 3 hours from ten permanent coastal stations in North Carolina for all of 1972 should be ready for publication by late summer 1973.

In addition to the three major rivers (Pamlico, Neuse and Pungo) emptying into the Pamlico Sound, there are six major tidal inlets that must be studied. Four of these are coastal inlets that communicate directly with the sea (Oregon, Hatteras, Ocracoke and Drum), the other two communicate with Albermarle Sound (Croatan and Roanoke Sounds). Currituck Sound also connects with the eastern end of Albermarle Sound and the northern end of Croatan Sound.

During the first years of this project no funds were available to buy equipment and no field data was gathered. Equipment was purchased, however, during the latter part of 1971 and in July and September 1972 a research effort was begun at Drum Inlet, N. C. in cooperation with the CERC office of U. S. Army Corps of Engineers. Extensive flow, temperature and salinity data were obtained, but because the tide guages maintained by CERC on the ocean and sound side were inoperative during these periods, no volume transport as related to tidal height could be made and the data obtained was used only to delineate the flow patterns and salinity intrusions into the sound, and as a training ground for the development of sampling and analysis techniques. The wind was negligible during each of these periods, so the patterns shown below are primarily a result of the tidal currents.

Drum Inlet, which was originally opened with a width of 80 ft. by the U. S. Army Corps of Engineers in December 1971, was in July 1972 about 1100 ft. wide with three major interior channels through the spoil areas. A topographic survey made by the Army Corps of Engineers

and depth soundings taken by us were used to determine the depth contours of Drum Inlet and its associated channels.

At maximum flood tide the current in the inlet reached a speed of nearly 4 kts with a mass flow of about 720m^3/sec. Nearly 610m^3/sec of this mass flow entered Core Sound through the main center channel. During flood tide, oceanic water of 36^o/oo salinity penetrated a short distance into the main center channel (see Figure 3) and water as high as 30^o/oo salinity extended to over half the width of the 2 mile wide sound and a considerable distance north of the inlet opening, as shown in Figure 4. The prevailing circulation of Core Sound during the research period appeared to be southwest with a current speed of less than 1/2 kts, especially in the Sound's western half, but during periods of either maximum flood or ebb tide, the major circulation patterns of the sound were dominated by the tidal currents and had velocities that approached 1 kt. At one high tide, with slack water in the main center channel, an ebb flow had already begun in the left channel with a velocity greater than 1/2 kt, as shown in Figure 3. Apparently, the ebb circulation around the spoils area is initially counterclockwise (see Figure 5) and the ebb flow manifests itself near the inlet first at its left channel. Within 30 minutes, the ebb is well established in all three channels and flows toward the inlet.

The main center channel curved in an S-shape before crossing the spoils area into the sound proper. There was a sill at a distance of about 1200 yds. from the inlet itself that had a depth of about 2 feet a low tide. The data taken during this period indicates that erosion should keep the inlet open if the main center channel remains relatively straight near the inlet so that ebb current velocities of greater than 2 knots can be maintained.

A detailed report and a thesis, including all data collected, are presently being written with a publication date of October 1973 anticipated.

An example of a valuable analysis technique that resulted from this experiment at Drum Inlet has to do with the fact that one of the sensor arrays (CTD) used at Drum Inlet measured in situ absolute specific conductance C(S, T, 0), temperature (T) and depth. A new international standard definition of salinity (S) in terms of the conductivity of seawater has been proposed by Cox et al (1967) and has gained wide acceptance. Cox's definition, however, is based upon the ratio of the <u>in situ</u> absolute specific conductance to the specific conductance of water having a salinity of 35^o/oo where samples are at 15°C and atmospheric pressure, i.e. R_{15} = C(S, T, 0)/C(35, T, 0). It was necessary then to provide a means of calculating C(35, T, 0). Using the experimental temperature-salinity-conductivity data published by Reeburgh (1965), the coefficients of a third order polynomial were computed by the method of least-squares and an equation for calculating C(35, T, 0) was obtained. The results of this calculation,

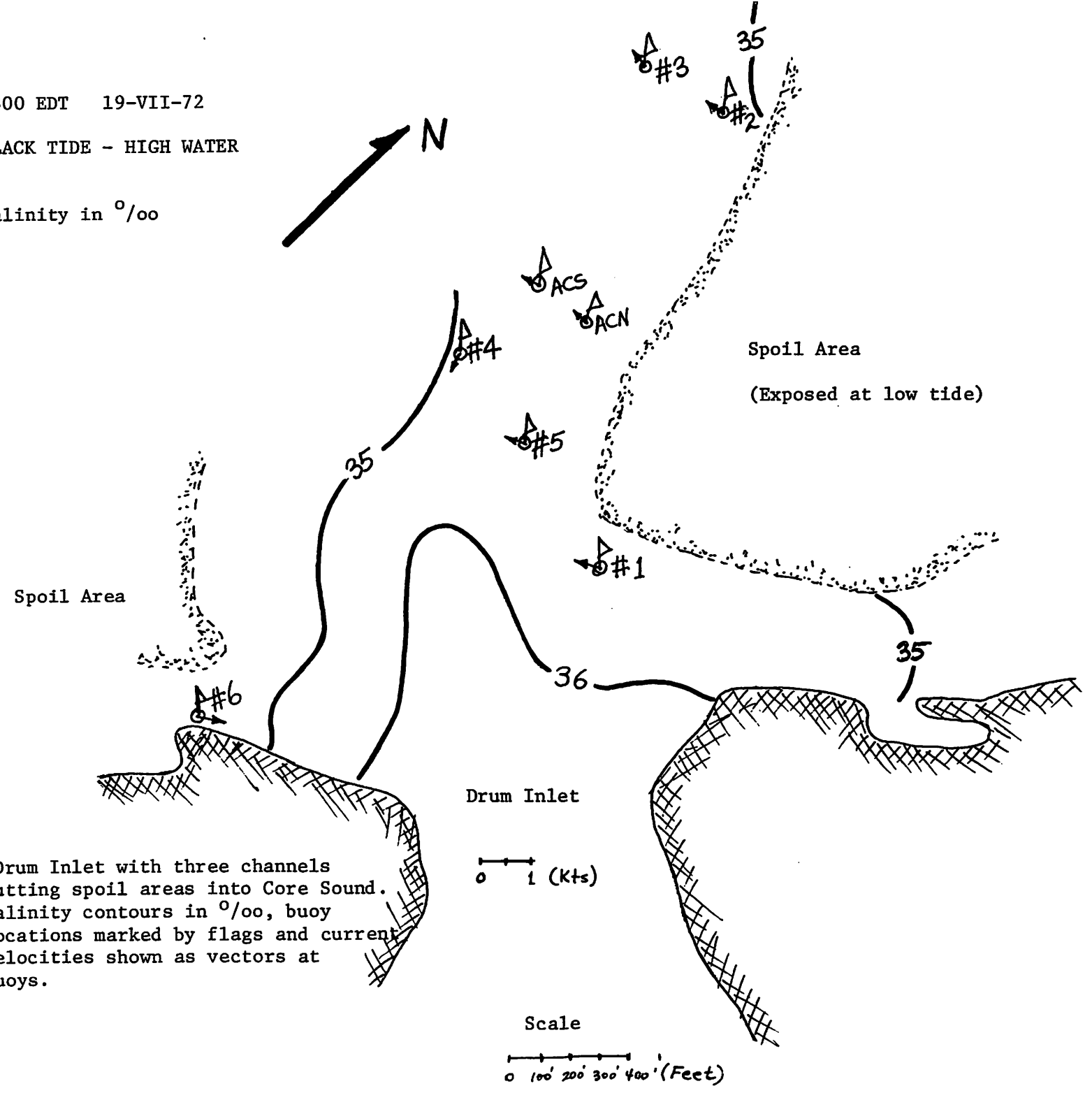

Figure 3. Drum Inlet with three channels cutting spoil areas into Core Sound. Salinity contours in °/oo, buoy locations marked by flags and current velocities shown as vectors at buoys.

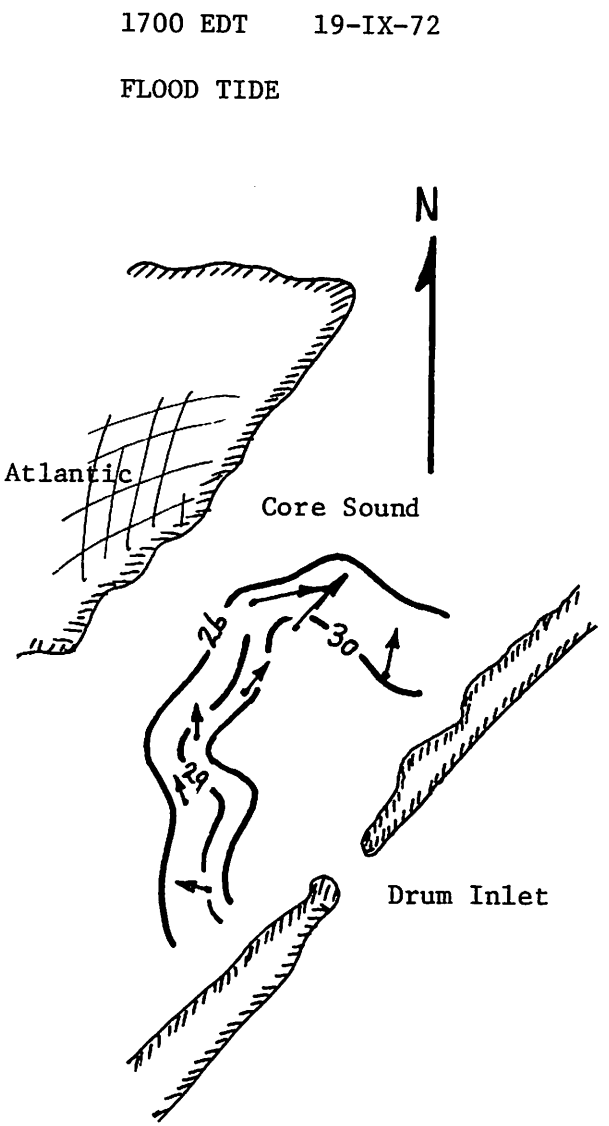

Figure 4. Penetration of 30°/oo water into Core Sound. Salinity contours in °/oo and current velocities shown as vectors.

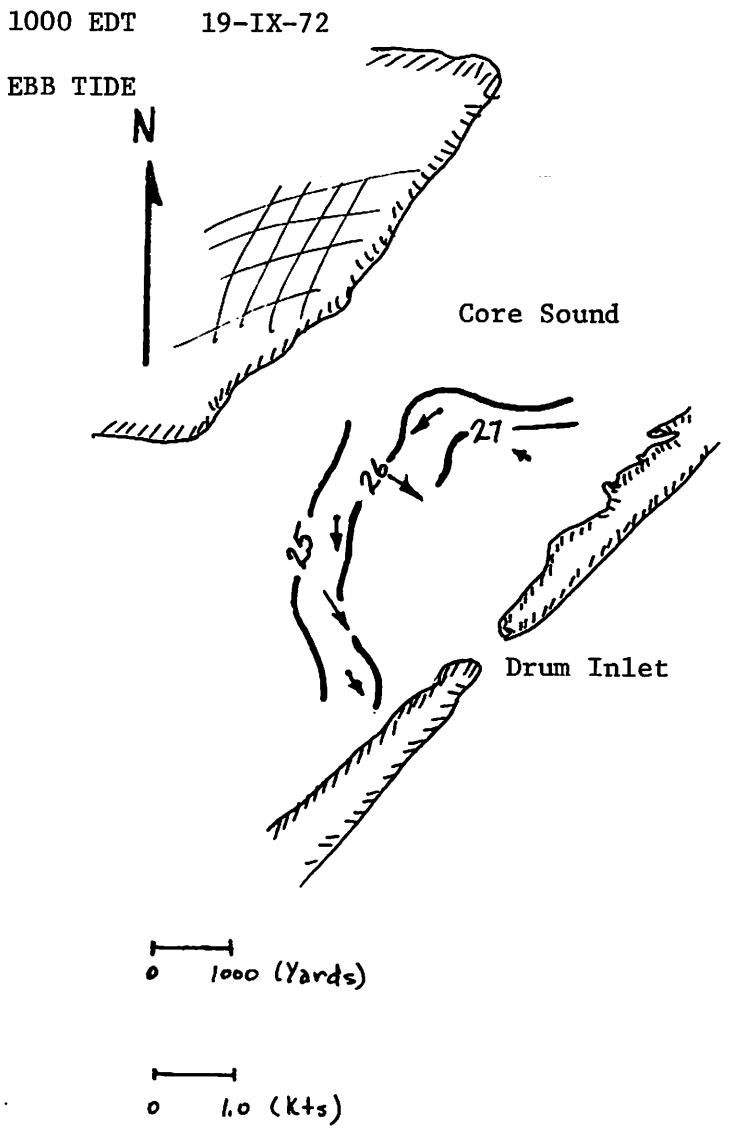

Figure 5. Apparent initial counterclockwise circulation on ebb tide. Salinity contours in °/oo and current velocities shown as vectors.

the need for which comes as a direct result of this project's field research, will be presented in a paper at the 54th Annual meeting of the AGU, April 1973.

This result and all of the other sampling and analysis techniques developed from the field experience of 1972 will be used to collect and analyze data in other inlets and rivers as discussed above in 1973 and 1974.

Project accomplishments - Results applied

The following is a list of reports, publications, other projects funded, and papers that either have been or will be published, obtained or presented as a direct result of the research conducted under the funding of this project.

A. Reports

Amein, M. "Computations of Flow through Masonboro Inlet, N. C."(in preparation)

Boone, John and Norden Huang. "Current-wave refraction patterns near an inlet". (thesis and report in preparation).

Chen, Davidson and Norden Huang. "A statistical analysis of tidal and wind induced oscillations of Pamlico Sound". (in preparation).

Knowles, C. E. and Paul Blankinship. "The stability and flow dynamics of Drum Inlet, N. C." (thesis and report in preparation).

Knowles, C. E. "Seasonal, monthly and diurnal wind patterns along the North Carolina coast". (in preparation).

B. Papers presented

Guttman, Ned and N. Huang. "Calculation of vertical turbulent diffusivity for a stratified shear flow". Trans. AGU, 52 p. 233, 1971.

Huang, Chen, Tung and Smith. "Influence of currents on surface wave spectra and its application to current measurement". Bull. Am. Meteor. Soc., 52, p. 939, 1971.

Knowles, C. E. "Salinity determination for use with CTD sensors". Trans. AGU, 54, p. 300, 1973.

C. Other projects funded

Huang, N. "Ocean dynamics; surface currents". NASA Wallops Station; Wallops Island, Va. ($19,747.00 for 1972; part of long term contract).

D. Paper published

Huang, Chen, Tung and Smith. "Influence of currents on surface wave spectra and its application to current measurement". J. Phy. Ocean. Vol. 2(4), pp. 420-431, 1972.

References

Budinger, T. F., Coachman, L. K. and C. A. Barnes, "Columbia River effluent in the Northwest Pacific Ocean 1961, 1962," Selected aspects of Physical Oceanography, U. of Wash. Tech. Report No. 99, 78 pp., 1964.

Cox, R. A., F. Culkin, and J. P. Riley, "The electrical conductivity/chlorinity relationship in natural seawater," Deep Sea Res., 14, 203-220, 1967.

Duxbury, A. C., Morse, B. A., and N. McGory, "The Columbia River effluent and its distribution at sea, 1961-1963," U. of Wash. Tech. Report No. 156, 105 pp., 1966.

Reeburgh, W. S., "Measurements of electrical conductivity of seawater," J. Mar. Res., 23(6), 187-199, 1965.

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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 41-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT NO.	PROJECT TITLE [ ] NEW [X] CONTINUING [ ] CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
R/OE-1	Safety Analysis of Marine Structures	July, 1970
GRANT NO. (FOR OSG)	(If different) Reliability Analysis and Optimum Design of Marine Structures	DATE OF THIS FORM
2-35178		May, 1973
INSTITUTION		ESTIMATED COMPLETION DATE
UNC		Dec., 1975

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
C.C. Tung, Dept. of Civil Engineering, NCSU	20%	J. F. Ely	20%

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (By numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 32,038	$ 16,019	$ 21,171	$ 10,585	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Ocean Engineering	Ocean Engineering/Meterials & Structures

OBJECTIVES:

The objectives of this research project are to yield information regarding the concept, methods, and research results of safety analysis and optimum design of marine structures to engineers engaged in the design of such structures. This includes:

1. probabilistic modeling of ocean and coastal environmental conditions relevant to the design of marine structures. This requires the determination of wave field and fluid force statistics;

2. reliability analysis of a rigid pier and a flexible platform. This requires the determination of the probability function and peak distribution of the stresses in the members of the structural systems;

3. development of mathematical programming techniques for the optimum design of marine structures. This includes the application of first and second order gradient techniques to the optimization of floor systems, plane frames, and a fixed bottom platform.

HOW INFORMATION WILL BE APPLIED:

Information obtained from this research project will be disseminated to the profession through the publication of technical reports in engineering journals, delivery at technical conferences, and recommendations to code writing bodies regulating the design and construction of such structures.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS: (Accomplishments)

The investigation of fluid force statistics in a random wave field under the action of current is near completion. This includes the determination of fluid force spectra, probability function and peak distribution; both quanities are necessary for the reliability analysis of the rigid pier and the flexible platform. The utilization of various mathematical programming techniques for structural optimization has encountered difficulties. It appears that for large structural systems, the presently available techniques are technically infeasible to handle the problems under consideration.

Project No.: R/OE-1

Title: Safety Analysis of Marine Structures

Principal Investigators: C. C. Tung and J. F. Ely

BACKGROUND

The objectives of this research project are to yield information regarding the concepts, methods, and research results of safety analysis and optimum design of marine structures to engineers engaged in the design of such structures. This includes:

1. probabilistic modeling of ocean and coastal environmental conditions relevant to the design of marine structures requiring the derivation and determination of wave field and fluid force statistics;

2. reliability analysis of rigid pier and a flexible platform requiring determination of the spectra, probability function, and peak probability function of the stresses in members of the structural system being considered for evaluation of the safety of the structure against catastrophic and fatique failure;

3. development of mathematical programming techniques for the optimum design of marine structures including application of the first and second order gradient techniques to plane frames, floor systems, and a fixed bottom platform in the ocean environment.

PROGRESS REPORT

In the period July, 1971 to December, 1972, most of the research has been on the subjects of 1 (probabilistic modeling of ocean and coastal environment) and ? (development and application of mathematical programming techniques to the optimum design of structures).

1. Probabilistic modeling of ocean and coastal environment:
The fluid forces to which marine structures are subjected are the wave and current forces. When waves encounter a current, the wave characteristics undergo changes, as do those of the fluid forces. Much of the effort in modeling of fluid force has, therefore, been devoted to the examination of the effects of the presence of currents and the phenomenon of wave-current interactions on the statistical properties of fluid forces. These are discussed below:

(a). Effects of currents on wave frequency and wave-number spectra.

The study found that in concurring current, (i.e. when the current is in the direction of wave propagation ($U>o$)) waves are lengthened and their amplitudes decrease, resulting in a lowering of the frequency spectrum and shifting of the wave-number spectrum to a lower wave number range. When the current opposes waves ($U<o$), the waves steepen and shorten. Results indicate that currents affect waves to an appreciable extent so that wave-current interactions can not be ignored in the evaluation of fluid forces. The work was published in the Journal of Physical Oceanography (1).

(b). Effects of currents on fluid force spectra.

The element force, total force, and statical moment of fluid force on single and arrayed cylinders were considered. It was found that drastic changes take place due to the presence of currents. This is particularly so when wave-current interactions are considered and when there is an adverse current. The work was published in Ocean Engineering (3,4) and as a NCSU Center for Marine Coastal Studies Report (5).

(c). Effects of currents on the probability function of fluid force.

There is discernible difference between the probability functions of fluid force when wave-current interactions are considered compared to when they are ignored. Results include the case when the Gaussian assumption of fluid force is invoked. That fluid force is non-Gaussian is clearly seen, especially when wave-current interactions are considered. The work is summarized in a Sea Grant Report (6).

(d). Effects of current on the peak distribution of fluid force.

It was found that wave-current interactions have more pronounced effects on the quantity examined than the probability function of fluid force. Results also indicate that the Gaussian assumption of fluid force is decisively inadequate for use in the evaluation of the peak statistics of fluid force.

All of the above quantities are required in preparation for the safety analyses of marine structures scheduled to begin in the latter part of 1973.

It is acknowledged here that Dr. D. T. Chen, a former graduate student at NCSU, completed his Ph.D. requirements with the financial support of Sea Grant funds allocated to this project.

2. Optimum design of marine structures.

An optimum structural design is one in which a particular objective (the objective function) is best satisfied while not violating certain conditions (constraints) to which the structural system must comply. The constraints are usually those imposed by strength and serviceability requirements and the measure of optimality may be in terms of cost. Structural optimization problems so formulated generally result in non-linear, mixed integer, convex-concave mathematical programming problems for which no general technique that guarantees a global optimum is presently available. Various techniques, therefore, need to be examined, programmed for the computer, and applied to simple structures to assess their adequacy.

In the past year, the first order gradient method of J. B. Rosen was used to determine a minimum cost, reinforced concrete portal frame, designed by ultimate strength theory but analyzed by elastic theory. Because of slow speed of convergence, the second order gradient unconstrained extremal method of Fiacco-McCormick was employed. The method was applied to an inclined leg, braced, offshore platform. Because of the large number of variables and the second order derivatives required, the method is practically infeasible for solving the problem under consideration. To reduce the number of variables involved, the method was applied to a "regular structure", one that has identical structural units and results were readily obtained.

It is mentioned here that Dr. J. F. Ely, the co-principal investigator who was responsible for this part of the work, has decided to withdraw his participation from the project due to other unforseen University duties beginning January 1973.

PUBLICATIONS SUPPORTED BY SEA GRANT

1. Huang, N. E., D. T. Chen, C. C. Tung, and J. R. Smith. 1972. Interactions between steady non-uniform currents and gravity waves with applications for current measurements. Journal of Physical Oceanography, 2(4):420-431.

2. Tung, C. C., and N. E. Huang. 1971. Ocean wave force spectra. Proc. of the Conference on Application of Probability and Statistics to Soils and Structural Engineering, University of Hong Kong, Hong Kong . September.

3. Tung, C. C. and N. E. Huang. Combined effects of current and waves on fluid force. Ocean Engineering (to appear).

4. Tung, C. C. and N. E. Huang. Influence of wave-current interactions on fluid force. Ocean Engineering (to appear).

5. Tung, C. C. and N. E. Huang. 1972. Wave-current force spectra. Center for Marine Coastal Studies Report No. 72-2. North Carolina State University, Raleigh.

6. Tung, C. C., and N. E. Huang. 1972. Some statistical properties of wave-current force on objects. Sea Grant Publication, UNC-SG-72-14, University of North Carolina.

7. Huang, N. E., D. T. Chen, C. C. Tung, and J. R. Smith. 1971. Influence of currents on surface wave spectra and its application for current measurement. Bull. Am. Meteor. Soc., 52.

8. Tung, C. C. and N. E. Huang. 1971. Spectra of gravity waves under variable currents. Trans. of Am. Geophy. Union. December.

9. Huang, N. E. and C. C. Tung. 1971. Current-wave interactions and the effect on equilibrium range spectra. Trans. Am. Geophy. Union. December.

10. Tung, C. C. and N. E. Huang. 1972. Non-Linear pressure fluctuation in a random wave field. Trans. Am. Geophy. Union. December.

11. Chen, D. T., N. E. Huang, and C. C. Tung. 1972. Directional fetch limited spectrum for wind generated waves. Trans. Am. Geophy. Union. December.

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SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT NO.	PROJECT TITLE	( ) NEW (X) CONTINUING	( ) CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
R/L 1	Marine Resources Legal Research			July, 1970
GRANT NO. (previous)	OLD TITLE (if different)			DATE OF THIS FORM
2-35178				May, 1973
INSTITUTION				ESTIMATED COMPLETION DATE
UNC				Dec., 1975

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
Seymour W. Wurfel, Law School, UNC-CH	22	T. J. Schoenbaum	22

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (list numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 26,058	$ 13,029	$ 19,910	$ 9,955	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Legal and Socio-Economic Studies	Ocean Law-Coastal

OBJECTIVES:

1. To conduct research, and publish, in the international law areas of sea, seabed and air space environmental control with emphasis on legal problems confronting, and arising from, the United Nations sponsored 1974 Conference to draft a new conventional law of the sea. Resolution of conflicting territorial water claims is paramount.
2. To research coastal states' fishing and off-shore mining laws, particularly as these may effect Southeastern United States coastal zone regions.
3. To examine legislation by states of the United States to extend state territorial waters into historically high seas areas. Such bills, seeking to preserve marine resources, raise both constitutional and international legal problems.
4. To analyze N.C. coastal area resources law and to develop legal concepts and institutions to create a comprehensive coastal zone management plan. This includes estuarine pollution control, existing public rights in land and water resources of coastal zones and the development of a legal and administrative model.
5. To continue active participation, cooperating with the N.C. Legislature, Attorney General, Marine Science Council, Coastal Zone Planning Committee and the Commissioner of Commercial and Sports Fisheries, in developing appropriate marine resources legislation. Both investigators are members of the N.C. Coastal Zone Planning Committee.

HOW INFORMATION WILL BE APPLIED:

1. Research has assisted and will continue to assist the N.C. Legislature, the Attorney General, the North Carolina Marine Science Council and the Coastal Zone Planning Committee to develop and enact appropriate coastal zone management plans and other marine resources legislation.
2. Research will lead to further Sea Grant publications dealing with international and domestic legal aspects of marine resources conservation and development.

ACCOMPLISHMENTS DURING THE PAST EIGHTEEN MONTHS:

1. Supervision of research and writing, and editing of Sea Grant publications: (a) Symposium of 11 international legal articles, entitled, "Attitudes Regarding A Law of the Sea Convention to Establish An International Seabed Regime," UNC-SG-72-01. (b) Symposium of 28 international legal articles on marine resources, entitled, "The Surge of Sea Law, 1972," UNC-SG-73-01. (c) (In progress) "Sea Law: The View of Developing Nations In Latin America," (d) (In progress) "Legal Problems of Marketing Internationally Securities of Marine Enterprises."
2. Investigator Wurfel prepared for the Coastal Zone Planning Committee a legal report on public access rights to beaches.
3. November, 1972 publication of Schoenbaum, "Public Rights and Coastal Zone Management" in Volume 51, North Carolina Law Review; UNC-SG-72-13.
4. Investigator Schoenbaum, chairman of the Legislative Sub-Committee of the N.C. Coastal Zone Planning Committee, headed preparation of the second draft of a bill, "Relating To Management of the Coastal Zone of N.C.," which bill, further revised, is pending before the N.C. Legislature.

Project No.: R/L-1

Title: Marine Resources Legal Research

Co-Principal Investigators:
Dr. Seymour W. Wurfel, Professor of Law and
Dr. Thomas J. Schoenbaum, Associate Professor of Law,
University of North Carolina, Chapel Hill, N.C.

PROGRESS REPORT

A previous progress report for this grant appears in the University of North Carolina Sea Grant Program Annual Report, 1 July 1970-30 June 1971, pp. 46-49. The period here covered is from 1 July 1971 to 31 December 1972. The continuing "research objective is to formulate an appropriate legal regime to promote North Carolina ocean exploration and to improve the capability to develop and conserve marine resources."

Two coordinated but distinct projects are in progress. For administrative purposes they are consolidated. They are here separately stated in the interest of clarity.

SUB-PROJECT "A"

Title: The Law of the Sea and Territorial Waters.

Principal Investigator: Dr. Seymour W. Wurfel, School of Law, University of N.C., Chapel Hill, N.C.

Work for the grant period continues the long range purpose of researching, writing and publishing in the ever-changing areas of international, interstate and constitutional law as these pertain to marine resources conservation. However, each legal subject researched is a separate project in itself, normally susceptible to completion in the grant period, subject always to reexamination when new data become available. Research priorities are established in accordance with the development of events, the availability of materials and the urgency of a given study.

A primary activity under this grant in its second year, from 1 July 1971 to 30 June 1972, was intensive guided research by graduate students of international law evaluating "Attitudes Regarding A Law Of The Sea Convention To Establish An International Seabed Regime." Eleven resulting papers were edited and issued as a 143 page Sea Grant Publication in April 1972 under Grant # 2-35178. There have been substantial requests for this document beyond the standard Sea Grant distribution.

In the grant extension period, 1 July to 31 December 1972, research of selected ocean law subjects pertinent to the development and conservation of marine resources was conducted. This guided research by graduate students of international law produced 28 articles which were edited and, as a symposium entitled, "The Surge of Sea Law, 1972," became a Sea Grant publication in March, 1973. This is a single spaced document of approximately 300 pages.

Two other research projects in progress are expected to become Sea Grant Publications by mid-1973. The first of these, "Sea Law: The View of

Developing Nations in Latin America," will run approximately 175 pages. The other, "Legal Problems of Marketing Internationally Securities of Marine Enterprises," will be approximately 75 pages in length.

Additional activities of this investigator include:

(1) Service as a Commissioner of the ten member North Carolina General Statutes Commission which serves in an advisory capacity to the North Carolina Legislature and the office of the Attorney General.

(2) Service as a member of the North Carolina State Coastal Zone Planning Committee. Preparation of a legal memorandum for use by the Recreational Needs Subcommittee thereof, on the subject of Public Access Rights To Beaches.

(3) Participation in the Law of the Sea Institute at the University of Rhode Island, June 26-29, 1972.

(4) Participating in developing appropriate marine resources legislation for submission to the North Carolina Legislature. This will be facilitated by membership on the North Carolina Coastal Zone Planning Committee. Such legislation ties in directly with implementation of recommendations resulting from all Sea Grant research projects pertaining to North Carolina.

(5) Continued cooperation with the General Statutes Commission, the Attorney General, the Coastal Zone Planning Committee and the Commissioner of Commercial and Sports Fisheries of North Carolina in marine resources matters.

SUB-PROJECT "B"
Title: Legal Aspects of Coastal Zone Conservation

Principal Investigator: Dr. Thomas J. Schoenbaum, School of Law, University of North Carolina, Chapel Hill, N.C.

PROGRESS REPORT

The principal investigator has (1) systematically analyzed the statutory laws of North Carolina which deal with the coastal zone, (2) systematically collected and analyzed all of the cases decided by North Carolina courts and many of the cases decided by federal courts and other state courts regarding the coastal area to the beginning of the nineteenth century, (3) collected and studied the secondary literature, books, and articles dealing with legal problems of the coastal zone of North Carolina, the United States and individual coastal states, (4) collected and studied the reports of hearings of Congressional committees and proposed federal legislation on the coastal zone and (5) conducted interviews with agency officials on enforcement of existing laws. This research produced the article, Public Rights and Coastal Zone Management published in 51 N. C. L. Rev. 1 (1972).

This investigator served as Chairman of the Legislative Subcommittee of the North Carolina Coastal Zone Planning Committee and in this capacity prepared a second draft of a bill "Relating To Management of the Coastal Zone of North Carolina" which bill, further revised, is now pending before the North Carolina Legislature.

During the current school year, September, 1972-May 1973 this investigator has served as Visiting Professor of Environmental Law at Koln University in Germany and will resume his Sea Grant activities in the summer of 1973.

Independent Evaluations.

Two evaluations of these combined projects made in connection with submissions for 1974 renewal are here given as independent statements of the progress made under the present grant. The first is by Dr. Lewis M. Alexander, Director of The Law of the Sea Institute at the University of Rhode Island. He wrote:

"I have the copy of your 15 February 1973 Sea Grant Project Summary on 'Marine Resources Legal Research' as well as the Marine Resources Symposium Issue of the University of North Carolina Law Review and the Sea Grant Publication, 'Attitudes Regarding a Law of the Sea Convention to Establish an International Seabed Regime.' I must at the outset congratulate you on the quality and quantity of work you have produced under what seems to me a relatively modest expenditure of Sea Grant funds.

"In two respects you and Professor Schoenbaum have managed to develop a multi-faceted approach to marine law matters. A first is through your concentration both on international law of the sea matters, and on legal problems of coastal zone management. It is important to recognize certain elements of interaction between these two levels of activities, and this you and your students have done.

"Second, you have combined education and research in a meaningful way. Several of the articles by your students in 'Attitudes Regarding a Law of the Sea Convention. . .' are first-rate, and will, I suspect, be expanded and submitted to journals for further publication. I was also impressed by the agenda of your February 1971 Regional Meeting of the ASIL, and hope that before long you will conduct a follow-up session. Meetings of this type conform, I believe, with the educational goals of the Sea Grant Program.

"In addition, particularly through the writings of Professor Schoenbaum, your project is responsible for meaningful research in the evolving area of coastal zone law. Here again is an activity of great concern to the Sea Grant Program.

"In the description of Proposed Work, included in the February 1973 Project Summary, I note five areas of activity for calendar year 1974. These are listed as 'Specific research undertakings' and it is within this context that I would offer the following two suggestions.

"First, I hope that the description of 'research undertakings' does not imply that you will downgrade the valuable educational work with which the project to date has been associated. If at least some of the research is to be carried out by your law students and subsequently published, then I have no problems with your terminology.

"A second point is that you are obviously going to have to establish priorities within and among the five categories listed. For example, fishing and off-shore mining laws of coastal states is to me of greater significance

at this time than the 200-mile legislation of certain states. And since your law students have already examined national attitudes toward seabed regimes, why not have them now concern themselves with territorial and exclusive-fishing limits? Such priority problems can, of course, best be ascertained by yourself and Professor Schoenbaum on the basis of what's happening at the UN at the time when choices of emphasis in your project must be made.

"To repeat what I stated at the beginning of this letter, I congratulate you on your achievements, and wish 'Marine Resources Legal Research' continued success under Sea Grant sponsorship."

The second is by Dr. Milton S. Heath, Jr., Associated Director of the Institute of Government of the University of North Carolina at Chapel Hill. He wrote:

"The area of research covered by the Wurfel-Schoenbaum project corresponds to one of my primary interests at the Institute of Government. I have been involved in related research and consulting work in North Carolina for the past five years. During the past year I have served as Co-Chairman with Professor Schoenbaum of the Legislative Subcommittee of the North Carolina Coastal Zone Planning Committee, and currently (in Professor Schoenbaum's absence on leave) I am closely involved in revisions of a proposed North Carolina coastal zone management bill. (The first draft of this bill was prepared by Professor Schoenbaum and a student research assistant.)

"The completed aspects of the Wurfel-Schoenbaum project have been quite productive. Among their accomplishments are:

* The generation of considerable law student interest and useful published student work products.

* A significant input to ongoing policy development at the State level. During the past year Professor Wurfel produced an excellent report to the Coastal Zone Planning Committee on public access to beaches and related matters, and Professor Schoenbaum produced a draft of a proposed coastal zone management bill that has set the pattern for further consideration of this subject in recent months. (Professor Schoenbaum's November 1972 article on this subject in the N.C. Law Review is also to be noted.)

"There is no question about the continuing significance of the proposed research. Coastal area and marine resources management will undoubtedly be a subject of major policy interest for state government in North Carolina during the next few years, and it is important that continuing research on the legal aspects of the subject be conducted along the lines proposed by Professors Wurfel and Schoenbaum. Their previous work has already been valuable to me in my own consulting activity in this field, and I welcome the prospect that they will continue to be active in this area of legal research. I support the proposal for additional Sea Grant funding of the Wurfel-Schoenbaum project.

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SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT NO.	PROJECT TITLE ☐ NEW ☒ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
R/SST-1	Development of Marine Industries Harvesting and Processing Systems: Seafood Science and Technology, Applied Research	July, 1970
GRANT NO. (Leave blank) 2-35178		DATE OF THIS FORM May, 1973
INSTITUTION UNC		ESTIMATED COMPLETION DATE continuing

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
Dr. Neil B. Webb, Dept. of Food Sci., NCSU	25%	Dr. George G. Giddings	20%

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (R. numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	A/EA-1, A/EA-2, A/EP-1
$ 52,596	$ 26,297	$ 37,421	$ 18,710	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Advisory Services	Resource Recov. & Util./Seafood Sci. & Tech.

OBJECTIVES:

OBJECTIVES:

A. To develop new systems of processing and methods of evaluating seafoods.
B. To develop and operate an applied research laboratory at a coastal location.
C. To conduct cooperative applied research investigations on processing and evaluation systems in commercial plants.

HOW INFORMATION WILL BE APPLIED:

The information obtained from this research will be demonstrated in the coastal research laboratory by pilot plant systems and in commercial plants by using protopype systems. This includes both process improvements or developments and new products. New developments will be applied by the cooperative efforts of the applied research and advisory services personnel working with commercial firms and regulatory personnel.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

Progress has been made on research projects including: (1) freezing and pasteurization methods for blue crab meat, (2) crab plant sanitation, (3) waste reclamation from crab plants, (4) mechanically deboned fish and crab meat tissue for yield and functional properties, and (5) Rangia clam utilization.

Accomplishments have included: (1) establishment and operation of a coastal laboratory, (2) ice/salt chilling of scallop meats, (3) utilization of scallop viscera, (4) development of comminuted seafood products utilizing mechanically deboned tissue, and (5) use of the resazurin technique for determining the bacterial level of scallop meats.

Project No.: R/SST-1

Title: Development of Marine Industry Harvesting and Processing Systems - Seafood Science and Technology, Applied Research.

Principal Investigator: Neil B. Webb, Dept. of Food Science, North Carolina State University, Raleigh, N.C.

This project has been complementary to projects A/EA-1 and A/EA-2 and much of this work has been done in support of the work and problems identified with these two projects. This was the basis for conducting several diversified sub-projects in this report period. The results and applications from the combined efforts of the three projects have been beneficial to selected segments of the commercial and sports fishery and seafood industries of North Carolina. Also, the work to date has established the Sea Grant program on a sound basis with the industries and related groups in North Carolina. The Sea Grant Program has given the basis needed by the University to establish much needed assistance in research and development for the seafood industry of the state. The project results and accomplishments for this period are as follows:

1. Effect of freezing on the quality of blue crab meat.

An investigation was conducted on the effect of various methods of freezing, packaging and storage on the quality of blue crab meat. The crab meat was stored for eight months and evaluated by microbiological, chemical and sensory methods. The evaluations indicated that IQF Freon freezing was superior to conventionally frozen crab meat and that -25°F was superior to 0°F storage. There was no significant difference in the quality of the crab meat stored in vacuumized flexible film pouches versus non-vacuum cans. However, all methods resulted in a substantial reduction of quality when compared to fresh, refrigerated crab meat. The results are presently being prepared for publication.

2. Study of Time/Temperature treatments in combination with food grade additives for the pasteurization of blue crab meat.

This investigation involved the application of various pasteurization temperatures (155-185°F) and times (1 to 30 min.) on the level of microbial kill in blue crab meat. A time/temperature treatment of 1 min. at 185°F was used as the control. This study also involved the application of citric acid and phosphates to various treatment groups within the time/temperature studies. Detailed microbiological (6 groupings), sensory evaluation and chemical analyses were conducted on the samples. The results indicated that pasteurization substantially reduced the numbers of bacteria for all times and temperatures. However, none of the heat treatments was totally effective in killing all vegative bacteria, including the control. There was no substantial benefit in the addition of citric acid or phosphates to the crab meat with subsequent time and temperature treatments. The results are presently being prepared for publication and further studies are underway to improve the pasteurization process.

3. Protein losses from the processing of blue crab.

A study was conducted to determine the amount of protein in the cook loss fluid and in the process rinse waters from simulated crab meat processing. This study was conducted under controlled pilot laboratory conditions. The results indicated that protein losses due to fresh water rinsing for 30 sec. were 15.2% and 12.6% for crabs cooked at 100°C for 10 min, respectively. When the crab meat was dipped in a salt brine (8% for 30 sec.) the losses were 11.2% and 7.3% for crabs cooked at 100°C for 10 min., respectively. Studies are being continued in the laboratory on the quality of the proteins lost by these pilot processes. These studies should lead to methods for the reduction of protein losses as well as reclamation of protein which is unavoidably lost. A manuscript has been submitted for publication on this work.

4. Application of chilling techniques for scallops.

The commercial application of an ice/salt brine chilling technique previously developed in this laboratory was initiated for the chilling of fresh scallop meats in selected mechanical processing operations. This method resulted in the rapid reduction of scallop meat temperature (from approximately 65°F to 40°F in less than 5 min.) and an increased shelf life for fresh scallop meats. The use of food grade phosphates in the chilling brine was found to be advantageous for improving yield, texture, and appearance of the meats. Studies were completed in the laboratory and in commercial operations with a high degree of success.

5. Scallop by-product utilization.

Studies have been conducted on the separatory extraction and subsequent utilization of scallop viscera in an intermediate moisture pet food product. Extensive investigations were conducted on methods for the removal of sand and grit from the scallop viscera in order to reclaim the edible portion of the viscera for pet food products. Proximate composition of the various phases of the process indicated that the product has economic value as a protein source. An intermediate moisture pet food product was developed utilizing the viscera which had similar characteristics to currently marketed products which utilize other protein sources. The results will be published in the near future.

6. Mechanical deboning of finfish and blue crab waste products.

Experiments were conducted on procedures for mechanically deboning and skinning those species and sizes of finfish which are not presently utilized to any appreciable extent in standard processing operations in North Carolina. Also, techniques have been developed for obtaining crab meat tissue from crab legs and shell by mechanical deboning. These studies have indicated that a substantial quantity of high quality meat can be prepared by the mechanical deboning technique. Experiments are being conducted to determine the functional properties of these tissues.

7. Comminuted fishery products.

With the development of mechanical deboning techniques for fish and crab muscle tissue, it was evident that work was needed on methods of utilizing the deboned muscle tissue. Studies have been conducted on product development concepts for mechanically deboned muscle tissue. The results have been encouraging but further work is underway. The approach has been to combine mechanically deboned muscle tissue with various other ingredients; including fish muscle, crab meat, clam and shrimp in combination with food grade additives, to develop products which would be acceptable to the consumer. Emphasis has been in the areas of frozen heat-and-serve and ready-to-eat products. These studies have been conducted in the laboratory and a prototype system has been demonstrated to commercial processors. However, additional laboratory and pilot plant work is underway which will improve the products as a result of suggestions from the processors.

8. Seafood plant sanitation.

Investigations were made on the status of crab meat plant sanitation. Data have been recorded on the total microbiological levels at each stage of the process and on products and plant facilities. These data will subsequently be used to compare the plant sanitation status after improved processing and cleaning systems have been developed. Further studies are planned in the pilot laboratory and these will be followed by additional plant operating studies. The results of the plant status study will be published in the near future.

9. Resazurin reduction technique.

The reduction time of the resazurin chemical compound has been applied as a technique for estimating the microbiological level of scallops. The reduction time of the resazurin chemical was found to be related to the numbers of bacteria present on fresh scallops by laboratory experiments. A special field test kit was developed and tested in commercial plants. The method was found to be simple, relatively accurate and practical. A manuscript has been published on this research.

10. Rangia clam processing.

The Rangia clam resource offers considerable potential in North Carolina. However, an off-flavor is present and thereby prevents utilization as a food product. Several studies were conducted on techniques for the removal or reduction of the level of off-flavor in the finished product. Various curing solutions and smoking techniques were investigated. However, the results were not satisfactory and work has temporarily been discontinued.

11. Coastal research laboratory.

The seafood research facilities are located in the Department of Food Science, North Carolina State University campus at Raleigh. It has been evident for several years that a small coastal laboratory should be made available for the purpose of adequate sampling of the various species as well as the preparation of samples for subsequent research studies in the Raleigh laboratories. The Sea Grant program has made it possible to develop and

operate a coastal research laboratory to support the facilities in Raleigh as well as to do field research studies in commercial operations located on the coast. This laboratory has been developed by the leasing of a commercial facility in the interim period until such a facility could be constructed for use by the University. The leased facilities are equipped for limited microbiological and chemical analyses as well as research sampling and prototype demonstrations. The facilities are used to support the research conducted by the Raleigh laboratories.

The coastal laboratory was developed as part of two projects (Development of Marine Industries, Harvesting and Processing Systems, A/EA-2:Seafood Science and Technology, Advisory Services and R/SST-1:Seafood Science and Technology, Applied Research). The laboratory will support these projects as well as the project A/EA-1:Engineering Advisory Services.

The laboratory, presently located in the leased facilities at Ocean, N. C., will move into the new N. C. Division of Commercial and Sports Fisheries Building, Morehead City, North Carolina in 1973. A floor plan of the new facility is shown in Figures 1, 2 and 3. These plans were developed as a part of the Sea Grant Project. The functions of the laboratory have been:

1. To serve as an integral part of the seafood research program at Raleigh by operating as an appendage of the Department of Food Science.

2. Location near the coast provides one of the requisites for conducting technological research on fishery products while establishing direct contact with those people most interested in using the results of the research.

The Seafood Science and Technology Project is exerting substantial impact on the fishing industry and the laboratory facilities at Morehead City provide visible proof of this long range, continuing effort. It is taken for granted that marine biology laboratories should be near the species being studied. It is not as well recognized that correctly conducted fishery technology investigations must be near the fishery. Selection of the new site has included proximity to the sea as a basic requirement. Similarly, the coastal Seafood Laboratory provides Raleigh with a "window on the sea" in carrying out advisory services for people most concerned with the fisheries, in collecting raw materials as an integral part of the research program in Raleigh, and in aiming for close cooperation with the engineering programs.

The above research areas have resulted in significant progress in several areas of the seafood industry of North Carolina.

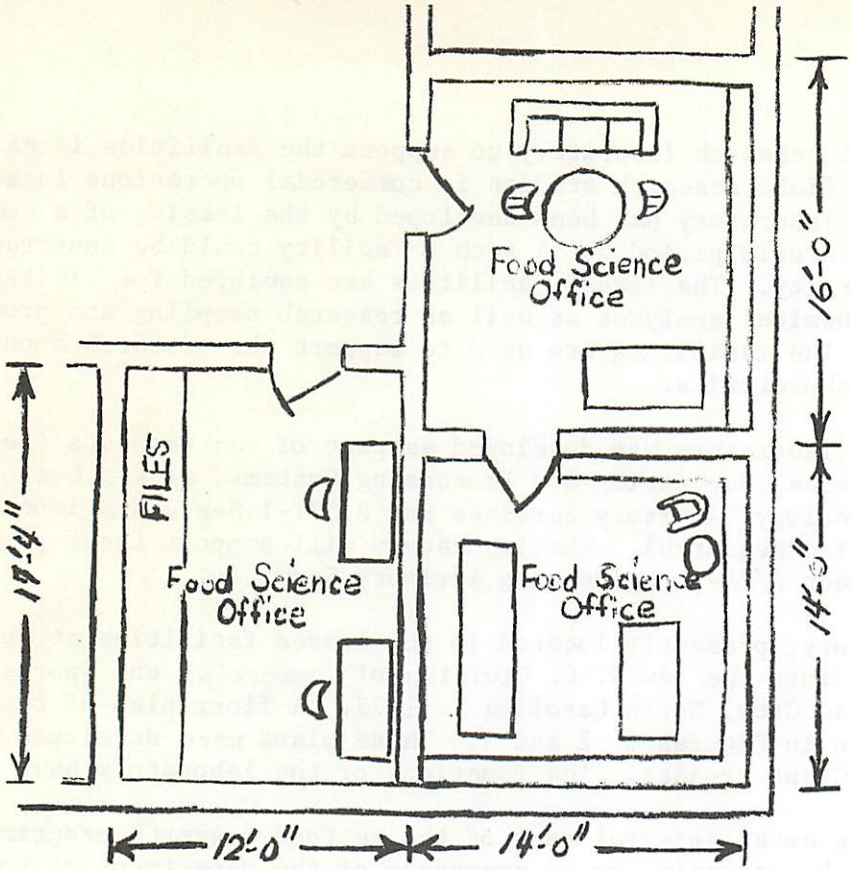

Figure 1. Advisory Services Offices, 2nd Floor, N. W. Corner of New Fisheries Building

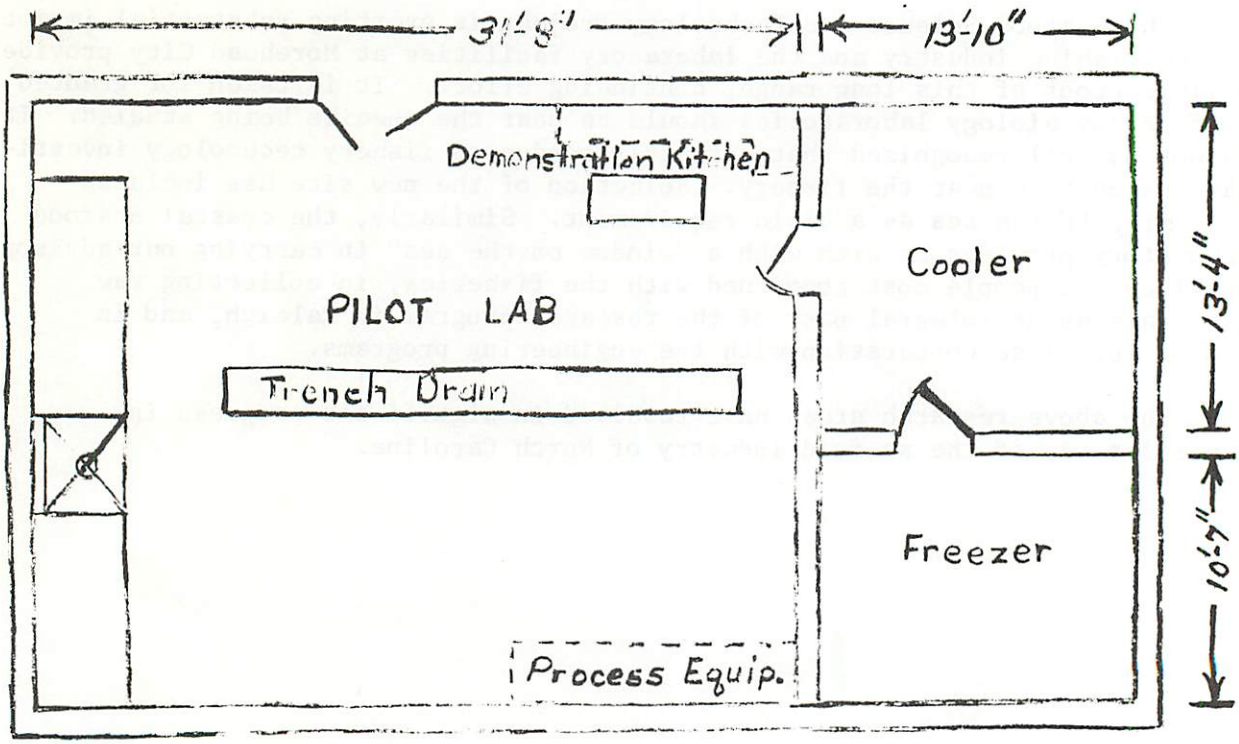

Figure 2. Pilot Laboratory, Cold Storage and Freezer Layout, 1st Floor

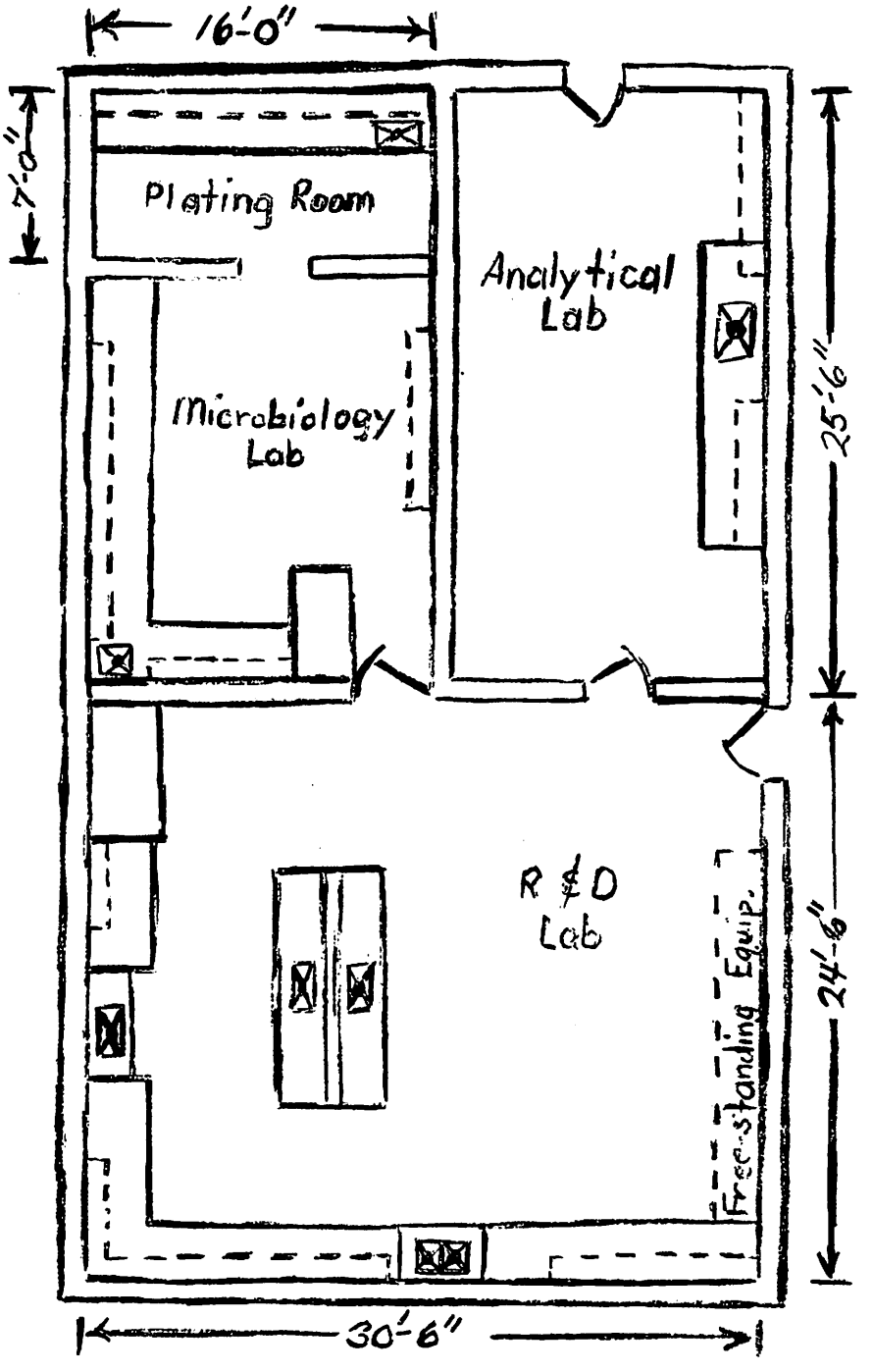

Figure 3. Laboratory Complex, 2nd Floor, for Applied Research, Quality Control, Sanitation, and Environmental Studies

PUBLICATIONS AND PAPERS PRESENTED FROM RESEARCH SPONSORED TOTALLY OR IN PART BY THE SEA GRANT PROGRAM:

Webb, N. B. and F. B. Thomas. 1971. Influence of Mechanical Processing on the Quality and Yield of Bay Scallop Meats. Special Sci. Report No. 624, Natl. Marine Fisheries Service, U. S. Dept. of Commerce, Seattle, Wash.

Webb, N. B., F. B. Thomas, F. F. Busta and L. S. Kerr. 1972. Evaluation of Scallop Meat Quality by the Resazurin Reduction Technique. J. Milk and Food Technol. 35:664-668.

Hanover, L. M., N. B. Webb and A. J. Howell. 1973. Effects of Cooking and Rinsing on the Protein Losses from Blue Crabs. J. Milk and Food Technol. (Submitted for publication).

Holland, B. F., Jr., George F. Yelverton, Edward G. McCoy and Neil B. Webb. 1972. Lobster Offshore North Carolina and Evaluation of Lobster Handling Methods. Information Series Report No. 5 Division of Commercial and Sports Fisheries, N. C. Dept. of Natural and Economic Resources.

Webb, N. B., S. J. Stokes and F. B. Thomas. 1972. Effect of Sanitation Procedures on Bacterial Levels in Blue Crab Processing Plants. Presented at the 25th Annual Session of the Gulf and Caribbean Fish. Inst., Miami, Fla.

NOAA Form 90-2

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 41-R260

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJ. NO.	PROJECT TITLE ☐ NEW ☒ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
A/EA-1	The Development of Marine Industry Harvesting and Processing Systems - Engineering Advisory Services	July, 1970
GRANT NO. (OFFICE USE) 2-35178	OLD TITLE (If different)	DATE OF THIS FORM May, 1973
INSTITUTION UNC		ESTIMATED COMPLETION DATE continuing

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
Norman B. Angel, Industrial Extension Serv; NCSU	100%	Arthur G. Chleborowicz	100%

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (Rx numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	R/SST-1, A/EA-2, A/EP-1
$ 70,012	$ 35,007	$ 48,760	$ 24,381	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Advisory Services	Advisory Services/Ext. Agent Services

OBJECTIVES:

The primary objective of the Engineering Advisory Service is to increase the efficiency, productivity, and profitability of North Carolina's marine enterprises. This objective is being accomplished by providing a continuing service for:

1. The practical application of improved engineering practices.
2. The increased economic use of known or newly developed technical advances in marine harvesting and processing equipment.
3. The evaluation of major new marine harvesting and processing systems for application in North Carolina.
4. The provision of engineering assistance in support of the advisory service programs of the Department of Food Science and the Department of Economics.
5. The dissemination of valued results of these and other studies by demonstration, conferences, newsletter or other appropriate information transfer methods to test effectiveness and promote adoption.

HOW INFORMATION WILL BE APPLIED:

The information developed will be applied in direct cooperation with the commercial fishing and seafood handling and processing industry: to increase the flow of raw fish products of higher quality through North Carolina's landings; to facilitate the early and orderly conversion of North Carolina's seafood industry from that of a low-cost source of supply to out-of-state processors to that of a significant competitor offering high quality kitchen-ready products to the world market; and to develop techniques for the economic use of previously under-exploited species and for fin-fish caught incidental to shrimping.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

1. The conduct of the Annual Sea Grant Harvesting, Marketing & Processing Conference, attended by members of the commercial fishing & processing industry and R&D personnel. 2. The publication and distribution of the "Marine Advisory Service's Reporter" to 1700+ members of the commercial fishing industry & others. 3. Developed a system of heat transfer in the thermal shocking tank of a scallop shucking machine. 4. Conducted initial successful sea tests of an Electric Shrimp/Fish seperator trawl built by the project staff. 5. The successful development of a method of installing insulation in older fishing vessels - reduced costs of icing shrimp 4¢ per pound. 6. Conducted initial successful sea tests of the electronic shrimp trawl gear and methods built by the project staff. 7. Installed facilities for and conducted investigation of eel harvesting & handling methods, i.e., pots, traps, holding tanks, purging, transporting, grading and packaging for live freezing, and shipment to European markets.

Project No.: A/EA-1

Title: Development of Marine Industry Harvesting and Processing Systems-
Engineering Advisory Services
Principal Investigator: Norman B. Angel, Industrial Extension, N.C. State Univ.

This report is an account of the work performed on Sea Grant Project, No. A/E1, The Development of Marine Industry Harvesting and Processing Systems - Engineering Advisory Services, during the period July 1971 through December 1972.

The report is prepared as a concise summary with the activities listed in more or less sequential order. The extent and depth of our investigations have increased significantly, due principally to the attainment of a project Staff Engineer and a Research Technician, who are rapidly developing real expertise in the skills peculiar to the commercial fishing industry.

The close working relationship established with the appropriate state and federal agencies early in the project (during the last reporting period) have been maintained and strengthened. A frequent exchange of information and data as well as actual working support has been the rule. Also, there has been significant increase in the number of referrals of coastal problems to individuals and agencies having the capability of constructive response. The close working relationship and joint project activity of the three Sea Grant Advisory Services Projects, ie, this project, the Department of Food Science, North Carolina State University and the Department of Continuing Education, East Carolina University have developed a cohesive, well oriented overall Sea Grant Advisory Services effort in North Carolina.

INFORMATION TRANSFER ACTIVITIES

The "Marine Advisory Service's Reporter" is a quarterly publication prepared jointly by the Sea Grant Advisory Service's projects. It is distributed to 1700+ members of the commercial fishing industry and research and development personnel. The response to this publication has been excellent, over 240 requests for information have been answered as a result of capsule articles. A total of seventy-seven requests were answered on one subject. It was gratifying to learn that we have attained a responsive readership from as far away as India.

A total of five TV SHOWS ranging from 10 to 15 minutes in length were prepared and presented during this reporting period. The subjects covered were the 1972 Sea Food Harvesting, Processing and Marketing Conference, Eel Harvesting and Handling, and general updating on Sea Grant Advisory Service's Activities. An orientation tour of the commercial fishing industry was conducted by this project director for the program director of WCTI-TV Channel 12 in late 1972. Initial steps were taken to develope a coastal North Carolina information program over this station, more detailed planning and work in this area will be conducted in 1973.

The second Seafood Harvesting, Processing and Marketing Conference, a two day conference,was held in March 1972 at New Bern, North Carolina. A total of ninety persons from the commercial fishing industry, research programs and state and federal institutions and agencies attended. This results in a total of three hundred and three persons attending the two conferences, 1971-72. The program was developed and coordinated under this project, with significant input and support from the Department of Food Science, North Carolina State University, Department of Continuing Education, East Carolina University. The conference format

and subject matter was well arranged and timely with a high degree of interest displayed by all. Administrative and equipment support was provided by the Division of Continuing Education, North Carolina State University.

In October 1972 planning was begun for a third conference to be held in 1974. The format will be expanded to include exhibits by equipment manufactures,distributors of equipment pretaining to this region's commercial fishing,and marine industries.

Area Workshops - Eel Trap Construction, three formal workshops have been conducted, one at New Bern, North Carolina and two at Fairfield, North Carolina on eel trap/pot construction. A total of forty-seven persons attended the workshops. These were held as a part of our eel fishery development work, covered later in this report. While the forty-seven attentees were a gratifying figure, the number of individuals contacting the project staff for information and advice on trap construction and eel fishing methods has run into the hundreds.

This project director contacted the local area workshop for handicapped/disadvantaged persons and suggested that they make and sell eel traps. A short class in construction methods was held for the counselors and a cost analysis run. As of the end of 1972 they have made and sold over 500 traps. There will continue to be a demand for traps as the eel fishing effort is further developed.

Newspaper Articles - Eel Fishing, two articles announcing the Eel Harvesting and Handling project were written and placed in the New Bern, N. C., Sun-Journal. And an article was prepared by the feature writer of the "Shopper" a local advertising paper with a circulation of 27,000 in several eastern North Carolina counties. These articles were very effective in developing local interest and subsequent participation in the project.

An extensive Personal Contact program was started early in the project and has been maintained. Over 300 personal contacts have been made with commercial fishermen and processors. This effort has been most effective in establishing rapport with the industry and aided in the dissemination of information and in assisting the fishermen and processors with individual technical problems. The project's shop facility has developed into a focal point for this type of activity. As the staff personnel work closely with the industry and listen as well as talk, they open a good two-way avenue of communication. The traditional pragmatic approach of the commercial fishermen and this free exchange of information and thought has proved to be invaluable to this project.

During the entire project period Sea Trips aboard working commercial vessels ranging from a few days to as long as a week have been made by the project staff. These trips have served the purpose of keeping staff personnel in contact with the vessels, gear and problems of the industry. They also permit the project personnel to really get to know the commercial fishermen on an individual basis. The trips are working trips and all personnel are instructed to do at least a fair-share of the work at sea. This has been noticed by the captains and crews and all personnel are welcomed aboard any trawler at anytime. In fact more invitations to "make a trip" are received than can be accepted.

ENGINEERING ADVISORY AND TECHNICAL ASSISTANCE ACTIVITIES

The project director has been requested to serve on the Advisory Committee, Pamlico County High School, Commercial Fishing Training Program. Mr. Styron, the instructor, has been advised of subject matter known to be of value to commercial fishermen. The subject recommendations offered were:

Business Management
Diesel Engine Maintenance
Periodic Maintenance Scheduling
Navigation
Radio Communications and Procedures
Net Making and Mending
Basic Physics
Handling The Catch Aboard The Vessel
Vessel Sanitation

The majority of the young men enrolled have a good basic knowledge of the fishing industry - but - it was felt that the above subjects cover the majority of the short commings of many presently working commercial fishermen.

Provided Engineer Advisory Services to a seafood processor and shipper by preparing a layout and evaluation of the existing plant, dock facilities and available land with a view toward expansion. The owner is seriously planning on going into further processing of seafood into commercial and consumer pack. Arrangements were made for represenatives of the Economic Development Administration to visit the plant and provide information on the requirements to apply for an expansion loan from their agency. The Department of Food Science and the Department of Economics, School of Agriculture and Life Sciences, North Carolina State University, assumed responsibility for continuing the project work at this point. Initial investigations have supported the feasibility of the planned expansion, which will result in approximately forty full-time jobs in an economically depressed area.

The providing of Technical Assistance to eel fishermen in the construction of traps and in the use and preservation of baits is a continual activity. The construction of eel holding tanks both ashore and aboard the boats has been another area of extensive work. The selection of tank sites, pump types and locations, installation of control valves, etc., have been the principal technical assistance problems. Also, a continuing program of emphasizing caution and care in the overland transport of live eels is being carried on. Additional information on the eel harvesting and handling project appears later in this report. A detailed report is in preparation and will be ready for publication and distribution in 1973.

Provided Engineering Advisory Service to a fish and shrimp packer and shipper concerning the construction of a flake ice holding room in his plant. Construction of the room and floor details were worked out; contact was made with an industrial

insulation company to apply sprayed in-place polyurathene foam. The insulation company also fabricated and installed a sliding insulated door. The owner advised project personnel at the end of the 1971 shrimp season - a particularly heavy one - that he could not have handled this years volume using their old icing and packing methods. At least two other plants have built similar facilities as a result.

Provided Direct Technical Assistance to a scallop processing plant operator in the design of a direct oil fired heat exchanger,submerged in the scallop thermal shocking tank, to facilitate the shucking and harvesting of scallop meats. This involved the problem of maintaining a constant water temperature of 190^{o} while moving one hundred bushels of scallops per hour through the bath. The addition of this heat transfer system increased the capability of the scallop shucking operation 100% over the old system. It is felt that this system or a variation thereof will be adopted by other scallop processors after a sufficient period of operational evaluation. A completed report of this project activity - "A Direct Oil Fired Heat Exchanger For The Thermo Shocking Tank Of A Scallop Shucking Machine", Sea Grant Publication, UNC-SG-72-04, June, 1972 has been published and distributed.

ACTIVITIES INVOLVING HARVESTING & PROCESSING EQUIPMENT/METHODS

Electric Shrimp/Fish Separator Trawl. The investigation of shrimp/fish separator trawls has been a major project activity. All companies or agencies having experience in this area have been contacted ; the best points of their development efforts were included in a separator trawl made by this project's personnel. The purposes of this investigation are two-fold. First, to reduce as much as possible the substantial damage being done to fin-fish stocks caught incidental to shrimping operations. Secondly, to reduce the amount of labor involved in on-deck culling operations.

A 90' trawl was constructed with a 3" stretch separator panel inserted inside the back third of the trawl. A 24" x 18" opening was cut in the top of the trawl just forward of the tailbag. An electrode was secured on each side of the long axis of the opening. An electrical impulse was applied to the electrodes and closely measured. The electrical field established between the electrodes repelled the shrimp forcing them back down into the net and they were captured by the separator panel. The low voltage and low pulse rate had less effect on the fin-fish allowing the fish to pass through the hatch and escape. The sea tests conducted so far are very encouraging but were not conclusive due to limitations of personnel and budget and equipment restrictions during this phase of the program. The results obtained have certainly supported the theory. In the latter tests the amount of shrimp caught was exactly the same as in the standard starboard trawl, while the amount of fin-fish was reduced by 66%. The development work planned for this was not conducted in the summer of 1972 due to extensive rough weather and gear handling problems. This activity is certainly continued worthy of further development and more work is scheduled for 1973.

Shrimp Traps - The successful use of wire shrimp traps in New England waters prompted an investigation of these devices for possible use on North Carolina shrimp grounds. Sixteen traps were constructed and fished in all areas using a

large variety of baits, etc., with a notable lack of success. This was not conducted as a major effort but was carried on in conjunction with other activities. The investigation is considered to have been very thorough, however. One advantage has been a new research tool for the Office of Fish and Wildlife Resources, North Carolina Department of Natural and Economic Resources. They have requested the traps for use in the shrimp nursery areas for statistical and marine biological work.

Insulation of Fish Holds in Older Fishing Vessels - One of the serious limitations of a large number of North Carolina's fishing vessels is their ice holding and fish keeping capability. The lack of proper insulation of the ice bunkers and fish holds is the primary reason for this limitation. The cost of ice is becoming an increasingly large factor in the operational cost of a fishing vessel, particularly during summer shrimping operations. First year project investigation activity included a study of existing procedures employed on the vessels and at dockside. The fish holding capability of vessels and product quality were two very apparent early areas of concern.

With the cooperation of a North Carolina industrial insulation company it was decided to develop and demonstrate a simple method of insulating an older vessel using sprayed in-place polyurathene foam. An 83' standard shrimp trawler was selected as the project vessel. All work except the actual operation of the spray equipment was accomplished by the project staff and the vessel's crew. At all times during the planning for and actual installation of the insulation, methods and materials selected were those readily available in the area. Also, no skills were employed beyond the scope of local carpenters and metalsmiths. In fact, all of the hold preparation and sealing off work could be accomplished by a good boat crew.

The total cost of all materials and labor was approximately $1,610.00. The only labor involved other than the vessel crew and two members of the project staff, was the spray crew. A total of twelve days were used including three days to dry the hold before work started and two days to permit the paint to dry thoroughly. The actual installation involved three men for seven days, and the two man spray crew for one day working concurrently.

During the course of the shrimp season records were kept on hold temperatures and ice consumption. There were two other vessels included for comparative purposes, one an uninsulated vessel, the other a vessel insulated approximately five years ago with block polyestyrene. Data collected over a nine week period indicated a saving of as high as 4¢ per pound of headed shrimp for the project vessel over the uninsulated vessel and a higher quality product was landed. During the nine week period the project vessel landed 38,000 pounds of shrimp at an average of 4¢ per pound savings or $1,420.00.

The comparison with the vessel insulated with block polyestyrene indicated a saving of 1¢ per pound of headed shrimp or $380.00.

The cost of ice per 300 pound block blown into the ice bunkers is the same to all vessels. The above indicates that the cost of insulating a non-insulated vessel can be recovered in one shrimping season. The majority of North Carolina's older trawlers are uninsulated.

The insulating efficiency, ease of installation, lower water absorption characteristics and the permanent bond made with the vessel hull of sprayed in-place polyurathene foam as opposed to block polyestyrene are definite plus factors favoring its use.

This is considered a highly successful project and has led to the similar insulation of several vessels and on-shore ice holding facilities.

At this writing a commercial fishermen advised this project director of an expected increase in the price of ice per 300 pound block blown into the ice bunkers to increase by fifty to seventy-five cents during 1973.

A completed report of this project activity - "Insulating Ice Bunkers And Fish Holds of Older Fishing Vessels", Sea Grant Publication, UNC-SG-72-05, July 1972 has been published and distributed.

Electronic Shrimping - The recent development in electronic shrimp trawling equipment and methods by Gulf Coast shrimp fishermen and Texas A&M University is of particular interest to North Carolina fishermen. It was determined early in this project that North Carolina's trawling equipment and grounds are very similar and this method was worthy of investigation in this fishery. During the months of August and September shrimping operations are suspended from mid-morning until about sundown due to virtually no production during these hours. This results in about one-third of the sea time during a weeks trip (the normal length of trips during this period) as lost time.

Research with this gear conducted by Texas A&M University Sea Grant Program produced 80 pounds of shrimp per hour while conventional gear was completely unproductive. Taking a very optimistic look at this production we arrived at an additional 40 hours shrimping time per week with two nets producing 160 pounds per hour or 6400 pounds at an average price of $1.50 per pound, resulting in increased income of $9,600.00 per week. If one-fifth of this figure could be reached the project will be considered an outstanding success.

In order to get a feel for the gear and to point up the most salient problems, the following preliminary work was carried out late in the 1971 shrimp season. The electrical circuitry designed for use with the separator trawl was modified and used. Conductors were fastened along the foot rope and the ground chain of a 90' trawl net and electrified and then moved over the bottom at normal trawling speed.

The limited observations permitted due to rough weather and gear handling problems were of value. The requirement for a better electrical conductor cable handling method and the need for a more responsive instrumentation system was selected as an area of emphasis, as was the underwater electrode arrangement.

Close liaison has been established with Texas A&M University's Sea Grant personnel and this project's staff engineer visited the Texas Gulf Coast to observe their electronic shrimping operations and gear. He also observed and obtained specifications and data on the four-net trawl method under development there.

The work conducted during the 1972 shrimp season was more definitive and provided a sound working knowledge of the electronic gear's capabilities and limitations.

The 1972 shrimp season was not a typical year in that early rough weather and a seemingly wider dispersal of the shrimp made normal trawling operations difficult. These conditions coupled with new project personnel and serious power supply problems did not permit the conduct of sea trials to the extent desired.

However, several former serious problem areas were eliminated - the instrumentation and electrode array components were improved and made reliable and effective. The methods of rigging, shooting and retrieving the trawls were perfected, virtually eliminating all lost time during these phases.

The good potential for increased shrimp production certainly warrants a continued investigation of this method in North Carolina's waters. It is felt that the preliminary report, "Electronic Shrimp Trawling" supports the above conclusion. It is anticipated that the investigative and development work on this project will be completed during the 1973 shrimping season.

Eel Harvesting, Handling and Processing - The introduction of North Carolina eels to the Eurpean market is a recent development. The North Carolina Department of Economic and Natural Resources and a North Carolina exporter have done an excellent job of identifying markets and establishing quality and shipping parameters. The demand for high quality eels is far exceeding production and this situation is expected to continue for sometime. The principal problems have been in harvesting, holding and purging of the eels and delivering them live to the freezer plant.

The objective of this project, begun in early 1972, has been to inform the fishermen of the market, advise them on catching methods, pot construction, transporting techniques and demonstrations. Concurrently with this, the evaluation of pots, traps and nets used in other eel fisheries is being conducted by project personnel. As a new device was found to be productive the information was passed on to the fishermen. The project director has made three television appearances explaining the program and several articles have been placed in the local newspapers.

In order to develop this activity, holding tank facilities have been established on the Neuse River at New Bern, N. C. Three 1,000 gallon concrete tanks have been set up and a water circulation system installed for the purpose of holding and purging eels.

The tanks are accessible by water and near the confluence of the Trent and Neuse Rivers, both good eeling grounds.

The following projection of potential income to the fishermen is considered to be realistic.

Number of Traps - 30		
Production Per 5 Day Week (40 lbs. per trap)		1,200 pounds
Income: $ .30 per pound x 1,200 pounds		$360.00
Less operating costs: bait and fuel		35.00
	Net	$325.00
Basic equipment cost (assuming the fisherman owns a boat) pots, line, etc.		$125.00

The above income can be realized with a full time operation which involves working the traps at six to eight hour intervals maximum.

As the demand for eel traps by fishermen wanting to get into eel fishing has increased,a very beneficial side effect developed. The project director contacted the local area workshop for handicapped/disadvantaged persons and suggested that they make and sell eel traps. The counselors were given instruction in trap building by this staff's personnel and a cost analysis was run - they have made and sold over 500 traps. There will be a continuing demand for traps and 1973 will show a significant increase.

Late in 1972 the applied research in pot/trap construction, fishing and holding techniques and live transporting was for all practical purposes completed. A very detailed report covering all phases of the harvesting and handling of eels is in preparation and will be ready for distribution in early 1973.

The level of interest in eel fishing remains high both with the fishermen and the broker/shipper. Requests for information are received regularly.

Several individuals and organizations are interested in the large scale development of the eel industry. A migrant labor project, East Carolina Industries, Fairfield, North Carolina is planning a freezer facility for the primary purpose of processing eels. The interest by State agencies, financial institutions and food brokers has been active. In December 1972, a meeting was held in Raleigh, North Carolina sponsored by the Marketing Division, North Carolina Department of Agriculture to discuss eels. The meeting was well attended by persons capable of assisting with the development of the eel industry.

This is an active and rewarding project; substantial input will continue to be required of this Advisory Services project over the next two years to continue development.

Project Gear and Equipment Shop - In the fall of 1971 a gear development and equipment maintenance shop was set up within a few blocks of the New Bern office. While not ostentatious and equipped for the most part with surplus Federal and State tools, it has been a valuable addition to the projects' facilities. At least 95% of all equipment development and fabrication work is accomplished there. A substantial savings in time, money and material has been and will continue to be realized.

Activities Involving Referral Services - Several requests for information and assistance with coastal engineering problems, ie., erosion and land damage due to the effects of Hurricane "Agnes" have been forwarded to the Department of Civil Engineering, North Carolina State University. Dr. Jerry Machemehl has responded to these requests and in all cases has provided the necessary information/assistance.

Numerous requests for assistance have been forwarded directly to his office as a result of the publicity given his activities by this project's staff personnel.

FORMATION OF CAPTAIN'S COUNCILS

Initial steps have been taken toward the formation of "Captain's Councils" to act as an advisory group to the Sea Grant Advisory Services Project, representing the northern, central and southern districts of North Carolina. The response for requests to serve has been excellent. It is felt that good representation of all segments of North Carolina's Marine Industries can be obtained. The intent here is to provide solid interface with the industry and maintain continuing two-way communications.

PUBLICATIONS AND PAPERS PRESENTED

Angel, N. B. 1972 - INSULATING ICE BUNKERS AND FISH HOLDS OF OLDER FISHING VESSELS,
University of North Carolina Sea Grant Engineering Advisory Service Program, Sea Grant Publication UNC-SG-72-05

Chleborowicz, A. G. 1972 - A DIRECT OIL FIRED HEAT EXCHANGER FOR THE THERMO SHOCKING TANK OF A SCALLOP SHUCKING MACHINE,
University of North Carolina Sea Grant Engineering Advisory Service Program, Sea Grant Publication UNC-SG-72-04

Chleborowicz, A. G. 1973 - ELECTRONIC SHRIMP TRAWLING-PRELIMINARY REPORT
University of North Carolina Sea Grant Engineering Advisory Service.

Angel, N. B. 1971 - THE DEVELOPMENT OF MARINE INDUSTRY HARVESTING AND PROCESSING SYSTEMS-ENGINEERING ADVISORY SERVICES
Presented at the -Workshop on Marine Activities of Coastal Plains Region Southeastern United States - December 17, 1971, Quail Roost Conference Center, Rougemont, North Carolina.

Angel, N. B. 1972 - THE SEA GRANT PROGRAM OF THE SCHOOL OF ENGINEERING North Carolina State University, presented at the Seminar for County Extension Agents - February 1972- Morehead City, North Carolina.

NOAA Form 90-2 (5-73)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 11-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to this page)

PROJECT NO.	PROJECT TITLE (If continuation)	☐ NEW ☒ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
A/EA-2	Development of Marine Industry Harvesting and Processing Systems - Seafood Science and Technology, Advisory Services		July, 1970
GRANT NO. (Previous) 2-35178			DATE OF THIS FORM May, 1973
INSTITUTION UNC			ESTIMATED COMPLETION DATE continuing

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
Frank B. Thomas, Dept. of Food Science, NCSU	30%	Neil B. Webb T.M. Miller	5% 66%

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (Give numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 38,159	$ 19,079	$ 23,427	$ 11,713	$	$	A/EA-1, R/SST-1, A/EP-1

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Advisory Services	Advisory Services/Extension Agent Prog.

OBJECTIVES:

OBJECTIVES:

The project is concerned with disseminating information obtained through applied research to improve the sanitation, quality, and efficiency of seafood handling at all stages from time of harvesting until finally used by the consumer. In some instances, the results of applied research are evaluated to determine feasibility under practical conditions. The advisory services are used as effectively as possible to interface with the human element in coastal North Carolina.

HOW INFORMATION WILL BE APPLIED:

Results and applications of information from this program are presented to the fisheries/seafood industries through personal contact of the Advisory Services personnel, newsletters, brochures, local and area meetings, conferences, short courses, mass media, i.e. press, radio and T.V. Trade Journal and Scholarly articles are prepared for the business and scientific community.

HOW INFORMATION WILL BE APPLIED (Be specific):

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

1. Prepared and distributed quarterly newsletter "Advisory Services Reporter" of 1,700+ copies per issue.
2. Radio, T.V. and press coverage of project and special programs brought before the N. C. audience arena.
3. Established Advisory Services Offices in coastal area for maximum interface with the public.
4. Direct assistance given seafood plants on expansion, planning, sanitation, pollution, quality control, etc. resulting in: (a) 16 new plants with an estimated value of $1.5 million created 285 new jobs. (b) 13 plant expansions have an estimated investment of over $750,000, adding 75 people to work. (d) work being pursued with proposed new seafood industries and facilities with a projected investment of $1.75 million and creating about 285 new jobs.

Project No.: A/EA-2

Title: Development of marine industries, harvesting and processing systems - seafood science and technology - advisory services

Principal Investigator: Frank B. Thomas, Dept. of Food Science, North Carolina State University

I. Introduction:

This report concerns project activities, results and accomplishments from July 1, 1971 to December 31, 1972. This advisory services project is aimed at supplying the varied requirements of a diversified fisheries oriented audience* and has provided the following services to users:

A. Expertise and the supporting technological information bearing on specific problems.

B. Suggestions and methods regarding the improvement of preservation, sanitation, and efficiency of handling seafoods at all stages from time of catch until consumed.

C. Demonstrating methods for improving quality of raw and processed forms, and assisting in developing new products derived from seafoods.

D. Evaluating applied research and assisting in determining feasibility under practical conditions.

E. Advising on general details of modifying and/or constructing new processing facilities.

F. Assisting in delineating the problems of disposal and/or utilization of seafood waste, making assessments of environmental impact of processing operations, and assisting in developing useful products from such wastes.

G. Working with some of the established fish farming operations in North Carolina, and examining the possibilities of producing useful fish farming rations from waste products.

H. Cooperating with various state agencies and educational institutions in connection with regulations applying to seafoods, marketing, consumer education, and assistance to students and researchers.

I. Developing the SEAFOOD LABORATORY at Morehead City as an arm of the Department of Food Science capable of interfacing with the coastal audience on all aspects of this project.

II. Audience:

*Diversified fisheries oriented audience refers to groups of people who in one way or another are directly concerned with N. C. fisheries, including:

A. Fishermen - Example: Helping them derive higher return on the catch as the result of improved sanitation and preservation.

B. Handlers of Seafoods in the Round - Example: Dealers with shore establishments who are interested in improving all practices which relate to obtaining longer shelf life and quality maintenance of seafoods shipped in ice.

C. Basic Processors - Example: Those who need advice and the carrying out of practical demonstrations aimed at arriving at installations which can qualify as sanitary food handling establishments, operating with improved efficiency, selecting and applying most suitable freezing methods, or correct preservation in ice.

D. Further Processors - Example: Those needing assistance in meeting the stringent food handling requirements involved in preparing convenience foods or requiring help in developing new products.

E. Handlers through Marketing Channels - Example: Those who are interested in preserving and properly distributing seafoods and who wish to consider methodology in correctly shipping via various transportation methods.

F. Operators of Public Feeding Establishments - Example: Those concerned with the latest methods of preparing seafoods for use in restaurants, school lunch programs, and in other institutions.

G. Fish Farmers - Example: Providing information and working with those engaged in raising freshwater and marine species.

H. Tourists and Ultimate Consumers - Example: Advising sports fishermen on proper preservation of catch, providing answers on many technical matters relating to preparation, nutritional aspects, and best approaches to economical use of seafoods.

III. Personnel:

The resignation of Mr. Stephen J. Stokes, Extension Specialist at the Morehead City location was accepted, effective June 30, 1972. Mr. T. M. Miller, Director, Marine Chemurgics, Inc., was retained on a part-time basis to participate in the programs during summer 1972. He was then employed full time, effective September 1, 1972 (Food Science Extension Specialist; 66% Extension, 34% research - Seafoods).

Personnel involved in the project are:

1 Extension Food Science Specialist (Seafoods)	- 30%*
1 Extension Food Science Specialist (Seafoods)	- 66%
1 Extension Food Science Specialist (Engineering)	- 25%*
1 Field Agent and Lab. Technician	- 100%
2 Laboratory Assistants (Students)	- Part Time
1 Laboratory Assistant, Sea Duty	- Part Time
1 Secretary	- 30%*

*Not Funded by Sea Grant

IV. Project Activities and Results:

A. Providing Expertise and Technological Information:

This objective has been concerned with supplying the varied audience with information and answers derived from other phases of the project, or from background knowledge and acquired expertise. Examples are as follow:

1. Mass Media: Quarterly distribution of 1,700 copies of Newsletter; radio and ETV Shorts; "Timely Tips" sent to smaller groups in reference to urgent problems of technical nature.

2. Nuclear Power Plant: Discussions regarding mariculture potential and other possible uses of heated water.

3. Program Development: Assisting in developing details of proposed "Fishery Agent" position for Carteret County at the request of the County Extension Chairman and Carteret County Commissioners. This job will be primarily concerned with independent, small fishermen.

Northeastern N. C. Area Seafood Extension Specialist: Based on the needs of the area and the Albemarle Area Development Association Resolution of 7/13/72 in which a seafood extension specialist was requested.

4. Advisory Groups: As a first step in establishing a number of groups who will work with the project on a volunteer basis, with the support of Mrs. Floy Garner, Home Economics Extension Agent, established a Nutrition Leaders Committee to work monthly in the Seafood Laboratory on assigned problems.

5. Miscellaneous Inquiries: Hundreds of requests for information and assistance, from industry, schools, students, etc., were routinely handled by the staff in Raleigh and in Morehead City.

6. Pamphlets in Preparation: "Smoking of Fishery Products" will be issued after further work is completed on a prototype, improved smoker for fabrication at home. "Preserving the Sports Fisherman's Catch" will be drafted after the proposed methodology is evaluated.

7. Publications:

a). Educational T.V. training program for School Lunch Supervisors on Seafoods. February and October 1972. A 30-minute "documentary-type" presentation directed to the 100 counties of N. C. and including: (1) Good Manufacturing Practices, Grades, Standards and Specifications; (2) Some aspects of quality control; (3) What, When, Where and Why to use seafoods; (4) Some ideas on new product development and (5) Commentary on safety in seafoods.

b). Retail Handling of Fish. June 1972, Extension Folder No. 303

B. Improving the Preservation, Sanitation and Efficiency of Handling Seafoods in North Carolina:

1. Finfish: Frequent visits were made to shore handling facilities to examine condition of the catch, glut situations, methods of sorting, rapidity of handling to avoid damaging temperature conditions, amount of ice applied, and other details which bear on shelf life en route to customers.

Devised a method of improving handling of sports fisherman's catch by use of insulated container, flake ice, and ice cream salt to attain eutectic combinations capable of super-chilling and adding several days to shelf life.

2. Handling Uncooked Crabs: Investigated problems of keeping crabs alive and actual state-of-the-art in terms of deliveries to crab meat picking plants.

3. Lobsters and Other Off-Shore Species: As part of the N. C. Dept. of Natural and Economic Resources lobster exploratory project, previous off-shore exploratory data were analyzed; lobsters, red crabs, Jonah crabs and other potential commercial species were studied.

C. Improving the Quality of Raw and Processed Forms (New Projects):

1. Finfish: Investigated results obtained with mechanical, nitrogen, and carbon dioxide methods of freezing dressed fish and fish fillets. Also, checked various methods of protecting such products from oxidative rancidity and freezer burn. Initiated a program of investigating and evaluating methods of packaging for consumers and institutions.

2. Crabs: Dr. Thomas assisted in the formulation of the proposed "Manual of Good Manufacturing Practices for the Sanitary Control of Blue Crab Meat Production, 1971" (Tri-State Seafood Committee, 12/15/71). Drs. Webb and Thomas, and Mr. Miller prepared the draft of "Quality Control and Operating Manual for the Blue Crab Industry," October, 1972.

Sanitary studies involving bacteriological tests and other criteria were initiated in crab plants as a means of demonstrating contamination vectors.

3. Calico and Bay Scallops: "Quality Control and Operating Manual for the Scallop Industry," issued by Food Science Advisory Services (Sea Grant) in March, 1971 by Drs. Webb and Thomas, was used to provide guidelines in checking the operation of such plants. Other publications by Webb and Thomas concerned with "Influence of Mechanical Processing on the Quality and Yield of Bay Scallop Meats " provided background for continuing studies concerned with sanitation, amount of water in the product, effect of seasonal changes, and other important factors bearing upon product quality.

D. Evaluating Applied Research and Determining Feasibility:

1. Deboning Equipment: Demonstrated the use of equipment applied to the removal of high protein meats from small dressed fish, crab legs, and shrimp heads.

2. Calico and Bay Scallops: Investigated salt-ice mixtures as a means of rapidly chilling scallop meats prior to refrigeration in one gallon cans. Applied resazurin dye test and bacteriological evaluations as measures of scallop meat quality.

3. Clams: Worked out methods of preparing and packaging several forms of hard clam concentrates for convenient use in chowders.

E. Modified or New Processing Facilities:

1. Freezing and Frozen Storage Facilities: For purposes of estimating the actual increase in cooling and freezing capabilities, a survey of all refrigeration capabilities applied to seafoods in Carteret County was initiated. Began gathering economic details and performance characteristics of various freezing methods (i.e., carbon dioxide, nitrogen, Freon, and mechanical). Prepared sketches of facilities which have installed or plan to install freezing and storage capabilities.

2. Crabs: Visited and worked with six crab meat plants in connection with new buildings or remodeling of old ones. The details of how such plants comply with proposed sanitary guidelines were presented.

3. Calico and Bay Scallop Mechanical Shucking: During the period covered by this report, work was conducted in connection with six new plants.

F. Waste Disposal and Utilization:

1. Finfish, Crabs, Shrimp and Scallops: Composition of the waste materials was determined. Preliminary data on various effluents was collected.

2. Fish, Crab and Shrimp Meals: Advised in connection with several reduction plants, suggested collection of a wider range of raw materials, and proposed modification of the plants for bulk handling of waste materials.

3. Shrimp Heads and Scallop Mantle: Food products for human consumption were prepared. These included flavor extracts and edible meats normally going overboard along with the entrails in the mechanical shucking of scallops.

G. Fish Farming:

1. Catfish: Collected extensive background information in view of requests regarding the feeding of fishery waste materials to this and other species.

2. Aquaculture Committee: Dr. Thomas served as Chairman and Mr. Miller as a member of this on-campus committee.

H. Interagency Cooperation:

Staff members are in close contact with federal and state agencies. As examples, not by way of limitation, the work on water content and seasonal changes in scallops involves collaboration with UNC-CH Institute of Marine Sciences; commercial development of additional species is in cooperation with R/D Division, N. C. Commercial and Sports Fisheries; some aspects of the crab sanitation studies involve frequent discussions with the Shellfish Sanitation, N. C. Health Department and consultation and coordination with the N. C. Seafood Marketing Program in the Department of Natural and Economic Resources.

I. Seafood Laboratory:

This coastal facility, which is still located in temporary quarters at Ocean, N. C., but due to move into the N. C. Commercial and Sports Fisheries Building in Morehead City, operated as an integral part of the studies described above.

The collection of furniture, equipment, and publications, while still in the temporary quarters, assured that a smooth transfer to the new 3000 sq. foot facility would be accomplished in March, 1973. Capabilities embodied in the Seafood Laboratory include: advisory offices for discussing problems with small groups and for the holding of large meetings; a very extensive information center for quick reference to technological information and for the use of laboratory personnel and students; a large R/D laboratory for working on seafood products with analytical capabilities including composition studies and water quality determinations; bacteriology laboratory and pilot plant equipped with walk-in freezer and cooler.

V. Accomplishments:

The rapid expansion of the project into diverse areas of fishing/seafood technology is the result of demands from industry itself as well as various consumer groups. The vast prior experience of the program personnel has enabled them to deal effectively with these problems. Neither this project, nor any other group, can take full credit for the recent, rapid development of the industry; but at the same time, there can be no doubt of the impact of what has been done, or the value of assistance rendered.

A 1972 survey indicates seafood plant expansion in North Carolina resulted in 16 new plants, valued at about $1.5 million, creating 285 new jobs. Installation of new equipment amounted to $500,000, creating 36 new jobs; new seafood industries were valued at $1.75 million, creating 285 new jobs. It is estimated that processed forms of seafoods increased from 15% of the catch to 30% of the catch.

Comparing the 1970 vs. 1972 list of licensed N. C. dealers involved in the following activities also indicates expansion in most categories:

Crab Processors increased from 24 to 32
Crab Handlers, Unprocessed, increased from 98 to 113
Shrimp Dealers increased from 185 to 208
Fish Dealers increased from 311 to 349
Shellfish Shippers increased from 195 to 212
Shellfish Shucker-Packers dropped from 52 to 51

Expansion activities can also be judged by considering some 34 clientele engaged in handling finfish, crabs and scallops. Recently constructed facilities totalled 21,915 sq. feet while those under construction totalled 16,100 sq. ft. Planned construction amounted to an additional 12,000 sq. ft. As to new freezer capacity, that which was recently constructed amounted to 13,184 cubic feet, that under construction was 16,384 cubic feet, and planned freezer capacity amounted to 42,688 cubic feet. Chill rooms, recently constructed totalled 33,216 cubic feet, under construction 21,328 cubic feet and planned 2,688 cubic feet.

NOAA FORM 90-2 (5-71) U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 41-R2600

SEA GRANT PROJECT SUMMARY
(Limit all information to the space provided)

PROJECT NO.	PROJECT TITLE [ ] NEW [X] CONTINUING [ ] CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
A/EP-1	Continuing Education Program for Commercial Fishermen	July, 1970
GRANT NO. (previous) 2-35178	SUB-TITLE (if different)	DATE OF THIS FORM May, 1973
INSTITUTION UNC		ESTIMATED COMPLETION DATE Continuing

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
James A. McGee, Div. of Continuing Educ., ECU	50%		

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (By numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	A/EA-1, A/EA-2 R/SST-1
$ 60,019	$ 30,008	$ 50,363	$ 25,180	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Advisory Services	Advisory Services/Extension Programs

OBJECTIVES:

OBJECTIVES:

1. To provide an intensive training program for commercial fishermen.
2. To introduce the latest equipment and techniques to commercial fishermen served by this program.
3. To encourage the development of cooperatives among the fishermen.
4. To improve the economic status of fishermen served.
5. To provide participants with current data on harvesting, conservation, preservation, and marketing.
6. To develop a marine advisory program that will expand from commercial fisheries into all aspects of development of North Carolina's marine resources.

HOW INFORMATION WILL BE APPLIED:

The information from this project will be applied directly and individually to the commercial fishermen and other users of the marine resources of this region. This will be accomplished on both an individual and a group basis by the personal efforts of sea agents through direct contact, group meetings, seminars, brochures, pamphlets, and news media.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

1. One cooperative marketing association of 200 members was formed.
2. Instruction in cooperative marketing & basic economics was provided to 60 groups of fishermen & several hundred individual fishermen.
3. Key people from State & Federal agencies and the fishing industry were brought into the target area to provide counsel to the fishermen and to gain insight into the needs of the area.
4. Information on financial assistance programs, mariculture, fishery technology, and management regulations was disseminated.
5. Close contact was maintained with the fishermen by the Sea Agent.
6. New equipment introduced: power gill net reel, new gill nets, lead core lines, float lines.
7. Assistance was provided the fishermen in participating in conferences and public gatherings relating to the fishing industry.
8. Assistance was given in conducting a feasibility study of the marketing Association and in development proposals for funding grants and loans.
9. Mobile library materials and vehicle placed on order.

Project No.: A/EP-1

Title: Continuing Education Program for Commercial Fishermen

Principal Investigator: James A. McGee, Division of Continuing Education, East Carolina University, Greenville, N.C.

During the period of July 1, 1971 through December 31, 1972, the continuing education program for commercial fishermen directed its effort toward three major target goals: Improvement of Marketing, Optimizing Fishing Effort, and Expanding Fisheries Options. Although considerable interest in marketing improvement is shown among fishermen in the central portion of the coast, the concentrated effort has been in the northeast or Albermarle region. The major part of the project effort in marketing improvement has been in the form of direct and indirect assistance to the Sound and Sea Fishermen's Association, Inc., and its membership of two hundred fishermen. Activities have included various workshops and study sessions with the Board of Directors, members, and other interested fishermen, on organization, financing, staffing and operation of a cooperative marketing business. The Project Director and the Sea Agent worked with the individual fishermen and the Association in training them in principles of management. Officials from the Columbia Bank for Cooperatives,N. C. Rural Fund for Development, and National Marine Fisheries Service also assisted in this effort.

Extensive surveys of the landings of the Association's membership were made. Assistance was secured from Dr. Fred L. Olson and Dr. Jack E. Greenfield, National Marine Fisheries Service. With the assistance of Drs. Olson and Greenfield, the Association's potential was assessed. This analysis was used as a basis of several planning and counselling sessions and workshops. These activities were conducted to assist in the development of a prospectus. Assistance in accounting practices, legal affairs, and business management was provided by a lawyer and a certified public accountant in addition to the two marine economists provided by the National Marine Fisheries Service. These resource persons were carried throughout the Albermarle region on several occasions where they met with individuals and groups of fishermen. These activities resulted in a proposed business operation for the Association showing suggested operating procedures, staffing, cash flow, and a proforma budget.

Other activities in economic affairs involved assisting the Association in the preparation of proposals for funding by agencies whose stated objectives are to assist in the economic development of particular regions of the United States. The agencies to which the Association applied are the Economic Development Administration, Coastal Plains Regional Commission, and North Carolina Rural Fund for Development (O.E.O.). The project assisted in the preparation of the proposals, brought officials from these agencies to meet with groups of fishermen, and provided travel for representative fishermen to visit officials of these agencies in Greenville, North Carolina, Raleigh, North Carolina, Atlanta, Georgia, and Washington, D.C. Key fishermen were provided travel to participate with the Sea Agent and Project Director in a workshop on cooperatives sponsored by the University of Rhode Island.

The economic condition of each individual fisherman is of vital concern to the project. The Sea Agent was available on an almost daily basis, either

by telephone or by personal visit. A telephone was installed in the home of the Sea Agent, and the number was distributed among several hundred fishermen. This telephone enables the fishermen to be able to reach the Sea Agent to make inquires of equipment or suppliers, financial assistance, meetings of fishermen, State and Federal regulatory agencies, etc. This phone is proving to be a very valuable phase of the project. Its use is becoming increasingly frequent.

In the area of optimizing fishing effort, the project has initiated several activities that would have considerable impact. The largest activity in this regard is the introduction of a hydraulic powered gill net reel to be rigged with various kinds of gill net to adapt to different species of fish that are commonly caught along the North Carolina coast and in the sounds. This particular project has seen the acquisition of the necessary netting, lines, floats, hydraulic reel and accessories, and agreements with different fishermen to rig the equipment and adapt it to their boats. When the various species of fish for which the equipment is rigged appear, arrangements will be made with different fishermen in different locations to demonstrate the equipment to other fishermen and evaluate the equipment and its value to their fisheries. Operating agreements with key fishermen are to be negotiated, and the equipment will be installed for operation during the next several months. An unusually long lead time is required in securing fishing nets and equipment. This is even more so when procuring equipment that is not common in the area. Therefore, the reel will be in full operation and demonstration will be for a minimum of one year. A great deal of interest has been shown by a large number of fishermen. Target areas are near shore and throughout the Pamlico and Albermarle Sounds.

Various other types of equipment will be demonstrated in conjunction with the powered gill net reel, particularly various types of net to harvest different species of fish and electronic gear, such as portable fishfinders, to maximize fishing effort. Important advances are anticipated in that this type equipment appears to be particularly well suited for the family size fishing operation that characterizes so much of the Albermarle fisheries. The efficiency of operating this type equipment should have a larger impact on quality control due to the ease with which nets can be set and retrieved, allowing for larger areas to be fished while at the same time retrieving the fish quickly and in prime condition.

Demonstration and evaluation of several different types of gill nets were made during the past six months and are still in progress. Several cooperating fishermen have either used the nets or are scheduled to do so. Results of these nets while being used in a variety of areas for a variety of species will be compared with results of more convential nets used in the same areas for the same species. Associated with the gill nets were new types of lead core lines and cork filled lines. These, too, were included in the evaluations. Their effectiveness will be concluded and will become part of the information to be disseminated. The handling, catching, and wearing qualities of the nets will be compared with the older types now used by the fishermen.

Vinyl coated wire for crab pots has been the object of some project effort. Investigations were made of manufacturers and distributors of this project.

Information has been referred to the fishermen and other concerns manufacturing crab pots. One small cooperative program, East Carolina Industries, used information supplied by our project to introduce the vinyl coated crab pot along with their convential pots. Our project will continue its role of information dissemination about this material and will carry through a demonstration of the pots as planned. Materials have been ordered and cooperating fishermen have been found to build a variety of designs and evaluate their effectiveness and resistance to corrosion.

Preparations were made for a mobile library to become operational early in 1973. Books and technical manuals, periodical literature, and general information from State and Federal agencies concerning management, conservation, regulatory statutes and enforcement, financial assistance, and a variety of subjects were gathered. Fishermen and other interested people will be able to get information on such subjects as boat design and construction, net repair, engine maintenance, navigation, electronic gear, marlinespike seamanship, and boating safety. Other subjects include aquaculture, national Sea Grant activities and publications, marine science, marketing information and statistics, along with directories of resource persons and agencies. The mobile library will be scheduled to make materials available on a regular basis.

In the area of expanding fisheries options, a major effort was begun to encourage clam culture. Areas that were productive at one time but have been upset or overfished have caused an important source of income to be lost or greatly reduced. Seed clams (50,000) of one centimeter size were provided cooperating fishermen. The seed clams were planted in selected areas and are being monitored. Their growth is being recorded. Materials were provided to fence out crabs and other predators. The effectiveness of screening against predators will be determined. The overall objective will be to determine the economic feasibility of clam culture as a fishery option.

Another option in fisheries being explored is that of harvesting freshwater clams as chum bait for party boat fishermen. Several fishermen were interviewed to determine interest, and several areas were sampled to determine the supply of clams for this purpose. A high level of interest was expressed by several fishermen, and samples taken indicate an abundant supply of clams. The Sea Agent visited the sports fishing fleet in Maryland, where this practice is common, and was assured of a potential for North Carolina Fishermen.

Efforts toward further professional development in extension work were made by both the Project director and Sea Agent. A two-week Marine Extension Workshop, Oregon State University, was attended by the Project Director. The Sea Agent attended the Fish Expo 1972 in Seattle, Washington. Various other conferences on marine science, coastal zone management, and fisheries were attended. The project director serves on an advisory council for seafood market development, also as a participant on the Research Education and Development Committee of the North Carolina Marine Science Council.

The 1972 North Carolina Sea Grant conference on seafood harvesting, processing and marketing was sponsored jointly by East Carolina University and North Carolina State University. Various programs on the conference topic were prepared and presented to fishermen, processors, brokers, State and Federal agency representatives, and representatives from other participating institutions.

The importance of being available to the people for whom the program is designed has been a cardinal principle in all this project's activities. The Sea Agent and Project Director spent countless hours, including nights and weekends, in direct contact with the fishermen or participation in a series of town hall meetings throughout the Albermarle region. Meetings were conducted on a regular basis. Another method of communication used is a brief and informal "Net Notes" sent periodically to participating fishermen and other interested individuals. The mailing list includes approximately three hundred names.

A publication on the menhaden fishing industry in North Carolina was sponsored by the project.

Any statement of progress must include the rapport established with the fishermen and the genuine reception given the project. The interest shown by the fishermen in the project activities are strong indicators of the need for a marine advisory service which this project is attempting to provide.

NOAA FORM 90-2 (5-71) U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED
DECEMBER 31, 1972
OMB NO. 11-R2600

SEA GRANT PROJECT SUMMARY

(Limit all information to this page)

PROJECT NO.	PROJECT TITLE [ ] NEW [X] CONTINUING [ ] CHECK IF SEPARATE PROJECT GRANT	DATE INITIATED, IF CONTINUING
A/P-1	Updated "Survey of Marine Fisheries"	July, 1970
GRANT NO. (assigned)		DATE OF THIS FORM
2-35178	SHORT TITLE (if different)	May, 1973
INSTITUTION		ESTIMATED COMPLETION DATE
UNC		December, 1973

PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION	% TIME	ASSOCIATE INVESTIGATOR	% TIME
A. F. Chestnut, Inst. of Marine Sciences, UNC-CH	40%	Staff	10%

FUNDS EXPENDED TO DATE		LAST YEARS FUNDING		PROPOSED FUNDING		RELATED PROJECTS (By numbers)
FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	FED.-SEA GRANT	MATCHING	
$ 16,300	$ 8,150	$10,500	$ 5,250	$	$	

PART OF UNIVERSITY PROGRAM	OFFICE OF SEA GRANT CLASSIFICATION
Advisory Services	Advisory Services / Publications

OBJECTIVES:

OBJECTIVES:

The objective of the project is to prepare a synopsis of the marine fisheries of North Carolina and related aspects. Descriptive portions of species of commercial value, of potential value, and others of common occurrence will provide information for those interested in commercial aspects. Related material will comprise physical description of area, statistical information, descriptive accounts of equipment and the variety of gear used in specific fisheries.

HOW INFORMATION WILL BE APPLIED:

Commercial fishermen, dealers, processors of seafood products are interested in having ready reference materials available for their use. Industrial and public propects continue to seek specific information of the type which is to be included in the "Survey." Administrators and members of the legislature concerned with coastal resource management and development, and teachers and students studying coastal problems are wide users of such information.

ACCOMPLISHMENTS DURING PAST EIGHTEEN MONTHS:

Statistical information has been compiled to date, from 1880 to 1972. An addendum to hydrographic atlas of North Carolina Sounds (UNC-SG-73-02) is ready for publication. A handbook of common seashore forms is in preparation, as a companion volume to Sea Shells (UNC-SG-72-09) and Fishes of North Carolina (UNC-SG-72-08).

Project: A/P-1

Title: Updated- "Survey of Marine Fisheries of North Carolina"

Principal Investigator: A. F. Chestnut , Institute of Marine Sciences, University of North Carolina, Morehead City, N.C.

Updating the synopsis of marine fisheries resources of North Carolina, with related information centered on the estuaries and near-shore ocean, has been in progress. This synopsis will appear as a series of publications presenting information on varied aspects of the fisheries resources. These publications will provide ready references to current information on geographical distribution, important commercial species, hydrographic information, statistical information, and recent developments as well as focusing attention on existing potentials.

Two handbooks - "Marine Fishes Common to North Carolina" and "Sea Shells Common to North Carolina" have been prepared with assistance from this project. These were originally published in cooperation with the N. C. Dept. of Natural and Economic Resources and have had wide use and reception necessitating at least three printings. A third handbook - "Sea Shore Forms Common to North Carolina" is in preparation as a companion volume. These booklets provide ready reference for commercial fishermen in identification of the varied forms of marine life they encounter in their operations and hopefully will be of value in relating abundance of specific commercial species to other forms as indicator species. Wide use is made of these publications by students and professionals with active interests in marine fisheries.

"A Hydrographic Atlas of Larger North Carolina Sounds" was reprinted during the year providing a summary of salinity-temperature data for coastal North Carolina. A series of 48 figures depict mean monthly surface and bottom isohalines and isotherms for Albermarle, Croatan, Pamlico, Core and Bogue Sounds. This atlas presents a digest of hydrographic data collected by personnel of the Institute of Marine Sciences from June, 1948 to June, 1966. An addendum to this atlas has been prepared containing similar information for the recent year of 1971-72 and is to be published in the near future.

Statistical information on the fisheries of North Carolina has been compiled for the period 1880 to 1969 from official federal publications. Preliminary data are included through 1972. This information , contained in more than forty-five separate publications many of which are not readily available and are difficult to obtain, presents a time consuming effort for a person seeking such information on his own. Such statistics are necessary and needed, and an attempt has been made to present an accurate and complete reference to such information.

Descriptive portions of important and valuable commercial species harvested in North Carolina are in preparation and will be published as a separate volume on "Living Coastal Resources and their Utilization in North Carolina."

University of North Carolina Sea Grant Publications*

UNC-SG-72-01. Lyman, J. and W. Rickards. University of North Carolina Sea Grant Program, Annual Report, 1 July 1970 - 30 June 1971.

UNC-SG-72-02. Wurfel, S. W., ed. Attitudes regarding a law of the sea convention to establish an international seabed regime.

UNC-SG-72-03. Upchurch, J. B. Sedimentary phosphorus in the Pamlico estuary of North Carolina.

UNC-SG-72-04. Chleborowicz, A. G. Direct oil fired heat exchanger for a scallop shucking machine.

UNC-SG-72-05. Angel, N. B. Insulation of ice bunkers and fish holds in older fishing vessels.

UNC-SG-72-06. Edzwald, J. K. Coagulation in estuaries.

UNC-SG-72-07. University of North Carolina. Proposal for institutional Sea Grant support.

UNC-SG-72-08. Schwartz, F. J. and J. Tyler. Marine fishes common to North Carolina.

UNC-SG-72-09. Porter, H. J. and J. Tyler. Sea shells common to North Carolina.

UNC-SG-72-10. Woodhouse, W. W., E. D. Seneca, and S. W. Broome. Marsh building with dredge spoil in North Carolina.

UNC-SG-72-11. Copeland, B. J. Nutrients in Neuse River and Albemarle Sound estuaries, North Carolina: survey. (in preperation).

UNC-SG-72-12. Whitehurst, J. H. The menhaden fishing industry of North Carolina.

UNC-SG-72-13. Schoenbaum, T. J. Public rights and coastal zone management.

UNC-SG-72-14. Tung, C. C. and N. E. Huang. Some statistical properties of wave-current force on objects.

UNC-SG-72-15. Tung, C. C. and N. E. Huang. Wave-current force spectra.

UNC-SG-73-01. Wurfel, S. W. The surge of sea law.

UNC-SG-73-02. Williams, A. B., G. S. Posner, W. J. Woods, and E. E. Deubler, Jr. A hydrographic atlas of larger North Carolina sounds.

UNC-SG-73-03. Gerhardt, R. R., J. C. Dukes, J. M. Falter, and R. C. Axtell. Public opinion on insect pest management in coastal North Carolina.

UNC-SG-73-04. Rickards, W. L. A bibliography of artificial reefs and other man-made fish attractants.

UNC-SG-73-05. Tyler, J., M. McKenzie, and D. King. To catch a million fish.

UNC-SG-73-06. Graetz, K. Seacoast plants of the Carolinas for conservation and beautification.

UNC-SG-73-07. Campbell, P. Studies of brackish water phytoplankton.

UNC-SG-73-08. Samet, J. H. and R. L. Fuerst. The Latin American approach to the law of the sea.

UNC-SG-73-09. Rhyne, C. F. Field and ecological studies of the systematics and ecology of Ulva curvata and Ulva rotundata.

UNC-SG-73-10. Kuenzler, E. J., A. F. Chestnut and C. M. Weiss. The structure and functioning of brackish water ecosystems receiving treated sewage effluent III, 1971-1972.

UNC-SG-73-11. Dahle, E. The continental shelf lands of the United States: mineral resources and the laws affecting their development, exploitation and investment potential.

UNC-SG-73-12. Schwartz, F. J. and A. F. Chestnut. Hydrographic atlas of North Carolina estuarine and sound waters, 1972.

UNC-SG-73-13. Lyman, J. and W. Rickards. University of North Carolina Sea Grant Program, Annual Report, 1 July 1971 - 31 December 1972.

*Available from: Sea Grant Program, 1235 Burlington Laboratories, North Carolina State University, Raleigh, North Carolina 27607.