W.H.O.I.-86-16

COASTAL RESEARCH CENTER
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Report of the Period May 1984 - February 1986

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April 1986

TABLE OF CONTENTS

	<u>Page</u>
Forward	ii
Abstract.	iii
Acknowledgements.	iv
Introduction to the Coastal Research Center	
History and Organization	1
1. General Activities.	5
2. Principal Project Areas	8
3. Facilities.	19
4. C.R.C. Publications	21
Appendix 1 - Curriculum Vitae of Dr. Cabell Davis, Dr. Hans Graber, Dr. Mark Altabet.	
Appendix 2 - Postdoctoral Student Support	
Appendix 3 - Guest Appointments and Invited Speakers.	
Appendix 4 - Meetings and Workshops Sponsored in part by C.R.C.	
Appendix 5 - Table of Contents - Georges Bank Richard H. Backus (editor)	
Appendix 6 - Buzzards Bay Science Symposium/Workshop Program.	

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

ABSTRACT

The Coastal Research Center activities for the period of 1984 to 1986 are described briefly. Major projects include: Assimilative Capacity-Buzzards Bay, Georges Bank book; Instrumentation-Experimental Seawater Flume, Sea Level Change - Measurement and Consequences; and Fisheries Ecology. General activities are also described.

ACKNOWLEDGEMENTS

The past six years have been exciting and enjoyable, and I wish to extend my appreciation to my friends and colleagues who have assisted me and worked with me in C.R.C. activities. The success of the Center is the result of inspired research and hard work by many people combined with generous, much appreciated financial support from private resources; the Andrew W. Mellon Foundation, the Richard King Mellon Foundation, Mobil Foundation, Inc., the Culpeper Foundation, and a private gift to Woods Hole Oceanographic Institution by Percy Chubb, II.

A very special note of appreciation goes to the Chairman of the C.R.C. Advisory Committee, Dr. William D. Grant, for his enthusiastic work and unselfish sharing of innovative research ideas with colleagues.

INTRODUCTION TO THE COASTAL RESEARCH CENTER: HISTORY AND ORGANIZATION

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 serve better 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 during 1984-1985 was:

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 and Chairman, Physical Oceanography
Department
Judith M. Capuzzo, Associate Scientist, Biology Department
David A. Ross, Senior Scientist and Chairman, Geology and Geophysics
Department; and Director, Sea Grant (ex officio)
Edward R. Sholkovitz, Associate Scientist, Chemistry Department
Maynard Silva, Research Specialist, Marine Policy and Ocean
Management Center

Advisory Committee membership is a three-year appointment with terms of the members staggered. During 1984-1985 the following joined as committee members:

Dr. John W.H. Dacey, Assistant Scientist, Biology Department
Dr. Kenneth H. Brink, Associate Scientist, Physical Oceanography Department

Drs. Beardsley and Capuzzo completed their terms and deserve a special acknowledgement for their many contributions in the formative years of the Coastal Research Center.

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. Mr. Tripp is on leave of absence, September, 1985, as Buzzards Bay Project Coordinator for the Executive Office of Environmental Affairs, Commonwealth of Massachusetts.

SUMMARY OF COASTAL RESEARCH CENTER ACTIVITIES

The activities of the C.R.C. are grouped into three interrelated categories:

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

1. GENERAL ACTIVITIES

These activities are of a nature which support and enhance the capabilities of the Institution to conduct scholarly research related to coastal areas on a worldwide basis.

New Scientific Staff and Postdoctoral Support

Our report of Coastal Research Center Activities for January 1982 - April 1984, Woods Hole Oceanographic Institution Technical Report WHOI-84-22 described C.R.C. assistance in bringing Dr. Kenneth Brink to W.H.O.I. as an Assistant Scientist in the Physical Oceanography Department in 1981. Dr. Brink is now an Associate Scientist and continues his research in coastal physical oceanography. He has recently been appointed to the C.R.C. Advisory Committee.

In the previous report we also identified fisheries ecology as an area of research where the C.R.C. planned to assist the Biology Department in cooperation with W.H.O.I.'s Center for the Analysis of Marine Systems (C.A.M.S.) in recruiting an Assistant Scientist to enhance and conduct research related to fisheries.

We are pleased to report that Dr. Cabell Davis had been appointed an Assistant Scientist in the Biology Department in 1985 with initial partial funding in a joint venture between C.R.C. and C.A.M.S. He has initiated a program in fisheries ecology research and is exploring further collaboration with the National Marine Fisheries Service, N.O.A.A., scientists of the Northeast Fisheries Center and colleagues at W.H.O.I. and elsewhere.

The Coastal Research Center provided support for a portion of the post-doctoral studies of Dr. Hans Graber in the Ocean Engineering Department. Dr. Graber had been appointed an Assistant Scientist in the Ocean Engineering Department during 1985 with funding from various federal agency projects. Dr. Graber's research on physical processes in coastal areas with emphasis on numerical modelling adds significance to W.H.O.I.'s capabilities in coastal research.

Dr. Mark Altabet, a Post-doctoral Scholar in the Chemistry Department studying the biogeochemistry of nitrogen in coastal and open ocean areas,

received a grant from the C.R.C. to extend his research for several months. He has been appointed an Assistant Scientist in the Chemistry Department and received full support from the National Science Foundation for a proposal he submitted in 1985 to continue his research. This attests to the merits of his research.

The curriculum vitae of Drs. Davis, Graber, and Altabet are attached in Appendix I.

Student Project Support

Dr. Cheryl Ann (Hannan) Butman was one of the first recipients of student support from the Coastal Research Center. Her thesis research in the Biology Department combined aspects of larval ecology with physical dynamics in near-bottom processes in coastal areas: "Initial Settlement of Marine Invertebrate Larvae: The Role of Passive Sinking in a Near-Bottom Turbulent Flow Environment," Ph.D. Dissertation (1984), Woods Hole Oceanographic Institution-Massachusetts Institute of Technology Joint Program. Dr. Butman conducted postdoctoral studies with Dr. William Grant, Ocean Engineering Department and Chairman of the C.R.C. Advisory Committee, and has recently been appointed an Assistant Scientist in the Ocean Engineering Department, where she continues her multidisciplinary biology-physical dynamics research.

This is an example of the longer term impact of a small amount of seed funding at the initial stages of graduate student projects in multidisciplinary areas of research. The Coastal Research Center has continued to encourage the involvement of the young scientists and their advisors in multidisciplinary research crucial to the significant advancement of knowledge of coastal processes. We provide funding in the range of \$2,000-\$7,500 for small equipment items, supplies, travel, computer time, and other non-stipend activities for the students to initiate or supplement their Ph.D. thesis research. This investment continues to be a great success. Initial results have subsequently led to most of the students and their advisors securing major funding from grants or contracts from sources such as the National Science Foundation, N.O.A.A. and Sea Grant.

Appendix 2 contains the names and projects of students funded during this period of time included in this report, as well as earlier student projects. Ph.D. theses completed and supported in part by C.R.C. funds are also listed in Appendix 2.

Visiting Investigators, Visiting Scholars, Guest Investigators,
Seminar Speakers

W.H.O.I. staff participating in the Coastal Research Center often find it advantageous for visiting investigators and guests to come to Woods Hole for periods of a few months to two years to participate in joint research projects and discussions of research. The presence of these visitors and guests also contributes substantially to the education of our graduate students. C.R.C. funds for these activities are mostly allocated to support travel and subsistence, although small amounts of salary support are accorded to Visiting Investigators. Guest Investigators are supported by funds of their home organization.

Visiting Scholars usually visit for a shorter period, from one to several days, and present seminars concerned with coastal research topics. A significant portion of a Visiting Scholar's time is devoted to discussions with students.

A list of the guests visiting the W.H.O.I. C.R.C. is given in Appendix 3. C.R.C. also sponsors informal seminars for guests. The list of the C.R.C. seminar speakers is given in Appendix 3 for all speakers since the inception of C.R.C.

Symposia and Workshops

Funds for workshops and symposia meetings are often difficult to obtain. C.R.C. has provided partial support to several workshops and symposia or funded the travel and subsistence allowances of key W.H.O.I. scientists. Appendix 4 presents the list of these meetings and the W.H.O.I. scientist responsible for, or participating in, the meeting. Only modest funds on the order of \$1,000 to \$6,000 have been allocated to this type of support. On several occasions initial C.R.C. support has attracted other sources of funds for the meeting.

Other Activities

The C.R.C. makes available small amounts of funds to students and staff for unanticipated travel requirements; especially for foreign travel for which normal government grants and contracts have special restrictions. Small amounts of funds are also made available for special opportunities in research. For example, Dr. Rudy Scheltema of the Department of Biology has collected in-

formation on bibliographic sources and existing data for common benthic invertebrates of the Woods Hole region. Funds were allocated to finalize the information and publish a technical report in late 1984 (see Appendix 5 - C.R.C. Associated Publications) ensuring that this valuable information is readily available to researchers and others.

2. PRINCIPAL PROJECT AREAS

The C.R.C. Advisory Committee discussions in the first year of C.R.C. activities established that available human and financial resources limited to three or four, the number of principal projects that C.R.C. could reasonably undertake during a two to three year period. The projects of the past four to five years are: 1) Georges Bank Book, 2) Assimilative Capacity, 3) Coastal Instrumentation, and 4) Rapid Response for Studies of Coastal Storms. These were discussed in the Coastal Research Center Report of the period January 1982 - April 1984 (W.H.O.I. Technical Report WHOI-84-22). The Rapid Response Coastal Storm Project has been completed and reports of that project have been published or are in preparation.

Lessons learned from the experience of the scientists involved in that project were incorporated into plans for larger research efforts related to measurement of physical dynamics and sediment resuspension in the Buzzards Bay project (see later section) and have provided input to larger experiments planned for the continental shelf areas Coastal Ocean Storm Sediment Transport (COSST) project funded by federal agencies.

The Georges Bank Book project is in its last year as discussed below. The Assimilative Capacity and Instrumentation projects continue and two new projects have been initiated - Changing Sea Level and Fisheries Ecology. A brief description and progress report for each project follow.

Georges Bank Project

The objective of the initial phase of the C.R.C.'s Georges Bank project was to summarize existing knowledge about Georges Bank in a book and atlas. Dr. Richard H. Backus, Senior Scientist in the Biology Department at W.H.O.I. is general editor of the book and, with the assistance of an editorial committee, has applied uniform editing of 57 chapters and 10 vignettes (short

pieces) submitted by 110 authors and co-authors. The contents of the book are presented in Appendix 5. The book is now in press and will be published in late 1986 by MIT Press. This past year has been a time of putting finishing touches on papers, proofing galleys and preparing to send page proofs to authors. It is not practical nor possible to do justice to the scholarly endeavors of the editor, editorial committee, authors, and manuscript reviewers in a short section here in this report. It suffices to state that this has been a major undertaking but well worth the effort given the importance of Georges Bank to the people of the United States, Canada and many other countries who enjoy or aspire to its resources.

Assimilative Capacity - Buzzards Bay Project

Scientists and engineers of the Coastal Research Center are involved in cooperative studies of Buzzards Bay with colleagues from the U.S. Geological Survey, Boston University Marine Program, and the Marine Biological Laboratory's Ecosystems Center. In addition, close liaison is maintained with the newly initiated (1985) U.S. E.P.A. Buzzards Bay program with its involvement of Massachusetts state agencies, state universities and contractors.

The Buzzards Bay project was initiated several years ago because:

(1) Scientific input was urgently needed to solve immediate critical environmental quality problems related to industrial contamination in the western part of the bay (Figure 1);

(2) Existing individual scientific research projects had reached a point where more focused multidisciplinary research projects were required to make significant advances in obtaining new knowledge;

(3) The requisite critical mass of scientists and engineers were enthusiastic about the project; and

(4) C.R.C. private foundation funds were available to initiate the project and sustain the project at critical times during the first few years.

Much of the research focuses on the biogeochemistry of PCBs (polychlorinated biphenyls) and other pollutants in the New Bedford harbor area and movement of these pollutants into Buzzards Bay. Most of the PCBs were discharged to the area by two electronics components manufacturers. The resulting PCB concentrations in many of the ecosystem components in western Buzzards Bay are

so high that tracing biogeochemical processes is not confounded by the usual analytical chemistry detection limit problems. The U.S. E.P.A. Superfund efforts at this site are devoted to remedial action. A few C.R.C. participants are engaged as subcontractors and consultants to this large Superfund effort. However, the objectives of C.R.C. portions of research in Buzzards Bay are to gather knowledge of generic value to understanding, managing and counteracting chemical pollution problems in general in coastal areas of the world. The initial research efforts have attracted Sea Grant funding via the W.H.O.I. Sea Grant Program with the required cost sharing portion of the research provided by C.R.C. private foundation funds.

The main sampling locations in Buzzards Bay are given in Figures 1 and 2 with a listing of joint C.R.C.-Sea Grant studies given in Table 1. The main processes investigated in C.R.C.-Sea Grant research efforts are depicted schematically in Figure 3. Biological effects research is of equal importance and involves efforts to probe sublethal responses of fish and bivalves to the stress imposed by high concentrations of polychlorinated biphenyls in combination with other natural and man-induced perturbations in coastal areas.

An important component of CRC activities in the Buzzards Bay Project has been the involvement of guest investigators from other countries. They come to W.H.O.I. to conduct research with C.R.C. associated scientists and engineers. There are many guests who work with us and contribute significantly to our research efforts. Three deserve special mention for their participation in the Buzzards Bay Project:

- Mr. Jia Xiaoping, a Chemist from Nan Hai Fisheries Institute,
Laboratory of Marine Fisheries, Environmental Protection, Guangzhou,
China (April 1984 - April 1986)
- Licentiate Pirjo Rantamäki, Biochemist from the University of Turku,
Finland (January 1986 - present).
- Ms. Yongping Wang, Biologist, Nan Hai Fisheries Institute, Laboratory
of Marine Fisheries, Environmental Protection, Guangzhou, China
(February 1986 - present).

Figure 1. Chart of Buzzards Bay water column and sediment PCB biogeochemistry stations (solid circles). Mussel (*Mytilus edulis*) transplant cage stations (circled X). Intensive sediment biogeochemistry studies conducted at Station M.

Figure 2. Physical oceanographic and sediment dynamics studies. Instrument deployment stations W.H.O.I. and U.S. Geological Survey (Dr. Bradford Butman).

BIOGEOCHEMICAL CYCLE OF ORGANICS IN A COASTAL ENVIRONMENT

Figure 3.

Table 1. C.R.C. Buzzards Bay Project - Synopsis of 1983-1986 Projects -
Joint W.H.O.I. - C.R.C. - Sea Grant Funding

1983-1984

Physical Processes and Biogeochemistry of Environmental Contaminants:
General Considerations and Application to PCB Pollution Problem in
Buzzards Bay.

Principal Investigators:

John W. Farrington, Chemistry Department and C.R.C.
William D. Grant, Ocean Engineering Department
Robert C. Beardsley, Physical Oceanography Department
Albert J. Williams, III - Ocean Engineering Department

Funding: N.O.A.A.-Sea Grant - \$143,500
W.H.O.I.-C.R.C. - \$ 68,165

1984-1986

- 1) Biogeochemistry of PCBs in Buzzards Bay, Massachusetts
Principal Investigator: John W. Farrington, Chemistry Department and
C.R.C.
- 2) PCBs in Buzzards Bay, Massachusetts: Effects on Energetics and
Reproductive Cycles in Bivalve Molluscs.
Principal Investigator: Judith M. Capuzzo, Biology Department and
C.R.C.
- 3) The Origin of Induced Cytochrome P-450 in Buzzards Bay Fish: A
Possible Effect of PCBs.
Principal Investigator: John J. Stegeman - Biology Department
- 4) The Effects of Size Class and Bioturbation on Fine-grained Transport
in Coastal Systems: Specific Application to Biogeochemistry of PCB
Transport in New Bedford Harbor.
Principal Investigator: William D. Grant, Ocean Engineering
Department and C.R.C.
Associate Investigator: Cheryl Ann Butman, Ocean Engineering
Department and C.R.C.

Funding: N.O.A.A.-Sea Grant - \$304,700
W.H.O.I.-C.R.C. - \$146,000

Each of these scientists' salaries are supported by their home institution or government with some modest expenses for subsistence provided by C.R.C. where appropriate. Their participation in C.R.C. sponsored research is part of an intensive effort to ensure that the generic aspects of the research - knowledge and practical experience - are transferred to other scientists working in coastal areas around the world. In addition, C.R.C. scientists and engineers are very active in national and international committees and working groups which are concerned with coastal research issues.

The Buzzards Bay project involves much more than research on the fate and effects of PCBs. For example, early in the assessment of the magnitude of the PCB problem, it became obvious that there was a lack of modern physical oceanography data for Buzzards Bay and thus there was a major gap in the capabilities to predict physical transport processes in the Bay. Local and state government agency appeals to federal agencies for a modern hydrographic survey failed to elicit a timely response because of budget constraints and also, apparently, political maneuvering.

A timely response was forthcoming by W.H.O.I.-M.I.T. Joint Program graduate students, Ms. Leslie Rosenfeld, Mr. Richard Signell and Mr. Glen Gawarkiewicz with advice from Drs. Robert Beardsley and William Grant and support from W.H.O.I.-C.R.C. joined by the W.H.O.I.-Sea Grant Program. The data of Rosenfeld, Signell and Gawarkiewicz were published as a technical report (see publications list) and led to the interesting observation that there might be evidence of groundwater intrusion in the eastern portion of Buzzards Bay. Professor Ivan Valiela of the Boston University Marine Program coupled this information with groundwater nutrients data for surrounding marshes. He and co-workers posed the hypothesis that these nutrients flowing into Buzzards Bay and other coastal areas may be significant to the overall nutrient budget of coastal areas; an important consideration in assessing the assimilative capacity of coastal waters for receiving nutrients from point source sewer effluents or dispersed sources such as runoff from agricultural lands and septic systems. These researchers, Valiela et al., have recently received funding from the National Science Foundation to research their hypothesis; funding in part made possible by the hydrographic data of Rosenfeld, Signell and Gawarkiewicz.

Another major impact of the data and interpretations of Rosenfeld et al. was a head start for E.P.A. Superfund related efforts when those efforts were finally funded. Scientists and engineers from W.H.O.I. have continued and expanded the physical oceanographic studies of Buzzards Bay with funding from E.P.A.'s Superfund study.

C.R.C. participants and colleagues from other organizations identified the need for a bibliography of published scientific journal articles, technical reports and other compilations of information and data concerned with Buzzards Bay. W.H.O.I.-C.R.C. responded with a bibliography compiled by Mr. Bruce W. Tripp, which was published with assistance of supplementary funds from Sea Grant.

There are many other facets to the C.R.C. Buzzards Bay Project, too numerous to describe in a brief report. The program of a recent informal symposium concerned with Buzzards Bay scientific research organized by W.H.O.I.-C.R.C. and co-sponsored by the Boston University Marine Program, the Ecosystems Center of the Marine Biological Laboratory, and the W.H.O.I.-Sea Grant Program provides a sampling of the breadth of topics under investigation by C.R.C. associated researchers and colleagues from other organizations (Appendix 6). The main thrust of the C.R.C.-related efforts is research to provide new knowledge of generic value for assessing the assimilative capacity of coastal and estuarine areas. Drs. Capuzzo and Farrington (and co-authors) incorporated aspects of their research and that of graduate student, Mr. Bruce Brownawell, into papers prepared for a NATO Workshop Volume on the Scientific Basis for the Role of the Oceans in Waste Disposal Options (G. Kullenberg, editor, Springer-Verlag, in press, 1986). Other C.R.C. associated scientists and engineers have published in the scientific literature and contributed to similar symposia and workshops.

Instrumentation Project

Installation in the Coastal Research Laboratory of the twenty-meter seawater flume designed by C.R.C. associated scientists and engineers was completed in January, 1985. Several tests have been carried out to determine conditions for experimentation with live benthic organisms and larvae of benthic organisms.

Research and engineering design have proceeded on two instruments to be installed on the flume and used with experiments. Dr. Yogi Agrawal and co-workers of W.H.O.I.'s Ocean Engineering Department are constructing a 2-axis LDV (Laser Doppler Velocimeter) with joint Sea Grant and C.R.C. funding. The second instrument is an optical particle sizing instrument. Dr. Agrawal and Joint Program graduate student, J. B. Riley, are conducting experimental and theoretical research to optimize the design and construction of this instrument to measure the angular distribution of scattered light from a sample of fluid. The measurement is then mathematically inverted to determine suspended particle size distribution. Both instruments, the LDV and the optical particle sizer will vastly improve the experimental capabilities of the seawater flume.

The existence of the seawater flume has made it possible to propose new types of research. Dr. Cheryl Ann Butman and Dr. William Grant have received Sea Grant funding for experiments and Dr. Butman has received N.S.F. funding for flume related research. Other proposals have been submitted or are in the process of revision for submission. Once the initial calibrations and experiments are completed the flume will be utilized for a variety of multidisciplinary experiments.

Sea Level Change: Measurement and Consequences

Changes of relative sea level have occurred throughout the geological record. As man has occupied more of the world's coast with an increasing population and a concomitant multiplicity of uses of the coast, there has been an increased awareness of the necessity for having accurate short- and long-term predictions of changes in sea level. Most of these changes are due to local phenomena due to tectonic disturbances, volcanic activity, and possible withdrawal of interstitial fluids.

Widespread eustatic-sea level rise occurred during the main melting of the latest ice sheets prior to about 5,000 years ago. Renewed rapid rise may be occurring from a combination of thermal expansion of the warming oceans and melting of the West Antarctica ice sheet, both due to increased atmospheric warming as a result of increased concentrations of so-called "greenhouse gases" such as carbon dioxide and methane in the atmosphere. There is an obvious need

to identify past and present sea level changes and to document present and future changes because of the effects of sea level rise on man's multiple uses of coastal areas, not the least of which are major population living centers. Effective coastal engineering and coastal management require accurate knowledge of sea-level position over the next 100 years.

Dr. David Aubrey and Dr. Kenneth O. Emery (Senior Scientist Emeritus) of the Geology and Geophysics Department have been conducting research on the changes in global sea levels over the last century. Seed funding from C.R.C. enabled Dr. Aubrey to initiate this work in 1984. The first results attracted additional major funding from N.O.A.A. and the National Science Foundation. Further modest C.R.C. support in terms of foreign travel has allowed Dr. Aubrey to establish and maintain contacts with colleagues in China for joint research efforts in this project.

A related effort was initiated in 1984-1985 to investigate the interactions between; i) changes in flow of water and suspended matter in rivers as a result of changing land use practices and river diversion projects, and ii) transgressing sea level. The project focuses on expected changes in the geomorphology, ecology, and human habitability of river delta areas as a result of these interactions. This project involves Dr. John Milliman and Dr. Aubrey of the Geology and Geophysics Department and Drs. James Broadus and Maynard Silva of the Marine Policy and Ocean Management Center. C.R.C. funding attracted much larger funding from the U.S. Environmental Protection Agency.

We anticipate that the research in this project area - measurement and consequences of changing sea level - will be a major C.R.C. project for several years. The research is global in scope and requires the mix of scientists, engineers, political scientists, economists, and social scientists that W.H.O.I.'s C.R.C. and Marine Policy and Ocean Management Center brings together effectively.

Fisheries Ecology

The Coastal Research Center in concert with W.H.O.I.'s Department of Biology and its Center for the Analysis of Marine Systems (C.A.M.S.) has initiated an effort aimed at establishing multidisciplinary research in fisheries ecology. The primary focus of this effort will be scholarly and academic in orientation although we fully recognize the ultimate practical application to

fisheries management issues in the long term. Thus, this effort will be complementary to the research efforts of the scientists of the U.S. National Marine Fisheries Service. Dr. Cabell Davis and Dr. Peter Wiebe, Director of W.H.O.I.'s C.A.M.S. have established cooperative efforts with scientists of the Northeast Fisheries Center of the National Marine Fisheries Service. Planning continues for field research and modelling of long-term data sets. The overall objectives are to understand the causes and effects of large natural variations and anthropogenic perturbations within marine ecosystems, and subsequently, fisheries.

We have mentioned earlier in this report that the Coastal Research Center assistance in hiring Dr. Cabell Davis as an Assistant Scientist in the Biology Department has been a significant step towards expanding W.H.O.I.'s research capabilities in fisheries ecology. The focus of Dr. Davis's efforts are in the Georges Bank fisheries at present and provide a natural second phase for the C.R.C. Georges Bank project.

3. FACILITIES

Coastal Research Laboratory

The Coastal Research Laboratory constructed in 1981-1982 and expanded in 1984, serves the needs of several scientific programs of the Institution with a mix of flexible experimental space and offices and assigned laboratories. The twenty-meter flume has been constructed and is operational in high bay area as described in a previous section of this report. The Geophysical Fluid Dynamics Laboratory of Dr. Jack Whitehead, equipped with a 2-meter rotating table and ancillary equipment, is used for a variety of research experiments by Dr. Whitehead and his colleagues at W.H.O.I. and attracts visitors from other organizations for joint experiments.

Dr. Judy Capuzzo's research laboratories and two temperature controlled culture laboratories are fully occupied with a variety of research efforts concerned with biochemistry, nutrition, physiology, reproduction, effects of natural and pollution related stress on marine organisms, and aquaculture.

The Physical Measurements Laboratory is home to some aspects of the development and testing of the laser doppler velocity meter and other flume related research. The Machine Shop is operated for Coastal Research Labora-

tory participants as well as others. It is the only machine shop on the Quissett Campus of W.H.O.I.

High Bay Space has been used for a variety of purposes over the past two years in addition to providing a home for the flume. The major uses have been:

- 1) Sea duct - an experimental bottom lander package for the High Energy Benthic Boundary Layer Experiment; construction and component testing, Mr. Cliff Winget, Ocean Engineering Department. HEBBLE's overall coordinator is Dr. Charles Hollister, Dean at the Institution.

- 2) Wave rider buoy calibration for Dr. Melbourne Briscoe, Physical Oceanography Department.

- 3) In-situ pump systems maintenance and modifications between cruises for geochemistry studies of Dr. Peter Brewer and Dr. Michael Bacon of the Chemistry Department.

- 4) Instrument bottom lander packages for benthic boundary layer - sediment geochemistry studies of Dr. Fred Sayles, Chemistry Department.

- 5) Box core sectioning and initial sample work-up for Buzzards Bay and coontinental margin area studies of sediment geochemistry by Dr. Ed Sholkovitz's and Dr. John Farrington's laboratories.

- 6) Modification, maintenance, and instrument calibration for the portable laboratory van for measurements of CO_2 and related parameters at sea - Dr. Peter Brewer and co-workers, Chemistry Department.

- 7) Construction and calibration of drifters and instruments related to physical oceanography studies in Buzzards Bay.

- 8) Refurbishment of in-situ pumps for organic geochemistry studies. Mr. C. H. Clifford, Chemistry Department for Drs. Stuart G. Wakeham and John W. Farrington.

In addition, numerous small, short-term experiments have been conducted in the area and several large vans or sea-going sampling and measurement devices have been housed for short-term refurbishment prior to going to sea or returning to storage elsewhere.

CRL Offices

Six offices are maintained at C.R.L. for use of visitors or W.H.O.I. staff participating in C.R.C. projects or utilizing the high bay space. Two

offices are assigned to Dr. Capuzzo's laboratory and one office complex is assigned to C.R.C. administration.

Small Boats

The Coastal Research Center maintains and operates the following small boats for use by W.H.O.I. researchers.

Outboard Motor Equipped

R/V Sea Truck - 25 ft.

17 ft. Boston Whaler

13 ft. Boston Whaler

11 ft. Inflatable Zodiac

11 ft. Yankee Skiff

Rowboats

8 ft. Aluminum

8 ft. Fiberglass

These boats are scheduled and maintained by Mr. C. H. Clifford.

4. CRC PUBLICATIONS

The results of the activities of the C.R.C. participants are made available in the published literature in journal articles and reports of various types. A list of publications follows for the entire range of C.R.C. activities up to January 1, 1986. Several more publications are in various stages of preparation and will report on activities during 1985.

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. WHOI Tech. Rpt. No. 83-20, Woods Hole Ocean. Inst., Woods Hole, MA, 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.
- Backus, R. H. (ed.) (in press). Georges Bank. MIT Press.
- 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.
- Brownawell, B. J. and J. W. Farrington (in press). Partitioning of PCBs in marine sediments. Chapter 7, In: Marine and Estuarine Geochemistry (A. C. Sigleo and A. Hattori, eds.). Lewis Publ. Inc., Ann Arbor, MI. WHOI Cont. No. 5870.
- Brownawell, B. J. and J. W. Farrington (submitted). Biogeochemistry of PCBs in interstitial waters of a coastal marine sediment. Submitted to Geochimica Cosmochimica Acta. WHOI Cont. No. 5839.
- 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. (1984). Sources and distribution processes of chemical contaminants in the coastal zone. In: The Law of the Sea and Ocean Industry: New Opportunities and Restraints, Proceedings, The Law of the Sea Institute (D. M. Johnston and N. G. Letalik, eds.), 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).
- Giblin, A. E. (1985). Comparison of the processing of elements by ecosystems II. Metals. Chapter 10, In: Ecological Considerations in Wetland Treatment of Municipal Wastewater (P. J. Godfrey, E. R. Kaynor, S. Pelczarski and J. Benforado, eds.). von Nostrand Reinhold Co., New York.
- Giblin, E. A., G. W. Luther, III and I. Valiela (1985). Trace metal solubility in salt marsh sediments contaminated with sewage sludge. Estuarine, Coastal and Shelf Science. In press.
- 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 Ocean. Inst., 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 Ocean. Inst., Woods Hole, MA.

- Libes, S. M. (1983). Stable isotope geochemistry of nitrogen in marine sediments. Ph.D. dissertation, Woods Hole Ocean. Inst., Woods Hole, MA.
- Lohrenz, S. (1985). Primary production of particulate protein amino acids: algal protein metabolism and its relationship to the composition of particulate organic matter. Ph.D. dissertation, Woods Hole Ocean. Inst., Woods Hole, MA.
- Martin, W. (1985). Transport of trace metals in nearshore sediments. Ph.D. dissertation, Woods Hole Ocean. Inst., 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.
- McElroy, A. (1985). Benz(a)anthracene in benthic marine environments: Bioavailability, metabolism, and physiological effects on the polychaete Nereis virens. Ph.D. dissertation, Woods Hole Ocean. Inst., Woods Hole, MA.
- Milliman, J. D., Ya Hsueh, Dun-Xin Hu, D. J. Pashinski, Huan-ting Shen, Zuo-sheng Yang, and P. Hacker (1984). Tidal phase control of sediment discharge from the Yangtze River. Est. Coast. Shelf Sci., 19: 119-128.
- Repeta, D. J. (1982). Carotenoid transformations in the oceanic water column. Ph.D. dissertation, Woods Hole Ocean. Inst., Woods Hole, MA.
- Rosenfeld, L. K., R. P. Signell and G. G. Gawarkiewicz (1984). Hydrographic study of Buzzards Bay, 1982-83. CRC Technical Report 84-01, Woods Hole Ocean. Inst., Woods Hole, MA.
- 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. WHOI Tech. Rpt. 82-28, Woods Hole Ocean. Inst., Woods Hole, MA.
- Scheltema, R. S. (1984). Development of planktonic larvae of common benthic invertebrates of the Woods Hole, MA region: summary of existing data and bibliographic sources. WHOI Tech. Rept. 84-13, CRC-84-02, Woods Hole Ocean. Inst., Woods Hole, MA, 37 pp.
- 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 Ocean. Inst., 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.

Steele, J. H. (1985). A comparison of terrestrial and marine ecological systems. Nature, 313(6001): 355-358.

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.

APPENDICES

Appendix 1

Curriculum Vitae of:

Dr. Cabell Davis
Dr. Hans Graber
Dr. Mark Altabet

CABELL S. DAVIS
Assistant Scientist
Biology Department

Born: 11 August 1950
Social Security No.: 224-76-6995

B.S., University of Tampa, 1975
Ph.D., Boston University Marine Program, 1982

Research Assistant, Boston University, 1976
Laboratory Instructor, Boston University, 1976-77
Teaching Assistant, Marine Biological Laboratory, 1979
Fishery Biology, NOAA, NMFS, 1977-1982
Postdoctoral Investigator, 1982-1984; Assistant Scientist 1984-
present, Woods Hole Oceanographic Institution

Member: American Society of Limnology and Oceanography; American
Association for the Advancement of Science

PUBLICATIONS

- 1982 Davis, C. S. Processes controlling zooplankton abundance on Georges Bank. Ph.D. Thesis, Boston University Marine program, Woods Hole, Ma.
- 1983 Davis, C. S. Laboratory rearing of marine calanoid copepods. J. Exp. Mar. Biol. Ecol. 71: 119-133.
- 1984 Davis, C. S. Predatory control of copepod seasonal cycles on Georges Bank. Mar. Biol. 82: 31-40.
- 1984 Davis, C. S. Food concentrations on Georges Bank: Non-limiting effect on growth and survival of laboratory reared Pseudocalanus sp. and Paracalanus parvus. Mar. Biol. 82: 41-46.
- 1984 Davis, C. S. Interaction of a copepod population with the mean circulation on Georges Bank. J. Mar. Res. 42: 573-590.
- 1985 Davis, C. S. and P. H. Wiebe. Macrozooplankton biomass in a warm-core Gulf Stream Ring: Time series change in size structure, taxonomic composition and vertical distribution. J. Geophys. Res. 90: 8871-8884.
- 1985 Wiebe, P. H., V. A. Barber, S. H. Boyd, C. S. Davis and G. R. Flierl. Macrozooplankton biomass in Gulf Stream warm-core rings: spatial distribution and temporal changes. J. Geophys. Res. 90: 8885-8901.

In Press:

Davis, C. S. Zooplankton Life Cycles. In: Georges Bank Atlas.
R. H. Backus (ed.), MIT Press.

In Preparation:

Davis, C. S. Components of the zooplankton production cycles in temperate marine areas.

Davis, C. S. and N. Marcus. The role of bottom resting eggs in maintaining stable abundance patterns of planktonic copepods on Georges Bank.

Abstracts:

1982 Davis, C. S. Interaction of a copepod population with the mean circulation on Georges Bank. EOS 63: 975.

1983 Davis, C. S. and P. H. Wiebe. Evolution of zooplankton size structure and taxonomic composition in a warm-core Gulf Stream ring as determined by silhouette photography. EOS 64: 1093.

Other:

1985 Davis, C. S., M. D. Grosslein, P. H. Wiebe, G. D. Grice and S. Murawski. WHOI-NEFC Fisheries Ecology Seminar Series. A Summary. Tech. Report WHOI 85-25, 57 pp.

1982 Davis, C. S. Zooplankton. In: Natural boundaries of the continental shelf ecosystem off the northeast coast of the United States. Source Document of Legal Brief presented to World Court (September 1982) with regard to U.S./Canada boundary dispute over Georges Bank. pp. 15-21.

1982 Davis, C. S. Fine mesh (0.165 mm) zooplankton on Georges Bank between September 1974 and February 1979. Data Report. NOAA, NMFS, Woods Hole Laboratory Reference Document No. 82-30. 283 pp.

1982 Davis, C. S. Size frequency of Sagitta elegans on Georges Bank between December 1974 and October 1975. Data Report. NOAA, NMFS, Woods Hole Laboratory Reference Document No. 82-29. 4 pp.

1982 Davis, C. S. Particulate organic carbon/nitrogen concentrations and particle size distributions on Georges Bank in October 1978 and February 1979. Data Report. NOAA, NMFS, Woods Hole Laboratory Reference Document No. 82-28. 15 pp.

CURRICULUM VITAE

HANS CHRISTIAN GRABER
Assistant Scientist
Ocean Engineering Department
Woods Hole Oceanographic Institution

Born: September 1, 1951
Married

RESEARCH AND SCIENTIFIC INTERESTS:

Modelling of wave and coastal processes, remote sensing of oceanographic processes, air-sea interactions and boundary layer dynamics

EDUCATION:

B.E., The City College of New York, 1977
S.M., Massachusetts Institute of Technology, 1979
Sc.D., Massachusetts Institute of Technology, 1984

EMPLOYMENT SUMMARY:

Research and Teaching Assistant, 1977-79, Modifying and applying a deep-water wave prediction model to extra-tropical storm systems, Massachusetts Institute of Technology, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics.

Guest Scientist, 1979-80, Field logistics during the MARSEN project (Marine remote sensing project under general coordination of K. Hasselmann), developing a spectral depth refraction model, Max-Planck Institute for Meteorology and Institute of Theoretical Geophysics, University of Hamburg, Hamburg, W. Germany.

Research and Teaching Assistant, 1980-84, Instructing and implementing the use of large computer models in two engineering courses; development of a spectral depth-current refraction model; developing a finite-depth wave prediction model, Massachusetts Institute of Technology, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics.

Post Doctoral Investigator, 1984, Applying a finite-depth wave prediction model to idealized shallow water situations, Massachusetts Institute of Technology, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics.

Post Doctoral Scholar, 1984-1985, Analysis of wave data during the CODE experiment, developing of a marine surface wind model, analysis of wind and wave climate in the Yellow Sea and studying their effects on wave-current interaction and sediment transport, investigating the energy balance of waves in shallow water, Ocean Engineering Department, Woods Hole Oceanographic Institution.

Assistant Scientist, 1985-present, Numerical modelling of wave evolution for idealized generation conditions, analysis and evaluation of Hurricane Gloria wave data, investigating the dynamics of shallow water waves, surface wave tomography, Ocean Engineering Department, Woods Hole Oceanographic Institution.

EXPERIENCE:

1. STAFF RESPONSIBILITIES (Woods Hole Oceanographic Institution)

Ocean Modeling and Remote Sensing Group, Committee Member,
1984-present.

2. EXTERNAL PROFESSIONAL ACTIVITIES

A. Consultant To: Applied Science Associates

B. Reviewer For: Journal of Physical Oceanography; Journal of
Geophysical Research; National Science Foundation.

C. Workshops - Invited Participant:

Wave Model Intercomparison Workshop, January, 1980, Miami

Wave Model Intercomparison Workshop, January, 1981, Miami

Third WAM (Wave Modelling Group) Workshop, May, 1985, Bergen,
Norway

Third JECSS (Japan and East China Seas Study) Workshop,
May, 1985, Tsukuba University, Japan

D. Invited Talks:

Bedford Institute of Oceanography, Halifax Canada, January 1985

Canada Centre for Inland Waters, Burlington, Canada, March 1985

Great Lakes Environmental Research Laboratory, Ann Arbor,
Michigan, March 1985

University of Western Australia, Perth, Australia, August 1984

E. Member: American Meteorological Society; American Geophysical
Union; Deutsche Gesellschaft fur Meeresforschung.

PUBLICATIONS:

- Grabner, H.C. and O.S. Madsen, 1985a.
A Finite Depth Wind Wave Model; Part I - Model Description (in prep.)
- Grabner, H.C. and O.S. Madsen, 1985b.
A Finite Depth Wind Wave Model; Part II - Application to ARSLOE Storm (in prep.)
- Grabner, H.C. and R.C. Beardsley, 1985c.
Hindcast of the Wind Stress and Sea State in the Yellow Sea for November 1983 (in prep.).
- Grabner, H.C. and O.S. Madsen, 1984.
A Parametric Wind-Wave Model for Waters of Arbitrary Depth, in: THE OCEAN SURFACE, Editors: Y. Toba & H. Mitsuyasu, D. Reidel Publishing Co.
- Grabner, H.C., 1984.
A Parametric Wind-Wave Model for Waters of Arbitrary Depth, Sc.D. Thesis, Massachusetts Institute of Technology, Cambridge, MA, 310 pp.
- Grabner, H.C. and O.S. Madsen, 1982.
The Directional Relaxation of a Windsea Spectrum using an Energy Flux Approach, Trans. Am. Geophys. Union, 65(45), 970.
- Grabner, H.C., 1979.
A Hybrid Wind-Wave Model, S.M. Thesis, Massachusetts Institute of Technology, Cambridge, MA, 349 pp.

CONFERENCE PRESENTATIONS:

- Grabner, H.C. and O.S. Madsen, 1984.
A Parametric Wind-Wave Model for Waters of Arbitrary Depth, Symposium of Wave Breaking, Turbulent Mixing and Radio Probing of the Ocean Surface, Sendai, Japan.
- Grabner, H.C. and O.S. Madsen, 1982.
The Directional Relaxation of a Windsea Spectrum using an Energy Flux Approach, AGU Fall Meeting.
- Grabner, H.C., H. Gunther, O.S. Madsen, K. Richter and R. Spanhoff, 1981.
Propagation of Swell Energy in the North Sea, IUCRM Symposium on Wave Dynamics, Miami, FL (poster presentation).
- Madsen, O.S., H.C. Grabner and T.A. Stefanik, 1981.
Wave Attenuation by Bottom Friction, IUCRM Symposium on Wave Dynamics, Miami, FL (poster presentation).
- Grabner, H.C., H. Gunther, O.S. Madsen, K. Richter and R. Spanhoff, 1981.
Propagation of Swell Energy in the North Sea, Symposium on North Sea Dynamics, Hamburg, West-Germany.

-33-
CURRICULUM VITAE

Mark A. Altabet
Department of Chemistry
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Date of Birth: November 22, 1957
Place of Birth: New York, New York
Social Security No. 079-38-8060

Education:

B.S. received from S.U.N.Y. at Stony Brook; graduated Magna Cum Laude (1979).

Ph.D. received from Harvard University (June, 1984). Thesis title: ^{15}N
Natural Abundance in Warm-Core Rings of the Gulf Stream: Studies of the
Upper-Ocean Nitrogen Cycle.

Employment:

Research Assistant, Brookhaven National Laboratory, Department of Oceanography
(summer, 1978).

Teaching Fellow for courses in Biological Oceanography, Introductory Biology,
and Physiological Ecology of Phytoplankton (1979 to 1983).

Research Assistant participating in the Warm Core Rings Program (1981 to June
1984).

Post-Doctoral Research Associate, Harvard University (Summer, 1984).

Post-Doctoral Scholar, Woods Hole Oceanographic Institution (September, 1984 to
August, 1985).

Post-Doctoral Investigator, Woods Hole Oceanographic Institution (September,
1985 to present).

Awards and Societies:

Phi Beta Kappa.

3-year National Science Foundation graduate fellowship.

American Society for Limnology and Oceanography.

American Geophysical Union.

Publications:

Glibert, P. M., F. Lipschultz, J. J. McCarthy and M. A. Altabet, 1982. Isotope
dilution models of uptake and remineralization of ammonium by marine
plankton. Limnol. Oceanogr., 27, 639-650.

McCarthy, J. J. and M. A. Altabet, 1984. Patchiness in nutrient supply:
Implications for phytoplankton ecology. In: D. G. Meyers and J. R.
Strickler (eds.) Trophic Interactions within Aquatic Ecosystems, Westview
Press.

- Altabet, M. A. and W. G. Deuser, 1985. Seasonal variations in ^{15}N natural abundance and the flux of particulate matter to the deep Sargasso Sea. Nature, 315, 218-219.
- Altabet, M. A. and J. J. McCarthy, 1985. Temporal and spatial variations in the natural abundance of ^{15}N in PON from a warm-core ring. Deep-Sea Res., 32, 755-772.
- Nevins, J. L., M. A. Altabet and J. J. McCarthy, 1985. Nitrogen isotope ratio analysis of small samples: Sample preparation and calibration. Analytical Chemistry, 57, 2143-2145.
- Altabet, M. A. and J. J. McCarthy, in press. Vertical patterns in ^{15}N natural abundance in PON from the surface waters of warm-core rings. Journal of Mar. Res.
- Altabet, M. A., A. R. Robinson and L. J. Walstad, in press. Vertical fluxes of nitrogen in the upper-ocean: A model simulating the alteration of isotopic ratios. Journal of Mar. Res.

Published Abstracts:

- Altabet, M. A. and J. J. McCarthy, 1983. Variations in ^{15}N natural abundance of PON as evidence for processes affecting the nitrogen cycle in warm-core rings. EOS, 64, p. 1083.
- Altabet, M. A. and J. J. McCarthy, 1984. Vertical patterns in the natural abundance of ^{15}N in PON from several warm-core rings. EOS, 65, p. 913.
- Altabet, M. A. and W. G. Deuser, 1985. Temporal variations in ^{15}N natural abundance in the Sargasso Sea. EOS, in press.

Appendix 2

Predoctoral Student Support

- Susan Libes, Chemistry — July 1980 - June 1981
The Geochemistry of Stable Nitrogen Isotopes in Marine Sediments
- Cheryl-Ann Hannan, Biology — Jan. 1981 - Dec. 1982
Experimental Evaluation of the Role of Passive Larval Settlement in
Benthic Marine Invertebrates: Do Hydrodynamic Processes Determine
Settlement Sites or Do Larvae Actively Choose Where to Settle?
- Daniel Repeta, Chemistry — Feb. 1981 - March 1981
Carotenoid Transformations in the Water Column
- Alan Klotz, Biology — Aug. 1981 - July 1982
Purification and Characterization of the Polysubstrate Monooxygenase
System from the Coastal Marine Fish Stenotomus versicolor
- Richard Mercier, Ocean Engineering — Sept. 1981 - Sept. 1982
Development of Experimental Methods for Studying Interactions Between
Environmental Processes and the Turbulent Microenvironment
- 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
- Bruce Brownawell, Chemistry — June 1983 - June 1984
Biogeochemistry of PCBs in a Coastal Environment
- Brian Binder, Biology — Jan. 1984 - Jan. 1985
Encystment, Dormancy and Germination in the Marine Dinoflagellate,
Scrippsiella trochoidea
- Melissa Lakich, Biology — 1984-85
Mechanisms of Chlorophyll Diagenesis in Coastal Marine Sediments
- Dean Jacobson, Biology — 1984-85
Feeding Mechanisms and Predation in Coastal and Oceanic Heterotrophic
Dinoflagellate Populations.

-36-
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 Hannan, Initial Settlement of Marine Invertebrate Larvae: The Role of Passive Sinking in a Near-bottom Turbulent Flow Environment, Feb. 1984
- William Martin, Transport of Trace Metals in Nearshore Sediments, Apr. 1985
- Anne E. McElroy, Benz(a)Anthracene in Benthic Marine Environments: Bio-availability, Metabolism, and Physiological Effects on the Polychaete Nereis virens, Mar. 1985.
- Steve Lohrenz, Primary Production of Particulate Protein Amino Acids: Algal Protein Metabolism and its Relationship to the Composition of Particulate Organic Matter, June 1985

Appendix 3

C.R.C. Guest Appointments

- Dr. Peter C. Smith, Bedford Institute of Oceanography, Nova Scotia, Canada
Sept. 1980 - Dec. 1980
- Dr. William C. Boicourt, Chesapeake Bay Institute, Johns Hopkins Univ., Shady
Side, MD, Feb. 1981 - June 1981
- Dr. Nick Staresinic, IAEA Laboratory, Monaco
Jan. 1981 - Jan. 1982
- Dr. Donald C. Malins, NOAA, National Marine Fisheries Service, Seattle, WA
April 1981
- Dr. Robert Guza, Center for Coastal Studies, Scripps Institution of
Oceanography, La Jolla, CA, August 1981
- Dr. Erwin Suess, School of Oceanography, Oregon State Univ., Corvallis, OR
March 1982
- Dr. Chi Yuh Tzao, Jinan Univ., People's Republic of China
- Prof. Chen Chiyu, Institute of Estuarine & Coastal Research, Shanghai Normal
Univ., People's Republic of China
- Mr. Dunxin Hu, Physical Oceanography Dept., Academia Sinica Oceanography Lab,
Tsingtao Univ., People's Republic of China
- Prof. Ying Wang, Nanking Univ., People's Republic of China
- 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 Whittedge, 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

CRC Guest Appointments (cont.)

- Dr. Jacek Sulanowski, Bridgewater State College, Bridgewater, MA
18 July 1981 - 30 Sept. 1981
- 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 Book, NY
1 March 1983 - 31 August 1984
- Dr. Anne Giblin, Ecosystems Center, MBL, Woods Hole, MA
1 Sept. 1983 - 31 Dec. 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 Dec. 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
Oct. 1984 - Sept. 1985
- Mr. Thomas Capo, Marine Biological Laboratory, Woods Hole, MA
1 Sept. 1982 - 31 August 1984
- Dr. Eric Henderson, Marine Laboratory, Aberdeen, Scotland
5 Sept. 1983 - 8 Oct. 1983, and Sept. 1984
- Ms. Beverly Alger, Marine Biological Laboratory, Woods Hole, MA
8 Oct. 1984 - 30 Sept. 1985
- Dr. Rene Schwarzenbach, Swiss Federal Institute (EAWAG), Zurich
March - Oct. 1985
- Dr. Harry Hemond, Dept. Civil Engr., MIT, Cambridge, MA
1 June 1985 - 31 Dec. 1985
- Mr. Jia Xiaoping, Nan Hai Fisheries Institute, Guangzhou, People's
Republic of China
1 April 1984 - 30 March 1986

Invited Speakers

- Dr. Richard Burroughs, Bureau of Land Management, Washington, D. C.
- Dr. Clifford Russel, Resources for the Future
- Dr. Kathryn Burns, IAEA Laboratory, Monaco
- Dr. Christopher Martens, Mar. Sciences Program, Univ. North Carolina, Chapel Hill, N.C.; also Guest Investigator, Chemistry Dept., WHOI
- Dr. David Cacchione, USGS, Menlo Park, CA
- Dr. John H. Vandermeulen, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada,
- Dr. Mark Melancon, Medical College of Wisconsin
- Dr. Alice Alldredge, Univ. of California, Santa Barbara, CA
- Dr. Kathe Bertine, Dept. of Geological Sciences, San Diego State Univ., San Diego, CA
- Dr. Bodo Von Dodungen, Univ. of Kiel (West Germany)
- Dr. Michael Conner, School of Public Health, Harvard Univ., Cambridge, MA
- Dr. John Dingler, U.S. Geol. Survey, Menlo Park, CA
- Dr. Jed Fuhrman, Marine Sciences Research Center, SUNY, Stony Brook, NY
- Dr. Frank Gillan, Australian Inst. of Marine Science (Australia)
- Dr. John Gray, Marine Biology and Limnology Inst., Univ. of Oslo (Norway)
- Dr. Jay Means, Chesapeake Biological Laboratory, Solomons, MD
- Dr. Mark Melancon, Medical College of Wisconsin, Milwaukee, WI
- Christoph Ousterhaut, Institut für Meereskunde, Kiel (West Germany)
- Dr. 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
- Dr. John Vandermeulen, Bedford Inst. of Oceanogr., Halifax (Nova Scotia)

Invited Speakers (cont.)

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

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

Dr. Richard Carpenter, Environment & Policy Institute, East-West Center,
Honolulu, Hawaii

Dr. Jaap Boon, FOM Inst. Voor Atoomen Moleculfysica, Amsterdam

Appendix 4

Meetings and Workshops

Gulf of Maine Workshop, March 1981, Univ. New Hampshire, Durham, NH
(R. Beardsley)

Fisheries Ecology Workshop, June 1981, Woods Hole, MA (J. Steele)

Ocean Pollution 1981, October 1981, Halifax, Nova Scotia, Canada
(J. Farrington)

International Symposium on Responses of Marine Organisms to Pollutants,
April, 1983, Woods Hole, MA (J. Stegeman)

Chemical Changes in the Coastal Zone -- Mussel Watch II, November 1983,
East-West Center, Hawaii (J. Farrington)

Coastal Ocean Storm Sediment Transport Steering Committee Meeting,
Jan. 1984, Keystone, Colorado (W. Grant, R. Beardsley, D. Aubrey)

Workshop on Climate Variability of the Eastern Pacific and Western North
America, March 1984, Pacific Grove, CA (D. Aubrey)

3rd International Conference on Toxic Dinoflagellate Blooms, St. Andrews,
N.B., June 1985 (D. Anderson)

Appendix 5

Table of Contents of

Georges Bank

Richard H. Backus (editor)

Contents

Foreword, Richard H. Backus

1. Scientific Exploration
W. Redwood Wright

2. Cartographic History, 1524-1850
Barbara B. McCorkle

*1 How the Bank Got Its Name
Barbara B. McCorkle

I

Physical Science

A. Geology
Richard H. Backus

3. Morphology
Elazar Uchupi and James A. Austin, Jr.

4. Shallow Structure, Surficial Geology, and the Processes Currently Shaping
the Bank
David C. Twichell, Bradford Butman, and Ralph S. Lewis.

5. Subsurface Geology
Kim D. Klitgord and John S. Schlee

6. Submarine Canyons
Richard A. Cooper, Page Valentine, Joseph R. Uzzmann and Richard A. Slater

*2 Georges Cape, Georges Island, Georges Bank
Kenneth O. Emery

B. Weather and Climate
Richard H. Backus

7. Atmospheric Variables and Patterns
Tom Sawyer Hopkins and S. SethuRaman

8. Wave Climate
Marshall D. Earle and Ole S. Madsen

*3 The Effect of Winter Storms on the Bottom
Bradford Butman

*4 Death on Georges Bank
Richard H. Backus

C. Physical Oceanography
Bradford Butman and Robert C. Beardsley

Bradford Butman and Robert C. Beardsley

9. Tides
Wendell S. Brown and John A. Moody

Wendell S. Brown and John A. Moody

10. Hydrographic Structure and Variability
Charles N. Flagg.

Charles N. Flagg.

11. The Seasonal Mean Circulation: Observation and Theory
Bradford Butman, John W. Loder, and Robert C. Beardsley

Bradford Butman, John W. Loder, and Robert C. Beardsley

12. Low-Frequency Current and Bottom-Pressure Variability
Kenneth H. Brink, Bruce A. Magnell, and Marlene A. Noble.

Kenneth H. Brink, Bruce A. Magnell, and Marlene A. Noble.

*5 Does Georges Shoal Ever Dry? Richard H. Backus

13. Physical Processes Causing Surficial Sediment Movement
Bradford Butman

Bradford Butman

14. Mixing Processes
Gabriel T. Csanady and Bruce A. Magnell

Gabriel T. Csanady and Bruce A. Magnell

D. Chemistry
John W. Farrington

John W. Farrington

15. Dissolved Gases
Mary I. Scranton and Jean K. Whelan

Mary I. Scranton and Jean K. Whelan

16. Trace Metals
Michael H. Bothner, Thomas R. Gilbert, and Donald C. Bankston

Michael H. Bothner, Thomas R. Gilbert, and Donald C. Bankston

17. Natural Radionuclides
Michael H. Bothner and Michael P. Bacon

Michael H. Bothner and Michael P. Bacon

18. Artificial Radionuclides
J. Kirk Cochran and Hugh D. Livingston

J. Kirk Cochran and Hugh D. Livingston

19. Natural and Pollutant Organic Compounds
John W. Farrington and Paul D. Boehm

John W. Farrington and Paul D. Boehm

II Biologic Science

E. Phytoplankton, Primary Production, and Microbiology
Charles S. Yentsch and Donald W. Bourne

Charles S. Yentsch and Donald W. Bourne

20. Phytoplankton
Jerome J. Cura, Jr.

Jerome J. Cura, Jr.

21. Primary Production
John E. O'Reilly, Chris Evans-Zetlin, and Donna A. Busch
22. Nitrogen Cycling on Georges Bank and the New York Shelf: a Comparison
between Well-Mixed and Seasonally Stratified Waters
John J. Walsh, Terry E. Whitledge, John E. O'Reilly, William C. Phoel, and
Andrew F. Draxler
23. Microbiology
John E. Hobbie, Thomas J. Novitsky, Parke A. Rublee, Randolph L. Ferguson,
and Anthony V. Palumbo
- *6 Do Seaweeds Occur on Georges Bank? James R. Sears
- F. Zoology and Secondary Production
Donald W. Bourne
24. Zooplankton Life Cycles
Cabell S. Davis, III
25. Zooplankton Production and the Fisheries of the New England Shelf
Kenneth Sherman, Wallace G. Smith, John R. Green, Edward B. Cohen, M. S.
Berman, Karen A. Marti, and Julien R. Goulet
26. Benthic Fauna
Roger B. Theroux and Marvin D. Grosslein
27. Variability of the Benthic Fauna, I. The New England Outer Continental
Shelf Environmental Benchmark Program, 1977
Allan D. Michael
28. Variability of the Benthic Fauna, II. The seasonal variation, 1981-1982,
Nancy J. Maciolek and J. Frederick Grassle
29. Production by the Benthic Fauna
Frank W. Steimle
30. Fishes and Squids
Thomas R. Azarovitz and Marvin D. Grosslein
31. Fish and Squid Production
Michael P. Sissenwine
32. Large Pelagic Predators
John G. Casey, John J. Hoey, and Marvin D. Grosslein
- *7 Some Georges Bank Statistics
Richard H. Backus and Donald W. Bourne

33. Sea Turtles
C. Robert Shoop
34. Seabirds
Kevin D. Powers and Richard G. B. Brown
35. Energy Transfer to Seabirds
Kevin D. Powers and Edward H. Backus
36. Whales, Dolphins, and Porpoises
Howard E. Winn, James H. W. Hain, Martin A. M. Hyman, and Gerald P. Scott
37. Production on Georges Bank Compared with Other Shelf Ecosystems
Edward B. Cohen and Marvin D. Grosslein
38. Some Biologic Implications of the Circulation
David G. Mountain and Ronald J. Schlitz
39. A Simulation of Some Physical and Biologic Interactions
Patrice Klein

III

The Fisheries

- G. The Fisheries
Donald W. Bourne
- *8 Bait up!--Dory Fishing on Georges Bank
R. Wayne Anderson
40. History of the Early Fisheries: 1720-1930
Andrew W. German
- *9 My First Trip on Georges Bank
James P. Ostergard
41. History of Fisheries Conservation and Management
Richard C. Hennemuth
42. Fishing Vessels and Gear in New England Waters: 1930-1983
Keith A. Smith
43. A Social and Economic View of the New England Offshore Fishing Industry
Leah J. Smith and Susan B. Peterson
44. The Canadian Fishing Industry and Georges Bank
Joseph Gough

45. The Georges Bank/ Gulf of Maine Boundary Dispute between the United States and Canada
Donna R. Christie
46. Fisheries Administration and Management in Canada and the United States: Implications for Georges Bank
Timothy M. Hennessey and Michael LeBlanc
47. The Fisheries Resources
Bradford E. Brown
48. Fish Population Dynamics
Michael J. Fogarty, Michael P. Sissenwine, and Marvin D. Grosslein.
49. The Future for Fisheries Management on Georges Bank: an Opinion
Spencer Apollonio
- *10 An Echo-Sounder Record from the Northern Edge
Francis G. Carey

IV Conflicting Uses

- H. Conflicting Uses
Richard H. Backus
50. The Petroleum Potential of Georges Bank Basin
Mahlon M. Ball, Robert E. Mattick, and Richard B. Powers
51. The Jurisdictional Framework for Petroleum Development
Milner S. Ball, Donna R. Christie, and Ian Townsend-Gault
52. The Potential Effects of Drilling Effluents on Marine Organisms on Georges Bank
Jerry M. Neff
53. The Potential Effects of Petroleum on Marine Organisms on Georges Bank
Robert W. Howarth
54. Environmental Protection Programs for Developing Georges Bank Petroleum Reserves
Thomas M. Leschine and William L. Lahey
55. The Politics of Oil Drilling on Georges Bank: a State's Perspective
Massachusetts
Patricia E. Hughes and Katrine Van Dusen
56. Exploratory Drilling, 1981-1982
Elmer P. Danenberger

57. Marine Surface Traffic, Thomas F. Murphy, Jr.

Afterword, Richard H. Backus

Appendix: Units

Authors and Reviewers

Index

Appendix 6

BUZZARDS BAY SCIENCE SYMPOSIUM/WORKSHOP PROGRAM

Sponsored by:

Coastal Research Center, W.H.O.I.

Sea Grant, W.H.O.I.

Boston University Marine Program

Ecosystems Center, M.B.L.

Redfield Auditorium

Water Street

Woods Hole Oceanographic Institution

Woods Hole, MA 02543

"Research Conducted in and Around Buzzards Bay"

3 and 4 February 1986

with informal discussions

on 5 February 1986

The objective of the symposium workshop is for scientists to inform each other of their latest research and ideas regarding Buzzards Bay. The emphasis is on informality although the structure of a program is needed to ensure equal time for presentations. Legible visual aids are required but finished graphics products are not required. Some presenters will have them, some will not have the time nor the inclination to prepare finished products.

Each presenter of a talk is reminded of the following points to make the most efficient use of our time:

- 1) Everybody knows where Buzzards Bay is and the fact that there are PCB pollution problems in New Bedford Harbor. The EPA Superfund talk and the presentations by Farrington et al., Capuzzo et al., and Brownawell will discuss PCB biogeochemistry in a general sense.
- 2) Please clearly indicate where your stations are for cross reference purposes.
- 3) The audience will be a multidisciplinary group of marine scientists.
- 4) Aim for fifteen minutes for presentation and five minutes of specific questions. More time is allocated for general discussions of groups of related papers throughout the program.
- 5) Present the highlights of your findings and indicate the areas of research for which you need input from others.
- 6) Students - This is not an examination. This is a meeting of colleagues with common scientific interests. Please, relax during your presentations, and please participate in the discussions.
- 7) Rapporteurs will keep notes of discussion points and each participant will receive a copy of these notes for their use.

Workshop:

The meeting will be more of a symposium and general discussion. The talks to be presented were so numerous that it has been decided to have a symposium and discussions within a workshop type format to identify topics for further, more intensive, smaller group workshops throughout the spring where participants could discuss mutual interests in more detail.

A small number of participants will be asked to meet at a later date with the EPA and state agency groups concerned with the science/policy interface.

3 February 1986 - Redfield Auditorium, W.H.O.I.

9:00 - 9:30	Registration, coffee, tea, rolls
9:30 - 9:50	Welcome and brief introduction to the goals of the symposium/workshop
Session I.	Chair, John Hobbie Rapporteur, Arthur Gaines
9:50 - 10:10	George Hampson - "Some preliminary historical data showing the 30 year stability of the benthic fauna in the middle of Buzzards Bay (Station R) at 20 meters depth"
10:10 - 10:30	Joseph Costa - "Eelgrass in Buzzards Bay: Present distribution and response to disturbance"
10:30 - 10:50	James Hoff and Sanford Moss - "The finfish resources of Buzzards Bay"
10:50 - 11:00	Break
11:00 - 11:15	Discussion
11:15 - 11:45	"EPA Superfund Study" (Representative of EPA or NUS Corporation)
11:50 - 12:00	Discussion
12:15 - 13:30	Lunch - to be provided (Instructions given at morning session)

Session II

Chair, William B. Grant
Rapporteur, Alan C. Davis

- 13:30 - 13:50 John W. Farrington, Xiaoping Jia, C. H. Clifford, Alan C. Davis, Bruce W. Tripp, Bruce Brownawell - "Biogeochemistry of PCBs in Buzzards Bay: Progress to date"
- 13:50 - 14:10 Judy M. Capuzzo, Bruce Lancaster, Dale Leavitt, C. H. Clifford - "Biological effects of PCBs in marine bivalve molluscs"
- 14:10 - 14:30 Roxanna Smolowitz - "Indirect peroxidase staining using monoclonal antibodies specific for Mya arenaria neoplastic cells"
- 14:30 - 14:50 John J. Stegeman - "Evidence for biochemical effects of PAH/PCBs in Buzzards Bay"
- 14:50 - 15:00 Break
- 15:00 - 16:00 General Discussion
- 16:00 - 18:00 Posters and Refreshments

Posters

Wendy Wiltse and Bruce W. Tripp - "EPA Buzzards Bay Program"

Pamela J. Kloepper-Sams and John J. Stegeman - "Application of immunochemical techniques in detecting biochemical effects of PAHs and PCBs on marine teleosts"

Beth Snowberger and John J. Stegeman - "The regulation of microsomal estradiol metabolism in marine teleosts and possible effects of xenobiotics"

Carolyn Winn, Information Resources - "Today's information today". Combined poster/demonstration of on-line bibliographic databases.

Merryl Alber - "Shellfish resources in Buzzards Bay: A resource assessment"

Xiaoping Jia, John Farrington, Bruce Tripp, C. H. Clifford - "No. 2 fuel oil release from oil spill contaminated Mytilus edulis"

4 February 1986

Session III

Chair, Ivan Valiela

Rapporteur, Bruce Tripp

- 9:00 - 9:20 Rocky Geyer (with assistance of Rich Signell) - "Circulation processes in Buzzards Bay"
- 9:20 - 9:40 Brad Butman - "Near-bottom flow and sediment resuspension"
- 9:40 - 10:00 William Grant, Paul Dragos, Sandy Williams - "Winter storm wave and current measurements"
- 10:00 - 10:20 William Grant, Paul Dragos, Brad Butman, Sandy Williams - "Winter time sediment transport in Buzzards Bay and New Bedford outer harbor - Observations and modelling"
- 10:20 - 10:30 Break
- 10:30 - 10:50 Hans Graber, William Grant, Paul Dragos - "Wind and wave measurements during Hurricane Gloria: Comparisons of open shelf with New Bedford outer harbor"
- 10:50 - 11:10 Cheryl Ann Butman - "Effects of benthic biological processes on sediment transport in outer New Bedford harbor"
- 11:10 - 11:30 Charlotte M. Fuller - "Rates of fecal pellet production by the polychaete, Mediomastus ambisetta"
- 11:30 - 12:30 Discussion
- 12:30 - 13:30 Lunch

Session IV	Chair, Ed Sholkovitz Rapporteur, C. H. Clifford
13:30 - 13:50	John Hobbie - "Sediment microbial activity in Buzzards Bay"
13:50 - 14:10	Bill Martin - "The effects of particle and solute transport on sediment chemistry"
14:10 - 14:30	Ann McNichol - "A study of the remineralization of organic carbon in nearshore sediments using carbon isotopes"
14:30 - 14:50	David Rudnick - "Controls of detrital decomposition in subsurface sediments"
14:50 - 15:10	Bruce Brownawell - "PCBs in sediments of Buzzards Bay: Sorption in biogeochemical cycles"
15:10 - 15:30	Ivan Valiela and John M. Teal - "Nutrient transports between wetlands, uplands, groundwater and Buzzards Bay"
15:30 - 15:45	Break
15:45 - 17:00	Discussion

5 February 1986

Demonstration and discussion of EPA's Estuarine Data Base System. More details available on 3 February 1986.

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SYMPOSIUM/WORKSHOP ON BUZZARDS BAY SCIENCE

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April 9, 1985

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