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Coastal Research Center
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Report of the Period January 1982 - April 1984

Compiled and edited by Bruce W. Tripp

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Technical Report
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Approved for Distribution:

William D. Grant

William D. Grant, Acting Director
March - July 1984

FORWARD

The logo of the Coastal Research Center depicting the coastal research vessel "Asterias" superimposed on the deep sea research vessel "Atlantis" is particularly appropriate.

"Asterias" was the Woods Hole Oceanographic Institution's first research vessel, delivered in June of 1931 and preceding the arrival of "Atlantis" by several months. From that date to the present "Asterias" and her successor of the same name have been a part of the Oceanographic's continuing commitment to coastal research.

"Atlantis" has always represented the Oceanographic and in this case represents the depth of support of the many scientific disciplines incorporated within the Institution and available to the Coastal Research Center.

A. D. Colburn

PREFACE

This report describes the major activities of the Coastal Research Center over a 28 month period up to April of 1984. This period is a particularly important stage in the development of the Coastal Research Center where concrete progress has been made on implementing many of the ideas and plans which accompanied the initial concept of the Center. This period also represents an important milestone for the next several years because the major projects reported here will be completed and new projects will be initiated.

The success of the Center is due to the enthusiasm and efforts of scientists involved in Coastal Research at W.H.O.I., the inspiration given by visitors, the support of the W.H.O.I. administration and the generous support of several donors and foundations. We greatly appreciate the efforts of all.

Dr. John W. Farrington
Senior Scientist
and
Director, Coastal Research Center

INTRODUCTION

The Coastal Research Center (C.R.C.) of the Woods Hole Oceanographic Institution was established in late 1979 to meet several research needs identified during a series of staff seminars and discussions in 1978 and 1979. These needs include:

- improved communication of research results between disciplines,
- more formal multidisciplinary interactions in order to effectively tackle some key coastal research problems,
- facilities for experimentation, and
- unrestricted funds to initiate new, multidisciplinary research ventures or to act as the "glue" binding together ongoing coastal research projects.

Coastal research at Woods Hole Oceanographic Institution has always been an integral and important part of ocean sciences and engineering. Early research of the Institution focused on the Gulf of Maine and Georges Bank, although this quickly expanded into all areas and depths of the world's oceans. With only a few organizations pursuing open ocean, deep sea research, the Institution's efforts are popularly identified as oriented toward the open ocean.

The establishment of the Coastal Research Center was not intended to counteract this perception, but to better serve the continuing coastal research efforts which have always been a major part of the Institution's activities. These efforts are characterized by Dr. Henry Bigelow's early work on Georges Bank. A further example which serves to illustrate this commitment is the co-sponsorship, with The Institute for Ecology, of the Workshop on Critical Problems of the Coastal Zone in Woods Hole, Massachusetts 22 May-3 June

1972 under the guidance and leadership of the late Dr. Bostwick H. Ketchum. The conference and its proceedings, The Water's Edge: Critical Problems of the Coastal Zone (MIT Press, 1972) are widely credited with maintaining the momentum and focusing the direction for present national coastal management policy, as well as research efforts. The working definition of the coastal zone which evolved from that pioneering meeting is still valid and is used to guide the Coastal Research Center's sphere of activities:

"The coastal zone is the band of dry land and adjacent ocean space (water and submerged land) in which land ecology and use directly affect ocean space ecology, and vice versa. The coastal zone is a band of variable width which borders the continents, the inland seas, and the Great Lakes. Functionally, it is the broad interface between land and water where production, consumption, and exchange processes occur at high rates of intensity. Ecologically, it is an area of dynamic biogeochemical activity but with limited capacity for supporting various forms of human use. Geographically, the landward boundary of the coastal zone is necessarily vague. The oceans may affect climate far inland from the sea. Ocean salt penetrates estuaries to various extents, depending largely upon geometry of the estuary and river flow, and the ocean tides may extend even farther upstream than the salt penetration. Pollutants added even to the freshwater part of a river ultimately reach the sea after passing through the estuary.

"The seaward boundary is easier to define scientifically, but it has been the cause of extensive political argument and disagreement. Coastal waters differ chemically from those of the open sea, even in areas where man's impact is minimal. Generally, the coastal water can be identified at least to the edge of the Continental Shelf (depth of about 200 meters), but the influence of major rivers may extend many miles beyond this boundary. For the purposes of the Coastal Zone Workshop, the seaward boundary has been defined as the extent to which man's landbased activities have a measurable influence on the chemistry of the water or on the ecology of marine life."

Today, coastal researchers recognize that there are important interactions between the open ocean and the coastal ocean which influence the biology, chemistry, geology and physics of each. These interactive processes are seen

in such phenomena as upwelling, interaction of eddies with the shelf edge, transport of sediments onto the continental slope and rise and into canyons and interactions of tides with the shelf slope and break. Thus, the seaward boundary also becomes more vague as we learn more about the coastal ocean. This merging of open ocean and coastal ocean phenomena is reflected in the philosophy and projects active within the Coastal Research Center.

We also continue to ascribe to the views of the importance of the environment set forth by Ketchum and co-workers:

"The coastal environment constitutes a complex ecosystem that is an important and unique resource of our nation and that must be maintained for the benefit and use of mankind. . . . A balance of use, conservation, and preservation of the coastal zone should be maintained so as to optimize man's use of coastal resources through the long term future, which requires that the natural environmental processes on which most of the long term continuing uses depend must also be maintained."

The objective of the Coastal Research Center of the Woods Hole Oceanographic Institution is to conduct research, contributing to an ever-expanding base of knowledge and improved understanding of the coastal ocean, its physics, chemistry, biology and geology. This improved understanding will also provide a basis for wise management of coastal resources. Our strategy for accomplishing this objective is to encourage the interaction of multidisciplinary groups of scientists at the Institution, and also to support multiorganizational (industry, government, academic) and multinational efforts as appropriate. The C.R.C. seeks to aid individual researchers of coastal problems by providing intellectual forums that encourage communication, research facilities and services. We have been, and intend to continue to be, active at the science-policy and management interface.

Coastal Research Center Organization

Research within the Center is carried out by scientists, staff and students from the five scientific departments of the Institution (Physical Oceanography, Geology and Geophysics, Biology, Chemistry, and Ocean Engineering) and by Guest Investigators. They are active in Center activities for varying periods of time, as the Center has no permanent scientific staff except the Center Director. Technical staff, research assistants, and administrative personnel are assigned to the Center for periods of time as needed for specific projects. The Center serves as a home for visiting scientists and post-doctoral investigators who are invited to the Institution to participate in specific research projects.

An Advisory Committee with representation from each of the departments and from the Marine Policy and Ocean Management Center provides advice for the Center Director in areas of research projects, budgets, and experimental facilities. The Advisory Committee membership is as follows:

William D. Grant, Associate Scientist (Advisory Committee Chairman)
Ocean Engineering Department

David G. Aubrey, Associate Scientist, Geology and Geophysics Department

Robert C. Beardsley, Senior Scientist, Physical Oceanography Department

Judith M. Capuzzo, Associate Scientist, Biology Department

David A. Ross, Senior Scientist, Geology and Geophysics Department;

Director, Marine Policy and Ocean Management Program; and Director,
Sea Grant

Edward R. Sholkovitz, Associate Scientist, Chemistry Department

Maynard Silva, Research Specialist, Marine Policy and Ocean

Management Program

Dr. John W. Farrington, Center Director, is responsible for Coastal Research Center activities and reports to Drs. John H. Steele, Director, W.H.O.I. and Derek W. Spencer, Associate Director for Research at W.H.O.I. Experimental

facilities construction and operation are coordinated with other Institution activities via Dr. George D. Grice, Associate Director for Scientific Operations. Assistance for the operation of the Coastal Research Center is supplied by Susan Kadar, Bruce W. Tripp and C. Hovey Clifford.

SUMMARY OF COASTAL RESEARCH CENTER PROJECTS

The original Planning Committee met several times during 1980 to establish strategies and priorities for the initial activities of the Center. Generous grants from The Andrew W. Mellon Foundation, The Kresge Foundation, The Charles E. Culpeper Foundation, The Mobil Foundation, Inc., and several private benefactors, made it possible to initiate and pursue these activities during 1980-1983. With this support the Center has provided and will continue to provide a means for nurturing innovative ideas in coastal research to a point where federal and private sector attention and funding are warranted. Thus far, in three years of efforts including the initial year of planning and organization, the Coastal Research Center has been a major catalyst or contributor to projects which ultimately obtained funding support from federal agencies such as the National Science Foundation, the Office of Naval Research, the National Oceanic and Atmospheric Administration's Sea Grant Program and Office of Marine Pollution Assessment, the U.S. Army Corps of Engineers and the Environmental Protection Agency.

Initial Center activities are grouped into three categories for ease of discussion, but all three are closely interrelated. These groups are:

- (1) Principal Project Areas
- (2) General Activities
- (3) Facilities

PRINCIPAL PROJECT AREAS

The Center chose four project areas for special emphasis during the initial three to five years of operation. The principal projects were selected with input from scientific and technical staff based on consideration of (1) the importance of the research, (2) the interest of a critical mass of Institution scientists, and (3) the unique contributions which the Institution could make to the research.

I. Georges Bank Project

Georges Bank is one of the world's most productive fishing grounds which recently has become the focus of oil and gas exploration. These two activities, coupled with the Bank's importance as the interface between the Gulf of Maine and Mid-Atlantic Bight, have resulted in Georges Bank becoming one of the most intensely studied shelf systems in the world. In spite of this study our understanding of this natural system is incomplete. This partial understanding is insufficient to assure valid management decisions that protect the fishery resource and an intense debate has resulted. To develop a fuller understanding of the Bank and to help facilitate improved exchange of information between scientists and decision makers there is a need to condense and evaluate the extensive data base already in existence.

The objective of the initial phase of the Coastal Research Center's Georges Bank project was to summarize existing knowledge by writing the book and atlas, Georges Bank, described below. Substantial progress has been made on the book and 1000 pages of manuscript text have already been sent to the publishers, MIT Press. The text and graphics will be completed by late spring and a 1985

publication date is anticipated. An approximate table of contents is appended (Appendix 1).

The Center has brought together academic scientists, representatives of local, state and federal organizations, and private contractors who have been engaged in research on Georges Bank over the past decade. Several organizational meetings of contributors took place early in the writing process. These meetings also functioned as mini-workshops which began the interdisciplinary synthesis and provided a contemporary forum for researchers active in the Georges Bank area to identify specific data bases, to exchange latest research results and interpretations, and to plan future research.

The cooperation among the scientists of the Woods Hole scientific community (the Marine Biological Laboratory's Ecosystems Center, the U. S. Geological Survey, the National Marine Fisheries Service, and the Woods Hole Oceanographic Institution) and colleagues at other universities, government laboratories, and private contracting agencies, has provided new interpretations of data and new ideas for future research. A cooperative research agreement, which includes joint participation in the preparation of this book and atlas, was signed with the Northeast Fisheries Center of the National Marine Fisheries Service.

Dr. Richard H. Backus, Senior Scientist in the Biology Department at W.H.O.I., is General Editor of the book. He is advised by an editorial board consisting of Dr. Robert C. Beardsley, Senior Scientist in the Physical Oceanography Department at W.H.O.I.; Dr. Bradford Butman, U. S. Geological Survey; and Dr. Marvin Grosslein, National Marine Fisheries Service. Dr. Richard Price, a geographer in the W.H.O.I. Marine Policy and Ocean Management Center

now at Colorado State University, is cartographic editor. Support for this project has come from the Andrew W. Mellon Foundation and Sea Grant.

The book, Georges Bank, is a scientific work and its style is unavoidably technical. However, an effort has been made to minimize specialized jargon, and unessential details have been omitted. The chapters incorporate the most recent research results about Georges Bank, but avoid narrowly technical arguments already published elsewhere. The book is intended to distill the essence of technical information for a broader audience. To extend its usefulness the book includes non-technical summaries of various sections. It will be produced as one hard-cover volume of about 1,000 pages in a large format (20+ x 30+ cm) to better accommodate the numerous charts and maps that will be used. Maps are an important aspect of this volume and a newly compiled bathymetric chart of the Bank will be included in a pocket of the back cover. Multi-color processes are used where appropriate to increase the information content and legibility of the maps.

Georges Bank is divided into approximately 58 chapters covering the physical and biological sciences, resources and public policy. In addition, several short essays of general interest are distributed throughout the text (Appendix 1). There are an estimated 575 illustrations consisting of color maps and color illustrations and black and white half-tones and line drawings. Most chapters have multiple authorship, and each chapter has been reviewed by a separate group of reviewers. Reviewers and writers have been chosen in such a way as to assure a balanced as well as authoritative view of the subject being treated.

II. Assimilative Capacity Project

The present and future role of the coastal ocean for receiving and assimilating wastes from man's activities has been undergoing reassessment in the recent past because it is now recognized that one system (oceans) cannot be arbitrarily excluded from the waste disposal discussion. When assessing the economic and environmental impacts of waste handling, all three media (air, land and ocean) must be considered together in a discussion of overall waste management that includes waste reduction through recycling. Research by C.R.C. investigators has focused on the critical role of particulate matter in the movement of many wastes, especially toxic chemicals, through and within coastal ecosystems. The Center's research activities are concerned with fluid processes responsible for mixing, diffusing, resuspending and controlling horizontal transport of particulate matter, fluid mechanical and geological aspects of sinking and sedimentation of particulate matter, geochemical questions related to the fate of chemical constituents in seawater and sediments and biological processes influencing the distribution, size and stability of sediments in the sea bed. Biological problems under investigation also include both adverse and possible beneficial effects (i.e., as nutrients) on multiple aspects of marine life. Several projects have been initiated within the overall context of this general topic. There are site-specific aspects to each of these activities, but the fundamental research into the dynamics of the systems is applicable to much of the world's coastal areas.

(A) Buzzards Bay Project

Buzzards Bay (Fig. 1) is an important segment of the Massachusetts coast which continues to be developed for various purposes including light and heavy

industry, recreation, and fishing -- the range of multiple use pressures found in the heavily populated northeastern U. S. coastal zone. In spite of this heavy use, there have been few systematic studies of this coastal area. In comparison, other areas of the U. S. east coast, such as Chesapeake Bay and Narragansett Bay, have been extensively studied.

The Coastal Research Center of W.H.O.I., in cooperation with colleagues of the U. S. Geological Survey, Boston University Marine Program, Marine Biological Laboratory's Ecosystems Center, and Massachusetts state agencies, initiated a Buzzards Bay study as one of its first projects and continues to make an effort in this area. This is an opportune time to pursue such a study because:

- (1) Scientific input is urgently needed to solve immediate, critical environmental quality problems related to industrial contamination in one portion of Buzzards Bay;
- (2) Existing individual scientific research projects have reached a point where focused multidisciplinary actions of a more formal nature are needed to make significant advances; and
- (3) A critical mass of scientists in the Woods Hole community are enthusiastic about pursuing a Buzzards Bay study.

A major emphasis has been the severe PCB pollution problem in the Acushnet River Estuary - New Bedford Harbor area (Figure 1). We have studied this problem with support from Sea Grant, the U. S. Environmental Protection Agency Mussel Watch Program, and the W.H.O.I. Coastal Research Center, via the Andrew W. Mellon Foundation grant to C.R.C.

Briefly, two electrical component manufacturing facilities discharged PCBs into the harbor area over the past two or three decades. Our measurement of

Figure 1

PCBs in cores of surface sediments coupled with those of survey measurements of grab samples by state agencies has provided a rough estimate of about 110 tons of PCBs in the upper 50 cm of inner harbor sediments (Area I, Figure 1). Thus, PCB loading in the inner harbor alone is about equal to the PCB loading of sediments in the upper Hudson River case that has been officially recognized as a severe PCB pollution problem by the state of New York and by the U. S. government. To protect public health, several portions of the harbor (Areas I, II and III; Figure 1) have been partially or completely closed to fishing.

The New Bedford Harbor-Acushnet River Estuary has been designated an EPA Superfund Site as of June 1982. Region 1 of the EPA has begun to develop a remedial action master plan, and C.R.C.-associated researchers have contributed to that process by supplying data and by commenting on the early drafts of the plan. New data are currently being gathered in the New Bedford area and the Center intends to continue its input where appropriate. Our activities are designed to conduct research of a fundamental nature on this problem, to gain knowledge of importance to coastal environmental quality problems in general and to provide input to remedial action efforts to reduce the PCB pollution at this site.

We have secured additional funding from Sea Grant for a multidisciplinary research project on the interactions of physical dynamics and biogeochemical cycles of PCBs in Buzzards Bay and on the effects of PCBs on marine organisms. This project combines the expertise of Dr. Farrington in biogeochemistry of pollutants in the marine environment, Drs. Judy Capuzzo, John Stegeman and Marve Freadman in biological effects, Dr. Robert C. Beardsley in physical oceanography of coastal areas, Dr. William D. Grant in coastal hydrodynamics

and sediment transport, Dr. Albert J. Williams 3rd in instrumentation and Dr. Cheryl Ann Hannan in benthic ecology. The project also involves three graduate students, each from a different department, and thereby provides an educational opportunity of the type we seek to foster by Coastal Research Center activities.

The Center has initiated a technical report series which will facilitate dissemination of the results of this work on a timely basis. Figure 2, showing one of the cruise tracks from a series of hydrographic surveys recently made in Buzzards Bay, is taken from the first C.R.C. technical report (Rosenfeld et al., 1984). The data from these four cruises constitute the most complete information available on Buzzards Bay hydrography. As a part of this project, a winter storm monitoring study was undertaken by Drs. Grant and Williams to investigate the importance of storms in the resuspension and transport of sediment. This work has demonstrated that surface wave activity plays an important role in sediment resuspension and has provided us with critical data for future modelling studies. New initiatives, combining biogeochemical, physical dynamics and biological effects studies, are planned for 1984-86 and proposals to support this research have been submitted to several agencies and foundations.

(B) Comparison of Assimilative Capacity of Marsh Ecosystems, Crop Land Ecosystems, and Estuarine Ecosystems for Sewage Disposal

The Coastal Research Center is completing a joint study with Cornell University's Ecosystems Research Center which compares the responses of different ecosystems to sewage input. The project initially used the extensive data gathered by the Great Sippewissett Marsh project, a joint venture of several

Figure 2

Woods Hole scientists over the past ten years, to evaluate the long-term response of a salt marsh to years of controlled experimental applications of sewage sludge. The research of several Cornell University scientists has focused on the response of crop lands to sewage sludge disposal. Cornell's Ecosystems Research Center (E.R.C.) scientists are also working in cooperation with scientists of the Marine Ecosystems Research Laboratory at the Graduate School of Oceanography at the University of Rhode Island, where experimental mesocosms are being used in eutrophication studies.

The Coastal Research Center project during 1982 and 1983 funded a Post-Doctoral Investigator, Dr. Anne Giblin, who worked under the supervision of Dr. John M. Teal, Senior Scientist in the Biology Department, and Dr. John W. Farrington. Dr. Giblin compiled the literature data necessary to characterize metal cycles across a number of ecosystem types including: marine, estuarine, wetlands, lakes, streams, agricultural systems, grasslands, and forests. Data have been collected from both pristine and sewage impacted ecosystems. At the same time Drs. Kelly, Harwell, and others at the Cornell E.R.C. collected data on nutrient cycles. Whenever possible, data for nutrient and metal cycles were collected on the same ecosystem. The overall goal was to provide a fundamental assessment of how to compare various ecosystem types when considering a multi-media (air, land, ocean) approach to waste disposal.

Initially, a subset of the data, which focused on metals and nutrients in wetlands, was examined. The results of this portion of the work were presented at the EPA/FWS-sponsored conference "Ecological Considerations in Wetland Treatment of Municipal Water". This report will appear in the conference proceedings which are to be published in 1984. Analysis of the complete data

set is underway. We are making two different comparisons: 1) the response of the same ecosystem type to metals or nutrients at different loading rates (i.e. comparing "pristine" and "polluted" wetlands), and 2) the "cross-system" response of different ecosystems to metal or nutrient inputs (i.e. the response of a forest to a change in metal inputs compared to the response of a wetland).

Nutrient and metals data from these ecosystems, along with other relevant information such as primary production and climate, was entered into an ecosystem data bank on element cycles at Cornell. Cornell E.R.C. plans to maintain this data bank and, as new information becomes available, hopefully it will be incorporated into this data bank, thus facilitating our ability to compare ecosystems.

Dr. Giblin was also involved in an interdisciplinary project studying the nitrogen budget of Town Cove, Orleans, MA on Cape Cod. The purpose was to assess the trophic status of the Cove and to help determine whether installing sewers in the central portion of the town would greatly change the nitrogen loading to the Cove. The project involved Drs. Aubrey, Gaines, Giblin, Goldman, and Teal from W.H.O.I. and was largely funded by the town. Drs. Giblin and Teal received salary support for this project from the Coastal Research Center, which also provided logistic support for the project. For 15 months the group made physical, chemical, and biological measurements in the Cove which helped them to construct a nitrogen budget for the Cove and to establish the contribution of the proposed sewerage area to the total nitrogen inputs of the Cove. They concluded that the proposed sewer project would divert only a small portion of the nitrogen presently entering the Cove. The impact of the proposed sewage/septage plant on nearby marsh land was also examined by Teal

and Giblin. After the study was completed the town voted to construct a plant to treat septage only and not to install a central sewer system. A small Sea Grant-sponsored study by Dr. Susan Peterson is currently in progress to investigate the effect the W.H.O.I. report had on this town meeting vote.

We intend to continue the valuable joint efforts with Cornell's Ecosystems Center and to maintain communication between scientists involved in research on oceanic, estuarine, lacustrine, riverine, and terrestrial ecosystems.

III. Coastal Instrumentation Project

One of the major activities of the Coastal Research Center has been to promote better facilities for carrying out laboratory experiments on coastal ocean phenomena. The ocean is a complex physical system. An effective way to study this complex ocean system is to isolate specific key processes and components in the laboratory where their behavior can be manipulated and controlled. The goal is a better understanding of the response of the natural system and through this work we can increase our ability to develop realistic hypotheses which are testable in the field environment. While the laboratory does not duplicate nature, critical cause-effect relationships between variables can be carefully observed there. Using C.R.C. facilities scientists and engineers can dissect the ocean system into a series of component processes and concentrate their research efforts on understanding one at a time. Once an understanding of individual components is achieved, attempts may then be made to reassemble them and study interactions between the components, thus learning how one part of the ocean system functions. This assemblage becomes a new component which, when put together with several other similarly derived assemblages, defines an ever-larger system, gradually moving towards the scale of observations in the ocean.

In our effort to develop the special tools needed to make accurate and quantitative observations we first identified specific areas of research that should receive priority attention. We accomplished this through meetings, seminars and discussions with W.H.O.I. staff members over the past five years. A major goal of facility improvement was the design and construction of the Coastal Research Laboratory (C.R.L.), completed in 1982.

In order to strengthen our experimental capability the design and construction of flumes for general research use were initiated. In particular, we focused on problems involving interactions between biogeochemical processes and turbulent near bottom flow. Processes in this category were identified by staff members at W.H.O.I., as well as by national groups, as having a high priority in coastal research. Benthic problems include questions requiring interdisciplinary efforts. For example: the influence of biotic reworking of the bottom sediments on the near bottom flow field and sediment transport; the uptake of polluted sediments by benthic organisms; the effect of near bottom flow on the distribution of benthic biota; and, the flux of chemicals into and out of pore water in the sediment under a variety of flow conditions. The initial effort in this research area has been the design of a unidirectional flow flume. This flume was designed to address the above questions but is also well-suited for more classical fluid mechanics experiments on, for example, internal waves, boundary layer flows, and sediment transport. The flume was pre-fabricated by a commercial fabricator (R. L. Industries, Miamitown, OH) and is currently being installed in the Coastal Research Laboratory. Flow control mechanisms and a water pumping system are being constructed in-house under the supervision of Mr. Kenneth Doherty and Dr. William Grant of the

Ocean Engineering Department. This exciting new addition to the C.R.L. will greatly enhance our ability to study several key aspects of coastal system dynamics.

The flume test section is 20 meters long, 0.6 meters wide, and 0.35 meters deep. By tilting the flume, water is driven by the force of gravity through the flume and into a downstream reservoir, from which it is recirculated by a pump back to the head of the flume. Carefully controlled flows of more than 100 cm/sec are possible, and both sediment and water can be recirculated. The option exists to isolate flow and sediment without recirculation, and new water may be introduced by diverting the flow out of the flume away from the reservoir.

Two features of the flume make it unique for specialized application to the study of marine systems. First, it is a salt water flume so that chemical processes and biological components of benthic systems can be properly maintained. For this reason the flume was constructed entirely of fiberglass with a non-toxic gel coating. The walls of the flume have 16 built-in glass windows on each side for observation at selected locations. A second feature of the flume is the inclusion of a well to hold a 0.5 m square core box from a field box-coring system. This feature will allow benthic sediment cores to be transplanted either from the field or from laboratory microcosms directly into the flume for experimentation. Flow measurements in this experimental flume will be made using a newly-designed, single-axis Laser-Doppler anemometer.

The coastal instrumentation project also includes assessment of future needs both for laboratory facilities and for field instrumentation. The Ocean Engineering Department at W.H.O.I. has a continuing effort to develop new in-

strumentation for making ocean measurements of interest to coastal oceanographers and engineers. Rather than duplicate this effort, we wished to determine how the Coastal Research Center could interact with ongoing activities in instrumentation development in order to help explain the needs of coastal oceanographers and to aid their efforts in raising funding. At the same time it was realized that many coastal researchers simply required commercially available instrumentation and some assistance with its use. Typical problem areas include a lack of expertise in the use of these instruments, expensive maintenance servicing and data processing operations. To address these issues, we formed an instrument pool for shared use, and the outfitting of the physical measurements laboratory within the C.R.L. so that instrumentation developers could conduct their testing and development there.

In addition to the construction of the general use 20 m flume, we identified a need for wave tanks and a large towing basin for instrument calibration. The need for careful instrument calibration was recently reinforced by studies of the dynamic behavior of electromagnetic current meters, commonly used in coastal work. The study (partly funded by C.R.C. and performed by Dr. Aubrey, Mr. Spencer, and Dr. Trowbridge of the University of Delaware) clarified the complex behavior of these current meters under steady, oscillatory, and combined steady/oscillatory flows. These wave tanks and towing basin represent future efforts for the Center.

IV. Rapid Response Program

An understanding of the influence of coastal storms on geological, physical, chemical, and biological processes is a very important aspect of our study

of coastal processes. Because storms are unpredictable in time and space, it has been difficult to obtain funds for studies during and immediately after storms.

We have undertaken a pilot project to ascertain the best procedures for such research to be conducted before, during, and after storms. Funds were allocated for planning studies to be conducted during a storm and for pre-storm surveys in an inlet/bay system near Nauset Beach on Cape Cod. This site was chosen because it is also an area of longer-term studies by several scientists from Woods Hole Oceanographic Institution who are investigating red tides, processes influencing the dynamics of beaches, geomorphology and geology of inlet/estuarine systems, and nutrient fluxes in marsh-estuarine-bay ecosystems. The background pre-storm data are of scientific use to these other projects and furthermore, the ongoing projects provided some of the initial characterization of the area prior to storm events.

Funds were committed in advance, to be released on short notice by the Director of the Coastal Research Center, for studies during and after a storm when the principal investigators identified the storms to be studied. Rapid response studies have been difficult to implement using federal or state funds because of the timing uncertainty and general bureaucratic inertia. Our hope is that we can provide sufficient experience from this exercise to convince more traditional funding sources that the increased knowledge of important coastal processes is worth the risk of reducing funding difficulties.

The project took place during August-November 1982. During this period of observation, two storms passed through the area. The first storm was not predicted and some critical pre-storm measurements in water chemistry were missed.

However, in situ instrumentation consisting of pressure sensors, a current meter array, and tide gauges recorded valuable data during the storm. The second storm was predicted and a full range of pre-storm field measurements was made, although this storm did not achieve predicted intensity.

While these problems indicate some of the frustrations encountered, there are still considerable data from both storms which are now being interpreted by the team of principal investigators: Dr. David G. Aubrey, Geology and Geophysics Department and Project Coordinator, Drs. John M. Teal and Donald M. Anderson of the Biology Department, and Drs. Kenneth H. Brink and Richard E. Payne of the Physical Oceanography Department.

A short summary of their findings to date indicates that the coastal storm program documented the effects of the first two postsummer storms along the Atlantic shore of Cape Cod. Biological response was well-documented in terms of salt marsh grasses and macro-benthic populations, and to some extent in terms of nutrient levels resulting from increased water exchange during storm passage. Sea surface elevation was well documented for the estuary as well as the shelf. Beach and cliff erosion, along with nearshore shoal structure, was documented with aerial photography. Results of this study will be used to quantify the effects of moderate coastal storms on nearshore environments, and may lead to a larger follow-up program to quantify the effects of these storm events over a longer time period.

More recently, the rapid response group was activated following the beaching of the 473' freighter 'ELDIA' close to Nauset marsh during a severe northeastern storm on 29 March 1984. Although empty of cargo, the freighter contained 140,000 gallons of diesel fuel oil. Concern about potential environ-

mental damage to adjacent beaches and marshes by leakage of this fuel resulted in the establishment of an informal group of W.H.O.I. scientists who closely monitored the fate of the grounded freighter. Working in collaboration with the U.S. Coast Guard and N.O.A.A., W.H.O.I. scientists followed the offloading of 140,000 gallons of fuel to ensure that minimal damage to the coastal ecosystem would occur. Rapid response program funds, although not needed during this crisis, provided assurance that proper follow-up studies could be initiated in the event of any substantial spill.

GENERAL ACTIVITIES

General activities of a nature which broaden the research base of the Institution in the coastal zone on both short- and long-term time scales and provide new initiatives in coastal research include:

New Scientific Staff

We are pleased that, in cooperation with the Physical Oceanography Department, the Coastal Research Center has contributed to the support of Dr. Kenneth H. Brink, an Assistant Scientist in the Physical Oceanography Department, during his first two years at the Institution. Dr. Brink has concentrated his research on low frequency wind driven continental shelf flows, which is an area of significant importance to coastal physical oceanography. Dr. Brink's research is now totally supported by his own grants and contracts. His initial support is a key example of the value of the use of private foundation support to supply seed funds which provide for longer-term research

opportunities. It also illustrates the important role played by uncommitted funding to help expand the Institution staff into new areas of coastal research.

We hope in the next two years to assist the scientific departments at W.H.O.I. in recruiting and establishing additional scientific research expertise within other critical areas of coastal research: for example, fisheries ecology. This fisheries ecology effort is made jointly with the Center for Analysis of Marine Systems (C.A.M.S.) and the Northeast Fisheries Center of NOAA/NMFS.

Support of Post-Doctoral Scholars and Graduate Students

Many of the exciting ideas in research are catalyzed by younger scientists who interface their thesis research experience with existing knowledge or by the probing questions of graduate students newly embarked on innovative research.

The Coastal Research Center has sponsored the following post-doctoral scholars within the Institution's post-doctoral scholarship program:

Paul V. Doskey, Chemistry
Richard H. Lambertsen, Biology
John W. Loder, Physical Oceanography
Douglas J. Sherman, Ocean Engineering

A short summary of the research conducted by each of these scholars is appended (Appendix 2).

We have also provided funding support for small equipment, supplies, travel, computer time, and other non-stipend activities in amounts of \$2,000 to \$7,500 to several graduate students to initiate or supplement their Ph.D. thesis research (Appendix 3). These projects represent a range of Center research interests, but all contribute in a general way to the further understanding of how coastal ecosystems respond to natural or man-induced stress, and support our interest in assimilative capacity. The investment of seed funds in student projects has proven to be a great success. Thus far, the initial results of the research have contributed towards seven students gaining major grant or contract support for their research efforts. Drs. Hamman, Libes, Repeta, and Klotz have all completed the Ph.D. degree in the past two years, and the other students are well on their way to that goal (Appendix 3).

Visiting Scientists and Visiting Scholars

The Coastal Research Center provided partial support for travel, subsistence allowances, and, on some occasions, salary support which made it possible for scientists from other organizations to visit with colleagues in Woods Hole for periods of a few months to a year (Appendix 4). These visits have proven to be mutually beneficial, and several collaborative efforts have evolved from them. Usually visiting scientists bring sabbatical or other salary support with them.

Visiting Scholars are invited to the Institution for shorter visits of from one to several days. The purpose of these short visits is the presentation of seminars in the various areas of coastal research. A requirement for the visiting scholars is that they devote a significant portion of their visits to discussions with students (Appendix 8).

Special Opportunities

The Center has provided funds for projects of unusual character requiring short-term support and rapid funding decisions. Normally, funds for this category of projects are in the range of \$2,000 to \$10,000. An example of a project of this type occurred at the initiation of the current Department of Interior-Bureau of Land Management monitoring program for Outer Continental Shelf exploration and development activities on Georges Bank. Dr. J. F. Grassle and co-workers were scheduled to begin benthic ecology sampling on Georges Bank. However, due to a delay in the paperwork within the agency, the funds for cruise participation would not have been approved until after the first two cruises. Ship scheduling requires a long lead time, thus, on a few days notice, the Coastal Research Center provided funds for salary of a research assistant to participate in the cruise, ensuring that valuable pre-exploration samples of the benthos would be secured.

The Center has also provided travel funds for short-notice meetings in several instances where other funding sources were not able to respond.

Symposia and Workshops

Meetings can be useful in examining the state-of-the-art, exchanging new ideas, and formulating new research ventures. The Center has partially supported a few meetings. In several instances, partial organizational support for the meeting and travel of key participants led to receipt of substantially more funding from federal agencies. Only modest funds, on the order of \$1,000 to \$6,000, have been used for these meetings.

This type of support has produced numerous rewards. For example, the Fisheries Ecology Meeting provided guidance and impetus to a joint C.R.C.-

C.A.M.S. activity in fisheries ecology. The Ocean Pollution 1981 meeting papers have recently been published in a special volume of the peer-reviewed journal Canadian Journal of Fisheries and Aquatic Sciences, Volume 40, Supplement No. 2, 1983, co-edited by Dr. Farrington, Dr. John Vandermeulen of the Bedford Institute of Oceanography, Halifax, Nova Scotia, Canada, and Dr. David Cook of the Canadian Journal of Fisheries and Aquatic Sciences. A list of meetings and workshops supported by the Center is appended (Appendix 5).

FACILITIES

The long-term need for experimental facilities was recognized early as a high priority. Plans were developed for the expansion and improvement of existing facilities and the addition of new, specialized buildings. These facilities were designed not only to meet certain special needs in coastal research, but also to maintain considerable flexibility for long-term use.

First in priority was the new Coastal Research Laboratory, seen in Figure 3. The C.R.L. provides much-needed space for experimental research and for instrument development, construction and testing. The main purpose of this 10,000 square foot building is to provide flexible space for flumes, tanks, and other apparatus required to experimentally test theories of physical, chemical, geological, and biological processes in coastal areas, and especially the interactions among these processes. The space is used for construction and servicing of large measurement devices such as current meter arrays, nephelometers, and tripods which are used in the field component of coastal research. A large, ocean deployable flume for benthic boundary experiments on sediment transport is under construction here. Instrumentation for water

Figure 3

sampling and current measurements requires careful preparation, and much instrument servicing is routinely done here also. A 20-ton overhead crane allows for movement of heavy pieces of gear within the area without disturbing ongoing experiments, maximizing usable floor space. Initial design of the building provided for convenient access to flowing sea water. A well-equipped shop provides support for most routine work, including machining, at C.R.L.

The building also contains three specialized laboratories on the first floor: a two-meter rotating table for the study of geophysical fluid dynamics, a laboratory for biogeochemical studies, and a specially designed clean room with filtered air and temperature-humidity control for work on specialized instrumentation for physical measurements. The rotating table, operated by Dr. Jack Whitehead of the Physical Oceanography Department, is one of the few facilities of this type in the world. The clean lab has been used for the development of a Laser-Doppler anemometer for in-situ field measurements by Dr. Yogesh Agrawal of the Ocean Engineering Department. Acoustic instrumentation for measuring suspended sediment concentration is also being developed here by Mr. Frederick Hess, also of the Ocean Engineering Department. The second floor of the building consists of offices, a computer room, and a conference room.

The Coastal Research Center was fortunate to receive generous support for construction of this unique facility from The Kresge Foundation, The Mobil Foundation, Inc., the late Percy Chubb 2nd, and numerous individual contributors. The building was completed and accepted in June 1982 and is now being used for the variety of activities envisioned in its design.

Envisioned future expansion of the C.R.C. facilities includes a 100-meter covered flume which will allow studies of the interactions of physical pro-

cesses (e.g., waves, turbulence), sediments, and geochemical and biological processes and instrument testing; a greenhouse to be constructed over an existing series of ponds which will be used for experimental salt marsh and similar ecosystem research; and an addition to the existing Environmental Systems Laboratory that will approximately double its laboratory and office space (Figure 4).

We remain committed to the philosophy that experimental laboratory studies form an essential link among in situ observations of the environment, mathematical models or theoretical calculations, and policy and management decisions. Complicated interrelations among chemical, physical, and biological processes often require experimental study at scales not easily achieved within conventional laboratory space. The Coastal Research Center will continue to strive to meet these larger scale and non-conventional needs for experimental space.

FUTURE ACTIVITIES

The preceding discussion of progress and present activities of the Coastal Research Center summarizes the type of research effort that will continue through the remainder of the decade. We intend to initiate several new projects during the next two years within the C.R.C. and cooperatively with other organizations as appropriate. Research areas currently being considered for new initiatives are:

- fisheries ecology
- methodology for estimating primary productivity
- measurement and consequences of sea level rise

Figure 4

Our assessments suggest that C.R.C. researchers can make significant contributions to new knowledge in each of these areas of endeavor and to the transfer of this new knowledge to individuals and agencies in need of the information.

The Coastal Research Center will continue to support a range of general activities, responding to research opportunities which require a rapid response and supporting initiatives in coastal oceanography which we feel warrant support despite their falling outside of the purview of federal funding. The Center will also continue to act as a means of focusing the attention of graduate students on the coastal ocean by providing them with support to work alongside senior scientists on projects undertaken by the Center. We consider this experience invaluable in educating capable future practitioners of coastal oceanography. The C.R.C. will also continue to serve as a focus for coastal research at the Institution by fostering communication between practitioners and other interested parties. These "general activities" have been an important ingredient in the success of the Center, and as such will receive continued emphasis.

APPENDICES

Appendix 1.

GEORGES BANK

Approximate Table of Contents (primary authors in parentheses)

INTRODUCTION

Preface, Backus

1. Scientific exploration (Wright)
- * The name (McCorkle)
2. Cartographic history, 1524-1850 (McCorkle)

PHYSICAL SCIENCE

A. Summary, geology, (Backus and Schlee)

3. Pleistocene geology (Emery)
4. Morphology (Uchupi and Austin)
5. Shallow structure (Twichell, Lewis, and Butman)
6. Subsurface geology (Klitgord and Schlee)
7. Submarine canyons (Cooper, Valentine, and Uzzmann)

B. Introduction/summary, climate (Backus, Beardsley)

8. Atmospheric forcing (Mooers)
9. Climate (Hopkins and SethuRaman)
10. Wave climate (Earle and Madsen)
- * The response of Georges Bank to the 1978 blizzard (Butman)
- * Death on Georges Bank

C. Summary, physical oceanography (Butman and Beardsley)

11. Tides (Brown and Moody)
12. Water structure (Flagg)
13. Mean circulation (Butman, Loder, and Beardsley)

14. Low-frequency current and pressure variability (Brink, Magnell, and Noble)

* Does Georges Shoal ever dry?

15. Near-bottom currents, stress, and sediment transport (Butman and Grant)

16. Mixing processes (Csanady and Magnell)

D. Summary, chemistry (Farrington and Backus)

17. Dissolved gases (Scranton and Whelan)

18. Trace metals (Bothner, Gilbert, and Bankston)

19. Natural radionuclides (Bothner and Bacon)

20. Artificial radionuclides (Cochran and Livingston)

21. Natural and pollutant organic compounds (Farrington and Boehm)

BIOLOGICAL SCIENCE

E. Summary, phytoplankton, microbiology (Yentsch, Falkowski and Bourne)

22. The phytoplankton (Cura)

23. Primary productivity (O'Reilly, Evans-Zetlin, and Busch)

24. Nutrient cycling (Walsh, Whitley, O'Reilly, Phoel, and Draxler)

25. Microbiology (Hobbie, Novitsky, Rublee, Ferguson, and Palumbo)

* Do seaweeds occur on Georges Bank? (Sears)

F. Summary-zoology, secondary production (Editors and Grosslein)

26. Zooplankton life-cycles (Davis)

27. Zooplankton production & the fishery of the northeast shelf (Sherman et al.)

28. The bottom animals (Theroux)

29. Variability of the benthic community (Michael)

30. A further description of the benthos (Maciolek and Grassle)

31. Benthic production (Steimle)
32. Fishes and squids (Azarovitz and Grosslein)
33. Fish and squid production (Sissenwine)
34. Large predatory fishes (Casey, Hoey, and Grosslein)
- * Some Georges Bank statistics
35. Turtles (Shoop)
36. Seabirds (Powers and Brown)
37. Consumption by seabirds (Powers and Backus)
38. Whales and porpoises (Hain)
39. Total ecosystem production (Cohen and Grosslein)
40. Implications of circulation and residence time (Mountain and Schlitz)
41. A model for part of the Georges Bank ecosystem (Klein)

THE FISHERY

- G. Using Georges Bank -- the fishery (Bourne and Peterson)
 - * Bait up! (Anderson)
42. History of the early fishery, 1720-1930 (German)
- * U-boats on the Bank (Rockwell)
43. History of the modern fishery (Hennemuth and Rockwell)
- * First trip on Georges Bank (Ostergard)
44. Recent developments in fishery technology (Smith)
45. The United States fishing industry on Georges Bank (Smith and Peterson)
46. The Canadian Fishing industry on Georges Bank (Gough)
47. The boundary dispute between the United States and Canada (Christie)
48. Fishery administration and management in the U.S. and Canada (Hennessey and LeBlanc)

49. The fisheries resources (Brown)
 50. Fisheries research (Fogarty, Sissenwine, and Grosslein)
 51. The future for fisheries management on Georges Bank (Apollonio)
 - * Echogram (Carey)
 - H. Conflicting Uses and Public Policy -- Fisheries, Oil and Gas, Shipping
(Peterson, Christie, Backus)
 52. The petroleum potential of Georges Bank Basin (Ball, Mattick, and Powers)
 53. The jurisdictional framework for petroleum development (Ball, Christie, and Townsend-Gault)
 54. The potential impacts on living resources of drilling mud and other effluents from petroleum development (Neff)
 55. The potential impacts of petroleum production and transport on living resources (Howarth)
 56. Environmental protection relating to petroleum development (Leschine and Lahey)
 57. Exploratory drilling, 1981-1982 (Danenberger)
 58. Traffic (Murphy)
 - I. Georges Bank -- a grand summary (Backus and Bourne)
- Index
- List of Contributors

*Short chapters of general interest are found throughout the book.

Appendix 2.

Postdoctoral Awards

Paul V. Doskey:

Ph.D., Water Chemistry, Univ. Wisconsin

Now at: Pritzker Dept. of Environ. Engineering, Illinois Inst. of Technology, Chicago, IL

Dr. Doskey's background in chemical analysis and biogeochemistry was expanded through his participation in an investigation into the concentration levels of organochlorines in whale tissue. He analyzed several types of tissue of three whale species from the Icelandic whale fishery to determine the influence of species and feeding habit on the distribution and concentration of organochlorine pesticides and PCBS.

Richard H. Lambertsen:

Ph.D., Comparative Medicine and Cell Biology, Univ. of Pennsylvania

Now at: Dept. of Physiological Sciences, Florida State Univ., Gainesville, FL

Dr. Lambertsen, trained as a marine veterinarian, was involved in feeding mechanism studies of rorqual whales, whale pathology, diving physiology and radiotag design and development. As a postdoc he successfully applied for and now holds the most flexible NOAA permit available for importation of marine mammal specimen material. His studies of histology and wound healing have assisted W.H.O.I. staff with the design of a new radiotag that should improve retention.

John W. Loder:

Ph.D., Oceanography, Dalhousie Univ.

Now at: Bedford Inst. of Oceanography, Halifax, Nova Scotia, Canada.

Dr. Loder extended or applied the results of his thesis research through joint projects with several members of the scientific staff in the Dept. of Physical Oceanography. These projects included: cross-frontal transfer mechanisms in shallow seas, a study of the rate of horizontal exchange controlling nutrient flux on the central shoals of Georges Bank, a theoretical examination of tidal rectification, and the relation of variability in the striped bass population to long-term variation in the physical environment.

Douglas J. Sherman:

Ph.D., Geography, Univ. of Toronto

Now at: Dept. of Geology, Univ. of Southern California, Los Angeles, CA

Dr. Sherman worked at applying quantitative boundary layer and sediment transport models for combined wave and current flows to explain surf zone measurement taken as part of his thesis work. He also attempted to use the results from this analysis to plan a follow-up experiment which would answer some of the questions that could not be addressed using his thesis data set. Use of these models and interaction with the W.H.O.I. staff allowed Dr. Sherman to expand his background in coastal hydrodynamics.

Appendix 3.

Student Support (1982-1983)

Brian Binder, Biology -- Jan. 1984 - Jan. 1985

Encystment, dormancy and germination in the marine dinoflagellate,
Scrippsiella trochoidea

Bruce Brownawell, Chemistry -- June 1983 - June 1984

Biogeochemistry of PCBs in a Coastal Environment

Stephen Lohrenz, Biology -- Mar. 1982 - Aug. 1983

Determination of the Dynamics of Carbon Metabolism in Minor Phyto-
plankton: Low Molecular Weight Metabolism and Biosynthesis of Major
Cellular Polymers

William Martin, Chemistry -- Mar. 1982 - June 1983

The Transport of Dissolved Trace Metals in Coastal Sediments

Anne McElroy, Biology -- May 1982 - May 1983

Biogeochemistry and Physiologic Effects of Polycyclic Aromatic Hydro-
carbons and their Metabolites in Controlled Benthic Ecosystems

Ann McNichol, Chemistry -- Apr. 1983 - Apr. 1984

The Decomposition of Organic Carbon and the Isotopic Signature of
Dissolved Inorganic Carbon in a Nearshore Environment

Richard Mercier, Ocean Engineering -- Sept. 1981 - Sept. 1982

Development of Experimental Methods for Studying Interactions Between
Environmental Processes and the Turbulent Microenvironment

Ph.D. Theses

Daniel J. Repeta, Carotenoid Transformations in the Oceanic Water Column,
Sept. 1982

Susan M. Libes, Stable Isotope Geochemistry of Nitrogen in Marine sediments,
Feb. 1983

Alan Klotz, Purification and Characterization of the Hepatic Microsomal
Monooxygenase System from the Coastal Marine Fish Stenotomus chrysops,
Sept. 1983

Cheryl Ann Hamman, Initial Settlement of Marine Invertebrate Larvae: The Role
of Passive Sinking in a Near-bottom Turbulent Flow Environment, Feb. 1984

Appendix 4.

Visitors
(appointments made in 1982-1983)

Georges Bank Study Group (14 November 1981 - 14 November 1982):

Mr. Donald Bourne, Woods Hole, MA
Dr. John Walsh, Brookhaven National Laboratory, Brookhaven, NY
Dr. Terry Whitley, Brookhaven National Laboratory, Brookhaven, NY
Dr. Marvin Grosslein, National Marine Fisheries Service, Northeast
Fisheries Center, Woods Hole, MA
Dr. Michael Sissenwine, National Marine Fisheries Service, Northeast
Fisheries Center, Woods Hole, MA
Dr. Robert Howarth, Ecosystems Center, Marine Biological Laboratory,
Woods Hole, MA
Dr. Bradford Butman, U. S. Geological Survey, Woods Hole, MA
Dr. Paul Boehm, Battelle New England, Duxbury, MA

Dr. Mary Scranton, Dept. of Marine Sciences, SUNY, Stony Brook NY
25 July 1983 - 31 August 1983

Dr. Graham Giese, Marine Sciences Research Center, SUNY, Stony Brook, NY
1 March 1983 - 31 August 1984

Dr. Anne Giblin, Ecosystems Center, MBL, Woods Hole, MA
1 September 1983 - 31 December 1983

Dr. Christopher Martens, Marine Sciences Program, UNC, Chapel Hill, NC
1 August 1981 - 31 July 1982

Dr. Eckart Schumann, National Research Inst. of Oceanology, Republic of
So. Africa
1 August 1982 - 31 December 1982

Dr. James T. Carlton, Mystic Seaport and Williams College, Mystic, CT
1 June - 31 August 1983

Dr. Keith Stolzenbach, Dept. of Civil Engineering, MIT, Cambridge, MA
1 September 1983 - 31 August 1984

Mr. Thomas Capo, Marine Biological Laboratory, Woods Hole, MA
1 September 1982 - 31 August 1984

Dr. Eric Henderson, Marine Laboratory, Aberdeen, Scotland
5 September 1983 - 8 October 1983

Appendix 5.

Support of Meetings and Workshops

Gulf of Maine Workshop, 2-5 March 1981, University of New Hampshire
Fisheries Ecology Workshop, 8-11 June 1981, Woods Hole, MA
Ocean Pollution 1981, October 1981, Halifax, Nova Scotia, Canada
International Symposium on Responses of Marine Organisms to Pollutants,
27-29 April, 1983, Woods Hole, MA
Chemical Changes in the Coastal Zone -- Mussel Watch II, November 1983,
East-West Center, Hawaii
Coastal Ocean Storm Sediment Transport Steering Committee Meeting,
Jan. 1984, Keystone, Colorado

Appendix 6.

Funding Support, 1983

General Activities	\$164,500
Specific Projects	
Georges Bank	186,000
Assimilative Capacity	36,000
Coastal Storm	18,000
Instrumentation	52,000
Student Projects - 1982-83	37,500
	<hr/> 494,000

Appendix 7.

C.R.C.-Associated Publications

- Aubrey, D. G. and K. O. Emery (1983). Eigenanalysis of recent United States sea levels. Continental Shelf Research, v. 2, pp. 21-33.
- Aubrey, D. G. and P. E. Speer (1983). Sediment transport in a tidal inlet. W.H.O.I. Tech. Rpt. No. 83-20, 110 p.
- Aubrey, D. G. and P. E. Speer (in press). Updrift migration of tidal inlets. Journal of Geology.
- Aubrey, D. G. and P. E. Speer (submitted). A study of non-linear tidal propagation in shallow inlet/estuarine systems. Part I: Observations. Estuarine, Coastal and Shelf Science.
- Brink, K. H. (1982). The effect of bottom friction on low-frequency coastal trapped waves. J. Physical Oceanogr. 12: 127-133.
- Brink, K. H. (1982). A comparison of long coastal trapped wave theory with observations off Peru. J. Physical Oceanogr., 12: 897-913.
- Brink, K. H. (1983). Low-frequency free wave and wind-driven motions over a submarine bank. J. Physical Oceanogr., 13: 103-116.
- Butman, B. and R. C. Beardsley (in press). The physical oceanography of Georges Bank: Introduction and summary. In: Georges Bank (R. H. Backus, ed.). MIT Press.
- Butman, B., J. W. Loder and R. C. Beardsley (in press). The seasonal mean circulation on Georges Bank: Observation and theory. In: Georges Bank (R. H. Backus, ed.). MIT Press.
- Farrington, J. W., B. W. Tripp, A. C. Davis and J. Sulanowski (in press). One view of the role of scientific information in the solution of environmental problems. In: Proceedings of the International Symposium on Utilization of Coastal Ecosystems: Planning, Pollution, Productivity, 22-27 Nov. 1982, Rio Grande, RS, Brazil.
- Farrington, J. W. (in press). Sources and distribution processes of chemical contaminants in the coastal zone. In: Proceedings, The Law of the Sea Institute, XVI Annual Conference, 22 June 1982, Halifax, NS, Canada.
- Farrington, J. W., J. M. Capuzzo, T. M. Leschine and M. A. Champ (1982-83). Ocean Dumping. Oceanus, 25(4): 39-50.
- Farrington, J. W. (1983). Bivalves as sentinels of coastal chemical pollution: The Mussel (and Oyster) Watch. Oceanus, 26(2): 18-29.

- Farrington, J. W., J. H. Vandermeulen and D. Cook (eds.) (1983). Can. J. of Fisheries and Aquatic Sciences, Vol. 40, Suppl. 2, Ocean Pollution 1981, including summary sections therein.
- Farrington, J. W., E. D. Goldberg, R. W. Risebrough, J. H. Martin and V. T. Bowen (1983). U.S. "Mussel Watch" 1976-1978: An overview of the trace-metal, DDE, PCB, hydrocarbon, and artificial radionuclide data. Environ. Sci. & Technol., 17: 490-496.
- Giblin, A., I. Valiela and J. M. Teal (1983). The fate of metals introduced into a New England salt marsh. Water, Air, Soil Pollution, 20: 81-98.
- Giblin, A., M. Piotrowski, B. Leighty, I. Valiela and J. M. Teal (1983). Response of a salt marsh microbial community to inputs of heavy metals: Aerobic heterotrophic metabolism. Environ. Toxicol. Chem., 2: 343-351.
- Giblin, A. and A. G. Gaines (1983). Importance of benthic remineralization to the nitrogen budget of a marine cove. EOS, 64: 1075 (abstract).
- Hannan, C. A. (1984). Initial settlement of marine invertebrate larvae: the role of passive sinking in a near-bottom turbulent flow environment. Ph.D. dissertation, Woods Hole Oceanographic Institution, Woods Hole, MA.
- Kelly, J. R., M. A. Harwell, A. E. Giblin (1982). Comparisons of the processing of elements by ecosystems: I. Nutrients; II. Metals. Ecosystems Research Center (Cornell) Report No. 21.
- Klotz, A. V. (1983). Purification and characterization of the hepatic microsomal monooxygenase system from the coastal marine fish Stenotomus chrysops. Ph.D. dissertation, Woods Hole Oceanographic Institution, Woods Hole, MA.
- Libes, S. M. (1983). Stable isotope geochemistry of nitrogen in marine sediments. Ph.D. dissertation, Woods Hole Oceanographic Institution, Woods Hole, MA.
- McElroy, A. (1984) (in press). Effects of stress on marine organisms. In: 18th European Marine Biology Symposium (J. S. Gray and M. E. Christiansen, eds.). J. Wiley and Sons.
- Milliman, J. D., Ya Hsueh, Dun-Xin Hu, D. J. Pashinski, Huan-ting Shen, Zuo-sheng Yang, and P. Hacker (1984). MS. Tidal phase control of sediment discharge from the Yangtze River.
- Repeta, D. J. (1982). Carotenoid transformations in the oceanic water column. Ph.D. dissertation, Woods Hole Oceanographic Institution, Woods Hole, MA.
- Rosenfeld, L. K., R. P. Signell and G. G. Gawarkiewicz (1984). Hydrographic study of Buzzards Bay, 1982-83. C.R.C. Technical Report 84-01. Woods Hole Oceanogr. Inst.

- Rothschild, B., C. Clark, R. Hennemuth, R. Lasker, M. Sissenwine, W. Wooster and J. Steele (1982). Report of the Fisheries Ecology Meeting, June 8-11, 1981. Tech. Rpt. WHOI 82-28, Woods Hole Oceanographic Institution, Woods Hole, MA.
- Shen, G., E. R. Sholkovitz and D. R. Mann (1983). The coagulation of dissolved $^{239,240}\text{Pu}$ in estuaries as determined from a mixing experiment. Earth Planet. Sci. Lett., 64: 437-444.
- Sholkovitz, E. R., A. E. Carey and J. K. Cochran (1983). Laboratory studies of the diagenesis and mobility of $^{239,240}\text{Pu}$ and ^{137}Cs in nearshore sediments. Geochim. Cosmochim. Acta, 47: 1369-1379.
- Speer, P. E. (1984). Tidal distortion in shallow estuaries. Ph.D. dissertation, Woods Hole Oceanographic Institution, Woods Hole, MA.
- Speer, P. E. and D. G. Aubrey (submitted). A study of non-linear tidal propagation in shallow inlet/estuarine systems. Part II: Theory. Estuarine, Coastal, and Shelf Science.
- Staresinic, N., J. W. Farrington, R. B. Gagosian, C. H. Clifford and E. M. Hulburt (1983). Downward transport of particulate matter in the Peru coastal upwelling: Role of the anchoveta, Engraulis ringens. In: Coastal Upwelling, Pt. A. (E. Suess and J. Thiede, eds.), pp. 225-240. Plenum Publ. Corp.
- Staresinic, N. (submitted). Downward flux of bulk particulate organic matter in the Peru coastal upwelling. J. Mar. Res.
- Teal, J. M. (1983). The coastal impact of ground water discharge: an assessment of anthropogenic nitrogen loading in Town Cove, Orleans, MA. Final Report to the Town of Orleans, MA.

Appendix 8.

Invited Speakers

Alice Alldredge, Univ. of California, Santa Barbara, CA

Kathe Bertine, Dept. of Geological Sciences, San Diego State Univ.,
San Diego, CA

Bodo Von Dodungen, Univ. of Kiel (West Germany)

Michael Conner, School of Public Health, Harvard Univ., Cambridge, MA

John Dingler, U.S. Geol. Survey, Menlo Park, CA

Jed Fuhrman, Marine Sciences Research Center, SUNY, Stony Brook, NY

Frank Gillan, Australian Inst. of Marine Science (Australia)

John Gray, Marine Biology and Limnology Inst., Univ. of Oslo (Norway)

Jay Means, Chesapeake Biological Laboratory, Solomons, MD

Mark Melancon, Medical College of Wisconsin, Milwaukee, WI

Christoph Ousterhaut, Institut für Meereskunde, Kiel (West Germany)

James Quinn, Graduate School of Oceanography, Univ. of Rhode Island,
Kingston, RI

Dr. J. Dungan Smith, Dept. Geology and Geophysics, Univ. of Washington,
Seattle, WA

Dr. Erwin Suess, School of Oceanogr., Oregon State Univ., Corvallis, OR

John Vandermeulen, Bedford Inst. of Oceanogr., Halifax (Nova Scotia)

Stephen Walter, U.S. Geol. Survey, Menlo Park, CA

Don Wright, Virginia Inst. of Marine Science, Gloucester Point, VA