U of M Tech Report #13

MULTIDISCIPLINARY RESEARCH IN THE GREAT LAKES BASIN

THE UNIVERSITY OF MICHIGAN 1817

U of M
Sea Grant Program
NOAA

OCEANOGRAPHY FIELD PRACTICUM

1971

OFFERED THROUGH THE CO-OPERATION
OF THE MARINE BIOLOGICAL LABORATORY
AND THE WOODS HOLE OCEANOGRAPHIC INSTITUTION
IN WOODS HOLE, MASSACHUSETTS
WITH THE SUPPORT OF THE NOAA SEA GRANT PROGRAM

by
Edward C. Monahan

DEPARTMENT OF METEOROLOGY AND OCEANOGRAPHY

The University of Michigan

The University of Michigan Sea Grant Program

Spring Half-Term, 1971

University of Michigan
Oceanography Field Practicum

Offered through the Cooperation of the Marine Biological Laboratory and the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts with the Support of the NOAA Sea Grant Program

by

Edward C. Monahan

Department of Meteorology and Oceanography
College of Engineering

NOAA Department of Commerce

Contents

Preface

This report is an attempt to describe in detail the "Oceanography Field Practicum" conducted in May and June 1971 by The University of Michigan in Woods Hole, Massachusetts. It is intended for a varied readership, i.e.:

1) For the administrative officers of the several institutions which lent support to this venture, and likewise for my fellow members of The University of Michigan Sea Grant Program Advisory Committee.
2) For other University of Michigan faculty teaching in related areas whose students may wish to participate in this course in subsequent years.
3) For my colleagues on the Committee on Institutional Cooperation Ocean Sciences Panel as we consider possible joint ventures in the future, and for others who are contemplating inaugurating oceanography field courses.
4) For the members of the research staff of the Woods Hole Oceanographic Institution who contributed so greatly to this venture.
5) For the future student participants in this course, who will wish to build upon the studies begun this first year.

and 6) For the students who participated in M&O 560 during 1971, and to whom the eventual existence of this report represented an incentive to prepare the most complete reports on their individual research projects feasible in the time allotted.

I wish to express my appreciation for all of the aid given us in the conduct of M&O 560 by the scientific community in Woods Hole, Massachusetts. In particular, I wish to acknowledge the efforts of Dr. Bruce Luyendyk, Dr. Gil Rowe, and Mr. Marv Stalcup, in contributing to this course from beginning to end. I am grateful to Dean H. Burr Steinbach for the encouragement he gave us during the formulation of this program. I also wish to thank Dr. Harold E. Edgerton of M.I.T., and the personnel of E.G. & G. Environmental Equipment Division (Waltham and Woods Hole) for their participation in this course.

Dr. Melvin A. Rosenfeld was most helpful in making the arrangements that enabled the '560' students to use the computer facilities of W.H.O.I. The assistance of Mr. Homer P. Smith in the establishment of the course arrangements with the Marine Biological Laboratory is gratefully acknowledged.

In conclusion, I wish to acknowledge the unstinting efforts of the Teaching Assistants, Mr. Eduardo D. Michelena and Richard G. Johnson, and the assistance of Mr. G. Thomas Kaye in the editing of this report.

Edward C. Monahan
Associate Professor
of Oceanography
The University of Michigan
Ann Arbor, Michigan
July 1971

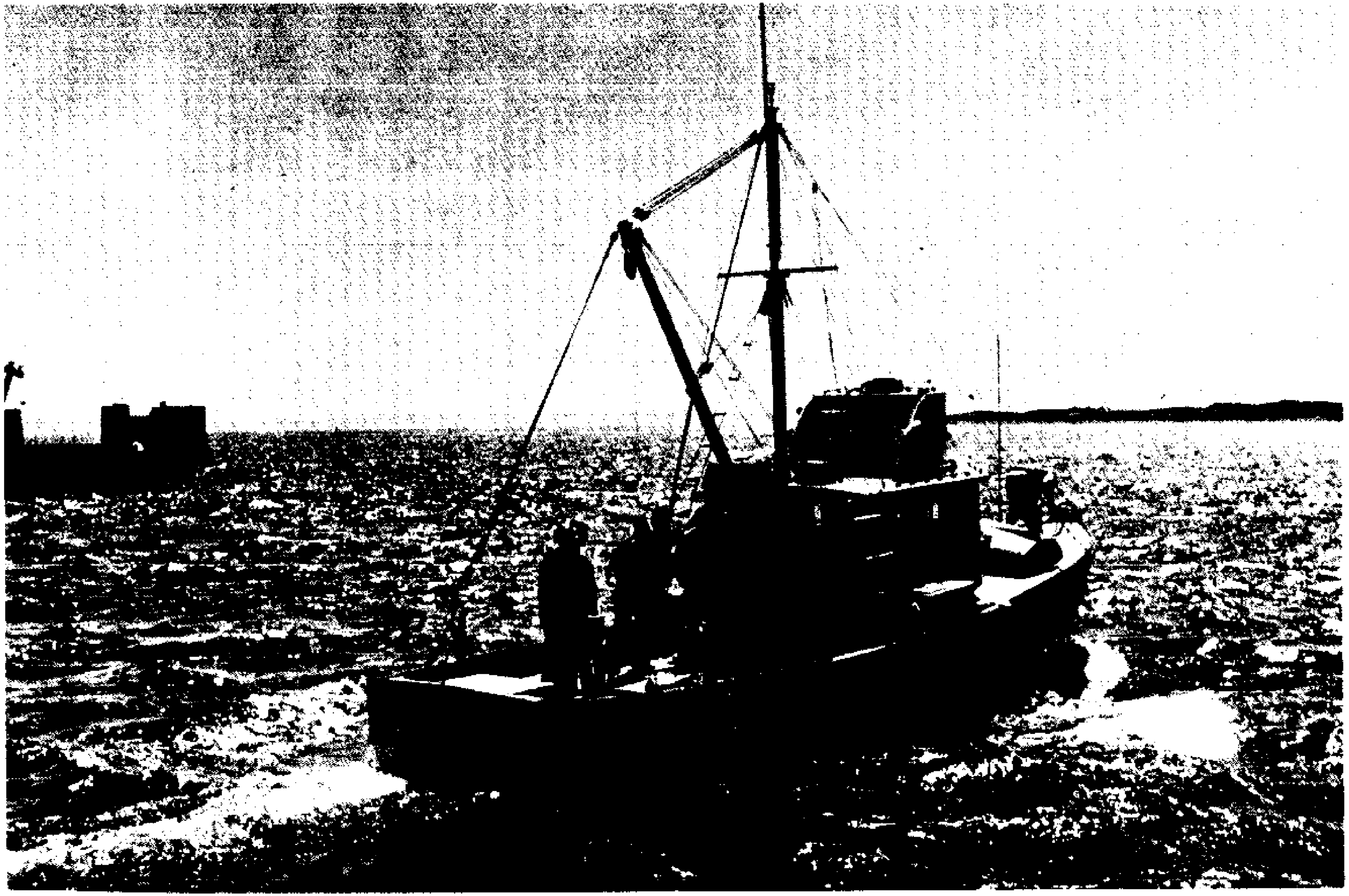


FIGURE #1 Research Vessel ASTERIAS putting out from Woods Hole Oceanographic Institution pier for a day cruise in Vineyard Sound with U-M students aboard.

Introduction

The "Oceanography Field Practicum" (M&O 560) was instituted to make available to the ever increasing number of graduate students in Oceanography (and related fields) at The University of Michigan the opportunity, at the beginning of their graduate education, to carry out experimental observations on the ocean, and to thus become acquainted at first hand with the practical techniques currently used in their discipline. It is intended to complement the undergraduate "Oceanographic Field Methods" course (M&O 360) which is offered annually during the same interval at The University of Michigan Biological Station on Douglas Lake, Pellston, Michigan.

The catalog description of the practicum is as follows:

> M&O 560 (8 hours credit)
> "Oceanography Field Practicum" Prereq. M&O 333 and graduate standing
>
> Design and implementation of oceanographic observational programs; marine data gathering capabilities: research vessels, buoys, etc.; shipboard data processing. Current techniques in physical, chemical, geological and biological oceanography, marine geophysics and marine meteorology. Course to be conducted at and in conjunction with a marine laboratory.

This course was offered for the first time during The University of Michigan's Spring Half-Term (Term IIIA) in 1971. It was taught at Woods Hole, Massachusetts, utilizing the facilities of the Marine Biological Laboratory, and the facilities and staff of the Woods Hole Oceanographic Institution. The Woods Hole staff participants selected had interests which complemented the interests of the seven Oceanography faculty members of The University of Michigan's Department of Meterology and Oceanography, only one of whom participated in M&O 560. There were twelve (12) students in the course this first year, not all of whom were students in the Meteorology and Oceanography Department, and not all of whom were graduate students (about half the class were seniors).

The course was divided into two time periods, an initial six week interval in residence at Woods Hole, and then a ten day period for the completion of the student research reports.

During the six week interval in Woods Hole, there were three distinct aspects to the course. These were the practicum exercises, the lectures (series and individual), and the individual directed research projects.

The practicum exercises, centered around a series of hydrographic stations occupied by the R/V ASTERIAS in Vineyard Sound, were directed by Mr. Marvel C. Stalcup, Research Associate in the Physical Oceanography Department of the Woods Hole Oceanographic Institution. The shipboard work was supplemented by sample analyses and data handling ashore. Mr. Nathaniel Corwin, Research Specialist at W.H.O.I., assisted the students in their chemical analyses. The details of the ASTERIAS cruises are included in the Course Log portion of this report. The students did participate in several other field exercises, such as the R/V VERRILL (M.B.L.) Cruise of 21 May with Dr. Charles D. Hollister, of W.H.O.I.

The lecture portion of the course was itself divided into two components. There were the lecture series, or "short courses", each consisting of some twelve (12) hours of classroom instruction (and each ending with a written test), and there were the individual lectures.

One of the lectures series, entitled "Topics in Biological Oceanography", was given by Dr. Gilbert T. Rowe, Assistant Scientist in the Biology Department of W.H.O.I. The other lecture series, "Current Topics in Marine Geophysics", was given by Dr. Bruce P. Luyendyk, Assistant Scientist in the Geology and Geophysics Department of W.H.O.I.

A total of 17 individual lectures, spread throughout the six week interval, were given by the following men:

Dr. David B. Boylan, W.H.O.I.
Mr. Dean F. Bumpus, W.H.O.I.
Prof. Harold E. Edgerton, M.I.T.
Dr. George R. Harvey, W.H.O.I. (2 lectures)
Mr. Richard G. Johnson, U. of Michigan
Mr. Eduardo D. Michelena, U. of Michigan
Prof. Edward C. Monahan, U. of Michigan (2 lectures)
Dr. Charles C. Remsen, W.H.O.I. (2 lectures)
Dr. David A. Ross, W.H.O.I.
Dr. Thomas Sanford, W.H.O.I.
Dr. Peter M. Saunders, W.H.O.I.
Mr. Paul F. Smith, E.G.&G., Inc.
Mr. Marvel C. Stalcup, W.H.O.I.
Mr. L. Valentine Worthington, W.H.O.I.

The titles of these seventeen (17) lectures are included in the Course Log portion of this report, as are notices of demonstrations, films, tours, and other related activities. Most of these lectures were given in the Loeb Building of the Marine Biological Laboratory, the same building that housed our assigned student research laboratory.

The third aspect of the course, the individual directed research projects, is covered in the final section of this report, where abstracts of all the student reports, along with the complete texts of selected student reports, are reproduced.

The students lived and ate during the Woods Hole interval in the new Dormitory-Dining Hall of the Marine Biological Laboratory. This living unit is close by the Loeb Building of the M.B.L. where most of the '560' activities were centered, and equally close by the Lillie Building of the M.B.L. which houses the combined library holdings of the M.B.L. and the W.H.O.I. Within short walking distance were the various buildings of the Woods Hole Oceanographic Institution (in several of which '560' students carried out their directed research projects) and the facilities of the Woods Hole Laboratory of the National Marine Fisheries Service.

FIGURE #2 U-M Ocean Practicum participants. Standing row, L to R: D. Deitemyer, I. Barinoff, A. Schaedel, D. Cayan, K. Leaman, D. Silverblank, R. Borys, C. Hyde, T. Kaye, D. Takacs, W. Burgel, Dr. G. Rowe (Instr., Bio. Ocean.), Dr. B. Luyendyk (Instr., Marine Geophy.). Front row, L to R: Mr. M. Stalcup (Instr., Field Practicum), Prof. E. Monahan ('560' Coordinator), R. Johnson (Teach. Asst.). Not shown: E. Michelena (Teach. Asst.).

Course Log

On the following pages are listed the lectures and demonstrations attended by the '560' students, and the seminars and cruises participated in by them. Included in this listing are many events, especially lectures and luncheon seminars, which were not formal, sponsored events of M&O 560. (In which case their sponsorship is indicated in the log.) They have been listed here because they were open to, and often attended by, the '560' students, and thus played a significant role in the overall student experience during the Woods Hole interval.

3 May 1971 (Monday)

1:00PM - Orientation Meeting
Room 126 Loeb Building (M.B.L.)
Monahan and Stalcup

2:00PM - Introduction to M.B.L. Library

2:30PM - Guided tour of W.H.O.I. facilities

8:00PM - "Paleobiogeography and Paleoceanography of the North Atlantic Ocean"
L.M.S. Auditorium (W.H.O.I.)

Dr. William Berggren, W.H.O.I.
Dr. Charles Hollister, W.H.O.I.
Dr. Bruce Luyendyk, W.H.O.I.

Sponsored by: W.H.O.I. Journal Club

....

4 May 1971 (Tuesday)

8:30AM - Discussion of Geophysical Topics to be Included
201 Loeb (M.B.L.)

Luyendyk

9:00AM - Introduction to Benthos project
201 Loeb (M.B.L.)

Rowe

10:00AM - Group discussions re Directed Research Topics
126 Loeb (M.B.L.)
Stalcup and Monahan
2-22 Redfield (W.H.O.I.)
Rowe

12:00N* - "Bedform Wave-Lengths and the Prediction of Flow Regimes"
L.O. Conference Room (W.H.O.I.)

Floyd W. McCoy, Harvard-W.H.O.I.

Sponsored by: W.H.O.I. Geology and Geophysics Group

*Alternate recommended lectures

4 May 1971 (Tuesday) CONTINUED

12:00N* - "Comparative Physiology of Field Populations of Jamaican Demospongiae"
22 Loeb (M.B.L.)

Mr. Henry M. Reiswig, Yale University

Sponsored by: M.B.L. Systematics-Ecology Group

1:45PM - Preparation for first General Practicum Cruise

(PM individual meetings with Luyendyk of students working under his direction)

2:30PM** "The U.R.I. Narragansett Bay Watch-Bay Model Program"
L.O. Conference Room, W.H.O.I.

Prof. Vincent Rose, U.R.I.

Sponsored by: W.H.O.I. Physical Oceans Group

....

5 May 1971 (Wednesday)

8:30AM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-1 (Vineyard Sound & Great Harbor)
Cruise List: Stalcup, Borys, Deitemyer, Kaye, Schaedel, Silverblank, Hyde, Michelena
(others work on Directed Studies)

1:30PM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-2 (Great Harbor)
Cruise List: Stalcup, Barinoff, Burgel, Cayan, Leaman, Takacs, Kardes
(others work on Directed Studies)

*Alternate recommended lectures

**Recommended lecture

6 May 1971 (Thursday)

9:00AM - Topics in Biological Oceanography, Lecture #1
201 Loeb (M.B.L.)

Rowe

10:30AM - Using Ships of Opportunity ("Banana Boat Oceanography")
Whitecap Study
201 Leob (M.B.L.)

Monahan

12:00N* - "Otis AFB, What's Next"
M.B.L. Club

Barrie Dale

Sponsored by: W.H.O.I. Biology Group

2:30PM* - "An Informal Discussion on Artic Oceanography"
L.O. Conference Room (W.H.O.I.)

Knut Aagaard, University of Washington

Sponsored by: W.H.O.I. Physical Oceanography Group

....

7 May 1971 (Friday)

8:30AM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-3 (benthic study)
Cruise List: (leg 1) Rowe, Deitemyer, Hyde, Schaedel, Silverblank, Takacs, Kardes

Cruise List: (leg 2) Monahan, Deitemyer, Hyde, Schaedel, Silverblank, Takacs, Kardes

12:00N - "Visit to Brittany"
M.B.L. Club

Henri Berteaux
("Peanut Butter Club")

*Recommended lecture

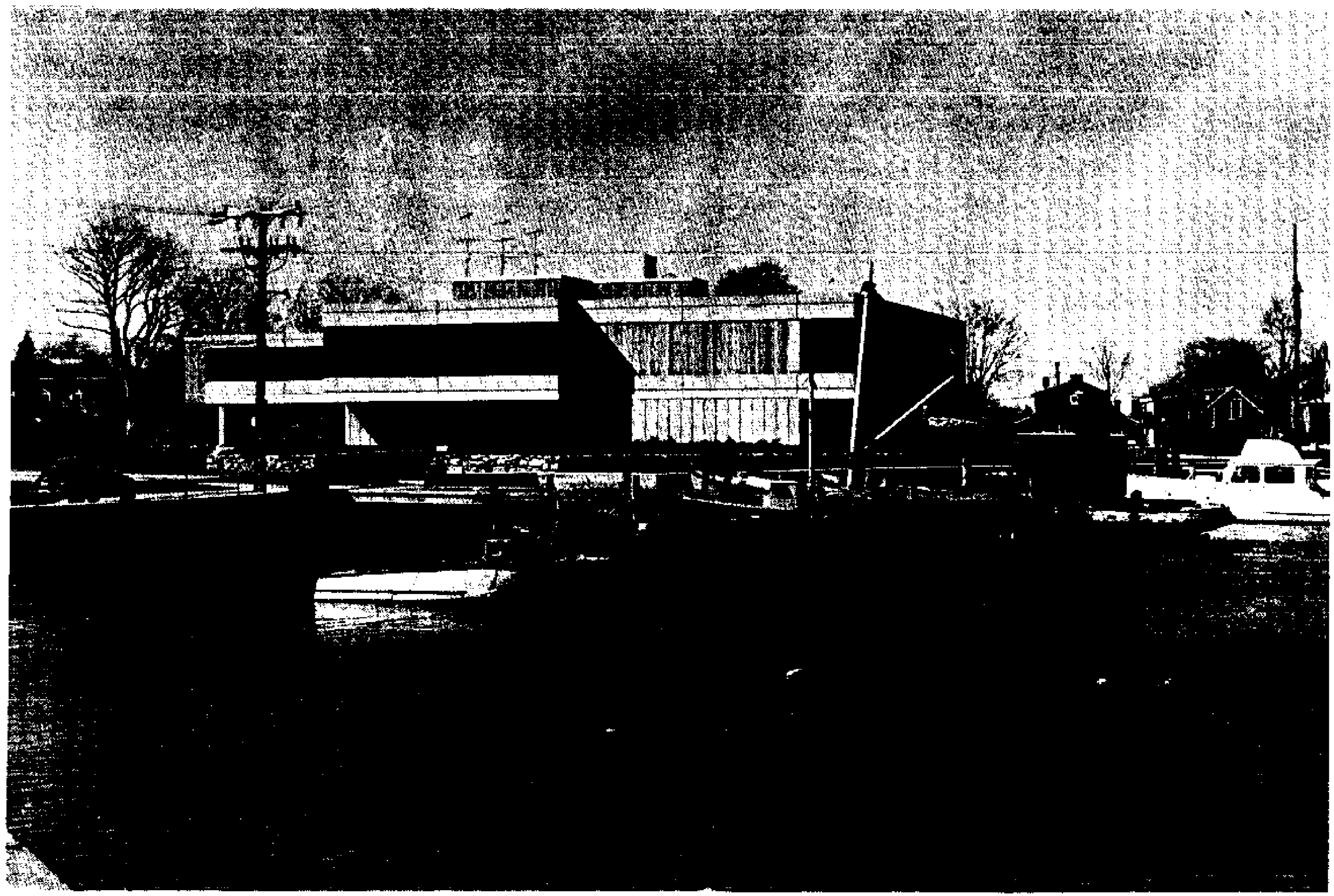


FIGURE #3 New Dormitory-Dining Hall of the Marine Biological Laboratory where '560' students resided.

7 May 1971 (Friday) CONTINUED

1:30PM Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U Mich 71-4 (Vineyard Sound Hydro. Stations)
CruiseList: Stalcup, Barinoff, Borys, Burgel, Cayan, Kaye

8:00PM-
9:15PM - Session to fill drift bottles, basement, Swift House (W.H.O.I.)

Monahan

....

8 May 1971 (Saturday)

8:00AM- - Current Problems in Marine Geophysics, Lecture #2
10:00AM L.O. Conference Room (W.H.O.I.)

Luyendyk

....

10 May 1971 (Monday)

10:00AM - "Underwater Photography and Sonar"
at M.I.T., Cambridge

Dr. Harold Edgerton, Inst. Prof. (Emer.), M.I.T.

1:30PM - Tour of factory of Environment Equipment Division,
E.G.&G, 151 Bear Hill Road, Waltham

Francis R. Germain

8:00PM - "New Geophysical Studies in the Southeastern Indian Ocean"
LMS Auditorium, W.H.O.I.

Dr. Dennis E. Hayes, Lamont-Doherty Geological Observatory

Sponsored by: W.H.O.I. Journal Club

11 May 1971 (Tuesday)

8:30AM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-5
Cruise List: Michelena, Burgel, Cayan, Hyde, Kaye
Schaedel

12:00N* - "Evolution of Cenozoic Calcereous Nanoplankton"
L.O. Conference Room, W.H.O.I.

Dr. Bilal Haq, W.H.O.I.

Sponsored by: W.H.O.I. Geology & Geophysics Group

12:00N* - "The Effects of Cornstarch and Dextrose Supplements on Oysters"
Room 22, Lecture Hall, Loeb Building, M.B.L.

Mr. Kenneth Turgeon, Department of Zoology
University of New Hampshire, Durham

Sponsored by: M.B.L. Systematics-Ecology Group

1:45PM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-6
Cruise List: Cayan, Deitemyer, Hyde, Kaye, Leaman,
Silverblank, Takacs, Kardes

2:30PM** "Internal Tides and Inertial Oscillations in the North Sea"
L.O. Conference Room, W.H.O.I.

Dr. Fritz Schott, W.H.O.I./Kiel

Sponsored by: W.H.O.I. Physical Oceanography Group

....

12 May 1971 (Wednesday)

9:00AM - Topics in Biological Oceanography, Lecture #2
201 Loeb (M.B.L.)

Rowe

10:30AM - Discussion of hydro-station data workup
126 Loeb (M.B.L.)

Stalcup

*Alternate suggested lectures
**Suggested lectures for those ashore

12 May 1971 (Wednesday) CONTINUED

1:30PM - Preparations for tomorrow's Hydrographic Cruise
126 Loeb (M.B.L.)

Stalcup

....

13 May 1971 (Thursday)

8:00AM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-7
Cruise List: (leg 1, hydro. work) Stalcup, Leaman, Kaye, Silverblank, Borys, Barinoff, Schaedel, Kardes, Cayan

Cruise List: (leg 2, Bathymetry) Kaye, Leaman, Barinoff

12:00N* - "Similarity of Euphasud Assembledges Collected from the Eastern and Western Basins of the Mediterranean Sea"
M.B.L. Club

Dr. Peter Wiebe, W.H.O.I.

Sponsored by: W.H.O.I. Biology Group

2:30PM - Dockside tour of R/V KNORR (AGOR 15) (W.H.O.I.)

Monahan

7:30PM-
9:30PM - Current Problems in Marine Geophysics, Lecture #2
W.H.O.I. Student Center

Luyendyk

....

14 May 1971 (Friday)

9:00AM - Topics in Biological Oceanography, Lecture #3
201 Loeb (M.B.L.)

Rowe

*Suggested lecture

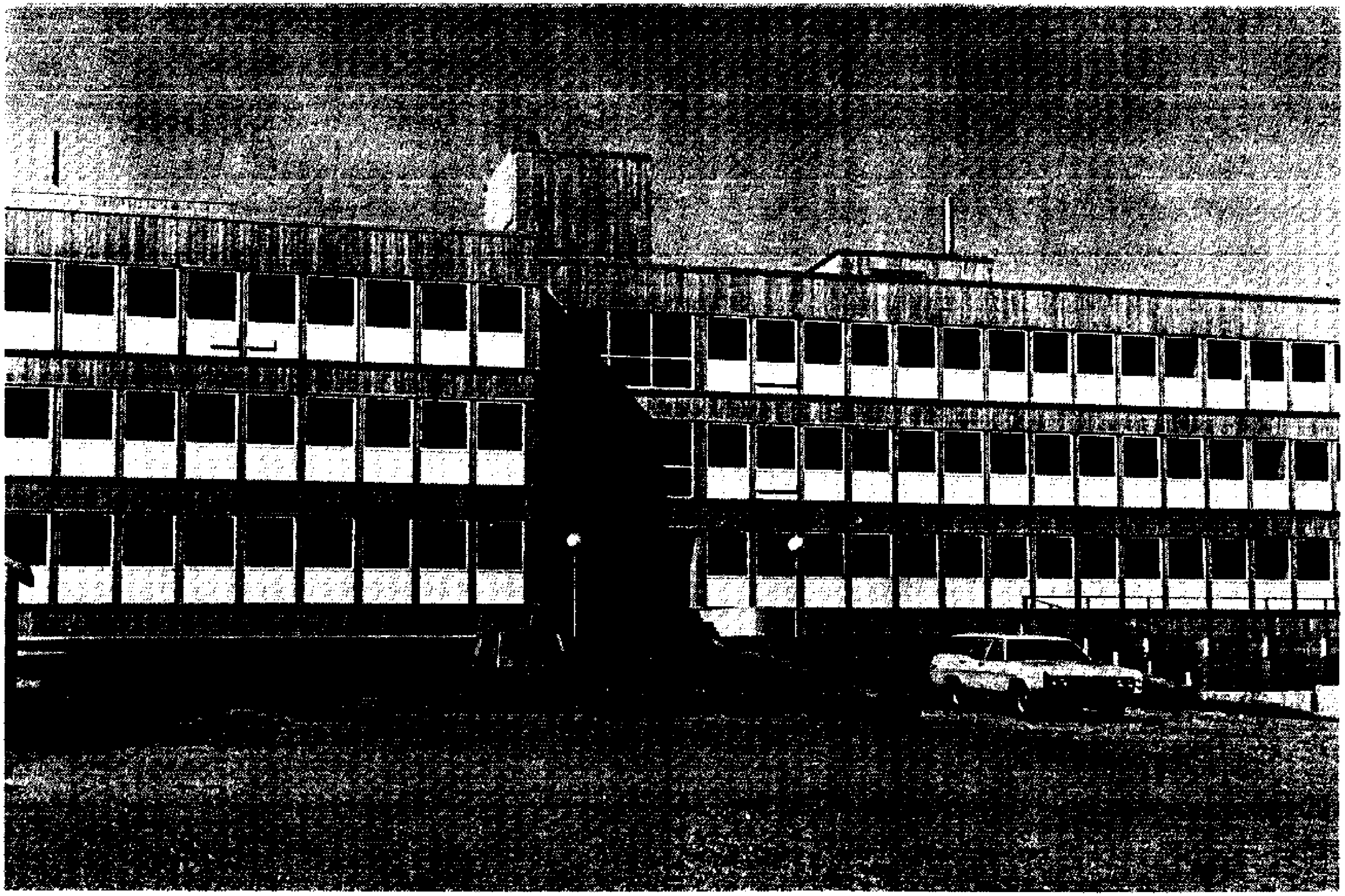


FIGURE #4 Loeb Teaching Building of the Marine Biological Laboratory. Focus for '560' Laboratory and Classroom activities.

14 May 1971 (Friday) CONTINUED

12:00N* - "From Barbados to the Roaring 40's -AII-60"
M.B.L. Club

Isabelle Williams

Sponsored by: W.H.O.I. "Peanut Butter Club"

2:00PM - "A Third of the Way Through-Some Comments"
201 Loeb (M.B.L.)

Monahan

....

17 May 1971 (Monday)

9:00AM - Topics in Biological Oceanography, Lecture #4
201 Loeb (M.B.L.)

Rowe

10:30AM - Boston Harbor Pollution Study
201 Loeb (M.B.L.)

Paul Ferris Smith, E.G.&G., Environment Equipment Division

12:00N* - "Organic Carbon Budget in the Black Sea"
LMS 3-04, W.H.O.I.

Dr. Werner Deuser, W.H.O.I.

Sponsored by: W.H.O.I. Chemistry Group

1:00PM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U Mich 71-8
Cruise List: Barinoff, Cayan, Schaedel, Silverblank

8:00PM - "Wind Waves--New Observations from the North Sea"
LMS Auditorium, W.H.O.I.

Dr. Klaus Hasselmann, W.H.O.I.

Sponsored by W.H.O.I. Journal Club

*Suggested lecture

18 May 1971 (Tuesday)

8:00AM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-9 (Hydro., drogue work, ALL DAY)
Cruise List: Stalcup, Barinoff, Borys, Cayan,
Deitemyer, Kaye, Leaman, Silverblank, Takacs

12:00N* - "New Geochemical Results from the Red Sea"
L.O. Conference Room, W.H.O.I.

Dr. Frank T. Manheim, U.S.G.S.-W.H.O.I.

Sponsored by: W.H.O.I. Geology & Geophysics Group

12:00N* - "Cluster Analysis: A Tool for Studying Marine Benthic Communities"

Dr. John Field, Dept. of Oceanography, Dalhousie University,
Halifax; and CSIR Oceanographic Research Unit,
University of Cape Town, South Africa

2:30PM*- "Numerical Computations for an Equatorial Undercurrent"
L.O. Conference Room, W.H.O.I.

Dr. William McKee, W.H.O.I.

Sponsored by: W.H.O.I. Physical Oceanography Group

....

19 May 1971 (Wednesday)

9:00AM - Topics in Biological Oceanography, Lecture #5
201 Loeb (M.B.L.)

Rowe

10:30AM - "Currents in the Lesser Antilles"
201 Loeb (M.B.L.)

Stalcup

4:00PM - Aboard R/V LULU (W.H.O.I.)
U-M Cruise List: Kaye, Cayan, Michelena, Stalcup
(Radar Beacon Test)

*Suggested for those ashore

20 May 1971 (Thursday)

8:30AM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-10 (Benthos)
Cruise List: Rowe, Deitmeyer, Hyde, Schaedel, Silverblank

11:00AM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-11 (drift bottles, hydro., drogues, through PM)
Cruise List: Stalcup, Michelena, Burgel, Cayan, Deitemyer, Hyde

12:00N* - "Twenty-Two Years of Acid Waste Dumping in the New York City Bight: Its Effects on the Biota"
M.B.L. Club

Dr. George Grice, W.H.O.I.

Sponsored by: W.H.O.I. Biology Group

7:30-
9:30PM - Current Problems in Marine Geophysics, Lecture #3
W.H.O.I. Student Center
Luyendyk

....

21 May 1971 (Friday)

9:00AM - Topics in Biological Oceanography, Lecture #6
201 Loeb (M.B.L.)

Rowe

10:30AM - "Radio Positioning of Current Drogues"
201 Loeb (M.B.L.)

Michelena

7:30AM-
5:00PM - Aboard R/V VERRILL (M.B.L.)
U-M Cruise List: Luyendyk, Borys, Burgel, Barinoff, Cardes, Schaedel, Hollister (Seismic refraction Buzzards Bay)

8:30PM - Motion Pictures: "Indian Ocean Expedition" (30 min.)
"The Restless Sea" (60 min.)
L.O. Conference Room (W.H.O.I.)

*Suggested for those ashore

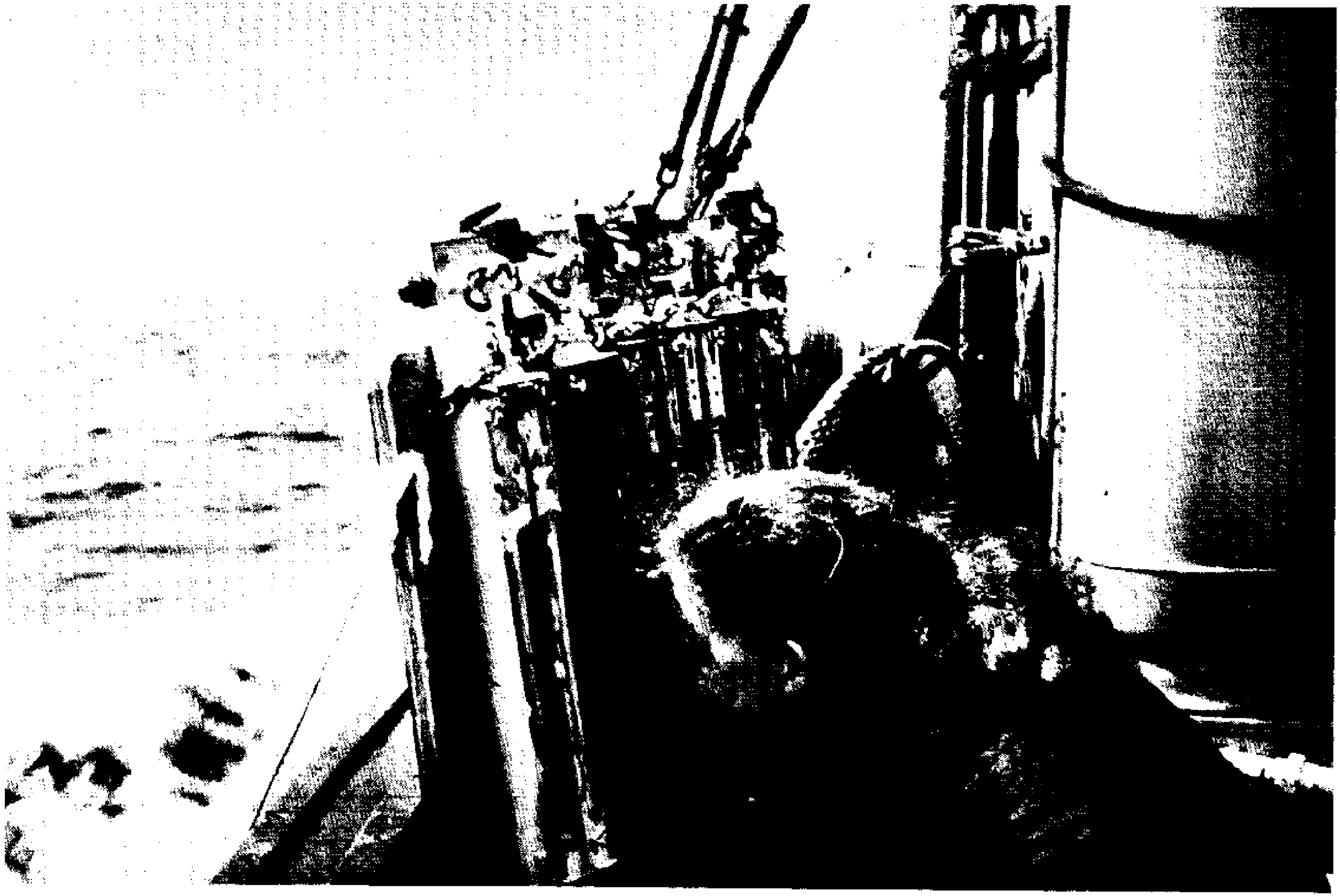


FIGURE #5 U-M student reading reversing thermometers mounted on Nansen Bottles.

24 May 1971 (Monday)

9:00AM - Topics in Biological Oceanography, Lecture #7
201 Loeb (M.B.L.)

Rowe

10:30AM - "Bacteria in the Ocean"
201 Loeb (M.B.L.)

Remsen

12:00N* - "Organic Carbon Budget in the Black Sea"
LMS 3-04, W.H.O.I.

Dr. Werner Deuser, W.H.O.I.

Sponsored by: W.H.O.I. Chemistry Group

4:00PM - Motion Pictures: "Modern Geodetic Surveying" (22 min.)
"Water Masses of the Oceans" (45 min.)
"Ocean Instruments for Deep Submergence Vehicles" (29 min.)
L.O. Conference Room (W.H.O.I.)

8:00PM - "Power Generation in the Tropical Thermocline"
LMS Auditorium, W.H.O.I.

Mr. James Anderson, Jr., Consulting Engineer

Sponsored by: W.H.O.I. Journal Club

....

25 May 1971 (Tuesday)

8:30AM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-12 (drift bottles)
Cruise List: Johnson, Borys, Cayan, Takacs

*Suggested lecture

25 May 1971 (Tuesday) CONTINUED

12:00N* - "Experimental Erosion of Deep-Sea Mud"
L.O. Conference Room, W.H.O.I.

Dr. Robert A. Young, W.H.O.I.-M.I.T.

Sponsored by: W.H.O.I. Geology & Geophysics Group

12:00N* - "Phytoplankton-Zooplankton Relationships: Aspects of a Biochemical Enigma"
Room 22, Lecture Hall, Loeb Building (M.B.L.)

Dr. H. Perry Jeffries, Associate Professor, Graduate School of Oceanography, University of Rhode Island, Kingston

Sponsored by: M.B.L. Systematics-Ecology Group

1:30PM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-13 (bathymetry, benthos)
Cruise List: Silverblank, Deitemyer, Kardes, Kaye, Barinoff, & two Temple U. students

2:30PM** "On the Reaction of a Stratified Sea to Meteorological Forces"
L.O. Conference Room, W.H.O.I.

Dr. Lorenz Magaard, W.H.O.I./Kiel

Sponsored by: W.H.O.I. Physical Oceanography Group

....

26 May 1971 (Wednesday)

9:00AM - Topics in Biological Oceanography, Lecture #8
201 Loeb, (M.B.L.)

Rowe

10:30AM - "Breakdown of Dissolved Organic Nitrogen (Urea) in an Estuarine Environment"
201 Loeb (M.B.L.)

Remsen

*Alternate suggested lectures
**Suggested lecture for those ashore

27 May 1971 (Thursday)

9:00AM - "Chemical Signals: Their Role in the Communication of Marine Organisms"
201 Loeb (M.B.L.)

Dr. David Boylan

12:00N* - "Ecology and Physiology of Hydrocarbon Using Micro-Organisms"
M.B.L. Club

Dr. J.J. Cooney, Professor of Biology, University of Dayton
Presently Visiting Professor, Tufts School of Medicine

Sponsored by: W.H.O.I. Biology Group

7:30 -
9:30PM - Current Problems in Marine Geophysics, Lecture #4
W.H.O.I. Student Center

Luyendyk

....

28 May 1971 (Friday)

9:00AM - Topics in Biological Oceanography, Lecture #9
201 Loeb (M.B.L.)

Rowe

10:30AM - "Pesticides in the Marine Environment"
201 Loeb (M.B.L.)

Dr. George Harvey

Followed by tour of Dr. Harvey's laboratory.

....

31 May 1971 (Monday)

HOLIDAY

*Suggested lecture

FIGURE #6 Sediment plug being removed from Van Veen bottom sampler by '560' student aboard R/V ASTERIAS.

1 June 1971 (Tuesday)

9:00AM - "Coastal Circulation"
201 Loeb (M.B.L.)

Dean F. Bumpus

10:30AM - "Open Ocean Current Meter Moorings: A Buoy Cruise Aboard the R/V KNORR"
201 Loeb (M.B.L.)

Monahan

11:30AM - "A Third of the Way to Go-Some Comments"
201 Loeb (M.B.L.)

Monahan

12:00N* - "The Acoustic Surface Reflection Channel as a Linear, Random Time-Varying Filter"
L.O. Conference Room, W.H.O.I.

Dr. Robert C. Spindee, W.H.O.I., Post-Doctoral Fellow

Sponsored by: W.H.O.I. Geology & Geophysics Group

12:30PM* - "Chemotaxis of Coelenterate Sperm"
Room 22, Lecture Hall, Loeb Building, (M.B.L.)

Dr. Richard L. Miller, Department of Biology
Temple University, Philadelphia, Pa.

Sponsored by: M.B.L. Systematics-Ecology Group

1:30PM - M & O 560 Photograph
W.H.O.I. Pier

2:30PM** "Synoptic Maps for PREMODE"
L.O. Conference Room, W.H.O.I.

Dr. Francis Bretherton, The Johns Hopkins University

Sponsored by: W.H.O.I. Physical Oceanography Group

*Alternate suggested lectures
**Suggested lecture

2 June 1971 (Wednesday)

9:00AM - "Geological Observations in Submarine Canyons from ALVIN"
L.O. Conference Room, W.H.O.I.

Dr. David A. Ross

10:45AM - "Deep Sources and Circulation in the North Atlantic"
L.O. Conference Room, W.H.O.I.

L.V. Worthington

2:00PM - "Demonstration of Rotating Tank in Hydrodynamics Laboratory"
111 L.O. W.H.O.I.

Luyendyk and Frazel

4:30PM - Motion Pictures: "Scientist in the Sea" (19 min.)
"Science of the Sea" (19 min.)
L.O. Conference Room W.H.O.I.

....

3 June 1971 (Thursday)

10:30AM - "Air Oceanography"
201 Loeb (M.B.L.)

Dr. Peter M. Saunders

12:00N* - "Seasonal Comparison of Meso-pelagic Fish in the Sargasso Sea"
M.B,L. Club

Dr. Richard Haedrich, W.H.O.I.

Sponsored by: W.H.O.I. Biology Group

7:30PM-
9:30PM - Current Problems in Marine Geophysics, Lecture #5
W.H.O.I. Student Center

Luyendyk

....

*Suggested lecture

4 June 1971 (Friday)

9:00AM - Topics in Biological Oceanography, Lecture #10
201 Loeb (M.B.L.)

Rowe

10:30AM - "Diagenesis and Transport of Organic Matter in Sediments"
201 Loeb (M.B.L.)

Harvey

....

7 June 1971 (Monday)

9:00AM - Topics in Biological Oceanography, Lecture #11
201 Loeb (M.B.L.)

Rowe

12:00N* - "^{90}Sr, ^{137}Cs, and ^{238}Pu Content and Distribution in Marine Sediments"
LMS 3-04, W.H.O.I.

Dr. Nicholas Noshkin, W.H.O.I.

Sponsored by: W.H.O.I. Chemistry Group

8:00PM - "Fish Protein Concentrate - Economic Analysis"
LMS Auditorium, W.H.O.I.

Dr. J. Devanney, Dept. of Ocean Engineering, M.I.T.

Sponsored by: W.H.O.I. Journal Club

....

8 June 1971 (Tuesday)

8:30AM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-14
Cruise List: Stalcup, Barinoff, Borys, Burgel, Kaye, Leaman

*Suggested lecture

FIGURE #7 Bendix Savonius Rotor Current Meter being lowered into Vineyard Sound by U-M students.

8 June 1971 (Tuesday) CONTINUED

12:00N* - "Broadening the Bandwidth of Echo Sounding Systems, and Its Application to Scattering Layer Studies"
L.O. Conference Room, W.H.O.I.

Dr. Paul T. McElroy, W.H.O.I.

Sponsored by: W.H.O.I. Geology & Geophysics Group

12:30PM* - "The Woods Hole Oceanographic Institution Educational Program"
Room 22, Lecture Hall, Loeb Building, M.B.L.

Dr. H. Burr Steinbach, Dean of Graduate Studies, W.H.O.I.

Sponsored by: M.B.L. Systematics-Ecology Group

1:30PM - Aboard R/V ASTERIAS (W.H.O.I.)
Cruise U. Mich 71-15
Cruise List: (leg A) Monahan, Deitemyer, Silverblank, Takacs
(leg B) Monahan, Deitemyer, Silverblank, Takacs, Stalcup

2:30PM** "On the Drift of Icebergs as Related to Wind-Driven Ocean Circulation"
L.O. Conference Room, W.H.O.I.

Christopher Welch, W.H.O.I./M.I.T.

Sponsored by: W.H.O.I. Physical Oceanography Group

....

9 June 1971 (Wednesday)

9:00AM - Topics in Biological Oceanography, Lecture #12
201 Loeb (M.B.L.) (EXAM)

Rowe

*Alternate suggested lectures
**Suggested lecture for those ashore

9 June 1971 (Wednesday) CONTINUED

12:00N* - "Abiotic Synthesis of Biomolecules on a Clay Mineral"
M.B.L. Club

Dr. George Harvey, W.H.O.I.

Sponsored by: W.H.O.I. Biology Club

1:30PM - Penultimate Comments
126 Loeb (M.B.L.)

Monahan

5:30PM - M&O 560 Dinner for Students and Invited Guests
Small Dining Room, M.B.L. Residence Facility

....

10 June 1971 (Thursday)

9:00AM - "Uses for Motionally Induced Electric and Magnetic Fields in Oceanography"
201 Loeb (M.B.L.)

Dr. Thomas Sanford

12:00N - "Into the Heart of Darkness"
M.B.L. Club

Dr. John Kanwisher, W.H.O.I.

Sponsored by: W.H.O.I. "Peanut Butter Club"

1:30PM - MEETING FOR EXCHANGE OF PRELIMINARY RESULTS OF FIELD WORK
201 Loeb (M.B.L.)

Stalcup

7:30PM-
9:30PM Current Problems in Marine Geophysics, Lecture #6
W.H.O.I. Student Center

Luyendyk

*Suggested lecture

11 June 1971 (Friday)

9:00AM - "Use of Sub-Surface Current Meter Moorings in Grand Traverse Bay of Lake Michigan"
201 Loeb (M.B.L.)

Johnson

10:00AM - "A Contrary View of Global Tectonics"
L.O. Conference Room

Professor McKenzie L. Keith, Penn State University

Sponsored by: W.H.O.I. Geology Group

FIGURE #8 Preparation of Drift Bottles for use in study of surface currents in coastal waters.

Student Research Reports

Following this page are the abstracts, or in selected cases, the entire texts, of the reports prepared by the students on the research they individually conducted while in Woods Hole. The reports chosen to be reproduced in their entirety in this section are those that will be of most use to future students in the course, as they prepare and conduct their own research.

All papers are on file in the meteorology and Oceanography Department.

Section on Hydrographic Station Data

by Irene Barinoff

A series of hydrographic station cruises were conducted aboard the R/V Asterias by students from the University of Michigan, in May and June, 1971. Temperature, salinity, sigma-T, and oxygen were measured and appropriate profiles were constructed. Also, meteorological data and bathythermograph records were obtained. It was found that temperature increased with time and decreased from Nobska Point to Martha's Vineyard. Salinity, sigma-T, and oxygen increased in value from Nobska Point to Martha's Vineyard. Salinity and sigma-T decreased with time; oxygen remained generally the same. These factors indicate that Buzzards Bay water may form the northern part of Vineyard Sound water, while water closer to Martha's Vineyard may be Atlantic Ocean water and/or Gulf of Maine Water. The amount of fresh water entering Buzzards Bay may cause changes in salinity in the Sound water. Further studies in the area will help in substantiating the above ideas.

A preliminary investigation of the water of Vineyard Sound, from Nobska Point to West Chop, was conducted by Bumpus (et al, 1969) in considerations on a marine sewer outfall. The action of tides in the Sound was studied by Redfield (1953), while currents were determined by the geomagnetic electrokinetograph (GEK) method by, among others, Sanford and Flick in 1969. A further examination of the area, including the possibilities of different water masses, their origins, current and circulation studies, and various water properties, was conducted by University of Michigan students on a series of hydrographic station cruises aboard the R/V Asterias in May and June, 1971. This section of the final report deals with the analysis of temperature, salinity, sigma-T, and oxygen profiles, and bathythermograph records.

The observational program consisted of making a series of hydrographic stations along a transect from Nobska Point to Martha's Vineyard (west of West Chop, Fig. 1). Approximately five stations were made on each cruise, one or two between Middle Ground and Martha's Vineyard, and four between Middle Ground and Nobska Point. Generally, a cast of five Nansen bottles, each containing a protected thermometer, with the bottom one, containing both a protected and unprotected thermometer, was made at each station. Also, a bathythermograph (BT) record was taken, and meteorological conditions were recorded. After retrieving the cast, samples were drawn for salinity, oxygen, and chemical analysis, and the temperature reading on each of the main and auxiliary thermometers was recorded. At certain stations drift bottles and/or drogues were released and the drogues were tracked by transits stationed at Nobska Point and Falmouth Heights Beach. A Bendix Q9 current meter was hand-lowered over the side of the ship to take concurrent measurements of the currents. On the first cruise, a bathymetric survey of the transect was conducted by G.T. Kaye, through the use of the ship's fathometer and positioning by transit.

The analysis program involved the correction of temperature, and depth, construction of temperature, salinity, oxygen, and sigma-T profiles, examination of the tidal cycles, and reduction of the data to a format suitable for computer processing. The temperature correction was based on Hansen's formula for the protected thermometers and Sverdrup's formula for the unprotected thermometers as these were considered the most accurate corrections by Keyte (1964). Most of the corrections were performed on the Hewlett-Packard 9100 calculator, but those obtained by

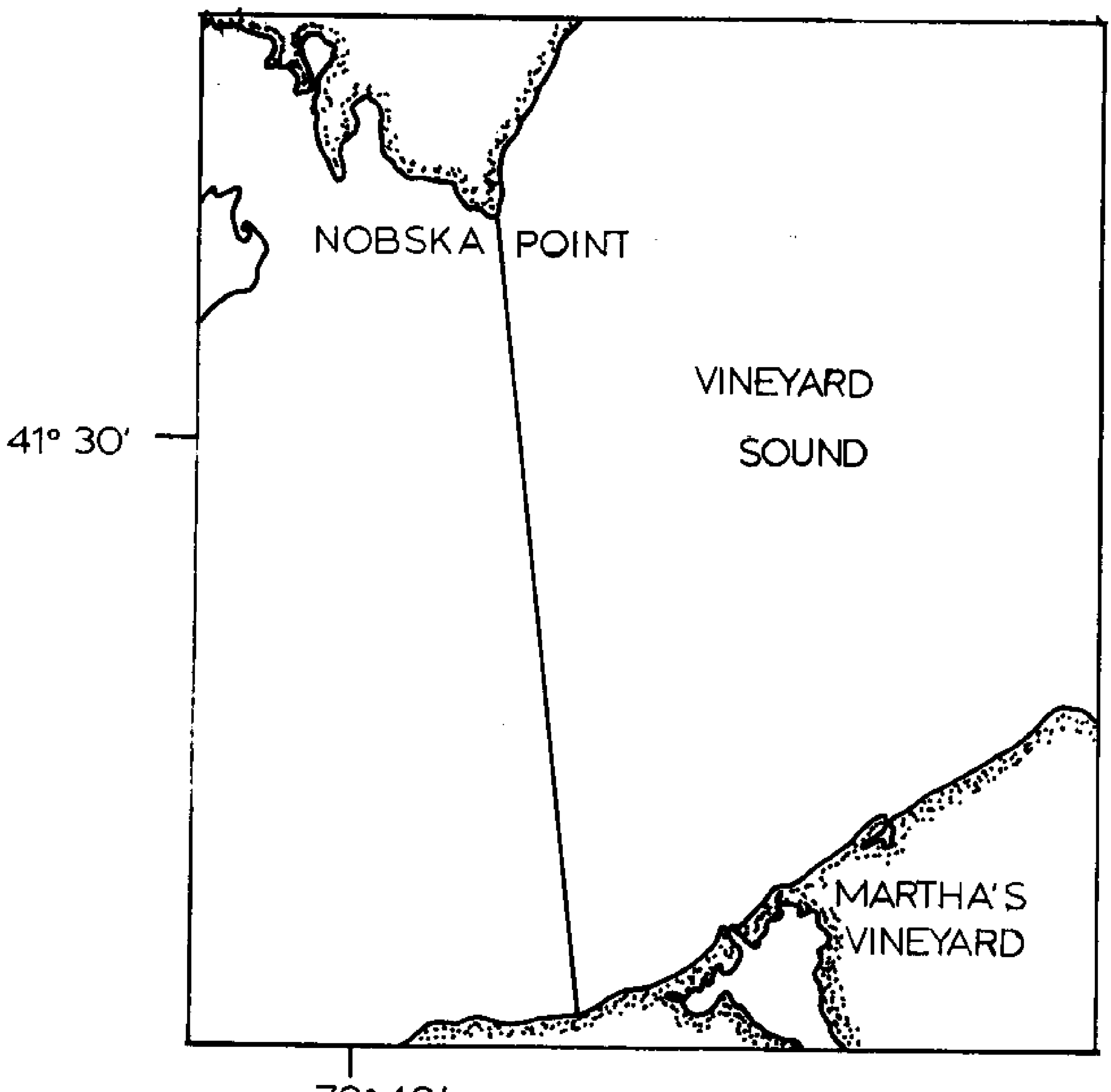


Fig. 1. Transect followed by
R/V ASTERIAS.

graphical interpolation (T' vs. t') did not differ from the calculated values at the order of accuracy desired. The bottom depths were thermometrically determined, with the aid of the calculator as were the anomalies of the density at atmospheric pressure (sigma-T). Salinities were measured on a WHOI Salinometer and oxygen content was determined by the Winkler method. The corrected temperature, salinity, oxygen, and sigma-T were plotted versus the corrected depth (on occasion the wire-out value for the depth was used). Then a convenient contour interval was chosen, the proper points were collected, and the various profiles from the BT record are shown in Fig. 15-17. Final work with the data demanded a reduction to NODC format. The data was then processed through the program OCCOMP (source Mary Hunt, WHOI). This data is on file with M.C. Stalcup at WHOI.

The general conclusions obtained from the temperature profiles are that temperature decreases from Nobska Point to Martha's Vineyard and the average value increases with time. In observing the temperature profiles, it is noted that a thermal gradient is located just north of Middle Ground in Fig. 2 (the earliest transect). As time increases the gradient lessens as seen in Fig. 3 and re-forms closer to Nobska Point (Fig. 4). The final temperature profile shows this gradient even closer to Nobska Point. There is a noticeable temperature inversion in Fig. 3 (corroborated by similar salinity and sigma-T inversions). These gradients seem to indicate at least two different water masses in the Sound, one perhaps Buzzards Bay water from the northwest (M.C. Stalcup, personal communication) and the others, Gulf of Maine water and Atlantic Ocean water. Another reason for the gradient may be the fact that currents

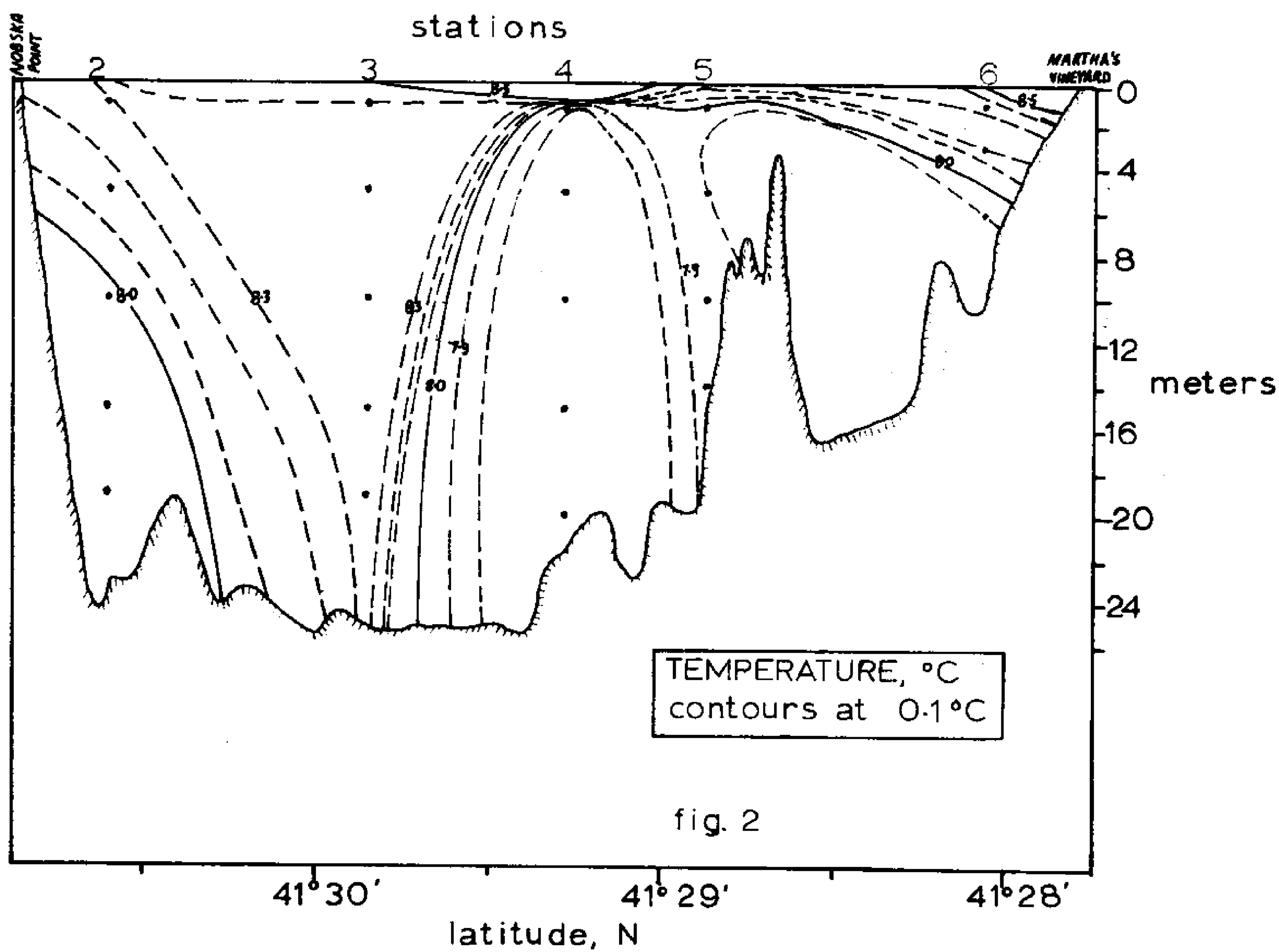

stations
NOBSKA POINT
2
3
4
5
6
MARTHA'S VINEYARD
0
4
8
12
16
20
24
meters
8.0
8.3
7.9
8.2
TEMPERATURE, °C
contours at 0.1°C
41°30'
41°29'
41°28'
latitude, N

fig. 2

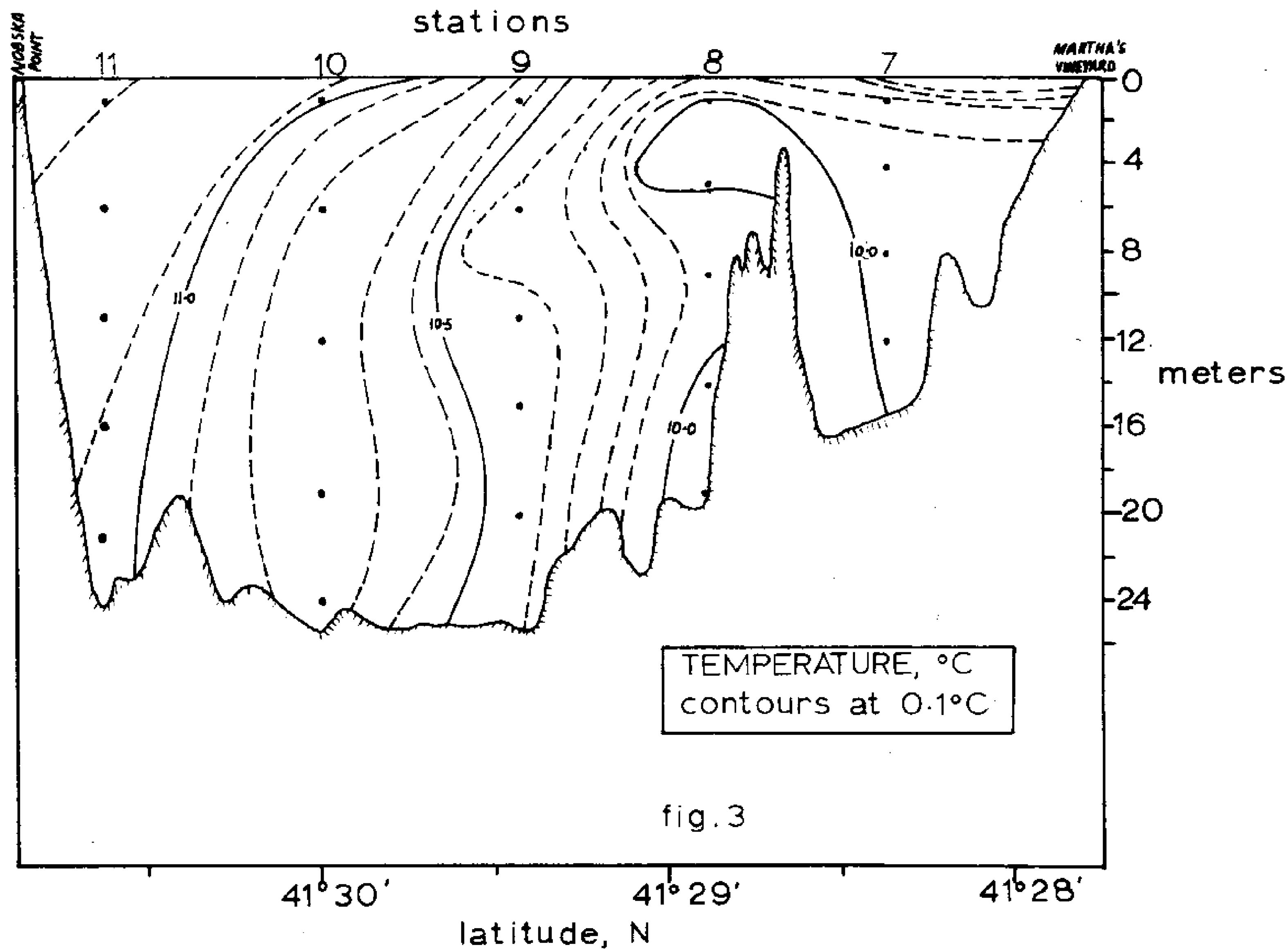
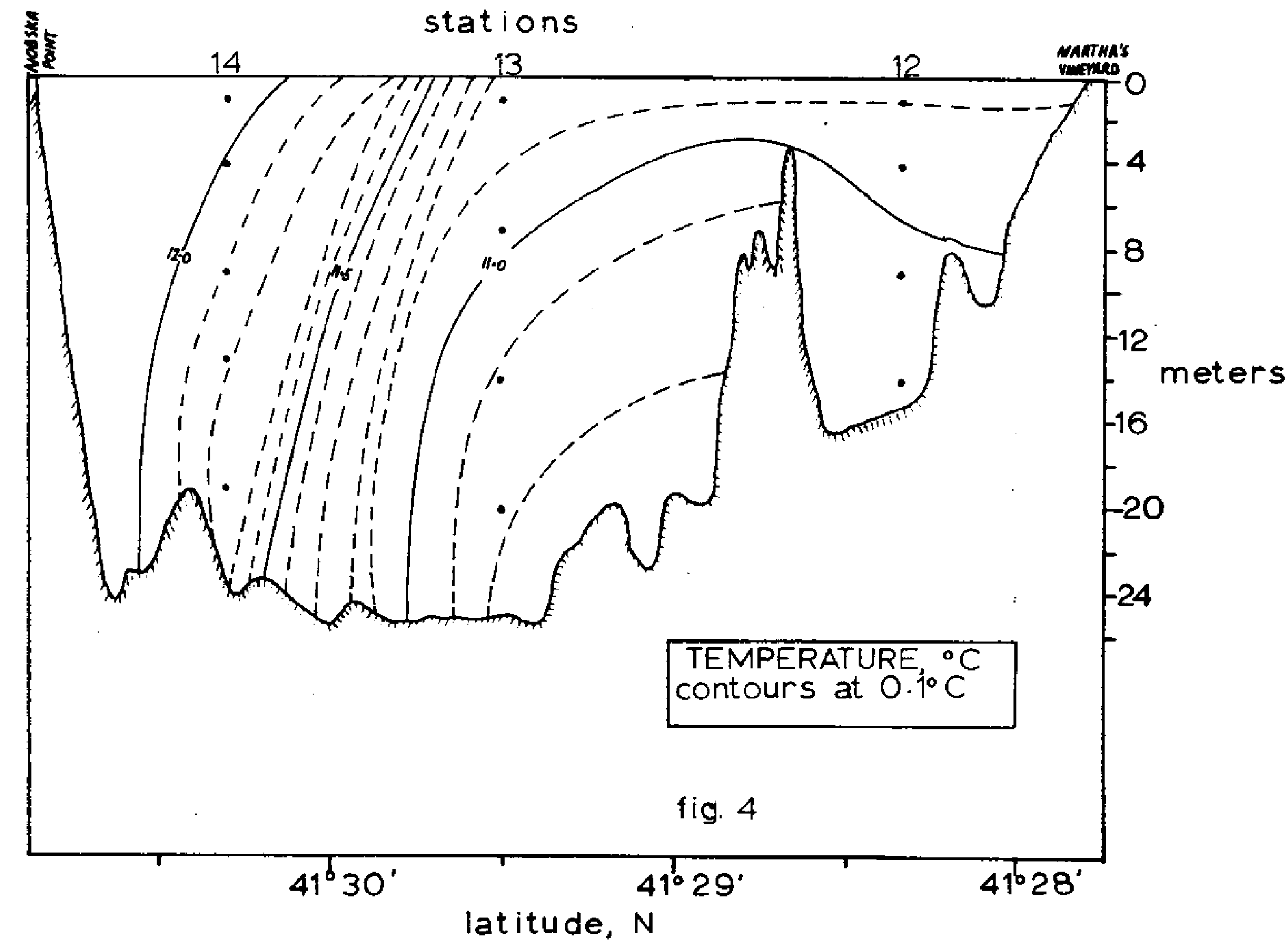

stations
NOBSKA POINT
11
10
9
8
7
MARTHA'S VINEYARD
0
4
8
12
16
20
24
meters
11·0
10·5
10·0
10·0
TEMPERATURE, °C
contours at 0·1°C
41°30′
41°29′
41°28′
latitude, N

fig. 3



stations
NOBSKA POINT
14
13
12
MARTHA'S VINEYARD
0
4
8
12
16
20
24
meters
12·0
11·5
11·0
TEMPERATURE, °C
contours at 0·1° C
41°30'
41°29'
41°28'
latitude, N

fig. 4

close to Nobska Point are slower than those in the middle portion of the Sound, and the duration of the currents is not equal (Bumpus et al., 1969). Since the individual temperature vs. depth profiles are essentially isothermal, it can be assumed that very thorough vertical mixing occurs, while the presence of gradients implies little horizontal mixing.

The general trend of salinity in the Sound is to increase from Nobska Point to Martha's Vineyard and slightly decrease with time. These salinity gradients occur concurrently with the temperature gradients. A reason for the slight decrease in salinity may be based on the fact that the time of residence of any material in the Sound is about 75 days (Bumpus et al., 1969). Thus winter ice, blocking the fresh water entering Buzzards Bay, would permit the salinity to increase, and the subsequent melting and entry of the fresh water into Buzzards Bay, then Vineyard Sound, would decrease the salinity slightly. If this is true, then it further substantiates thenorthern source of Vineyard Sound water as Buzzards Bay water.

The sigma-T profiles illustrate an increase in density from Nobska Point to Martha's Vineyard and a decrease with time, thus following the trend of the salinity profile. The density gradients also follow those of salinity and temperature. Besides the above-mentioned reasons, the decrease in density may be attributed to the 'spring bloom', where particulate matter in the water is removed by plankton.

Although not all of the total oxygen profiles could be obtained, those drawn show an increase in oxygen from Nobska Point to Martha's Vineyard and generally remain constant with time. However, since cold water can hold

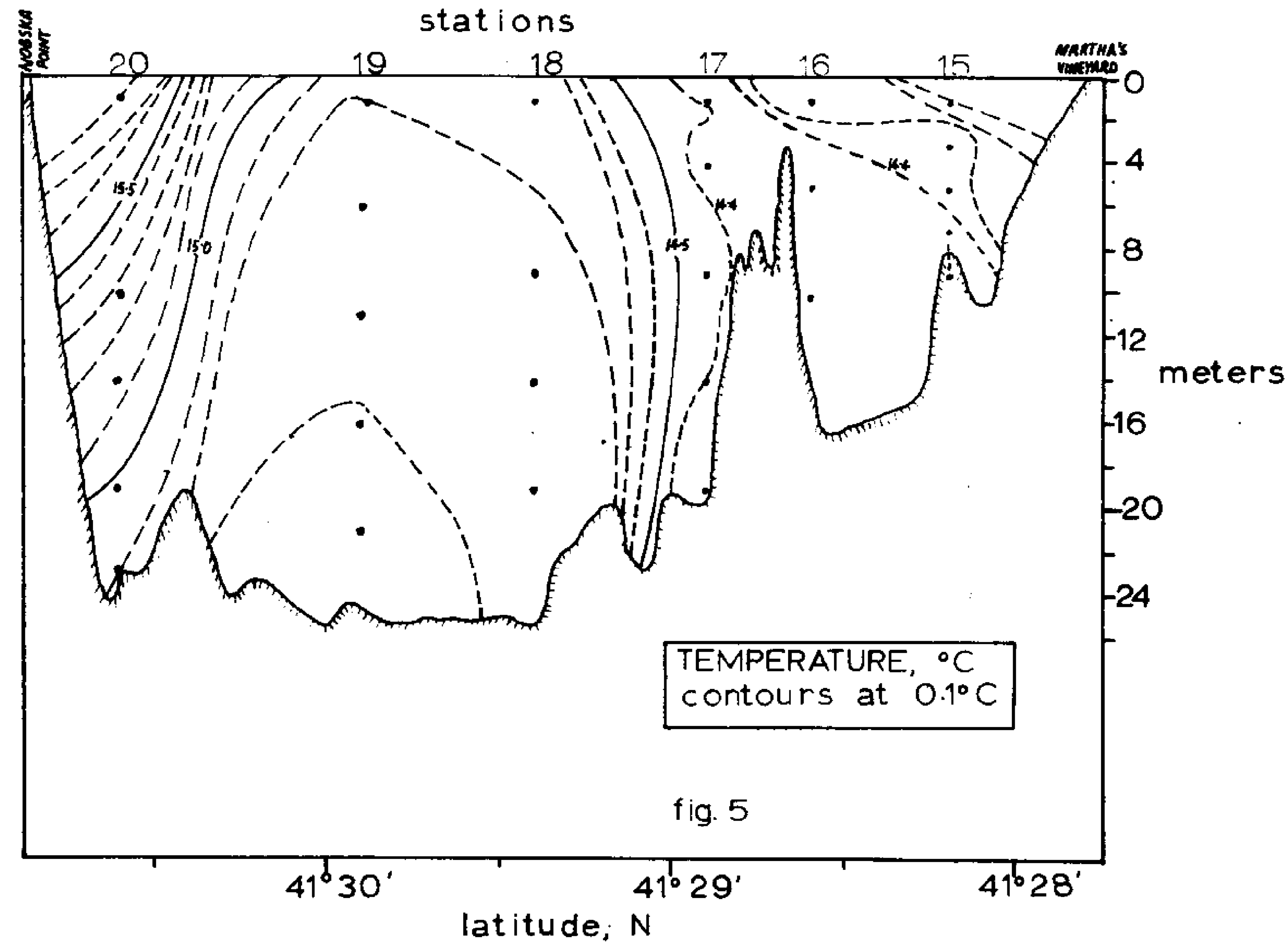
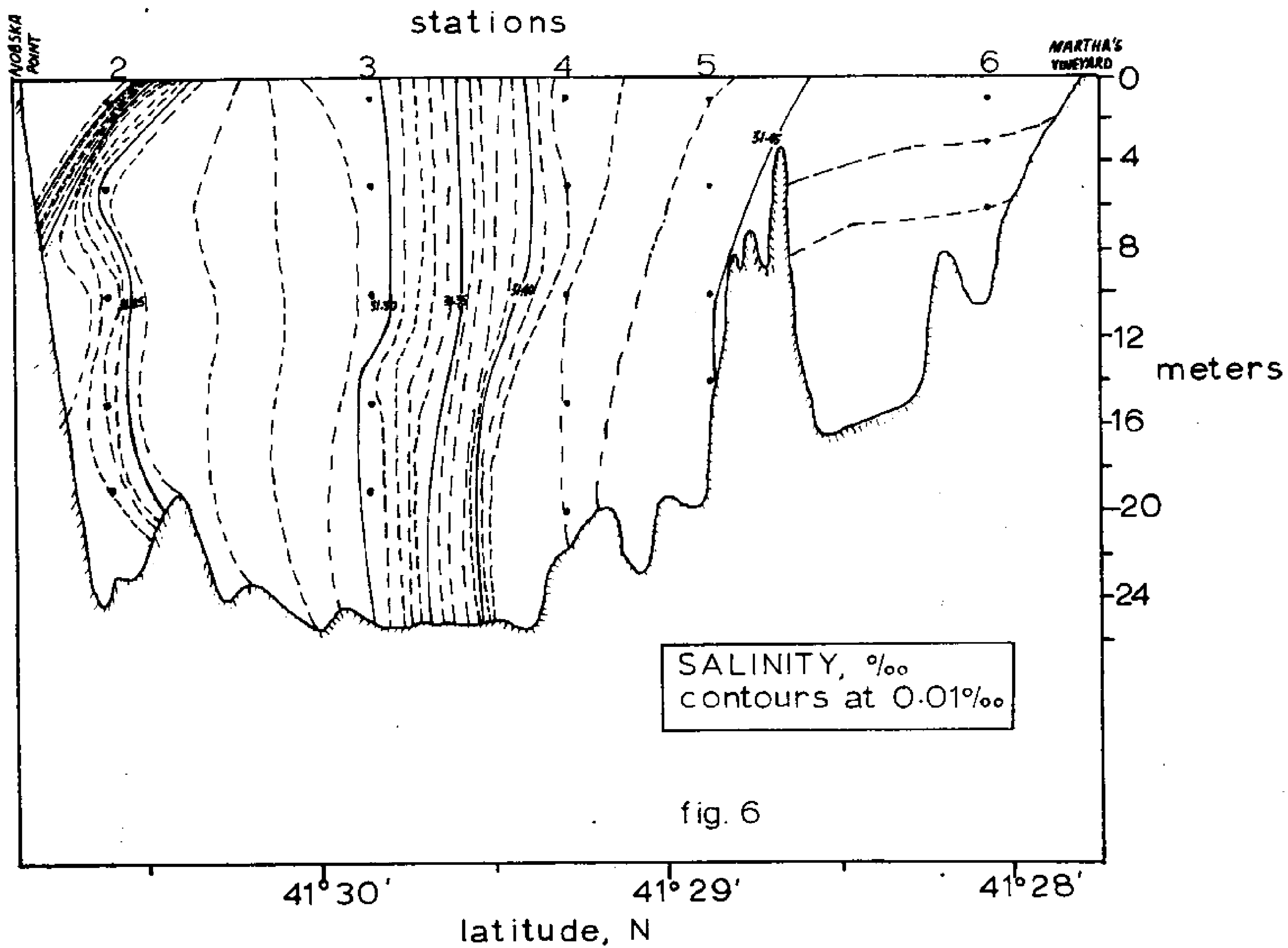

stations
NOBSKA POINT
MARTHA'S VINEYARD
20
19
18
17
16
15
0
4
8
12
16
20
24
meters
15.5
15.0
14.5
14.4
TEMPERATURE, °C
contours at 0.1°C
41°30'
41°29'
41°28'
latitude, N

fig. 5



stations
NOBSKA POINT
2
3
4
5
6
MARTHA'S VINEYARD
0
4
8
12
16
20
24
meters
31.46
31.40
31.35
31.30
SALINITY, ‰
contours at 0.01‰
41°30'
41°29'
41°28'
latitude, N

fig. 6

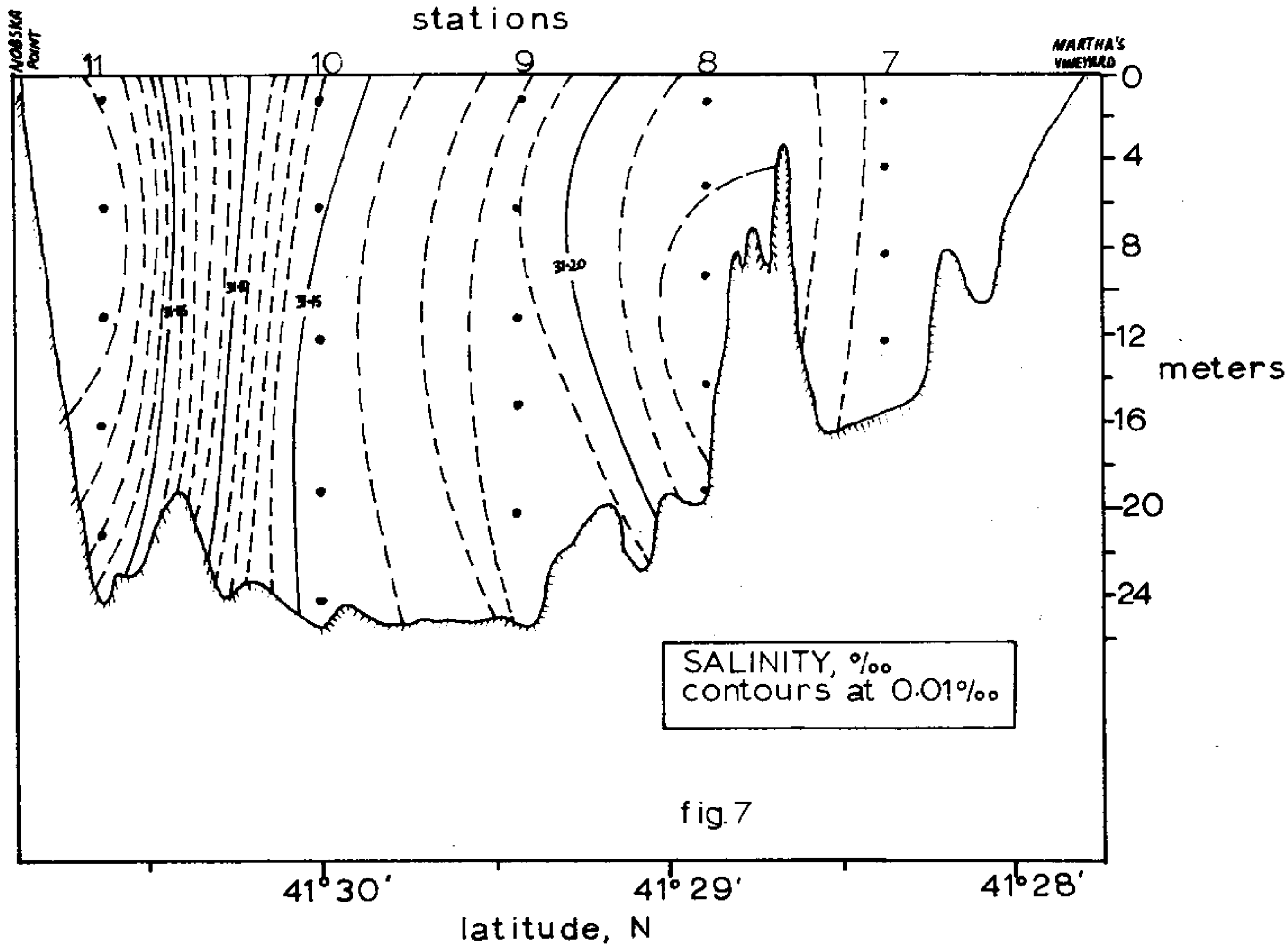

stations
NOBSKA POINT
MARTHA'S VINEYARD
11
10
9
8
7
0
4
8
12
16
20
24
meters
41°30'
41°29'
41°28'
latitude, N
SALINITY, ‰
contours at 0.01‰

fig. 7

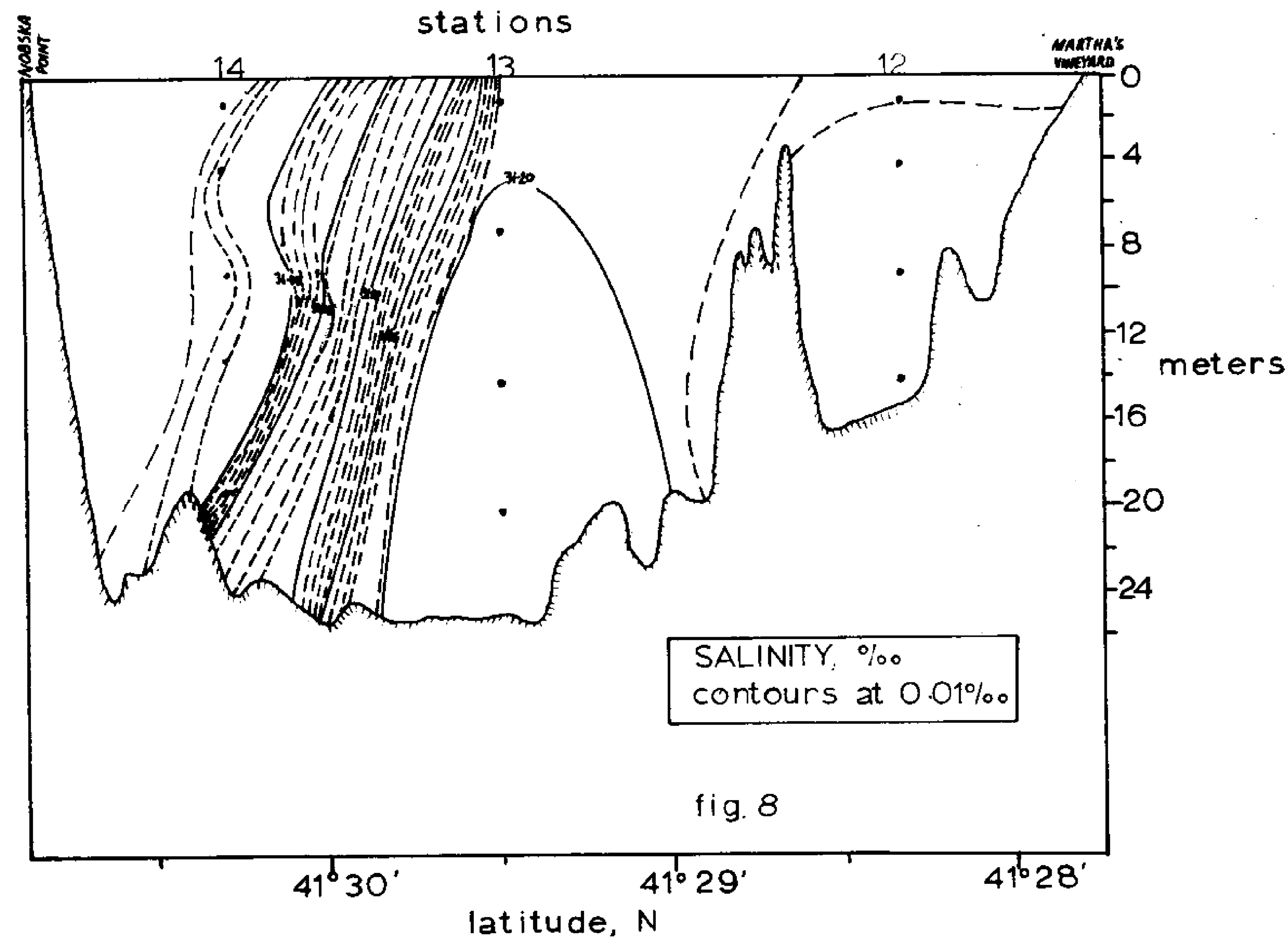
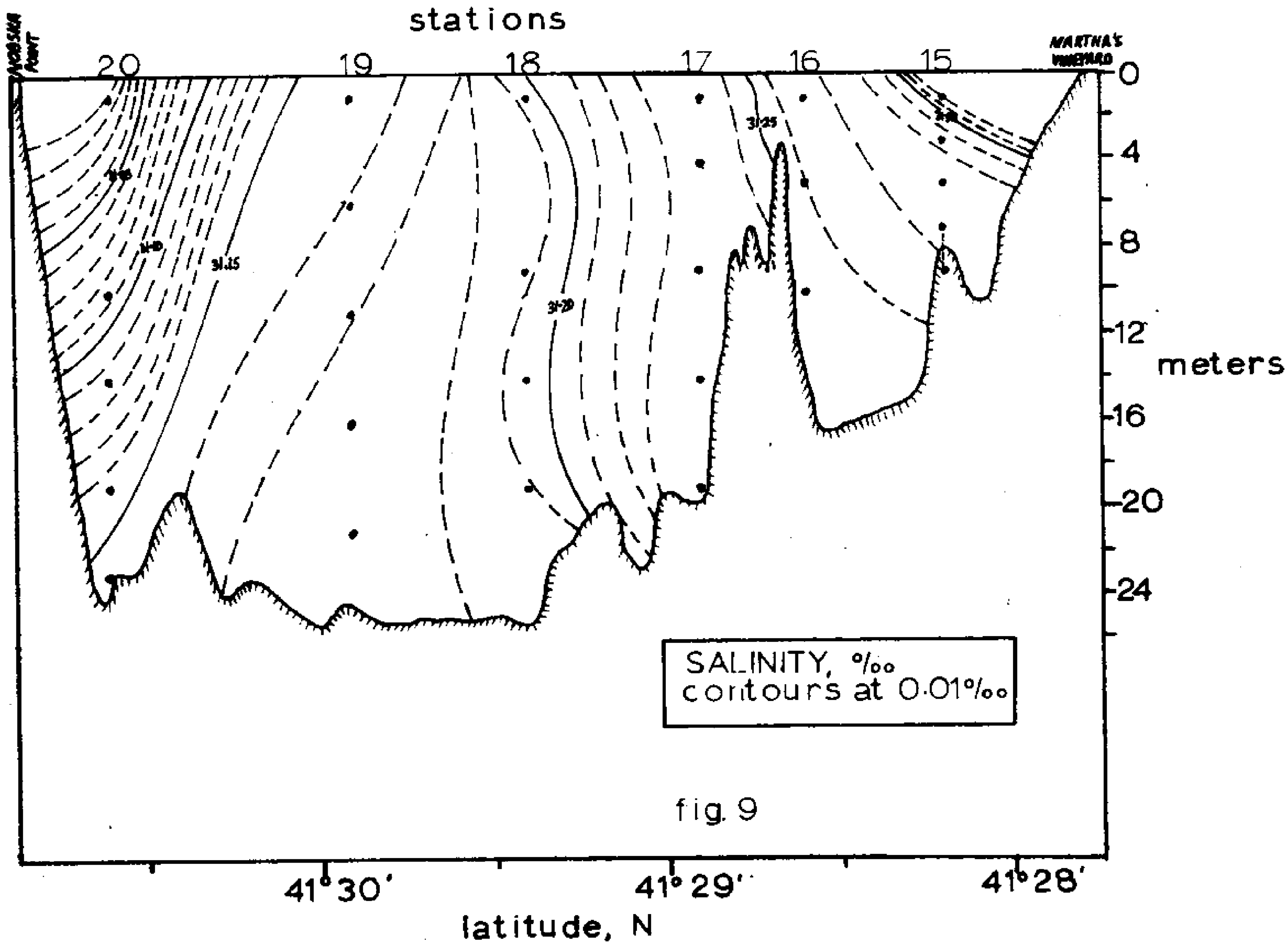

stations
NOBSKA POINT
14
13
12
MARTHA'S VINEYARD
0
4
8
12
16
20
24
meters
SALINITY, ‰
contours at 0.01‰
41°30′
41°29′
41°28′
latitude, N

fig. 8



stations
NOBSKA POINT
MARTHA'S VINEYARD
20
19
18
17
16
15
0
4
8
12
16
20
24
meters
31.15
31.20
31.25
SALINITY, ‰
contours at 0.01‰
41°30'
41°29'
41°28'
latitude, N

fig. 9

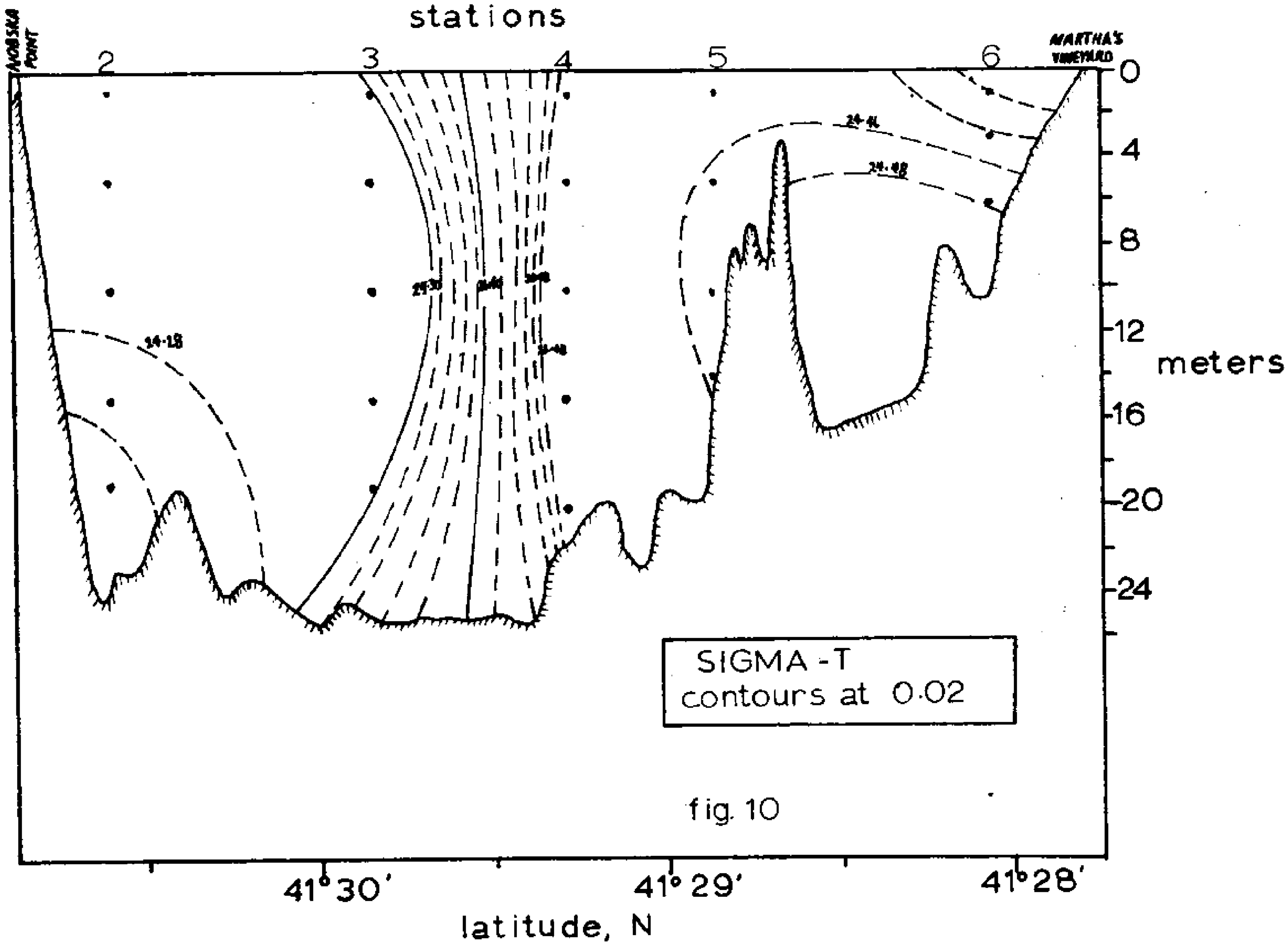

stations
NOBSKA POINT
2
3
4
5
6
MARTHA'S VINEYARD
0
4
8
12
16
20
24
meters
SIGMA -T
contours at 0.02
41°30'
41°29'
41°28'
latitude, N

fig. 10

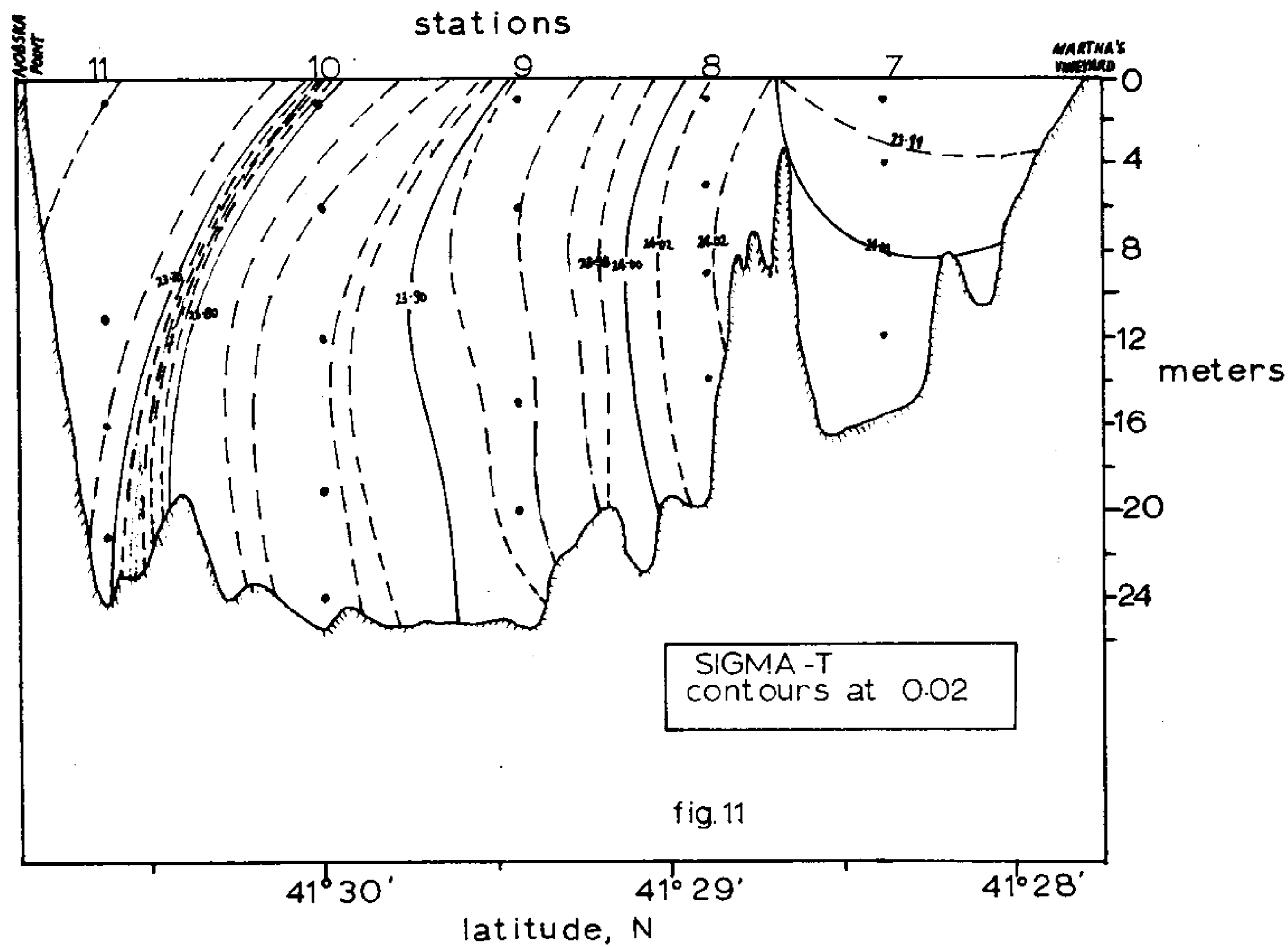

stations
NOBSKA POINT
MARTHA'S VINEYARD
11
10
9
8
7
0
4
8
12
16
20
24
meters
SIGMA -T
contours at 0·02
41°30′
41°29′
41°28′
latitude, N

fig. 11

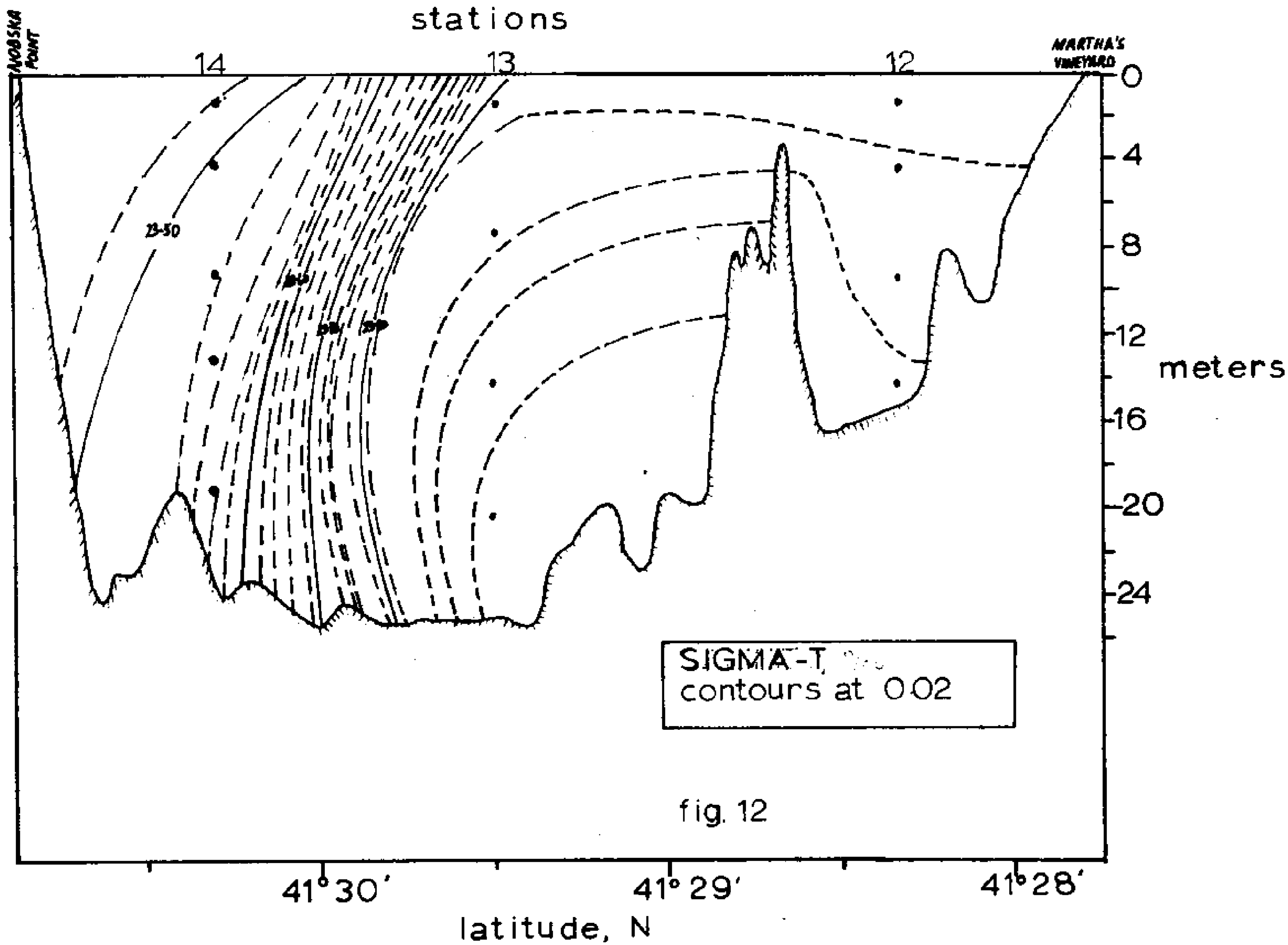

stations
14
13
12
NOBSKA POINT
MARTHA'S VINEYARD
0
4
8
12
16
20
24
meters
23-50
SIGMA-T,
contours at 0.02
41°30'
41°29'
41°28'
latitude, N

fig. 12

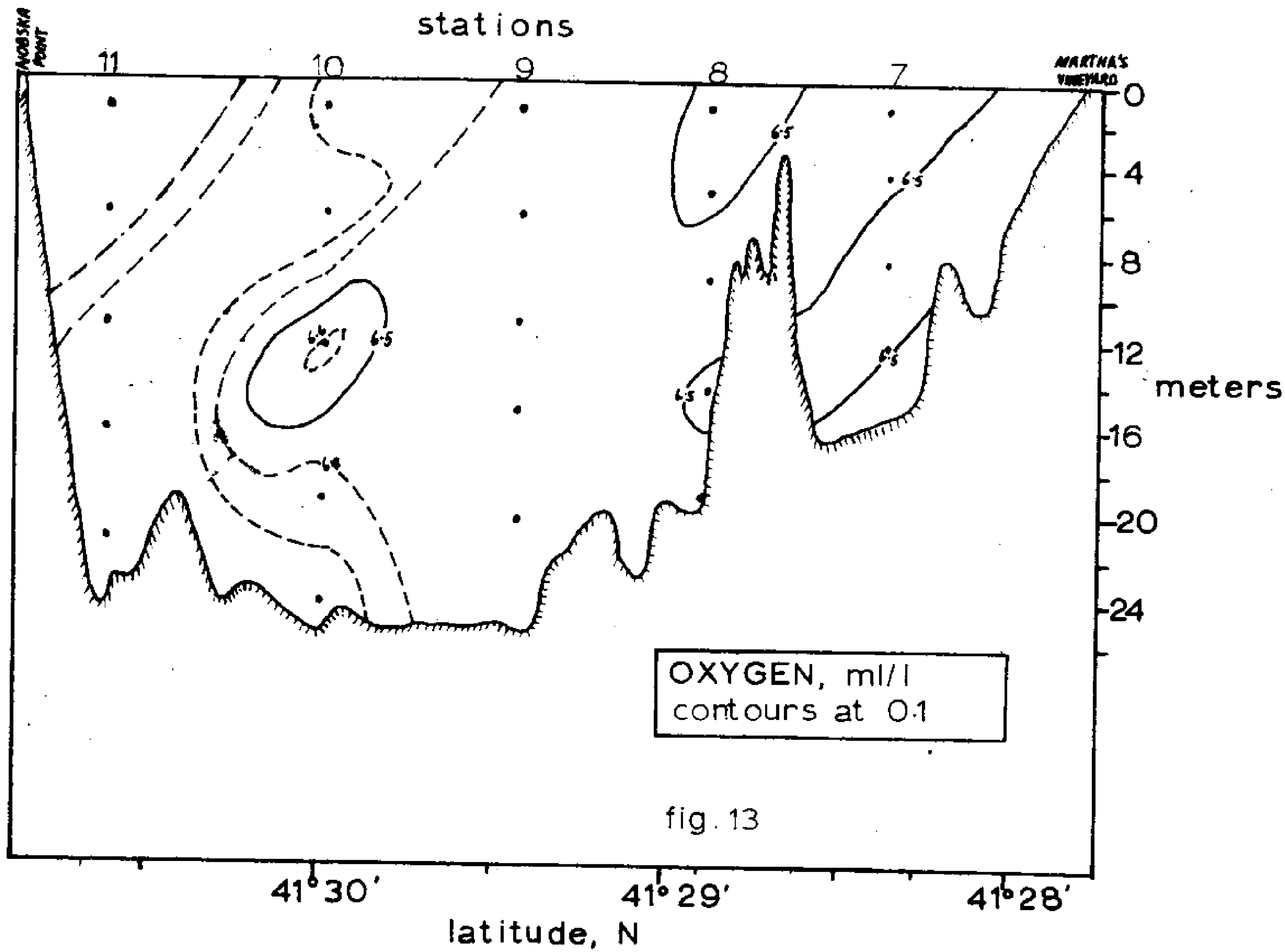
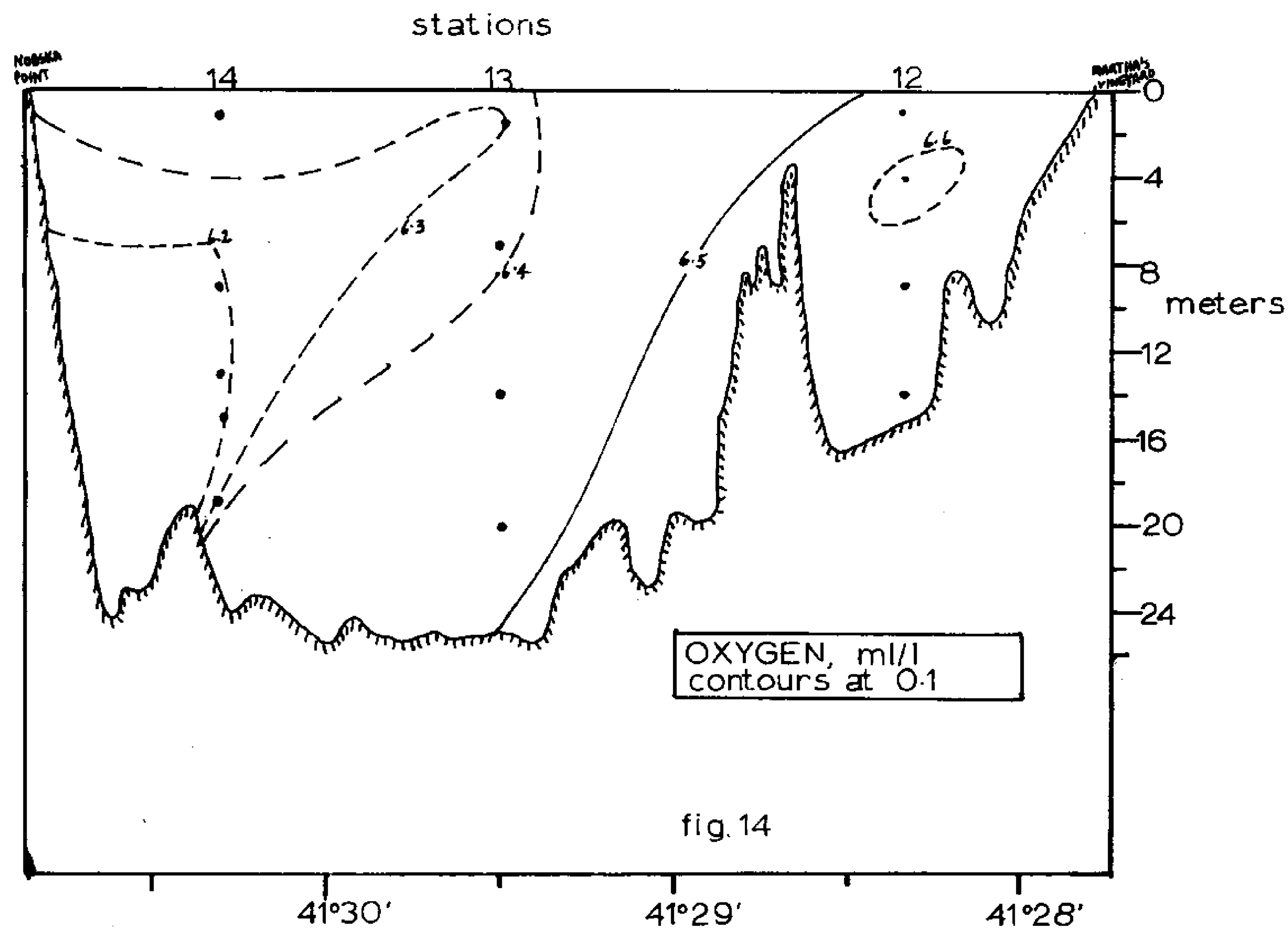

stations
11
10
9
8
7
NOBSKA POINT
MARTHA'S VINEYARD
0
4
8
12
16
20
24
meters
6.5
6.6
6.4
OXYGEN, ml/l
contours at 0.1
41°30'
41°29'
41°28'
latitude, N

fig. 13


stations
NOBSKA POINT
MARTHA'S VINEYARD
14
13
12
6.2
6.3
6.4
6.5
6.6
0
4
8
12
16
20
24
meters
OXYGEN, ml/l
contours at 0.1
41°30'
41°29'
41°28'
fig. 14

more dissolved oxygen than warm water, and total oxygen, rather than dissolved oxygen was measured, the results are not very conclusive (M.C. Stalcup, personal communication). The relation of oxygen to the chemical properties of the Sound water is explained in the chemistry section.

Although the depths were not corrected to mean low water, the general shape of the profiles can be observed. It was noted that not much correlation occurred between the BT records and temperature profiles. However, there was some problem with the BT slide viewers; consequently there is an error involved (G.T. Kaye, personal communication). Three out of the four transects were taken between slack water and maximum flood current. However, the other periods of the tide and currents should be measured on various transects to confirm the motions of the water masses.

More extensive discussion of the results is not possible at the present. Further studies of the area should include more than one transect of the Sound so that the path of the original water masses can be determined. Also, the change in the water masses with season would illustrate the basic flow patterns in the Sound.

In addition to the tremendous help and encouragement offered by M.C. Stalcup, I would like to acknowledge the assistance of M. Zemanovic, and the discussions between my fellow students and myself. Also, Mr. Dawson, of Blake, was of assistance with regard to the computer programs.

Bibliography

Bumpus, D. F., Wright, R., Vaccaro, R.F., Considerations on a Sewer outfall of Nobska Point, Unpublished manuscript. WHOI Reference No. 69-87, 1969.

Manglesdorf, P.C., Jr. 1963. "The world's longest salt bridge", _Marine Sciences Instrumentation,_ Vol. _1_, pp. 173-185.

Redfield, A.C., 1953. "Interference phenomena in the tide of the Woods Hole region", _J. Mar. Res._, _12_, pp. 121-139.

U.S. Dept. of Commerce, C & G S Tidal Current Tables, 1971. Buzzards Bay, Martha's Vineyard, based on Pollack.

U.S. Dept. of Commerce, C & G S Tide Tables, 1971. Martha's Vineyard, Nobska Point, based on Newport.

(Figures 15-17 are not included in this report, but are in the original paper)

The General Atmospheric Circulation
of the Cretaceous: Paleo-winds of the Northern Hemisphere
by Randolph D. Borys

The paper opens with a discussion on the nature of the gathering of the necessary information and data used in the paleoclimatic reconstruction. Since the investigation was to be a literature search, the final results of the project were only to be considered qualitative in their approach to the solution of the problem. A wide scope of paleoclimatic data was used to reproduce a climatic map of the Cretaceous period. The information used included oxygen isotope temperature analysis, wind direction inferred from fossil sand dunes, sea conditions from marine flora and fauna, terrestrial red beds, coal deposits, evaporites, fossils, and miscellaneous other techniques for deducing the climate at the period in investigation.

The Cretaceous was chosen as the point in geologic time to undergo the study because the Atlantic ocean basin was for the first time of considerable extent, and thus active in the heat budget of the earth. The Tethys Sea and the Isthmus of Panama were also open, thus affording a unique situation in the global geographic history of the earth.

As much of the paleoclimatic information as possible was used, although contradictions did occur and many data points were useless. The information was placed on the paleogeographic map of the period and a general climatic map was constructed. From this, and using current climatological - meteorological interrelationships, a general surface pressure map of the Northern Hemisphere was constructed and positions of major high and low pressure areas approximated. This was done for both winter and summer seasons, since one general construction would not show the important variations.

A brief discussion of what changes may have occurred since the Cretaceous to create the present weather patterns is presented, but it is emphasized that the lack of any substantial evidence to support any particular theory is the greatest problem.

The paper concludes with a statement on the continuation of such a study utilizing numerical models of the general atmospheric circulation which are already in existence and which could be modified to emphasize the important parameters of the mass and energy budget of this particular period in the geologic past.

Future Drift of the Continents

by William D. Burgel

Rotation of the continents about the poles of Bullard, et. al., Sith and Hallam, Chase and Le Pichon has resulted in envisioning possible future configurations of the continents. This was accomplished by moving the rigid continental plates in the directions and rates that they are presently drifting. In this exercise, the plates were rotated relative to Antarctica which was assumed fixed. It was also assumed that the averaged poles and rates responsible for the present day position of the continental plates would remain average for the next 400MY. One of the future configurations in which all the continents are again regrouped occurs within a predicted time window, which attests to the validity of the poles and rates used in this exercise, and suggests that these poles and rates are accurate for future as well as paleo-configurations. The effect of the collision of two plates is also discussed in the context of this future motion.

Introduction

Continental drift theory, having been in vogue for at least five years, has progressed to the point where the fantastic implications of drifting continents are just being realized. That the continents drifted is no longer questioned; the fit of the continents, paleomagnetism, and age of the sea floor are evidence strongly in its favor. These data are used to reconstruct the ancient poles and rates of rotation of the rigid continental plates. Using these poles and rates, it is possible to regroup the plates into one large super-continent, Pangea, at a time of 200 million years (MY) before present (BP). Then as the continents broke up, their respective drift about these various poles and at these various rates has brought them to their present position. This can be done because the motion of a plate on a sphere can be described by designating a pole and associating a rate with that pole. The average pole is the sum of all the instantaneous poles and the average rate, expressed in 10^{-7} deg/yr, is the amount of angular opening divided by the time opened.

Extrapolating into the future, employing these average poles and rates of rotations, is the primary purpose of this paper. The poles and rates of Bullard et. al., Phillips and Forsyth, Smith and Hallam, Chase and Le Pichon are used in combination and are moved relative to Antarctica which is an assumed fixed reference position.

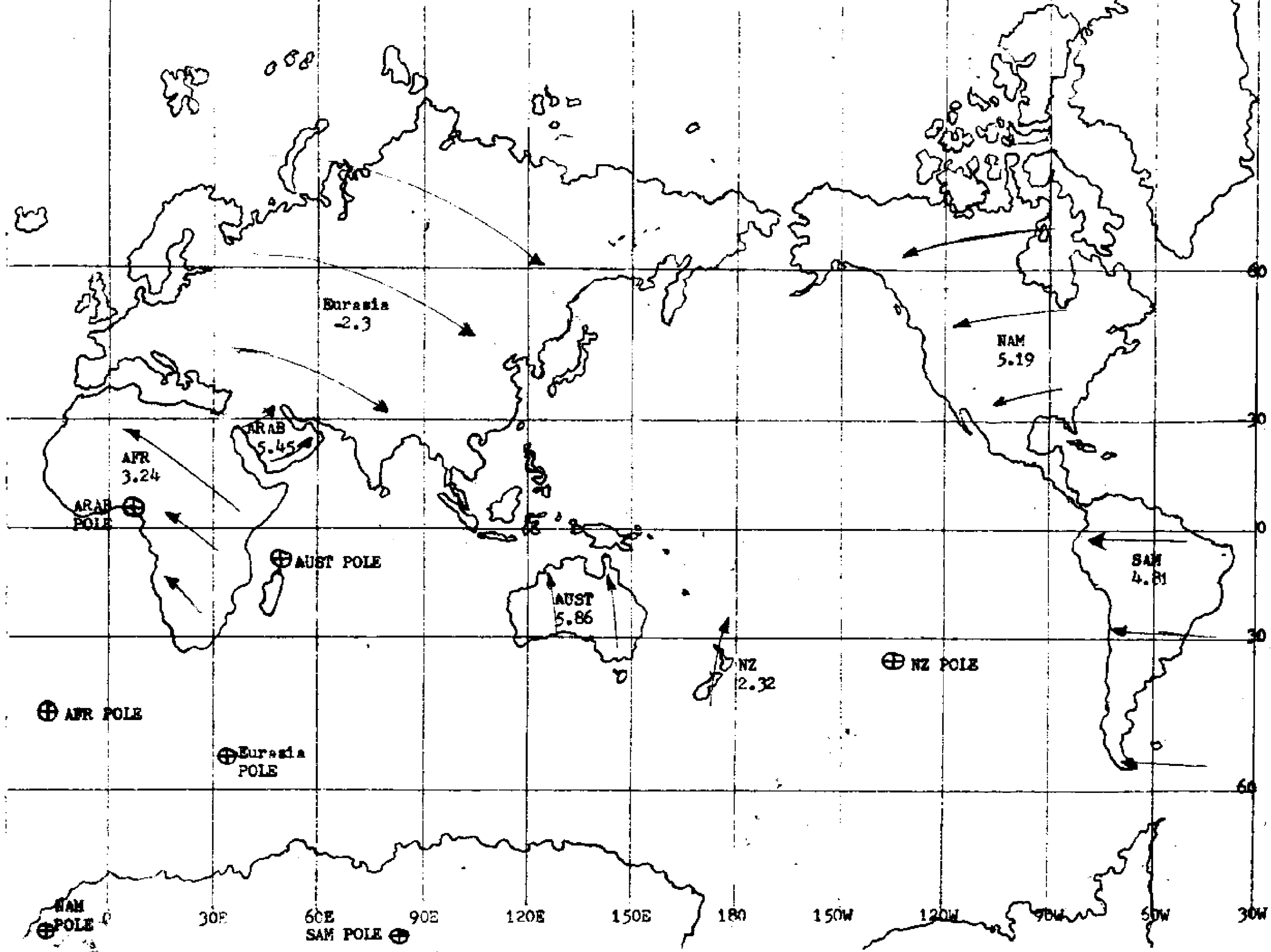
The complication of this future plate movement is the resultant pole and rate when one continental plate has collided with another. What occurs when, for instance, the African plate strikes the Eurasian plate can only be conjectured and various possibilities are considered.

Hurley and Rand have suggested that a regrouping of the continental plates occurs every 400-700 MY and, if this in fact is true, a regrouping may be expected from 200-500 MY after present (AP), assuming the continents were last regrouped 200 MY BP.

Methods

Seven major plates (see Fig. 1) for which poles and rates have been published are drifted about in this exercise. Where a pole and rate relative to the Antarctic plate exists, it has been used as is. Where none exist, a combination of published poles was computed to obtain a new pole and rate (see Appendix). The digital computer program of R. Parker, HYPERMAP, was employed to perform these future rotations. The plates are represented by the coastlines of the continents. As the Pacific plate has no continental coastline except for the thin silver of Baja California,

FIG. 1 PRESENT DAY WORLD WITH POLES AND RATES FOR THE SEVEN PLATES



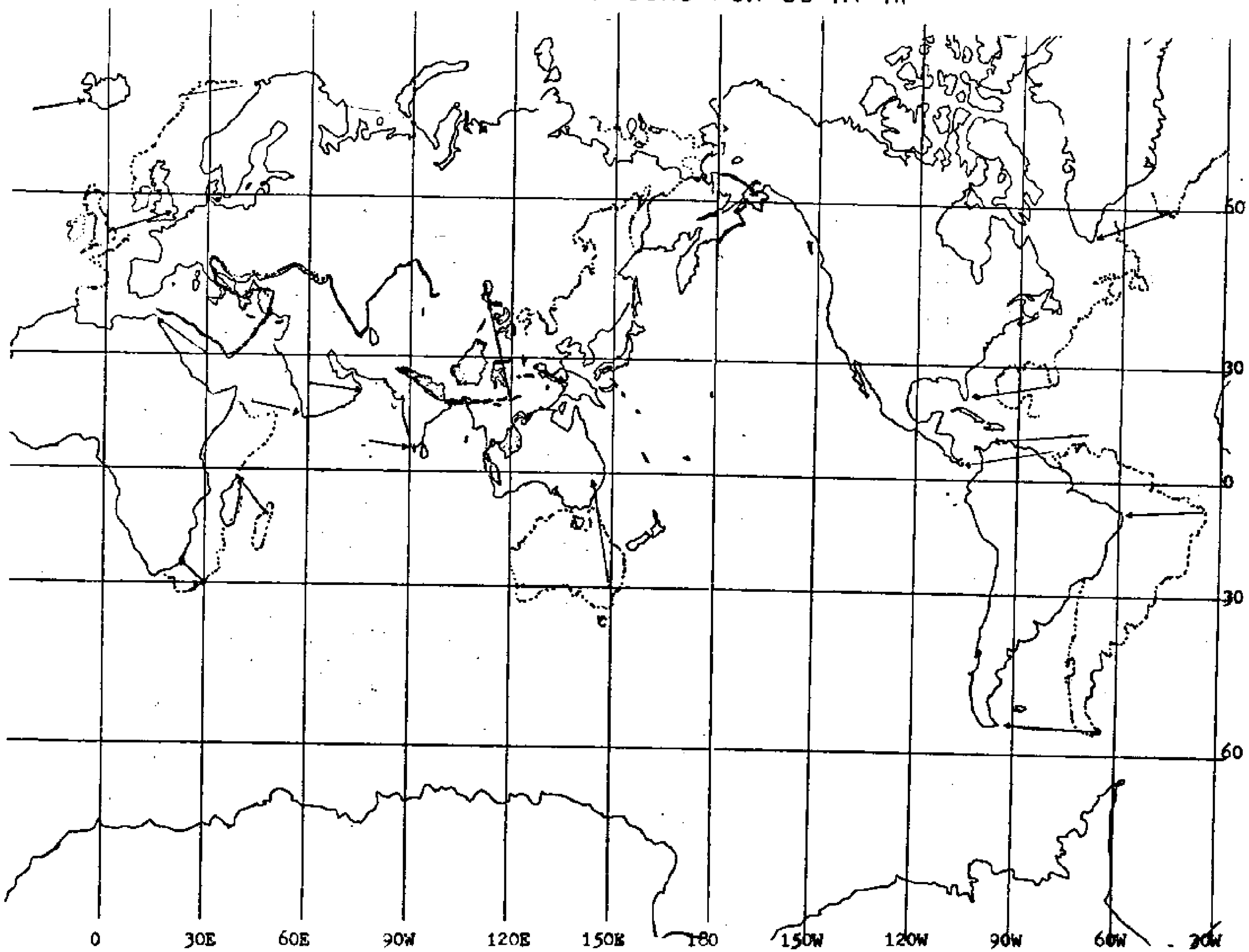
this plate's movement and effect on other plates was disregarded. The influence of subjunction zones was also disregarded owing to the fact that a continental plate, when contacting a zone, would probably ride over the down-sinking-zone because of the continent's bouyancy.

Collision of two plates could result in one of three outcomes. First, the two plates continue to pass into one another, perhaps the case where India has buckled into Eurasia. Second, the two plates striking and sticking with both plates assuming the motion of one of the plates. This might be the case where a large plate overruns a much smaller one, Asia colliding with Arabia, for instance. In both of these examples, whether striking & sticking, or passing through, there is also the question of which plate will end up on top and which will be the plate on the bottom. The answers to these questions probably depend on the relative size of the plates as well as the relative direction and rate of motion. For the most part in this exercise, it was assumed that when a plate collided with the Eurasian plate, it would halt its own motion, stick to Eurasia and assume the movement of the Eurasian plate. However, for the 50 MY AP projection (see Fig. 2), India was allowed both to continue to pass into the Eurasian plate as well as remain attached to Eurasia as it is today. Two Indias were therefore plotted, both conceivable positions. In subsequent projections, India was left in the attached position. Iceland was allowed to move with the Eurasian plate until it was recalled that Iceland would probably remain affixed on the crest of the Mid-Atlantic Ridge.

Poles and Rates: Table 1

The poles and rates used in these future configurations

WORLD ROTATIONS FOR 50 MY AP



Dotted continents are present day positions
Arrows, from present day to 50 MY AP positions

TABLE 1: POLES AND RATES

		AFR	NAM	ANT
North America NAM	LAT LONG RATE	67.6N (1) 14.0W 3.1	-	76.3S (*) 13.6W 5.19
South America SAM	LAT LONG RATE	44.0N (1) 30.6W 3.7	-	80.6S (*) 87.0E 4.81
Eurasia EUR	LAT LONG RATE	-	73.0N (1) 96.5E 3.3	55.1S (*) 32.1E -2.3
Africa AFR	LAT LONG RATE	-	-	42.2S (3) 13.7W 3.24
Australia AUST	LAT LONG RATE	-	-	7.0S (4) 44.0E 5.86
Arabia ARAB	LAT LONG RATE	36.9N (2) 18.0E 7.0	-	2.4N (*) 4.4E 5.45
New Zealand NZ	LAT LONG RATE	-	-	32.1S (2) 135.0W 2.32
Antartica ANT	LAT LONG RATE	-	-	-

(*) computed, see Appendix
(1) Bullard, et al.
(2) Smith and Hallam
(3) Le Pichon
(4) Chase

were obtained from the work of Bullard, et. al. (1965), Le Pichon (1968), Smith and Hallam (1970), Phillips and Forsyth (in press), and Chase (1968). Bullard contributed the poles of rotation for NAM-AFR, SAM-AFR and EUR-NAM. Using these poles, the best fit between the continents involved is obtained and for this reason, these poles were used. The rates of rotations for Bullard's poles were contributed by Phillips and Forsyth, who based their results on evidence of marine magnetic profiles and deep sea drilling data. Smith and Hallam also based the poles of ARAB-AFR and NZ-ANT on the fit of the continents. The rates associated with these poles were obtained by dividing the angular opening between the continents by the length of time open. The AUST-ANT pole and rate was obtained from the work of Chase, while the AFR-ANT pole was contributed by Le Pichon who based his poles and rates on spreading rates and fracture zone azimuths.

Admittedly, it would have been a more coherent exercise had all rotation poles and rates been based on the fit of the continents. However, the time available for this exercise was limited and the oversight was not realized until it was too late. In addition, the assumption that these poles and rates will remain constant for the next 400 MY does tend to cast doubt upon the veracity of this work. The only supporting evidence for this assumption is that the poles and rates used have brought the continents to their present day positions from their agglomeration some 200 MY ago. If the poles and rates for this interval can be accepted, then perhaps these poles and rates can be accepted for the next 400 MY. Whatever, the results are interesting.

Results

The computer-plotted future-configurations for the 50-400 MY AP interval call for a large degree of imagination on the part of the reader. It is fairly certain the Phillipines are not going to end up intact in the Gobi Desert, nor is Venezuala going to drift into Kansas City. The plates were allowed to collide until a fair degree of overlap occurred, at which time the plate's own motion was stopped and assumed the motion of the Eurasian plate. Keep in mind as well that the 30° latitude and longitude spacing is fixed; 60° W always passes through the Antarctic Peninsula. The continental plates move North and South, not the equator. This provides the reader with a reference grid.

World Rotations Projected for 50 MY AP

The average drift of NAM and SAM will, by 50 MY, (see Fig. 2) break the isthmus at Panama and close the Caribbean at the Lesser Antilles. This is evident today as the whole Carribbean region is experiencing compressional effects. NAM will have contacted Eurasia through the now non-existent Bering Strait. The Mediterranean will close <u>via</u> the combination of NE drift of Arabia and SE drift of Eurasia.

In Figure 2, two Indias and Arabias have been plotted. The one set, attached to the Eurasian plate was rotated about the Eurasian pole thus assuming no further drift of these plates from their present day position. The second set was rotated about the Arabian pole implying that these smaller plates have sufficient momentum to drive them into the Eurasian plate. India will probably compress still further, causing the Himalayas to upthrust. Simple calculations, based on the fact that 105 MY of drift of the Indian plate has resulted in a 29,000 foot Mt. Everest show that 105 - 50 MY drift will produce a 42,800 foot Mt. Everest.

Other effects of 50 MY of drift will bring Australia into contact with South East Asia and will open the junction of the African and Arabian plate, thereby producing a latter day Tethys Sea. African drift has made that plate an island.*

World Rotations Projected for 100 MY AP

Here, 100 MY into the future, (see Fig. 3) the motion of the Australian and Arabian plates have been halted at 50 MY and both of these plates have assumed the motion of the Eurasian plate. North America has been imbedded in the Eurasian plate. Hereafter, owing to the shape of the respective continents, subsequent drift of the NAM plate will be assumed to pivot about the pole in Alaska. NAM's southward drift (Florida now at 15°N) has essentially blocked any Tethys Sea flow.

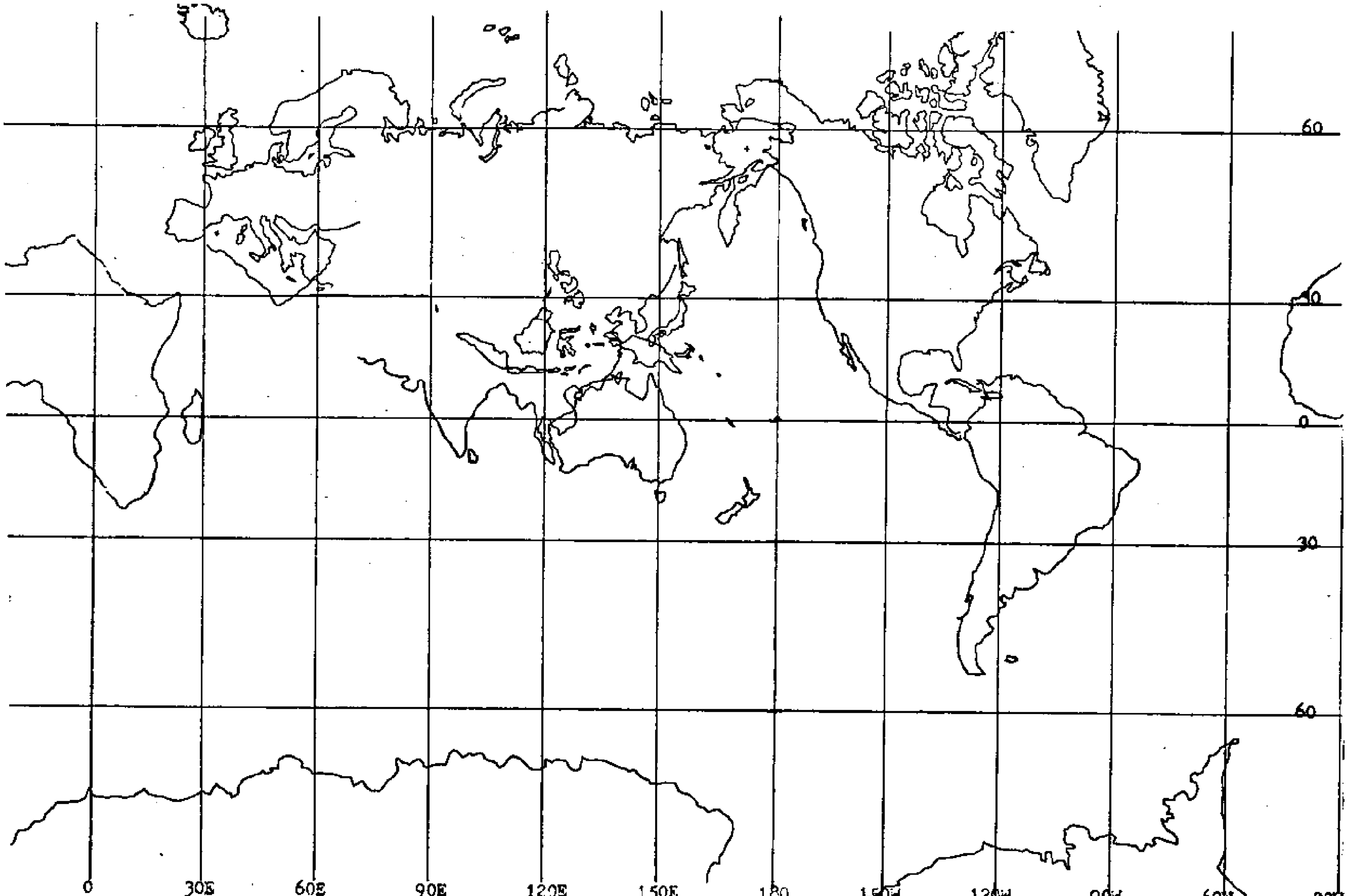
World Rotations Projected for 200 MY AP

By 200 MY, all continents except Africa have been grouped togehter somewhere in the present day western Pacific. NAM, to achieve its position attached to the Eurasian plate, has drifted for 100 MY on its own course. At that time

---

*Here two interpretations are in order. For the first, the one plotted, the poles and rates used have caused the African and Eurasian plates to glide past each other <u>via</u> a transform fault. The presentday tectontic activity evident in Italy and Turkey testify to this idea. The second is that these poles and rates are in error and the relative drift of these two plates are bringing them together resulting in the upthrusting of the Alpines, from the Atlas to Caucasus'. The former hypothesis seems valid based on recent activity, but the latter more likely when the poles and rates are averaged over 200 MY. Both positions are conceivable but which one is more valid?

WORLD ROTATIONS FOR 100 MY AP



Plate's own motion halted: AUST, ARAB
Plates still moving: Eurasia, NAM, SAM, AFR

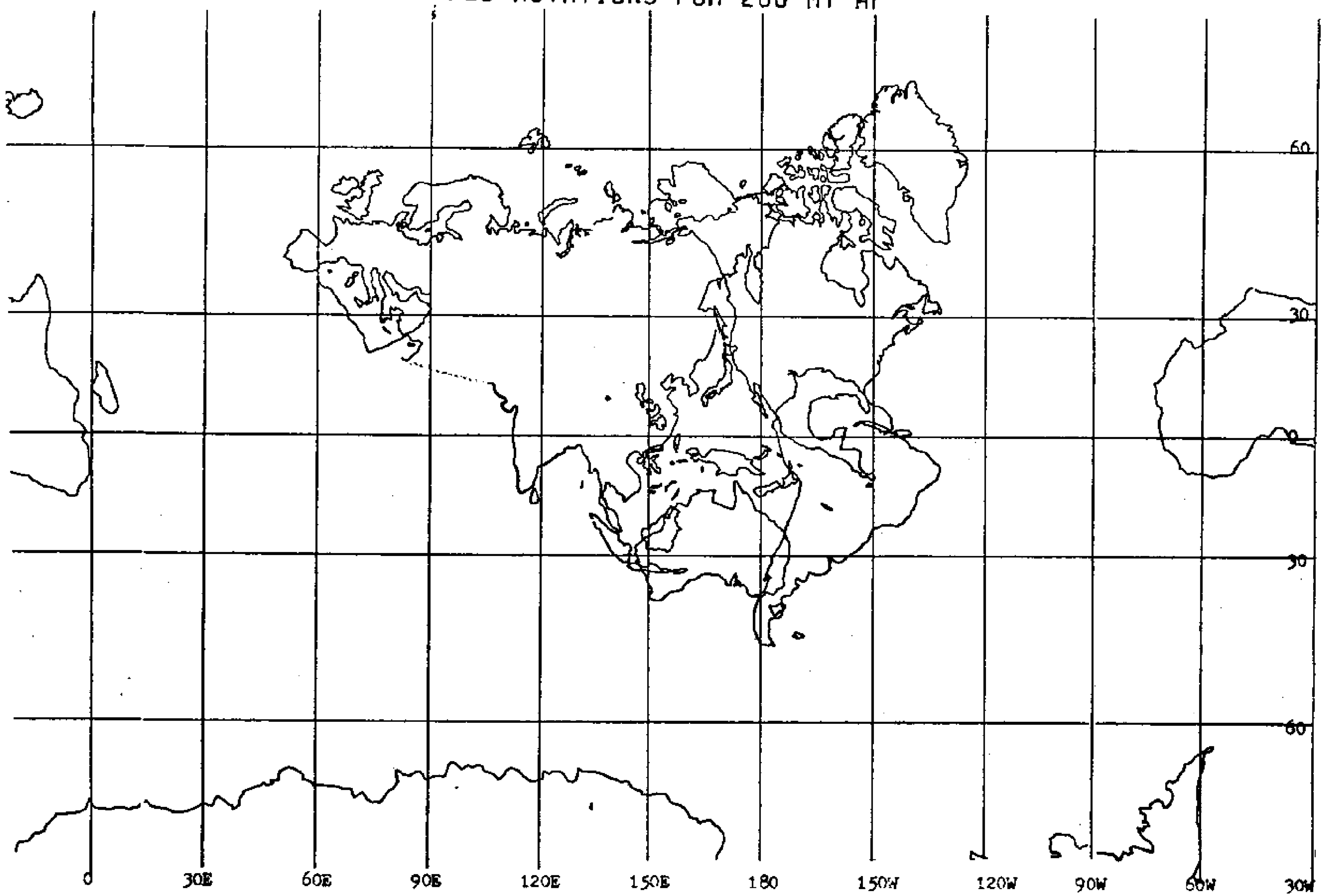
it was pivoted about a new rotation pole and drifted at the associated rate for 60 MY. As a result, the Pacific Ocean has disappeared. For the remaining 40 MY, it drifted at the pole and rate of the Eurasia plate.

The drift of the South American plate was allowed to continue for too long. It should have been stopped at 160 MY in order to fit snugly. By this time in the exercise, it was learned that Borneo, Sumatra, and Java were part of the Eurasian plate. They had hitherto been rotated with the Australian plate. The mistake was corrected in this and subsequent plots. Accordingly, the northward drift of the Australian plate was halted sooner, at 30 MY AP. The compressioned effects, however, of this northward drift into the Eurasian plate would probably close off the South China Sea.

NZ was rotated, in this projection, with respect to its own pole and rate. It ends up north of Australia impinging upon the SAM plate. Its motion was halted at this time, after 200 MY of drift and now except for Africa, all plates are moving connected to the Eurasian plate. In addition, Iceland in this and subsequent projections, was plotted at its present day position on the crest of the Mid Atlantic Ridge. This is assuming non-migration of the ridge system which is doubtful at best, but makes Iceland a handy reference point.

The 200 MY AP projected configuration is the minimum time condition set by Hurley and Rand. They implied that one could expect all of the continents to be regrouped anytime from 200 - 500 MY AP. The poles and rates used in this exercise fall short of the minimum estimate - with the African and Antarctican plate still unattached. How-

WORLD ROTATIONS FOR 200 MY AP



Iceland shifted back to its present day position ; NZ rotated
Plate's own motion halted: AUST, ARAB, NAM, SAM
Plates still moving: NZ, AFR, Eurasia

ever, they all seem to be rushing headlong toward each other to meet the 500 MY AP deadline.

World Rotations Projected for 300 MY AP

Not very much has occured during this 100 MY interval. The Arabian, Australian, Indian, North and South American plates are still attached to the Eurasian plate. Florida is in the tropics as is China and Africa, which has been rotated on its side. The only noticeable change is that the gap between Eurasia and Africa has shrunk.

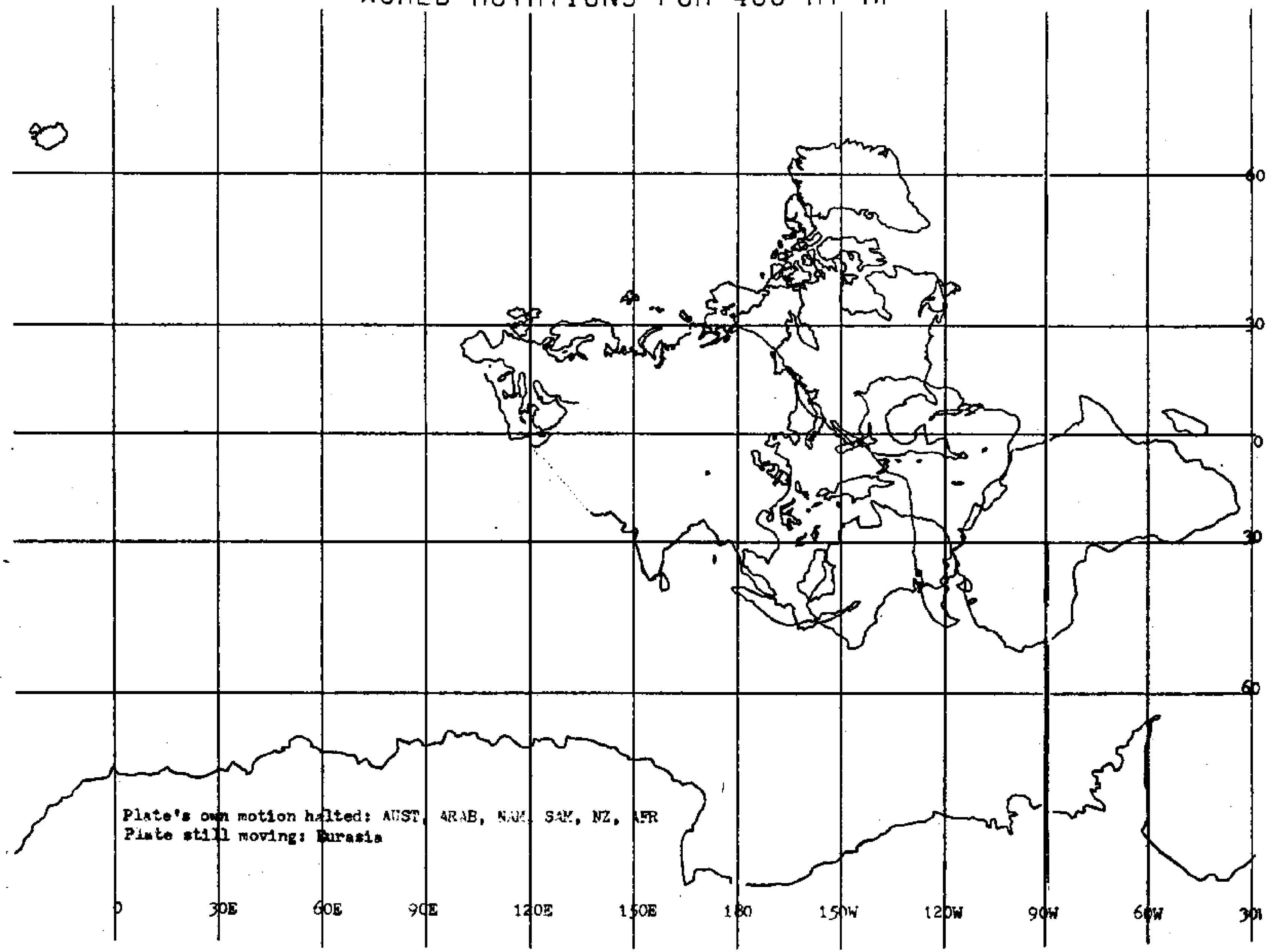
World Rotations Projected for 400 MY AP

400 MY of drift after the present day brings all the plates together except for the approaching Antarctic plate. It will probably collide within 150 MY. The 600 MY of total drift is within the 400 - 700 MY window of Hurley. Further drift will eventually bring all the plates together. The additional MY necessary exceeds the time limits. Whatever, the continents look comfortably clustered together and it appears that India will first contact Antarctica in the Ross Sea in 550 MY AP.

Conclusion

This exercise provided a conjectural view as to what might actually occur if the continents were to continue drifting in their present directions and at their present rates. Still, based on today's knowledge, the picture presented does have some merit in that the continents do conserve their 3000 MY old crust. The actual physics of colliding plates represents the frontier of global tectonics. Future work might determine whether this may be a function of relative

WORLD ROTATIONS FOR 400 MY AP



sizes, rates and directions, in other words, of the momentum of the two plates in question. Further work might also determine the effects of subjunction zones on the drift of continents. Future workers should also be advised to be consistent in choosing the poles and rates to be used in order that more coherent rationale is presented for future drift.

Acknowledgements

I would like to thank B.P. Luyendyk and J.D. Phillips for their many conjectural discussions; a good time was had moving the continents about. I offer my thanks to J.D. Phillips for suggesting the study. Thanks are also in order to E.C. Monahan for making the exercise possible in the first place. This work was supported in part by the Sea Grant program and a NSF grant contributed the computer time.

Appendix

Where there existed no published pole and rate for a plate's movement relative to Antarctica, one was computed using the existing data. For instance: NAM-AFR pole is known from the work of Bullard and the AFR-ANT from Le Pichon's work. The NAM-ANT pole is desired. Converting these poles and rates to components in the cartesian coordinate system, where

$$x = (\text{RATE})(\cos \text{LAT})(\cos \text{LONG})$$
$$y = (\text{RATE})(\cos \text{LAT})(\sin \text{LONG})$$
$$z = (\text{RATE})(\sin \text{LAT})$$

and adding the components, with much attention being paid to the rotation direction, results in a pole and rate for the NAM plate relative to the Antarctica plate. This method of computation was also available in the computer program

SUMROT, which summed the rotations, but as I was unsure as just what results to expect and to maintain a degree of confidence in the poles and rates obtained, I depended on my own computations.

Bibliography

Bullard, E.C., Everett, J.E., and Smith, A.G., 1965, The fit of the continents around the Atlantic in A Symposium on Continental Drift, edited by Blackett, Bullard and Runcorn, Phil. Trans Roy. Soc., London, 258,41.

Phillips, J.D. and Forsyth, D., "Plate tectonics, paleomagnetism and the opening of the Atlantic," (in press).

Smith, A.G. and Hallam, A., "The fit of the Southern Continents," Nature, 225, 1970.

Hess, H.H., "History of the Ocean Basins," Geological Society of America, 1962.

Le Pichon, X., "Sea Floor Spreading and Continental Drift, J. of Geophysical Research, 73, 1968.

Hurley, P.M., and Rand, J.R., "Pre-Drift Continental Nuclei," Science, 164, 1969.

Chase, 1968, Reference not known.

McKenzie, D.P., (Actual reference uncertain), Geophys. J. 18, 1969.

A Drift Bottle Study of Vineyard and Western Nantucket Sounds

by Dan Cayan

During the 1971 "Ocean Practicum", University of Michigan students aboard Woods Hole Oceanographic Institution's research vessel Asterias released 1004 drift bottles in Vineyard Sound and the far western section of Nantucket Sound. The bottles were seeded at stations along five transects across the sounds during the period May 11 - May 25 to determine the mass transport and residual current circulation in the Vineyard - western Nantucket Sounds system. As the system is dominated by strong tidal currents, release times of the bottles were correlated to tidal currents at times of release to determine if recovery positions were influenced by the initial tidal currents. Also, two bulk releases of 60 and 67 bottles at single points constituted a qualitative study of the dispersion in the system.

At the writing of this paper, 106 bottles (10.6% of those released) had been recovered. It is felt that this does not provide enough data to afford an intelligent conclusion as to any defined current patterns or mass transport features of the system. However, some preliminary tendencies are evident; these are: (1) a net eastward transport throughout the system, (2) a residual current in the southern region of Vineyard Sound that runs to the east and then to the southeast along the shore of Martha's Vineyard, (3) a correlation of direction traveled with initial tidal current direction for bottles released in the western part of the system, and (4) a good deal of mixing in the system, with much exchange between the sounds and their adjoining estuaries.

Vineyard Sound and the western part of Nantucket Sound is nearly an east-west oriented channel about 25 miles long and about 3 miles across, and according to Bumpus, et al., "Considerations on a Sewer Outfall off Nobska Point", has an average depth of 17.5 meters. It seems reasonable that the water in a vertical column in this narrow, quite shallow sound behaves as a unit, disregarding wind driven surface currents and a thin boundary layer at the bottom. A drift bottle path, then, is taken as representative of the entire water column.

The system is dominated by strong, roughly latitudinal tidal sloshing; the tidal current moves to the east during the flood tide and to the west during the ebb, which is opposite in direction to a pure equilibrium tidal current, which floods to the west. This phenomenon is explained by Tricker (1965) as being caused by the orientation and dimensions of the channel. Redfield (1953) discusses an ebb tidal current in the Woods Hole area that is shorter in duration than the flooding current which points to perhaps a net easterly transport. The northern boundary of Vineyard Sound is the Elizabeth Islands, and the gaps present between the islands form "holes", linking Vineyard Sound to Buzzards Bay. Flow through these holes interrupts the latitudinal flushing down the sound and perhaps adds net sinks or sources to the mass transport hierarchy. Bearing these complications in mind, bottles released at the same point at different times can not be expected to arrive at a single resultant position, but will be quite scattered. In looking for general features of the mass transport, then, statistics should play an important role.

Reportedly, there is a net mass flux to the east in the Vineyard-Nantucket Sound system (Bumpus, et.al. 1969). Also, Mr. Dean Bumpus of Woods Hole Oceanographic Institution has speculated the existence of a well-developed eastward flow in the southern part of Vineyard Sound between Middle Ground Shoal and Martha's Vineyard (personal communication). By seeding drift bottles across this section, it was hoped that this could be substantiated (or denied) by the returns.

Experimental procedure

The drift bottles were ballasted with sand to make them float with their tops flush with the water surface to eliminate direct wind effects. They were corked tightly and contained a post card addressed to Woods Hole Oceanographic Institution on which the finder was to report the date and position of recovery. Each card was numbered distinctly so that it could be discriminated from others. For returning the card, the finder was sent a letter describing the original release position of his bottle and date of its release.

Five relatively equally spaced transects, A-E, were established across western Nantucket and Vineyard Sounds, extending from Falmouth Heights to the east to Robinson's Hole to the west. Depending upon the mode of navigation, a number of release stations that ranged from seven to eleven were positioned along each transect (as close to being on the transect line as could be afforded by the navigational capability on the Asterias). Six, Seven, or in two instances 60 and 67, bottles were released at each station. Several methods of positioning were used. The most certain of these utilized two or three transits stationed on shore that took bearings on the Asterias. The times of release were made known to the shore stations from the ship by short wave radio. This method was useful for transects A and B, which were in view of an adequate number of useful shore transit stations. When working transects C and D, where two useful transit stations were not conveniently available, the Asterias set a heading along the transect and releases were made at the instruction of one transit station located at Nobska Point when the ship crossed predetermined transit angles from Nobska. Transect E was out of sight and radio communication range from all convenient transit stations. The Asterias again assumed a heading along the transect, shooting bearings with its magnetic compass. Then knowing its initial position, and having a good estimation of the speed that *Asterias* was steaming along the transect, time determined releases were made. At the end of the run, final position of the ship was taken, and knowing the total time elapsed and the total distance of the run, an actual speed over the ground was determined. Then knowing the time intervals between stations on the run, corrected station positions were determined. This method, of course, was susceptible to the error of unknown deviations from the transect in the run across, and a constant speed was assumed, probably to good approximation. The station positions of transects C, D, and E are subject to this deviation of course wandering, and are good to only about 200 yards either side of the transect, whenever this type of positioning was used. Finally, on the last two drift bottle cruises, the *Asterias* had been outfitted with a radar, and this was used, to quite fair accuracy to position the drop stations. The radar also aided in keeping the *Asterias* on the transect.

It is important to note that each bottle number was recorded upon release of the bottle, along with its station and time of release. Because of the expediency of the particular transect locations (transect B coincided with the transect used by Michigan students in their hydrostation work) and the ship time allotted, there was not an equal number of bottles seeded at each transect; the numbers released at each particular transect were as follows: A-156, B-332, C-237, D-171, E-108. Station "numbers" were designed such that the first character represented the transect that the station occurred upon, the second character distinguished the particular cruise on which the station was made, and the third character in the station identification gave a relative position of the station along the transect; the number one represented the northern-most station on that particular cruise proceeding consecutively through higher numbers as one ran south along the transect. Unfortunately, due to difficulties in navigation, the same station locations were not repeated throughout the course of the project; i.e., stations A01 and A21 are not coincident.

Data Analysis

Release data were compiled for each bottle; drift card number, station number, time and date of release, phase of the tide, and distance from shore were punched on IBM cards and listed (see appendix: release information). This information was forwarded to the National Oceanographic Data Center through Mr. Dean Bumpus of WHOI.

Recovered drift bottle cards began returning in the mail[1] within one week after the first bottles were released. 58 of them (about 55% of those recovered) were found within one week after their release, and 52 of them (49% of the total recovered) were found on weekend days, i.e. Friday, Saturday or Sunday. All returned bottles that originated from the same transect were plotted together on a chart (see appendix, charts A-E) showing release and recovery locations of each. It is emphasized that the lines connecting the release and recovery positions do not represent particle paths or streamlines but are simply a visual aid in showing the initial and final positions of the bottles' paths. Recovery information for each bottle was also recorded on IBM cards (see appendix, recovery information). In attempting to correlate final positions with initial tidal currents, returns were plotted on a graph of direction (from release to recovery) vs. time of release relative to time of maximum ebb current at Pollack Rip Channel, the tidal current reference station for Vineyard Sound.

Results

TRANSECT	A	B	C	D	E	TOTAL
Number released	156	332	237	171	108	1004
Number recovered	22	31	24	19	10	106
% recovered	14.1	9.3	10.7	11.1	9.3	10.5
Recoveries to East	12	26	17	11	9	75
% to East	54.6	83.8	70.8	57.8	90.0	70.7

Actually, 108 drift bottle cards were returned, but two of these were judged invalid as one was an obvious hoax and another professed a date of recovery that occurred before the date of release.

The percentage of bottles recovered to the east may be a deceptive statistic. The west end of Vineyard Sound is quite open to the ocean and the northern bound of the sound, the Elizabeth Islands, is sparsely populated. The bound of the system to the northeast is heavily populated; hence, one might expect a greater number of bottles returned to the east. There does exist a gap to the east however, the water between Martha's Vineyard and Nantucket Island. There is evidence that bottles are probably escaping the sound from its western end in those bottles recovered on Rhode Island shores.

The graphs correlating recovery positions with initial tidal currents are shown in the appendix. Bottles from transects A and B are plotted separately from transects C, D, and E. No simple relationship between tidal current at release and recovery position is apparent in the A and B plot. This region, especially the northern sector around transect B, is probably quite strongly influenced by tidal flushing through Woods Hole Passage, which would complicate the picture. On the other hand the plot of recoveries from transects C, D, and E do seem to indicate that there is a relationship. 89% of the bottles released within four hours after maximum ebb at Pollack Rip Channel (which would correspond to an ebb current in Vineyard Sound, as the Vineyard Sound tidal currents generally lag those at Pollack Rip Channel) were recovered at a location east of their release position. Note that the position along the transect of a station is used as a parameter in this plot; for convenience those stations whose third character in their identification was five or less were designated on the charts as circles and those with third character greater than five were plotted as triangles. The bottles recovered that were released from transects C and D within 3 1/2 hours before maximum ebb at Pollack Rip Channel, when plotted, clustered in two groups, one whose general direction was from the west to north, and the other whose direction from release to recovery positions was obviously to the southeast. Those bottles that ventured to the west were mainly bottles released in the north Vineyard Sound region; those found to the southeast were generally released in the southern sector of the sound. These release times occurred at flood current, which runs to the east, and yet the predominant number of all bottles found to the west were released on this tide. Also, the bottles that were released from these transects on ebb current, which runs in general to the west throughout the system, most frequently were found to the east of their release. Ostensibly, a contradiction seems to exist, but when one considers that the bottles were only subjected to at most the last half of the particular initial tidal phase, perhaps the most influential current, if the initial tidal current is of importance in fating the direction that the bottle travels, is the full phase of the following tidal current. If looked at with this in mind, the dominant directions taken by the bottles make sense. Records of the tidal currents were taken from the Coast and Geodetic Survey tidal current tables.

This correlation graph also points to a phenomenon that stands out on charts C and D. This is the suggestion by the bottles released on the southern portions of these transects that were recovered to the east to southeast (from West Chop to Cape Poge) that there is a well defined eastward current running along Martha's Vineyard, perhaps bounded to the north by Middle Ground Shoal. The possibility of a residual current here is enhanced by the presence of distinct water masses on either side of the shoal as found by another University of Michigan student, Irene Barinoff, in her study of temperature and salinity profiles along transect B (personal communication). However, a contradiction to this speculation is the lack of any recoveries along Martha's Vineyard shores of bottles released between the shoal and Martha's Vineyard; all of them were found to northeast. Tidal influences are probably quite dominant.

The dispersion study, given by the 67 and 60 bottles released at stations B96 and B98, respectively, yielded 14 B98 returns and just 4 B96 returns. The B98 bottles, with two exceptions, were recovered in the Waquoit Bay region east of Falmouth, Massachusetts. The B96 bottles were scattered, but with only 4 returns, a judgement of what is illustrated is not in order.

Conclusions

The following are not to be taken as absolute judgements but preliminary indications, made in the context that limited data is available.

The statistical evidence of a net drift to the east, even taking the aforementioned geographical considerations into account, seems to be quite apparent.

The contradiction of the easterly flowing residual current following the boundary of Martha's Vineyard may be strictly a tidal phenomenon as all bottle returns that originated from this region on transect B were of releases during a flood tide, which was followed by a full ebb phase, which may have brought the bottles into the middle of the sound from where they could have been carried to their northeast destination. The evidence of transect C and D bottles and the water mass characteristics lend good support for this residual current. The northern sound region seems more susceptible to tidal dominance.

The correlation of releases with initial tidal currents for returns from C, D, and E seem to point to an influence of the first full phase of tidal current upon the bottle's destination, emphasizing the dominance of the system's circulation by tidal flow, and the time variance of this circulation. This and the number of bottles that were recovered in the estuaries (25) point out the severe mixing and sloshing in the system.

Recommendations

For a thorough study and to enable better conclusions about the transport and circulation picture, the remaining returns to come in should be analyzed; the indications listed above may be substantiated. For further studies, drift bottles can be strategically seeded (as to tidal times and spatially along chosen sections) to confirm or deny the existence of the eastward current along Martha's Vineyard. Further releases in the transect B region at several tidal times are necessary.

A speculation of bottle direction as influenced by initial tidal current has been presented, and this could be explored by releases at predetermined tidal phase times.

Specifically, the bookkeeping effort of this project would have been simpler and the data easier to comprehend if there were nonvarying station positions along each transect.

An interesting study would be an attempt to discover the origin of Vineyard Sound water masses with drift bottle studies; this would require a cooperative effort with people working on hydro-station data.

Finally, current drogues can well be used to improve the knowledge of the circulation pattern; these could be observed during different tidal phases (ideally through the full phase) at interesting locations e.g. along the proposed residual current route north of Martha's Vineyard.

Acknowledgements

The author extends his thanks to Mr. Dean Bumpus, of WHOI for his advice and assistance, and for supplying drift bottles and cards free of charge for use during the M&O 560 course. Mr. Marvel Stalcup and Dr. Edward C. Monahan offered helpful thoughts and suggestions. Special thanks go to Darlene Silverblank, who punched all of the IBM cards. The project could not have been carried out without the cooperation of the public.

Bibliography

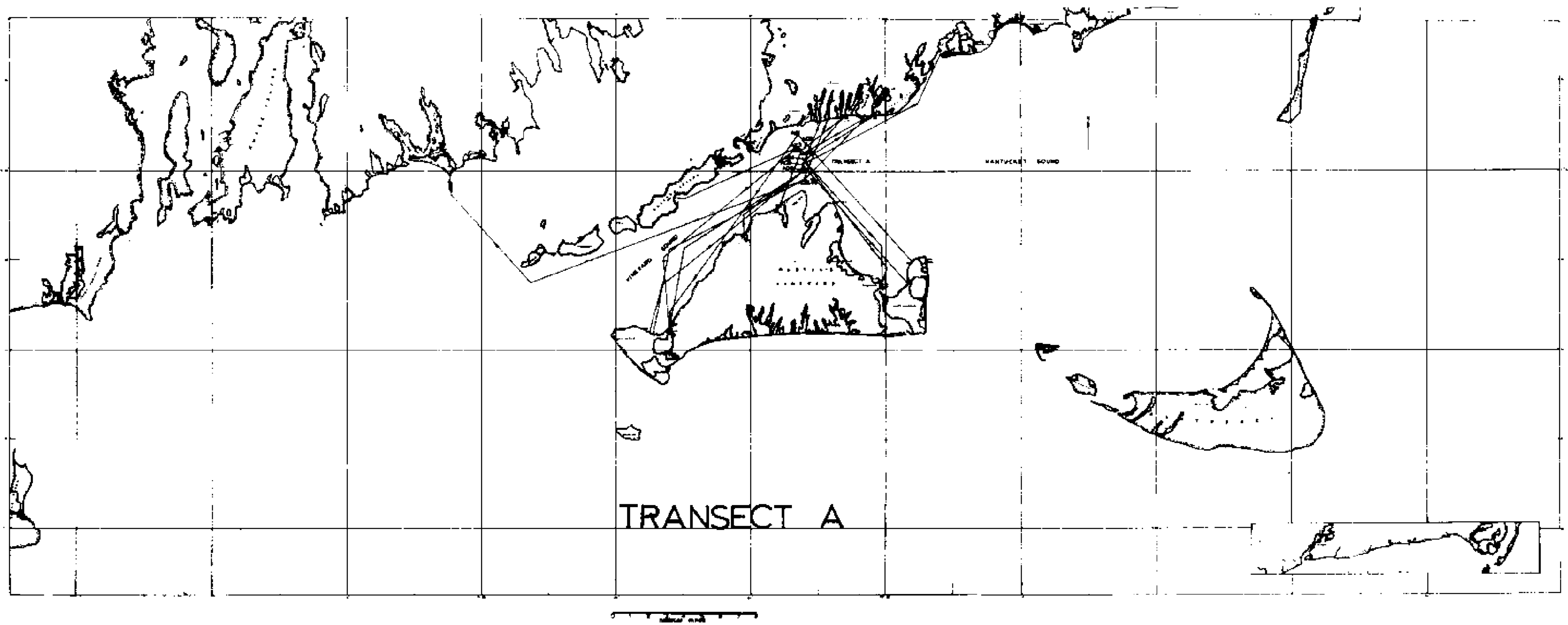
Bumpus, D.F., Wright, W. R., and Vaccaro, R.F., 1969. Considerations on a Sewer Outfall off Nobska Point, WHOI reference No. 69-87, Unpublished Manuscript.

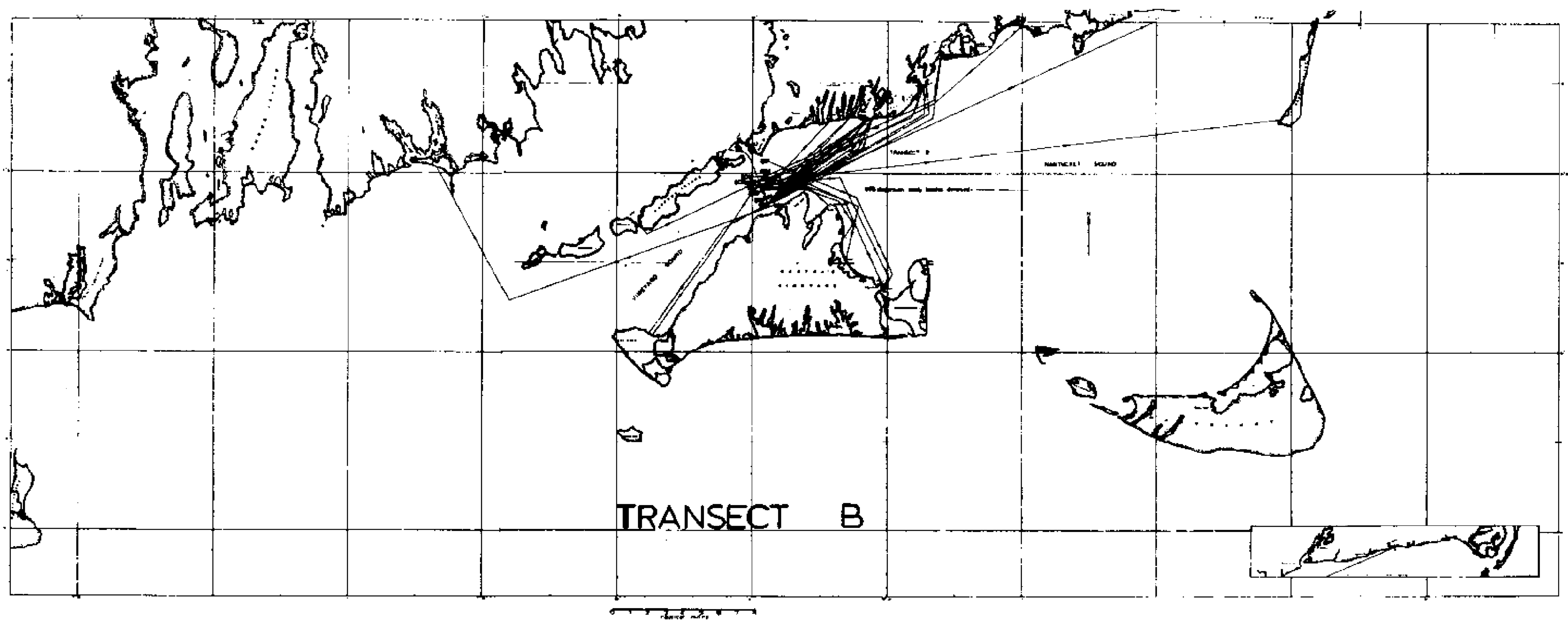
Redfield,A.C., 1953. "Interference Phenomena in the Tide of the Woods Hole Region", J. Mar. Res., 12, pp 121-139.

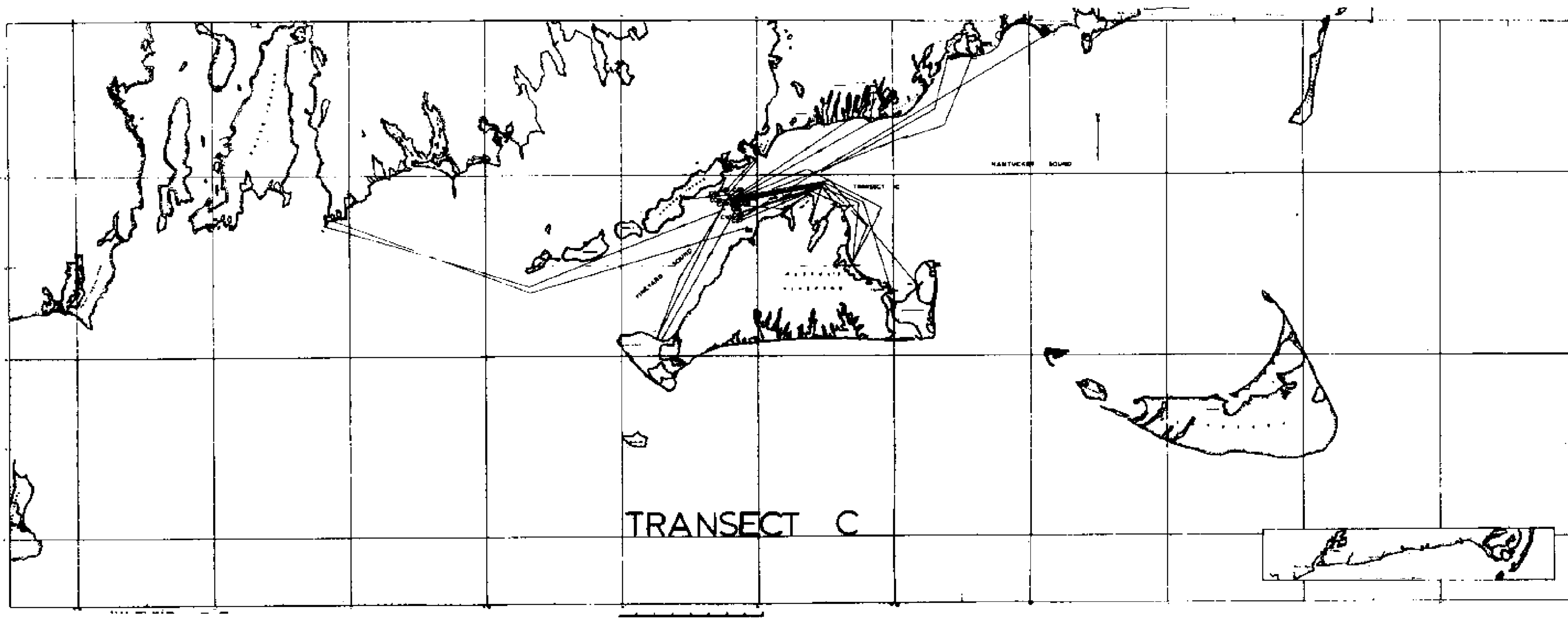
Tricker, R.A., 1965. Bores, Breakers, Waves and Wakes.

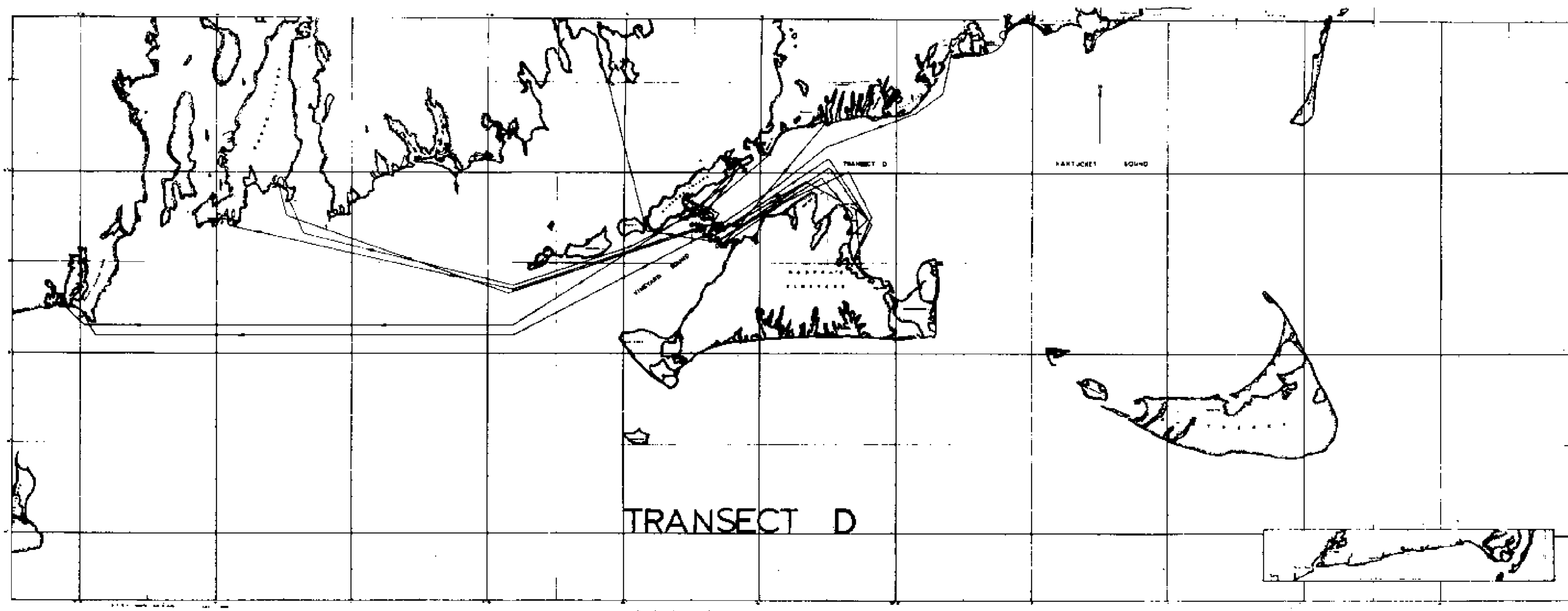
U.S. Department of Commerce (Coast and Geodetic Survey) issued 1970. Tidal Current Tables 1971, Atlantic Coast of North America. U.S. Goverment Printing Office: 1970 0 - 382-945.

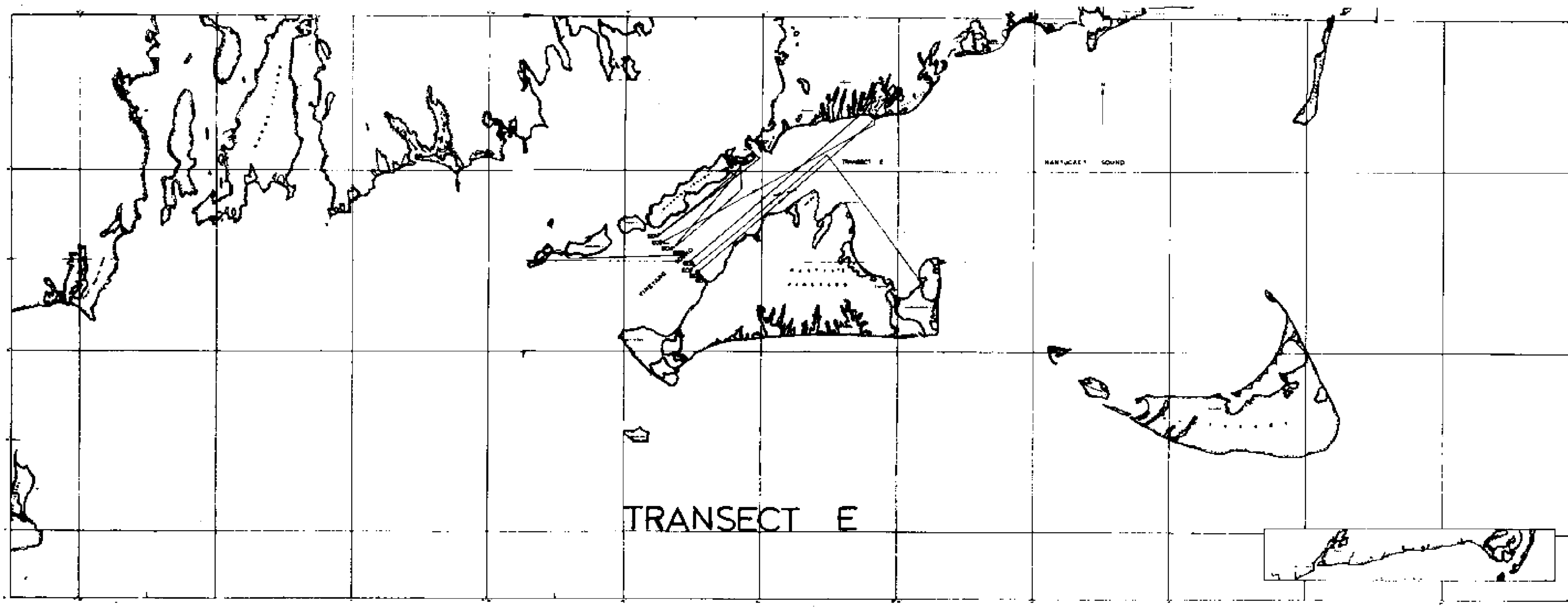
(At time of publication, over 100 additional returns had been received. All rough data is on file with the M&O Dept.)


NANTUCKET SOUND
TRANSECT A


TRANSECT B


TRANSECT C
NANTUCKET SOUND
VINEYARD SOUND


TRANSECT D
NANTUCKET SOUND
VINEYARD SOUND
TRANSECT D


TRANSECT E
NANTUCKET SOUND

Sta No.	Lat	Long
A01	41 316	070 363
A02	41 314	070 362
A03	41 312	070 362
A04	41 309	070 362
A05	41 306	070 362
A06	41 304	070 362
A07	41 301	070 363
A08	41 299	070 363
A09	41 295	070 361
B01	41 306	070 391
B02	41 303	070 391
B03	41 299	070 390
B04	41 296	070 390
B05	41 293	070 389
B06	41 289	070 389
B07	41 286	070 389
B08	41 283	070 388
B09	41 280	070 389
C01	41 291	070 425
C02	41 290	070 424
C03	41 289	070 422
C04	41 287	070 421
C05	41 286	070 419
C06	41 284	070 418
C07	41 283	070 417
C08	41 281	070 415
C09	41 279	070 414
C10	41 277	070 412
C11	41 275	070 420
D01	41 278	070 449
D02	41 276	070 446
D03	41 274	070 443
D04	41 272	070 440
D05	41 270	070 437
D06	41 268	070 434
D07	41 266	070 431
D08	41 264	070 429
D09	41 262	070 425
E01	41 263	070 476
E02	41 261	070 472
E03	41 258	070 468
E04	41 256	070 465
E05	41 253	070 461
E06	41 248	070 454
E07	41 246	070 450
E08	41 243	070 447
E09	41 241	070 443
A21	41 319	070 365
A22	41 316	070 365
A23	41 313	070 365
A24	41 307	070 364
A25	41 305	070 363
A26	41 301	070 363
A27	41 298	070 361
A28	41 295	070 361
A29	41 292	070 360
B21	41 307	070 390
B22	41 304	070 390
B23	41 300	070 391
B24	41 301	070 388

Sta No.	Lat	Long
B25	41 296	070 393
B26	41 296	070 391
B27	41 293	070 387
B28	41 291	070 387
B29	41 287	070 385
B30	41 283	070 382
C21	41 291	070 423
C22	41 288	070 421
C23	41 286	070 419
C24	41 283	070 417
C25	41 281	070 415
C26	41 277	070 411
C27	41 275	070 408
C28	41 273	070 406
C29	41 270	070 405
D21	41 278	070 429
D22	41 276	070 446
D23	41 274	070 443
D24	41 272	070 440
D25	41 270	070 437
D26	41 268	070 434
D27	41 266	070 431
D28	41 264	070 429
D29	41 262	070 425
E21	41 263	070 476
E22	41 261	070 472
E23	41 258	070 468
E24	41 256	070 465
E25	41 253	070 461
E26	41 248	070 454
E27	41 246	070 450
E28	41 243	070 447
E29	41 241	070 443
A41	41 321	070 365
A42	41 316	070 364
A43	41 311	070 363
A44	41 307	070 363
A45	41 300	070 362
A46	41 297	070 361
A47	41 295	070 361
A48	41 292	070 361
B40	41 413	070 397
B41	41 304	070 393
B45	41 295	070 390
B46	41 293	070 389
B47	41 290	070 389
B48	41 288	070 388
B49	41 284	070 388
C41	41 291	070 424
C42	41 289	070 422
C43	41 287	070 420
C44	41 285	070 418
C45	41 284	070 418
C46	41 280	070 416
C47	41 279	070 413
C48	41 276	070 410
C49	41 273	070 407
B61	41 304	070 392
B62	41 301	070 392
B63	41 299	070 391

Sta No.	Lat	Long
B64	41 297	070 390
B65	41 294	070 390
B67	41 291	070 389
B69	41 282	070 387
B96	41 293	070 389
B98	41 284	070 388
C61	41 290	070 424
C62	41 288	070 421
C63	41 285	070 419
C64	41 283	070 417
C65	41 281	070 415
C66	41 279	070 413
C67	41 276	070 411
C68	41 275	070 409
C69	41 272	070 407
D61	41 278	070 449
D62	41 276	070 446
D63	41 273	070 442
D64	41 271	070 440
D65	41 269	070 437
D66	41 268	070 434
D67	41 266	070 433
D68	41 263	070 429
D69	41 262	070 426

OCEAN PRACTICUM 1971 DRIFT BOTTLE RECOVERY DATA

BOT NO.	STA NO	REL DATE	SHO DIS	REL TIDE	REC DATE	REC LAT	REC LONG	REC DCR	DIS TRA	FLO TIME	MI/DAY
6629	A01	051171	09	F	061071	41 318	070 405	A	060	300	02
7066	A41	052071	05	F	052571	41 215	070 459	A	128	052	25
7038	A41	052071	05	E	052471	41 245	070 285	A	096	042	23
6508	A03	051171	14	F	051371	41 330	070 332	A	029	023	13
7080	A23	051771	13	F	052671	41 211	070 461	E	128	090	14
7518	A23	051771	13	F	053071	41 286	070 455	A	074	130	06
7020	A43	052071	15	E	052571	41 280	070 379	A	033	050	07
6509	A04	051171	16	F	052671	41 343	070 300	F	057	150	04
7237	A24	051771	19	F	052371	41 234	070 301	A	087	060	14
7239	A24	051771	19	F	052371	41 236	070 302	A	085	060	14
6650	A05	051171	17	F	051471	41 367	070 251	E	110	030	37
6657	A05	051171	17	F	051571	41 340	070 276	A	077	040	19
7233	A45	052071	16	E	052371	41 264.	070 408	A	051	030	17
7232	A45	052071	16	E	052171	41 212	070 462	A	118	.020	59
7225	A45	052071	09	E	052771	41 210	070 475	A	123	070	18
6655	A06	051171	15	F	051371	41 330	070 332	A	033	023	14
6663	A06	051171	15	F	052571	41 240	070 271	E	089	140	06
6666	A07	051171	11	F	051571	41 335	070 350	E	036	040	09
7271	A28	051771	06	F	060371	41 290	071 024	A	230	170	14
7282	A28	051771	06	F	052471	41 209	070 472	A	123	070	18
6511	A09	051171	05	F	052271	41 342	070 307	E	061	110	06
6516	A09	051171	05	F	051571	41 337	070 342	E	046	040	12
7050	B21	051871	03	E	052371	41 234	070 301	A	103	050	21
6586	B03	051171	09	F	051471	41 367	070 257	E	136	060	23
7054	B23	052871	17	E	060771	41 274	070 488	A	086	200	04
7037	B24	051871	17	E	052071	41 209	070 472	A	112	020	56
6598	B05	051171	15	F	051371	41 330	070 311	A	068	020	34
7021	B25	051871	17	E	053071	41 340	070 276	A	102	120	09
7403	B45	052071	15	F	060471	41 240	070 305	A	093	150	06
7022	B26	051871	13	E	052971	41 330	070 008	A	289	110	26
7465	B96	052571	13	F	060271	41 263	070 327	A	056	080	07
7420	B96	052571	13	F	060271	41 255	070 328	A	058	080	07
7452	B96	052571	13	F	060871	41 381	070 200	A	169	140	12
6964	B96	052571	13	F	052771	41 332	070 342	E	055	020	28
6621	B07	051171	10	F	060871	41 402	070 050	A	278	280	10
7242	B27	051871	09	E	060171	41 236	070 302	A	097	140	07
6616	B08	051171	07	F	051471	41 367	070 251	E	138	030	16
7264	B28	051871	09	E	052371	41 282	070 345	A	037	050	07
6955	B98	052571	06	F	052771	41 335	070 323	E	063	020	32
6904	B98	052571	06	F	053071	41 341	070 298	E	065	050	13
6909	B98	052571	06	F	052671	41 331	070 312	A	069	010	69
6921	B98	052571	06	F	060371	41 210	070 475	A	108	090	12
6937	B98	052571	06	F	052771	41 331	070 312	A	061	020	31
6946	B98	052571	06	F	053071	41 335	070 324	E	062	050	12
6953	B98	052571	06	F	052771	41 331	070 312	A	069	020	35
6924	B98	052571	06	F	052971	41 348	070 314	E	083	040	21
6935	B98	052571	06	F	052971	41 337	070 320	F	075	40	19
6923	B98	052571	06	F	053171	41 315	070 412	A	041	060	07
6914	B98	052571	06	F	053171	41 340	070 276	A	098	060	13
6900	B98	052571	06	F	052771	41 340	070 276	A	098	020	49
6907	B98	052571	06	F	052971	41 338	070 328	E	062	040	16
6910	B98	052571	06	F	052671	41 328	070 317	F	063	010	63

Drift Bottle Recovery Data

7288	B30	051871	03	E	060871	41	304	071	034	A	237	210	11
7371	C41	052071	05	E	060271	41	312	070	408	F	024	130	02
7308	C61	052571	05	F	052971	41	298	070	423	A	004	040	01
7482	C22	051771	09	F	060471	41	209	070	468	A	090	180	05
7390	C42	052071	08	E	052471	41	209	070	472	A	092	040	23
7319	C62	052571	07	F	060171	41	318	070	412	A	023	070	03
7298	C62	052571	08	F	060671	41	288	070	450	A	022	120	02
7396	C43	052071	10	E	060171	41	235	070	303	A	119	120	10
7355	C63	052571	12	F	060271	41	255	070	328	A	078	080	10
6830	C04	051171	06	F	052871	41	235	070	287	A	129	170	08
7101	C24	051771	14	F	060571	41	272	071	117	A	240	190	13
7191	C44	052071	11	E	052371	41	283	070	342	F	058	050	12
6642	C05	051171	12	E	051871	41	344	070	383	E	088	070	13
6698	C05	051171	12	E	051671	41	330	070	332	A	079	050	16
6695	C06	051171	13	E	051571	41	303	070	413	A	019	100	02
6720	C06	051171	13	E	053171	41	255	070	328	A	073	200	04
7195	C46	052071	15	E	052471	41	209	070	472	A	087	040	22
7312	C66	052571	11	F	053071	41	253	070	388	A	093	050	19
7303	C66	052571	11	F	060271	41	274	070	361	A	063	080	08
6694	C07	051171	15	E	051571	41	365	070	241	E	158	040	40
6640	C07	051171	15	E	052271	41	278	070	385	A	029	110	03
6729	C67	052571	08	F	053071	41	270	070	335	A	064	050	13
6970	C69	052571	05	F	060671	41	272	071	117	A	250	120	21
6691	C10	051171	09	E	051471	41	367	070	251	E	157	030	52
6686	C10	051171	09	E	051771	41	378	070	187	A	198	060	33
6565	D01	051171	05	E	051571	41	303	070	413	A	037	100	04
6563	D01	051171	05	E	051871	41	303	070	419	A	278	070	40
7492	D21	051771	05	F	060671	41	226	071	323	A	367	200	18
7349	D61	052571	04	F	060671	41	285	071	147	A	247	120	21
6560	D02	051171	08	E	051471	41	310	070	392	A	053	030	18
6555	D03	051171	11	E	051571	41	303	070	413	A	036	040	09
6791	D24	051771	14	F	060371	41	274	071	192	A	275	170	16
6840	D64	052571	14	F	060371	41	292	071	154	A	252	090	28
6535	D05	051171	23	E	051471	41	372	070	260	E	180	300	61
6879	D65	052571	15	F	053071	41	286	070	455	A	023	050	05
6890	D65	052571	15	F	053071	41	286	070	455	A	023	050	05
6805	D26	051771	23	F	060371	41	225	071	307	A	358	170	21
6884	D67	052571	10	F	060471	41	247	070	326	A	118	100	12
6896	D67	052571	10	F	060271	41	255	070	328	A	112	080	14
6880	D68	052571	08	F	060271	41	265	070	332	A	100	080	13
6878	D68	052571	08	F	053071	41	272	070	332	A	092	050	18
6705	D09	051171	04	E	051371	41	327	070	350	A	086	024	37
6843	D69	052571	05	F	060771	41	349	070	513	A	125	130	10
6842	D69	052571	05	F	060271	41	255	070	328	A	112	080	14
6573	E01	051171	05	E	051571	41	303	070	413	A	062	040	16
6571	E01	051171	05	E	051571	41	312	070	410	A	075	040	19
6577	E02	051171	07	E	060571	41	340	070	309	E	148	250	05
6774	E04	051171	14	E	051571	41	303	070	413	A	061	050	12
6773	E04	051171	14	E	051571	41	301	070	425	A	055	040	14
6770	E05	051171	17	E	052471	41	254	070	547	A	065	130	05
6764	E06	051171	15	E	051971	41	339	070	322	E	135	080	17
6758	E07	051171	11	E	060471	41	238	070	272	E	160	240	07
6749	E08	051171	07	E	052371	41	334	070	321	E	138	120	12
6746	E09	051171	04	F	052671	41	331	070	322	E	129	150	09

Benthic Diversity in Great Harbor Woods Hole, Massachusetts

by Camille Hyde and Andrew Schaedel

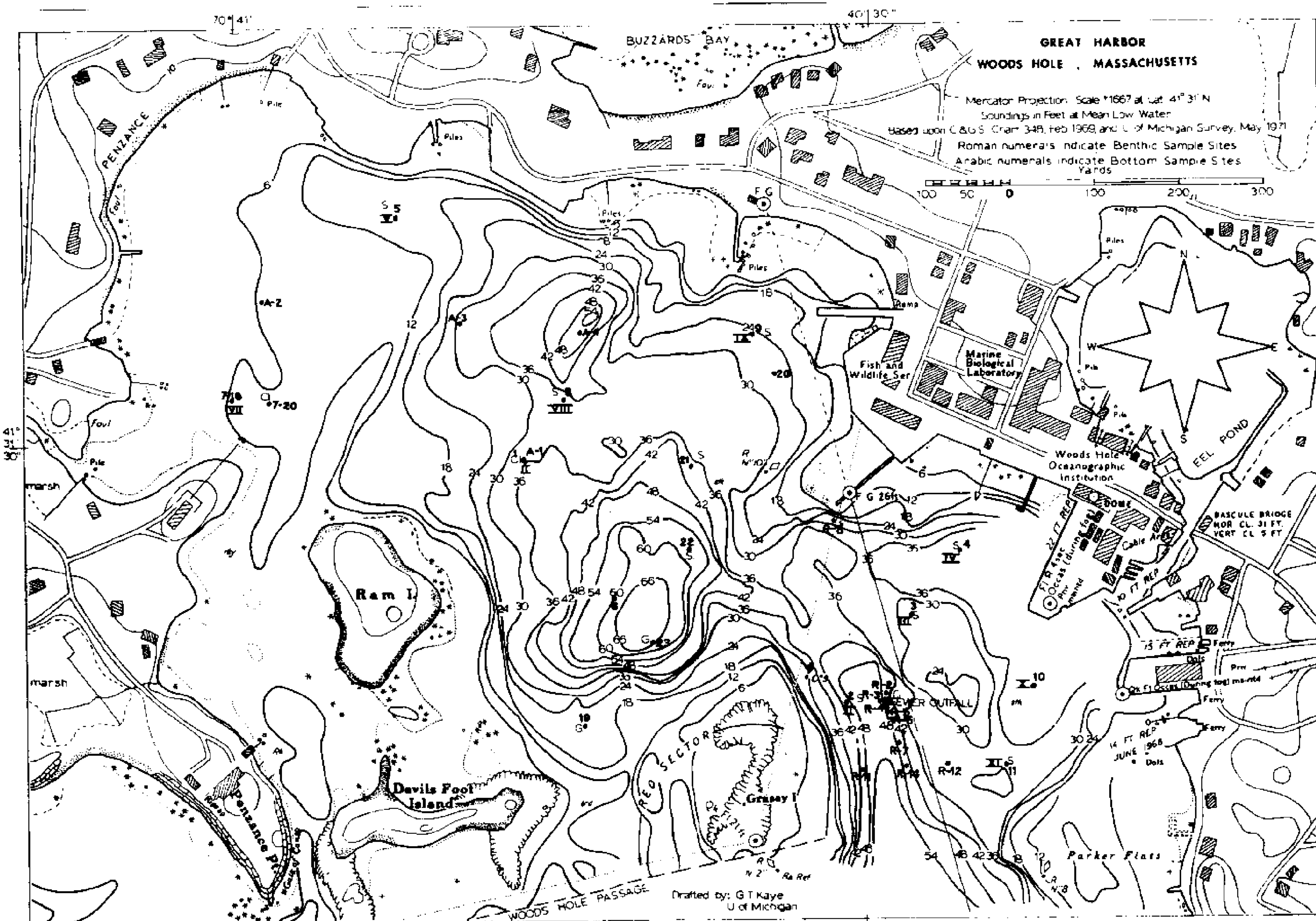
Great Harbor, Woods Hole, Massachusetts was, for purposes of sampling, divided into two areas: east basin, into which a sewage outfall flowed; and west basin, at some distance from the outfall. Benthos were collected from each area to determine whether a difference existed between the two basins and, if so, whether it was ostensibly due to the outfall or to other parameters known to affect benthic communities. Conclusions could not be drawn with any certainty from the graphical data; however, certain trends were suggested. Abundance of organisms varied directly with percent sand composition and inversely with percent organic matter and mean ϕ. Diversity (H) varied directly with percent sand and indirectly with mean ϕ. There was no relation of abundance of organisms with depth. A statistical analysis of the two basins indicated that the areas were significantly different in numbers of organisms and that the east end with the sewage outfall had the greater density. This study was not adequate to say that the outfall was directly responsible, but it remains a possibility. In conclusion, the untreated sewage outfall in Great Harbor may have a beneficial affect on benthic fauna.

Introduction

As society becomes more concerned with the environmental effects and control of its waste materials, the need increases for scientific data on which to base rational decisions. Some of the major questions which remain to be answered through research are whether a material is a pollutant, what its effects are in the environment and whether these effects are actually beneficial or detrimental.

The present study was conducted in Great Harbor, near Woods Hole, Massachusetts. The village of Woods Hole has been putting mascerated and chlorinated (essentially untreated) sewage into the harbor since 1949. State laws have been passed which now require treatment of domestic sewage. The outfall into Great Harbor will probably be closed and relocated when treatment facilities are built. This situation provided a good opportunity to begin a preliminary study of the effects of sewage effluent on benthic communities. The purposes of this study were to determine: 1) numbers and composition of benthic fauna both in the east basin of Great Harbor, which includes the outfall, and in the west basin, away from the outfall; and 2) whether any differences existed between the two areas which might be attributed to the outfall. Other parameters are known to influence benthic fauna and it was recognized that these must also be measured. For instance, Sanders (1958) reported that changes in community structure in Buzzards Bay (adjacent to Woods Hole) were related to sediment type and that distinctly different communities where found on sand and on silt-clay substrates. Depth is another parameter, used by Filice (1959) in his study of pollution in San Francisco Bay. Organic content of sediments is a third parameter which relates to benthic communities. Ruttner (1952) referred to the anoxic condition of bottom sediments with high organic content, caused by decomposition, which becomes a stress to the organisms and thereby limits the population. Other parameters likely to influence benthic communities are dissolved nitrates, phosphates, oxygen, urea and salinity changes.

These parameters were measured in addition to benthos as a group project but are reported separately. Topography was recorded by G. T. Kaye; sediments, plus a chart of all stations by D. Deitemeyer and D. Silverblank, and chemistry by D. Takacs. Reference should be made to their reports


GREAT HARBOR
WOODS HOLE , MASSACHUSETTS
Mercator Projection. Scale 1:1667 at Lat. 41° 31' N
Soundings in Feet at Mean Low Water
Based upon C&GS Chart 348, Feb 1969, and U of Michigan Survey, May 1971
Roman numerals indicate Benthic Sample Sites
Arabic numerals indicate Bottom Sample Sites
Yards
100 50 0 100 200 300
BUZZARDS BAY
PENZANCE
EEL POND
Marine Biological Laboratory
Fish and Wildlife Ser
Woods Hole Oceanographic Institution
BASCULE BRIDGE HOR CL 31 FT. VERT CL 5 FT
SEWER OUTFALL
Ram I.
Devils Foot Island
Grassy I
Penzance Pt
Parker Flats
RED SECTOR
WOODS HOLE PASSAGE
Drafted by: G T Kaye U of Michigan
70° 41'
40' 30"
41° 31' 30"
marsh
Foul
Piles
Pile
Ramp
Ferry
Dols
14 FT REP JUNE 1968
15 FT REP
10 FT REP
22 FT REP
F G
F G 26ft

for methods and results on these topics.

Procedure

Bottom samples were obtained by lowering a 1/25 m^2 van Veen grab sampler over the side of the R/V ASTERIAS. One core sample for sediment analysis and two bottom samples for benthic analysis were taken at each station except at station XI where only one bottom sample was obtained. Sediment analysis is included in another report. Each bottom sample was washed through a 1 mm mesh sieve and placed in a one gallon plastic container with formalin until samples could be sorted. Stations I through V were sampled on May 7, 1971; stations VII through XI were sampled on May 20, 1971. Benthic samples at Station VI were unsuccessful and only a core was taken. Three hand core samples (6.5 cm diameter) were taken by divers on May 18, 1971 near the outfall and analyzed for sediment type and benthos. Dye was used to determine the location of the outfall and the direction of the plume when the tide was flooding and ebbing.

In the laboratory, all benthic organisms were removed manually from each sample and identified by use of dissecting scopes and biological keys to genus and species when possible. Nematodes and oligochaetes were not further classified. Due to the sieve mesh size, most organisms smaller than 1 mm were washed through and subsequently lost.

Results

Table 1 is a listing of: the total number of individuals and of species per 1/25 m^2, total number of individuals per square meter for each sample, the mean number of individuals for each station, and the diversity indices. Graphs were drawn comparing the mean number of individuals for each

TABLE 1

Station	Total #/ 1/25 m^2	Total #/ m^2	Mean #/ m^2	Total # Species/ 1/25 m^2	Diversity
I-2	14	350		6	1.82
I-3	47	1175	766.5	11	1.82
II-5	122	3050		31	2.75
II-6	67	1675	2362.5	24	2.77
III-8	160	4000		35	2.74
III-9	350	8750	6375.0	41	2.66
IV-11	216	5400		30	2.72
IV-12	360	9000	7200.0	41	2.45
V-14	83	2025		25	2.49
V-15	166	4150	3112.5	36	2.88
VII-19	31	775		6	1.30
VII-20	43	1075	925.0	9	1.28
VIII-21	115	2900		31	2.91
VIII-22	132	3300	3087.5	26	2.88
IX-23	49	1225		21	2.44
IX-24	74	1850	1537.5	17	2.08
X-25	108	2700		35	2.92
X-26	130	3250	2975.0	29	2.14
XI-27	264	6600	6600	44	2.46
Cores:					
R11	31	9393	9393	15	1.78
R12	35	10605	10605	9	1.99
R14	15	4545	4545	6	1.95
Total	2497		59622	469	

station to various sediment parameters and to depth. Graphs of diversity (H) vs. several sediment parameters were also included. A "t" test was used to compare the east and west basins of Great Harbor. Diversity index (H) was computed using the information function described by Shannon and Weaver (1963). Histographs were drawn for each sample giving most numerous species, and are included in the appendix.

Conclusions

Figure 1: There appeared to be an inverse relationship between mean number of individuals per square meter and percent organic matter in the sediment. As the organic matter increased, the abundance decreased. Near the outfall, stations III, IV and XI had low percent organic matter, comparable to several other stations, yet abundance was considerably higher near the outfall, suggesting that some factor other than sediment composition supported a more populated community. For instance, the outfall probably contributed a high concentration of dissolved organic matter in the water which may have favored the support of larger communities in that area. Laboratory experiments and more measurements of these parameters would be of interest.

Stations I and VII at the west end of the harbor had high organic content, but abundance was low. Tidal currents may be diminished in these areas so that excessive organic deposits occur and create anoxic conditions in which few organisms can live.

Figure 2: There appeared to be a direct relationship between abundance of individuals and percent sand composition. That is, as the percent sand increased, so did the community

FIGURE 1

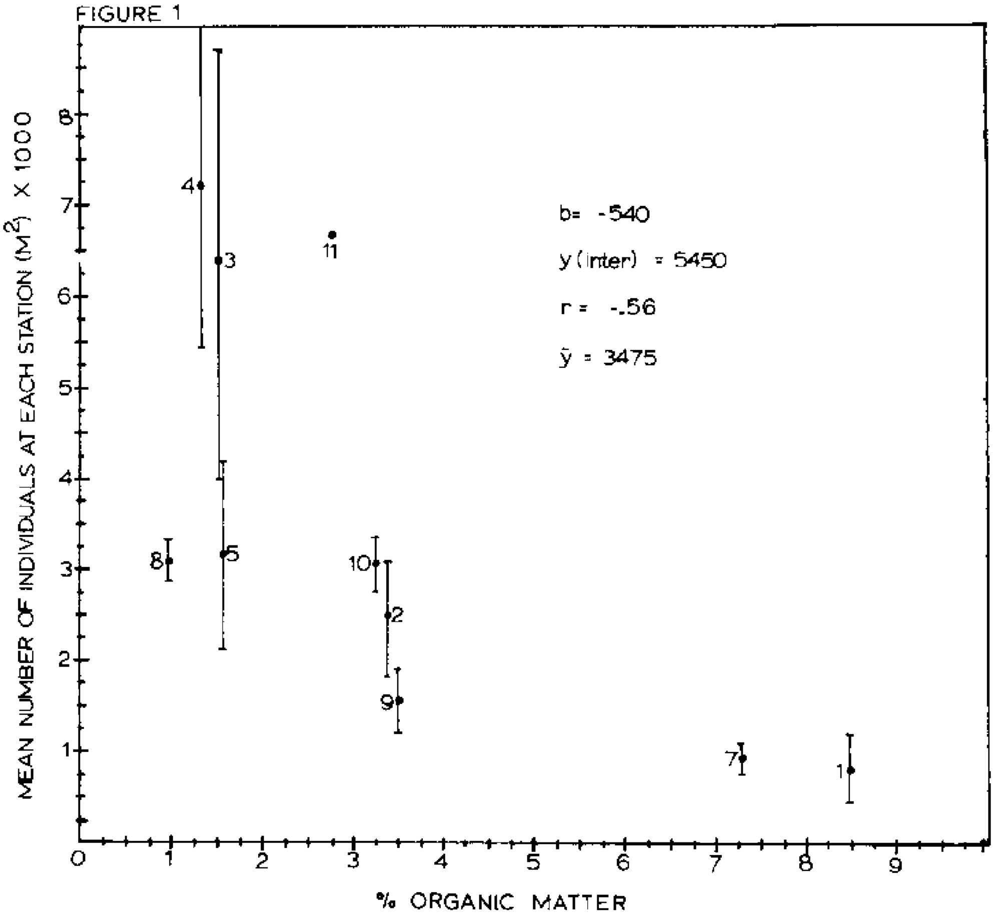
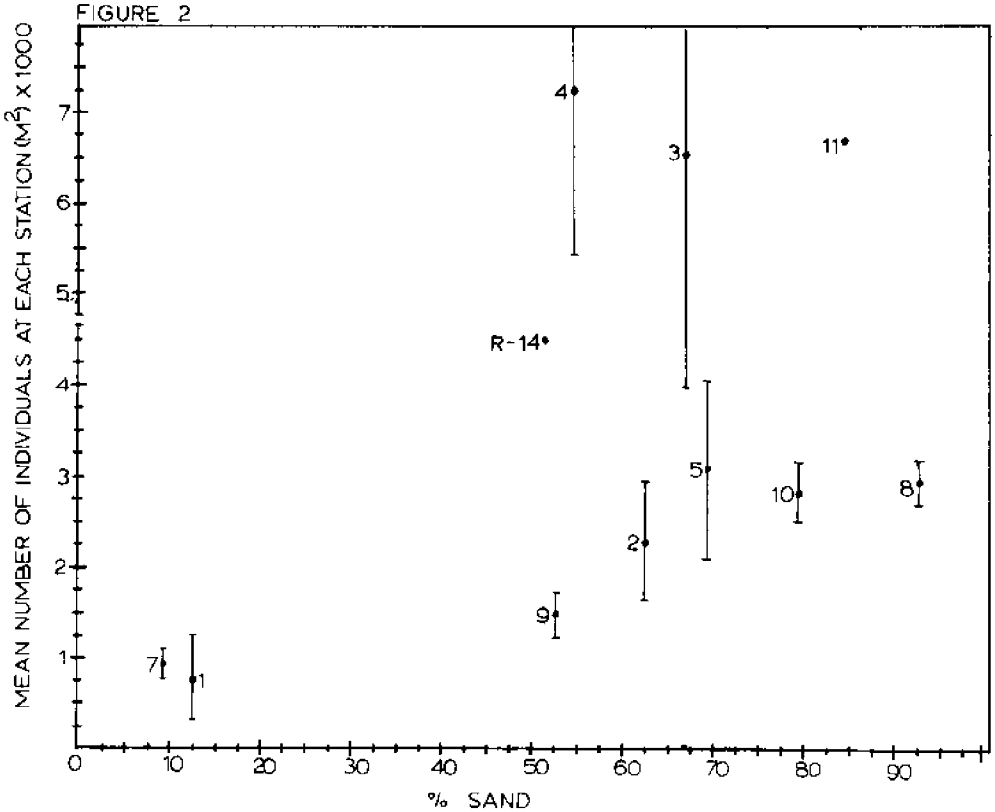


FIGURE 2



size. This may be related to the fact that sand size particles offer more microhabitats and there is less opportunity for the sediment to become anoxic.

Stations III, IV and XI, near the outfall, had percent sand composition comparable to stations at the west end of Great Harbor; yet, at stations III, IV and XI community size was much greater. Again, some factor other than percent sand composition, or even sediment type, may be a factor limiting community size. This limiting factor may be dissolved organics, as mentioned above.

It should be pointed out that two other stations near the outfall (stations II and X), with similar percent sand composition and somewhat higher percent organic matter, had smaller communities than did stations III, IV and XI. Why is not known. If high levels of dissolved organics favor large communities, tidal currents across these two areas may not carry much dissolved organics from the outfall. Since tidal currents may be affecting the benthic communities, a fluorimeter dye study should be conducted during different tidal phases to determine direction, dispersion area, and mixing of the sewage effluent. During the present investigation, several attempts were made at a dye study. Observations were not sufficient to draw conclusions except for general surface flow at two points in time. It was noted that the plume with dye flowed toward the National Fisheries breakwall in flood and out toward Martha's Vineyard Sound in ebb. This allowed the sampling stations to be divided into two general groups: those which were considered within the influence of the outfall (east end: stations II, III, IV, X, XI, and cores R11, R12, and R14) and those assumed not under the outfall's direct influence (west end: stations I, V, VII, VIII and IX). By computing a mean for each of these groups, a large difference was observed both in numbers of individuals and numbers of species:

	Numbers of individuals/m^2	Numbers of species/1/25m^2
West basin	1913	24.4
East Basin	6221	35.4

One can see that the stations close to the outfall had three times the number of individuals and a greater number of species per station than did the west basin. This leads one to conclude that, from an ecological point of view, the outfall may have a beneficial influence and increase the abundance of fauna.

Figure 3: Mean numbers of individuals per square meter appeared to be inversely related to mean ϕ. In other words, as sediment particle size became finer, the community density decreased. The finer ϕ particle size is usually of high organic composition so that those stations (I and VII) found to have high mean ϕ values also had high percent organic matter. Stations III, IV and XI with mean ϕ values comparable to stations in the west basin of Great Harbor had a larger community size. Since these three stations near the outfall consistently did not relate to the graphical pattern of the data, it would seem that these stations were influenced by some factor(s) not measured in the present study. The fact that two other stations near the outfall were not similarily affected suggest that some factor other than, or in addition to, the outfall influence community population in that area.

FIGURE 3

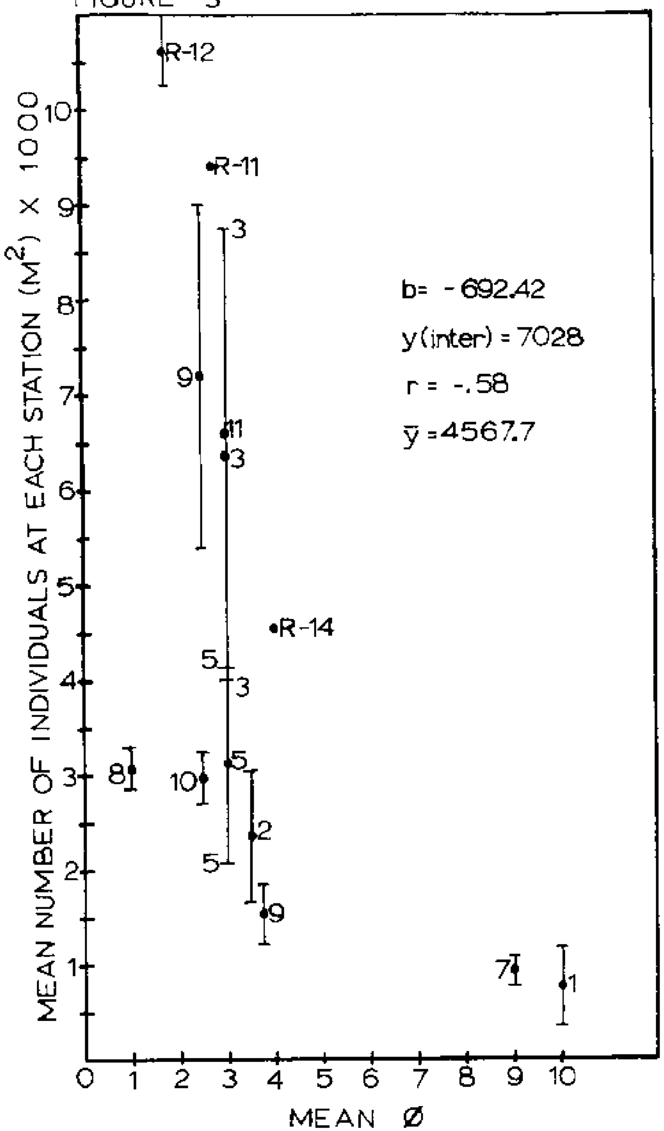


FIGURE 4

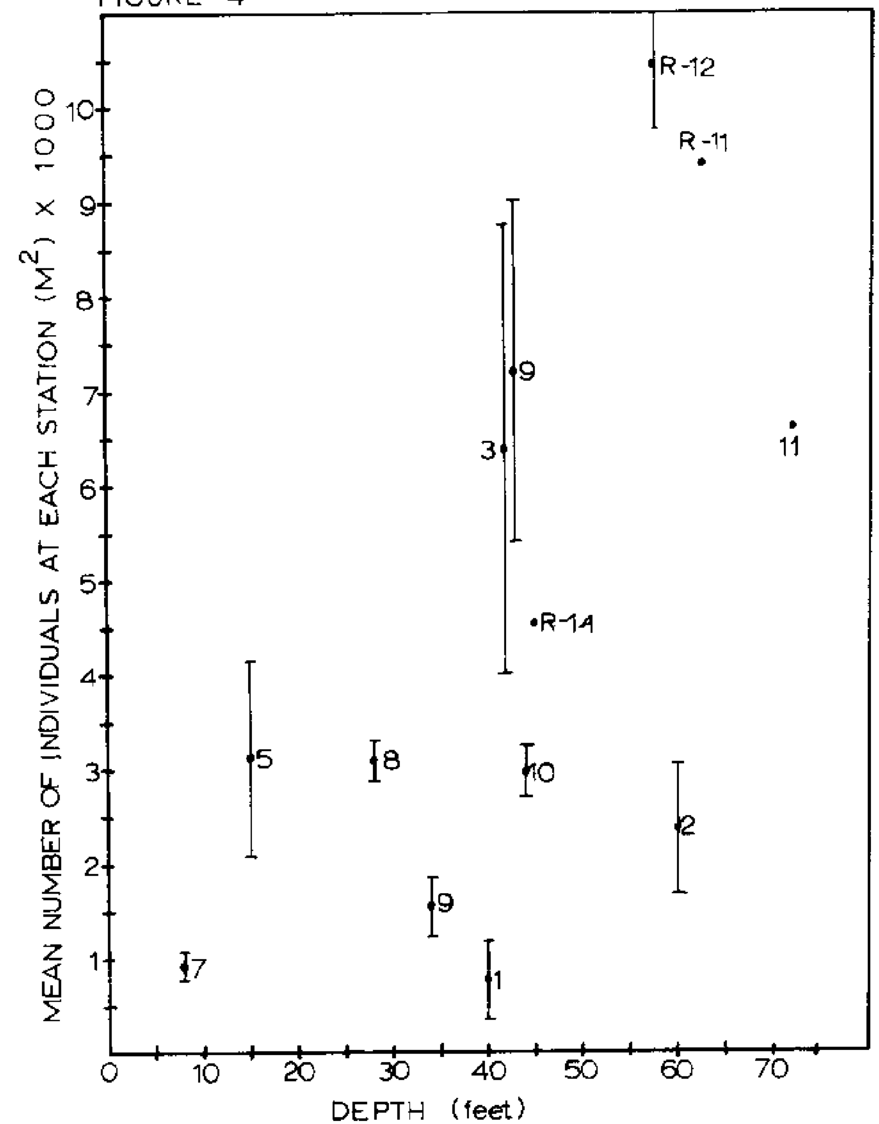


Figure 4: Depth did not seem to relate in any obvious manner to animal abundance.

Table 1: Both samples at all stations (except X) has similar diversity (H) values, indicating similar diversity between the two. At station X, H was 2.92 and 2.14. If these indices are significantly different, then the samples probably did not represent the same area or the faunal patchiness biased the data.

Those stations near the outfall had somewhat greater diversities than did those away from the outfall, in the western basin. Whether the outfall was responsible cannot be stated with certainty, although it remains a possibility. In contrast, the core samples (R11, R12 and R14) had the lowest diversity of all stations near the outfall; this may be an artifact resulting from the small sampling area of the core or it may indicate true differences in those areas of the harbor.

Figure 5: The graph indicated a linear relationship between diversity (H) and percent sand of the sediment. Statistical analysis might be conducted to verify it. More samples in the area of low diversity would also be of use. As mentioned above, as organic matter increases and sand decreases, conditions may become anoxic and unfavorable for most species. Consequently diversity would be low.

Figure 6: The data suggested a possible inverse relationship between diversity index (H) and mean ϕ. A statistical analysis should be carried out to determine such. If the relationship exists, then highest diversity in Great Harbor is found in sand sediment, while lowest diversity occurs in mud sediment.

Table 2: A "t" test was run to determine the probabil-

FIGURE 5

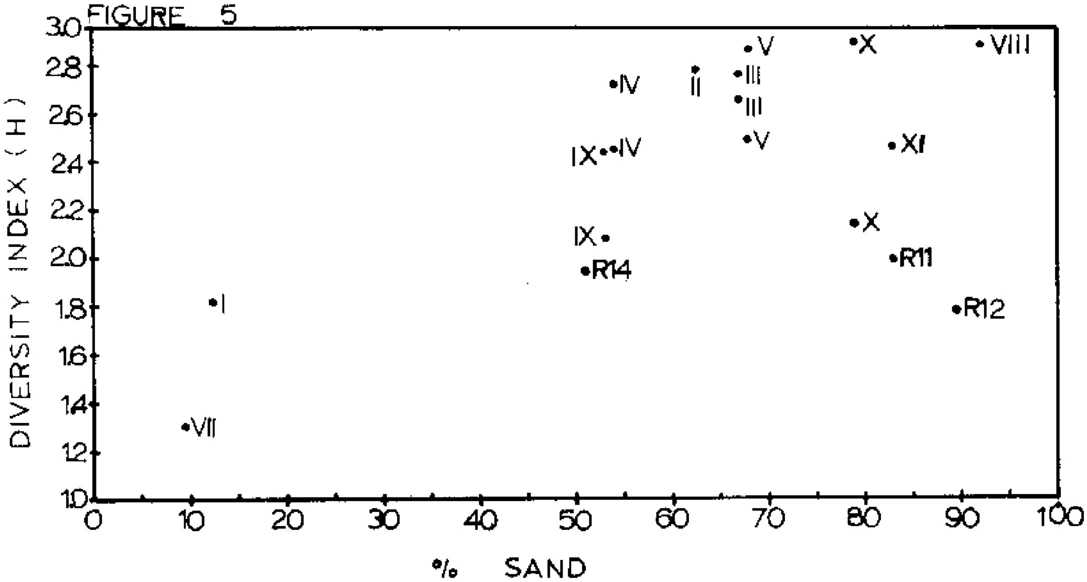


FIGURE 6

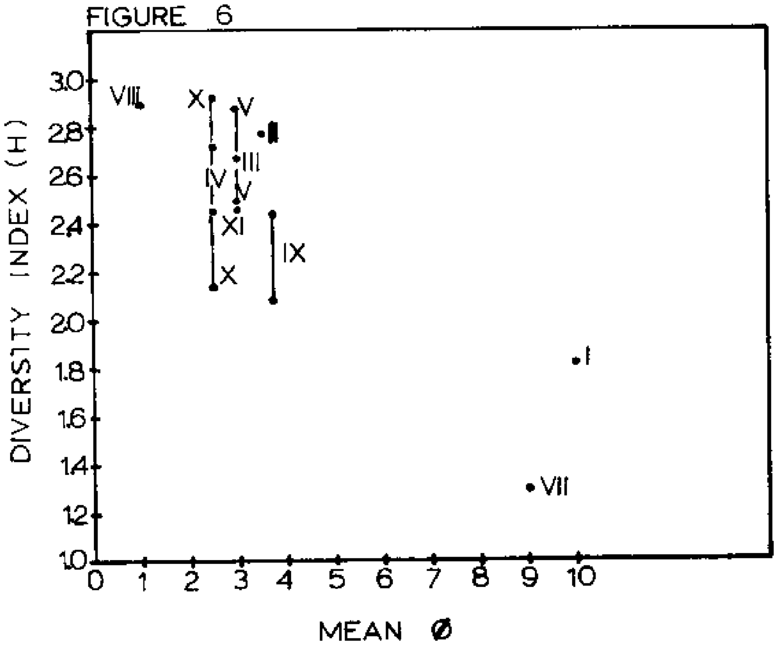


TABLE 2:
ABUNDANCE IN GREAT HARBOR: EAST BASIN vs. WEST BASIN

Station	East	Station	West
II	3050	I	350
	1675		1175
III	4000	V	2025
	8750		4150
IV	5400	VII	775
	9000		1075
X	2700	VIII	2900
	3250		3300
XI	6600	IX	1225
R11	9393		1850
R12	10605		
R14	4545		
Total/m^2	62368		18825
Mean/m^2	5747		1883

$p < 0.005$ (DF = 20)

ity of whether the mean number of individuals/m^2 in the eastern basin equaled that in the western basin. Mean number/m^2 for west end was 1883; for the east end it was 5747. A probability less than 0.005 was obtained, meaning the two basins are significantly different and that the east basin, with the outfall, had greater numbers of individuals. The additional nutriment may be the cause of greater numbers near the outfall.

One possible source of bias in the calculation, however, may be the addition of hand-held cores taken by the outfall. The area of core sample was 0.0033 m^2 as compared to the van Veen sampler with area of 0.04 m^2. When the core samples were extrapolated to square meters, total numbers/m^2 were exceedingly high in comparison to those obtained by van Veen sampler. Consequently, total numbers in the east basin may be erroneously large. Further studies should use only a single type sampling device or several cores should be taken from the west basin and estimates from them compared with the grab samples.

Suggestions

As in any initial, short-term study of an area, one can easily imagine many parameters that would be of interest to measure. Ludwig and Storrs (1970) describe several not included in this report which could be valuable in studying the effects of a sewage outfall on the aquatic environment. For a more complete analysis parameters which should be measured (especially where a sample is taken) are: 1) physical - temperature, currents, floatables, transparency, color, and more sediment types; 2) chemical - pH, dissolved oxygen, salinity, nutrients, toxicity, and 3) bacteria, phytoplankton, zooplankton, fish, and benthic plants. These could be incorporated into a group project consisting of current studies and hydrostations and might easily yield rewarding data.

Accurate mapping of sampling sites should be stressed from the beginning since there remains some doubt about the exact location of several stations in this report.

Identification of specimens should be checked to eliminate any error due to inexperience of investigators in identifying salt water species.

A more complete dye study with a fluorimeter at various tidal phases and wind speeds would be helpful in yielding accurate flow, stability, and dilution of the plume.

As with all studies, more samples, plus sampling during different seasons are needed to yield a better definition of the outfall's influence.

Diver-assisted grab samples would be excellent to lessen the effects of boat drift and thereby insure that all samples taken on station are from the same area.

Statistical analysis of data would allow more conficence in the interpretation of data.

Acknowledgements

The authors wish to acknowledge the assistance of Pam Polloni and Johanna Reinhart in identification of certain specimens, of Mr. Hughes, Water department, Falmouth, Massachusetts, for helping us with the dye study, and of Hovey Cliffor and Marti Kardes who assisted with the sampling.

Bibliography

Barnes, R.D. Invertebrate Zoology, Saunder Co., Philad. 1969.

Filice, F., 1959, "The effect of wastes on the distribution of bottom invertebrates in the San Francisco Bay estuary." Wasmann J. Biol., 17, pp. 1-17.

Ludwig, H. and Storrs, P., 1970, "Effects of waste disposal into marine waters." U. Calif's Program VII, Water Resources Engin. Ed. Series, S. F.

Miner, R. W., Field Book of Seashore Life, G.P. Putnam's Sons, N.Y., 1950.

Ruttner, F., Fundamentals of Limnology, U. Toronto Press, 1952.

Sanders H.L., 1958, "Benthic studies in Buzzards Bay. I. Animalsediments relations." Limnol. & Oceanogr., 3, pp. 245-258.

Shannon, C.E. and Weaver W. 1963, The Mathematical Theory of Communication, U. Illinois Press, Urbana, Ill.

Smith, R. I. (ed), Key to Marine Invertebrates of Woods Hole Region, Contribution No. 11, Marine Biological Laboratory, Woods Hole, Massachusetts, 1964.

(Rough data are on file with the M&O Dept.)

Navigation and Bathymetry During the Ocean Practicum

by G. Thomas Kaye

Navigation of the research vessel during the Ocean Practicum was done using the following means: (1) land-based transits, (2) horizontal angle sextant, (3) magnetic compass and compass bearing circle and (4) radar. Of these, transits proved the most accurate and reliable with fix error of ± 10 yards. The main disadvantage of this process is the large amount of manpower required to make the system work. Navigating with transits and communicating with citizen's band radio, the group was able to conduct a current measurement study with four drogues simultaneously while taking station with the research vessel for hydrographic casts or current meter measurements, by using a five-minute cycle of consecutive targets with one-minute fix intervals.

Bathymetry of the hydrographic transect on Vineyard Sound and of Great Harbor in Woods Hole was done using land-based transits and the fathometer onboard R/V ASTERIAS. The sounding of Great Harbor resulted in a bottom contour chart. Soundings and sediments in the northwestern area of the harbor indicate the possibility that off-shore areas near Penzance Peninsula may be filling in.

During the Ocean Practicum the author's responsibilities were as follows: (1) navigation of the research vessel, (2) bathymetry of Vineyard Sound along the transect of hydrographic stations and (3) bathymetric contouring of Great Harbor. Because the responsibilities were not necessarily related, they will be treated in this paper as separate.

Since ships first put to sea, navigation has been a necessary, but often thankless, chore. The art of knowing not only where you are going, but also where you have been is often not appreciated until one attempts to correlate his acquired data. Only then does the possibility of a "bum fix" appear to threaten the values obtained. To avoid this, man has devised many means of obtaining his position which can be classified roughly into electronic instruments such as LORAN, OMEGA, Navy Navigational Satellite, radar and sonar, and optical insturments such as the celestial sextant, horizontal angle sextant, transit and compass bearing circle.

For the Practicum visual positioning procedures were used primarily because of their availability. An arbitrary fix error of ± 200 yard was considered acceptable for the hydrographic stations taken in Vineyard Sound; actual fix error was considerably smaller than that.

During the first cruise day, the horizontal angle sextant was used to obtain horizontal angles between three fixed points from the vessel. With these two angles and a three-armed protractor, a fix could then be determined. The main difficulty with this method was the author's unfamiliarity with the sextant. It was found that angles greater than sixty degrees between points were difficult to shoot; however, angles of less than thirty degrees between points significantly increased fix error. Another problem, the instability of the research vessel, made use of the sextant difficult at higher sea states. The final difficulty with this method was that ship drift, whose observed maximum was 3.5 knots, compounded fix error. Any problem which slowed the angle-shooting process tended to increase fix error as the vessel did not remain stationary. In a four-fix comparison between the sextant and transits, minimum difference between fixes was 40 yards and maximum was 250 yards.

The majority of the navigation was done using land-based transits. By stationing one transit near Nobska Point Lighthouse and another in Falmouth Heights, the area between Nobska Point and Martha's Vineyard was easily covered. Communications between the transit stations and the research vessel were conducted via citizen's band radio and all timing of fixes was signalled from the vessel. Between fixes transit bearings were communicated to the ASTERIAS where the fixes were plotted. For fix intervals of less than three minutes, the bearings were recorded by each station and the fixes plotted later ashore.

This method proved extremely reliable with fix error bounded only by the accuracy of the plotter. Because the process yielded only two lines of position, a third transit station was established for one cruise day near West Chop Light on Martha's Vineyard to determine fix accuracy and reliability. The results were excellent with fix error on the order of ±10 yards. Unfortunately the establishment of the third station required one and half hours of ship time when no measurements could be made. Consequently it was decided that the reliability gained by a third station was not as important as the ship time and two stations were used for all subsequent cruise days.

This positioning process also proved excellent for tracking drogues. With four drogues in the water, a time-sharing plan of positioning the drogues and the vessel every five minutes by shooting consecutive targets with a one-minute fix interval was used. This five-minute cycle did not allow for plotting aboard the vessel, a drawback when positioning on a hydrographic station.

The disadvantage of this process was the requirement of at least five people to man the transit stations, a large drain on man-power. The advantages were the reliability and accuracy of the fixes and the ability to correct obvious mistakes made by the transit stations.

During one cruise day visibility decreased due to fog to the extent that the transit stations were useless. Positioning was done by use of a commercial X-band radar, newly installed aboard the ASTERIAS. The radar presented a relative picture with range rings which allowed interpolation of ranges to identifiable points. The accuracy of this process was not known, but from past experience, the author assumes that it is as good as the horizontal angle sextant in this area.

The last positioning process used was a magnetic compass with compass bearing circle located near the helm topside on the R/V ASTERIAS. By sighting fixed points through the circle, bearings could be read directly from the magnetic compass. Four lines of position were obtained for almost all fixes and fix error was on the order of ± 50 yards. The disadvantages of this process were that: (1) the research vessel changed its orientation quickly when drifting on station, making use of the circle difficult, and (2) the position of the compass is such that one must often drape himself between the helm and the controls in order to sight the desired targets.

Fortunately the area studied in Vineyard Sound generally did not require navigation over distances greater than seven nautical miles. In addition the area has many charted reference points easily visible from Vineyard Sound, which allows the navigator great latitude in selecting his targets.

All bathymetry was done using the vessel's fathometer for sounding and transits for navigation. Figure (1) is a bathymetric contour of Vineyard Sound from a point near West Chop on Martha's Vineyard to Nobska Point near Woods Hole. This contour covers the hydrographic stations taken during the Practicum and was useful in displaying the data accumulated.

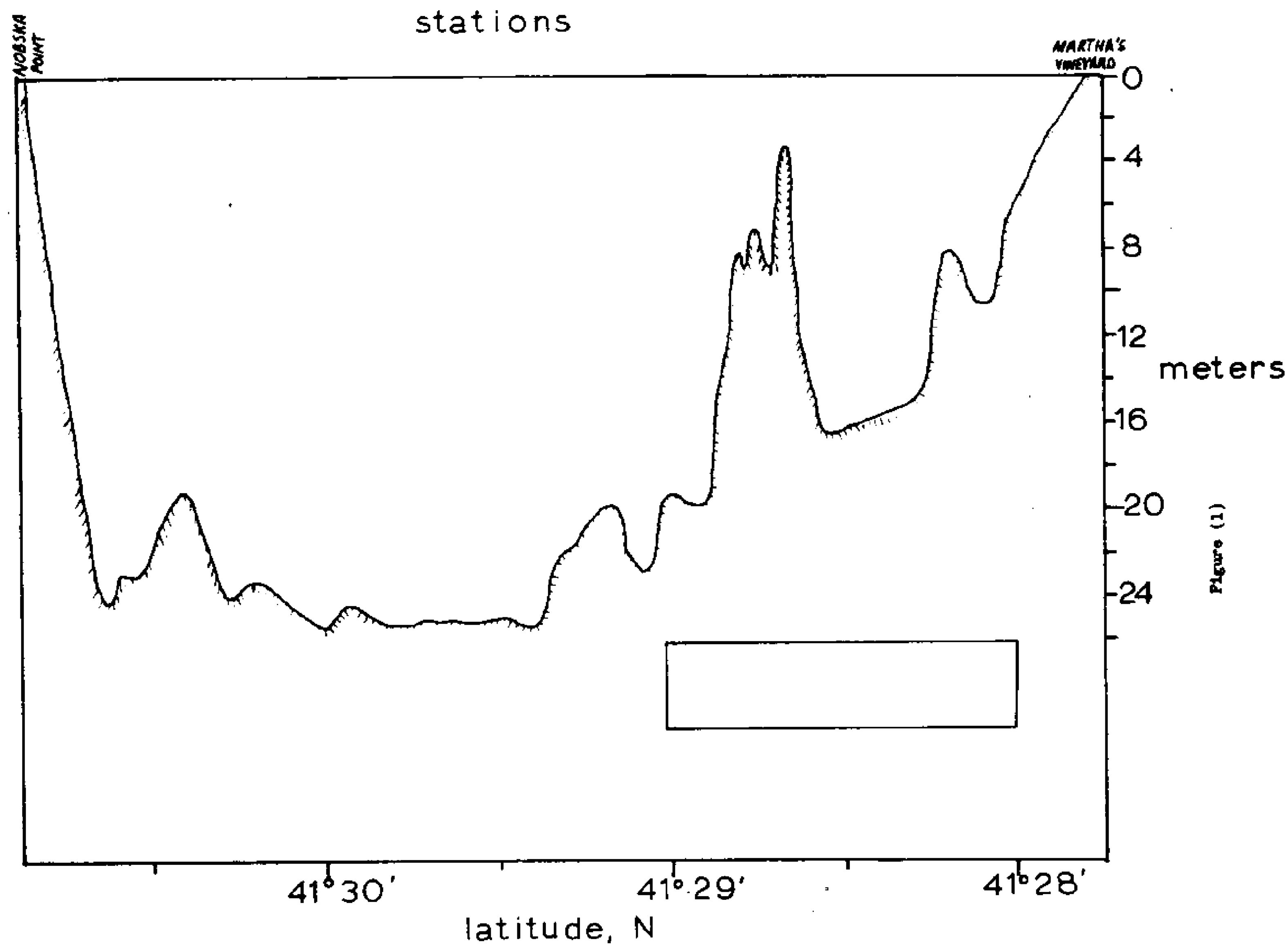

stations
NOBSKA POINT
MARTHA'S VINEYARD
0
4
8
12
16
20
24
meters
41°30'
41°29'
41°28'
latitude, N

Figure (1)

Transit Stations were at Nobska Point and Falmouth Heights. Fix interval was one minute and depths at the thirty second intervals were assumed to be at the midpoint between fixes. Water depths have not been corrected to mean low water, but can be, by subtracting one foot from all readings.

The illustration is deceptive in that it is "stretched" in width by about 10%. The track of the vessel was not a straight line, but instead a group of segments, meaning that the boat traveled a distance greater than the actual width of the sound at that point. However, it is felt that the value of the illustration lies in the relative depth contours, so that these disadvantages were not detrimental.

Figure 2 (distributed separately)*is a bottom contour chart of Great Harbor in Woods Hole. The requirement for such a chart arose when a marine biology group in the Practicum expressed interest in knowing the bottom contour of the harbor in order to correlate water depth with benthic samples. Accordingly, five hours of ship time were allotted for bathymetric sounding in Great Harbor on 13 and 25 May 1971.

Three transit stations were established for the first day and two for the second. Fix interval was thirty seconds and all time signals were originated from the R/V ASTERIAS and were relayed to the transit stations by citizen's band radio. For the first day, a large moored buoy in the west basin of Great Harbor was used as a reference point for the ship's track. This point served as the center around which the vessel was steered in a pinwheel design (see Figure 3). Upon plotting the data, the holidays, areas of no data, became obvious and a track for the second day's work was planned. On 25 May the holidays in the west basin and pertinent areas in the east basin were covered. Data from the 223 fixes plus

*See p. 90

soundings from the original chart of the area were then used to compile the contour chart.

All soundings from the fathometer trace were doublechecked prior to adding corrections. The first correction was + 3.5 feet, the depth of the fathometer transducer below the ASTERIAS' waterline. The second correction was the tidal component. Tides for the first day ranged between 1.4 and 1.6 feet above mean low water during the survey; 1.5 feet was the correction used for the data. There was no correction for tide needed for the second day. All tidal data was acquired from the Woods Hole Oceanographic Institution tide gauge, which can be read directly as feet above/below mean low water.

One correction that was not added was set-up, the effect of wind "piling up" water upon a coast. During both survey days, the wind was out of the southwest at 20-30 knots. The set-up for these conditions would be .3-.4 feet.[1]

Several errors in the data are possible. First, the fathometer was not calibrated with a known depth (a depth measured by lead line, for example). Second, one transit during the 13 May survey was not functioning properly, so readings taken on it were discarded. This meant that all fixes for the survey were based upon two lines of position, with no check on reliability. Third, the people manning the transits had minimal experience with the instruments and, therefore, could have made mistakes either in shooting or reading the bearings. Finally, the high winds could have induced human error in using the instruments.

In plotting the data, each mid-fix length was broken into four equal segments, as was the fathometer trace, so that four soundings were obtained from each fix. This procedure was

---

[1] Arthur Miller, WHOI, personal communication.

not used whenever the fixes indicated that the vessel was in a turn. In holiday areas, depths from C & G S Chart 348 were used to supplement the acquired data.

The resulting contour chart has one especially interesting indication. The water in the northwestern area of the west basin is shallower than was shown on the original chart. It should be noted that this survey did not generally cover the area inside the 12-foot contour (see figure 3). Instead the 6-foot and 12-foot contours from C & G S chart 348 have merely been duplicated. The 18-foot contour, however, was surveyed and extends further out than the original chart indicates. For example, this contour in the western portion on latitude 41°31' 30" N. extends out 90 yards further than the original chart. From looking at the sediment sizes of the area, it is interesting to note that sediments shade from gravel in mid-basin to clay in the off-shore area near the northwestern shore.[2] Also, the stream indicated on the western side of the harbor does not exist to its charted extent. Based upon this, one is sorely tempted to conclude that Great Harbor, near the northwestern shore of Penzance Peninsula is filling in. However without further information about the present positions of the 6-foot and 12-foot contours, this would be a hollow assumption.

For the next Ocean Practicum, it is recommended that either compass bearing circle or horizontal sextant positioning procedures be used for navigation. Both procedures can be used within the desired fix error of ±200 yards. This author favors the compass bearing circle, but recognizes that familiarity with the horizontal sextant can probably yield similar results.

---

[2]J.A. Vinlander, WHOI reference Publication #34-68, p.4.

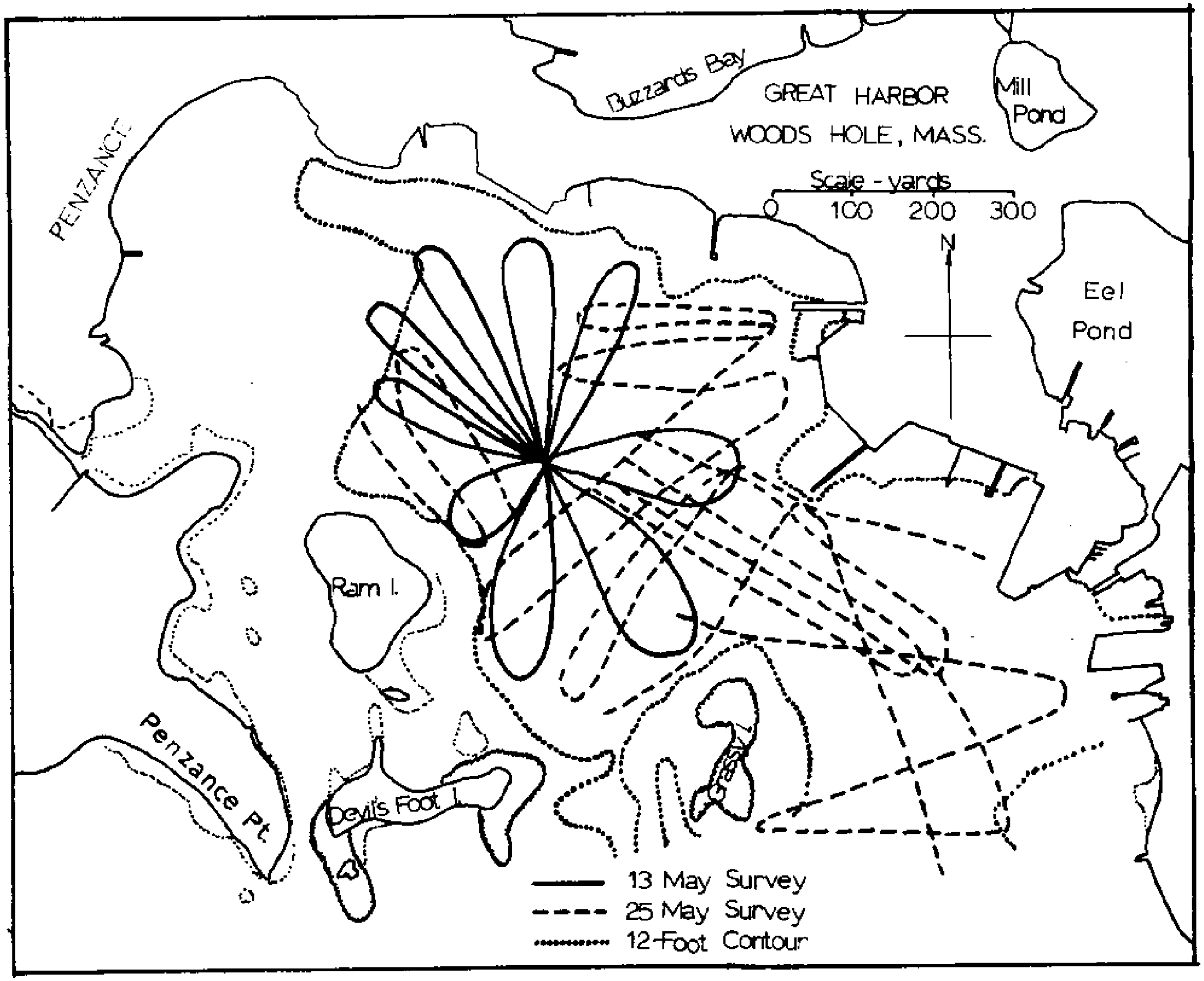


Fig. 3 Ship's track of bathymetric sounding

The author would like to acknowledge the help of Dr. E.C. Monahan, University of Michigan, and Mr. M. Stalcup, Woods Hole Oceanographic Institution, for ship time and technical assistance, Mrs. D. Rogers for tidal data interpretation, and, of course, the students in the Ocean Practicum who helped collect the data.

Bibliography

Manheim, F.T., Trumbull, J.V.A., Tagg, A.R., and Hulsemann, J., "Bottom Sediments of Woods Hole Great Harbor," Unpublished, WHOI Reference Publication #64-38, August 1964, pp. 10.

(The rough sounding chart is on file with the M&O Dept.)

Some Aspects of Current Measurement in the Woods Hole and Vineyard Sound areas

by Kevin D. Leaman

During the period from May 5 to June 11, 1971, the author had the opportunity to observe several different methods for the gathering of ocean current data in the Woods Hole-Vineyard Sound region of Massachusetts. These methods were: 1) drift bottles, 2) moored current meter, 3) ship-borne current meter and 4) several types of drogues. Since the author was not directly involved with the drift bottle study, only the last three methods will be discussed in this paper. Because of the relatively short time interval involved and the several types of apparatus employed, no truly detailed program of current measurement could have been carried out. Even with the moored current meter in Great Harbor, the data obtained was not sufficient in terms of either time or resolution and accuracy to attempt a simple harmonic analysis, let alone employ the more powerful techniques of time series analysis. (This is not to imply that the information gained from these experiments, particularly the moored current meter, will not be useful to people in areas of study other than strict current measurement and time series analysis).

Therefore this paper will have two aims: 1) to present the data gathered by the last three types of measurement mentioned above, and 2) to comment on the feasibility, that is, the relative advantages and disadvantages of the various methods. Part I concerns itself with introductory comments on the types of instruments used. Parts II-IV present the results obtained from the moored and ship-borne current meters, and the drogues. Part V will cover conclusions and suggestions for further observations by means of the various methods.

The Sediments of Great Harbor, Woods Hole, Massachusetts

by Darlene Silverblank & Dale Deitemyer

A study of Great Harbor, Woods Hole, Massachusetts was conducted during May and June 1971 in an attempt to interrelate the bottom fauna of the area, the sediment type, and the effects of the Woods Hole effluent. Samples were collected by lowering a 1/25 m^2 Van Veen grab from a ship and by divers using hand-held cores. Positions were located by eye, by transit, and by direct measuring by the divers. The fine sediments were analyzed using the pipette method based upon the settling velocities of various size particles. Sieving and the Modified Woods Hole Rapid Sediment Analyzer were used to determine the percents of the phi ranges in the sand fraction.

Many artifacts including cigarette butts, foil, and paper were noted in the samples taken near the outfall. These samples were composed mainly of fine black gelatinous sediments containing much H_2S and organic matter. The samples near the pipe contained the highest percents of organics. This seems to indicate that material flowing from the effluent pipe is settling and being decomposed in the area around the outfall. Samples in other parts of the harbor contained shells and Zostera which may account for the high organic percentages in other samples. In general an inverse relationship was noted between grain size and amount of organic matter present. No correlation between depth and particle size could be seen. An accurate map of sediment distribution in the harbor was not possible since most of the data were concentrated near the outfall.

Introduction

Woods Hole, Massachusetts is located in an area of glaciation. Geologically, it consists of basement crystalline rocks, Paleozoic in age, mainly metamorphic conglomerates, sandstones, and shales. The overlying rocks are Upper Cretaceous, Tertiary, and Quaternary. The exposed beds are mostly Pleistocene in age consisting of unconsolidated sands, gravels, clays, and tills (Ewing, 1950).

Although a general survey of the sediments of Great Harbor has been conducted (Manheim, et. al., 1964), crude, approximate methods were employed. Since his chart, no further attempts have been made to arrive at a more accurate representation of the bottom sediments of the area.

In addition to producing a more accurate and more detailed chart of the sediments of Great Harbor, our study attempted to find correlations between the types of benthic marine organisms and the substrates they inhabited. In his studies of Buzzards Bay, Howard L. Sanders (1958, 1960) reported filter feeders Ampelisca associated with sandy bottoms while Nephtys incisa-Nucula proxima inhabited areas of mud. When Barnstable Harbor was investigated (Sanders, et. al., 1962), suspension feeders were found in well-sorted fine sands of the intertidal islands and only few in the soft sediments. Deposit feeders were discovered in the sands and soft sediments. As stated in the above papers, the sediment type indicated the availability of food. It does not directly determine the feeding types.

J. L. Hough (1942) found coarse sediment in the areas exposed to wave and current action. This was either in shallow water or near the shore and shoals. Fine material was deposited in deeper areas and protected embayments. Thus low velocity currents enable material to settle out. This provides an adequate source of nutrients for deposit feeders. In areas of coarser particles, more turbulence and, therefore, more material in suspension is noted in general. Thus filter feeders and suspension feeders are more likely.

Driscoll (1967) also described a similar type of inter-relationship between fauna and substrate. Attached and sedentary epifauna species, suspension feeders, were more abundant in areas of low silt-clay content. Infaunal suspension feeders predominate in areas of finer sediments. It is hoped a correlation can be drawn between sediments and benthic fauna of Great Harbor. As stated before, grain size is also related to current and wave action. Thus a map of the sediments may help in future research in these areas.

Much work has recently been done to discover the effect of pollution on coastal and offshore marine environments (Olson and Burgess, 1967; McGowan, et. al., 1970; Bagge, 1969; Chen, 1969; Dugdale and Whitlege, 1970). Chen (1969) noted that in San Diego, sediment qualities tended to stabilize; however, they were more responsive to waste discharge than to water qualities. The stations within the dispersion area showed greater change than the reference areas. This was attributed to the fact that the outfall was located on the ocean bottom 60 m below sea level.

The Great Harbor study attempted to find correlations between sediments, fauna, and the effluent flowing into the harbor. Percent organic matter was measured to determine where the effluent flowed upon leaving the outfall.

Although this study will provide only broad conclusions, it will provide a sound basis from which an indepth study of the effect of the effluent on Great Harbor can be conducted.

Procedure

The core samples were collected in two ways. A 1/25 m^2 Van Veen grab was lowered by hand from the side of the ship. A sample was taken by inserting a core tube into the grab, usually at the point with the greatest depth of sediment. Divers also took samples using hand-held cores (samples R-1 through R-14).

Once taken, the samples were processed (Krumbein and Pettijohn, 1938). Since the upper few centimeters of the sample were often markedly different in color, composition, and texture from the lower portion - - lighter in color, less organic matter with more shells and artifacts, and coarser - - care was taken to use primarily only this top section. In some cases, due to mixing and addition of formalin, this was difficult, notably in samples R-1 through R-14.

A small portion of the sample was taken, 5-20 gms, and mixed with distilled water to which about 2.0 gm/l of a dispersant, $(NaPO_3)_6$, was added. A sanafier was used to further aid in mixing, eliminate lumps and separate the grains. The solution was wet sieved, again with dispersant solution, through a 63 micron sieve into a 1000 ml graduated cylinder. The cylinder was then filled with dispersant solution to the 1000 ml level. The solution in the cylinder was stirred with a stirring rod and placed aside for several (four to six) hours to observe if flocculation occurred. The sand fraction, the material remaining in the sieve, was washed with pure distilled water and put in the oven to dry. The procedure for analyzing the sand will be discussed later.

In the samples taken, no problems arose due to flocculation. The methods of analysis depend upon settling velocities which are a function of the sizes of the particles. Therefore if flocculation occurs, erroneous results will appear, biasing the sizes to the coarser fraction. Krumbein and Pettijohn describe alternate procedures in the event of flocculation. In this study, it was possible to procede directly to the pipette analysis. By application of Stokes' law and Wadell's practical sedimentation formula, the settling velocities of specific grain sizes can be calculated. Applying v = h/t (v = velocity, h = depth of particle, t = time), knowing the distance traveled or depth down the tube, and the settling velocity of the particles size (Zeigler, Gill, 1959), the time the sample should take can be calculated. From this a standard time schedule for sample analysis has been prepared. Since this method depends only upon time and depth, if for any reason the time schedule could not be met precisely, it was possible to restir the solution, wait the specified time, and continue sampling without any errors resulting.

Samples of 50 ml were pipetted at the specified depths and times. After taking a sample, the pipette was rinsed with distilled water and emptied into the appropriate beaker. This care was probably not necessary since the accuracy of the procedure was limited. The beakers were set in the oven to dry. A 50 ml sample of the dispersant solution was taken to determine the weight of the sample which was due to the addition of the dispersant. Once dry, the pipetted samples were weighed. By multiplying the figure by 20 the total weight in the sample of the 5 to 10 phi sizes was determined.

The following procedure was used for analyzing the sediments above 63 microns. After the beaker with the sample was fully dry, it was placed in a crucible and heated to 500-600° C to combust the organic material. The sample was wet sieved through a 63 micron sieve with pure distilled water to remove the ash. The sample was dried and then weighed to obtain the total weight of the coarse sample. The sample was sieved through a 2 mm (1 phi) sieve to separate the coarse gravel fraction. The gravel was then weighed and set aside for further analysis if necessary.

The sand fraction was split with a Jones sample splitter if necessary. In some cases (Samples 1-1, 7-20, R-4, R-5) to the small amount of sand size sediment present. In such cases hand sieving was done using metal sieves at 1 phi intervals. Hand shaking was used.

In the remaining samples a Modified Woods Hole Rapid Sediment Analyzer (Schlee, 1966; Zeigler, et. al., 1960; Whitney, 1969; Emery, 1938) was used. The analyzer measures the pressure differential between two columns of water having a common head. When sediment is introduced into a column, the pressure increases at the bottom of the column. This is measured by a water pressure transducer and the output is fed to and plotted by a Sanborn Dual Channel Carrier Amplifier Recorder. As the sand grains settle past the pressure trap, a sensing hole 1 meter down the tube, to the transducer, the pressure can no longer be detected by the transducer. Thus the pressure differential decreases with time. The rate of change of pressure represents the frequency distribution of sediment velocity in the sample since the largest grains settle out first. The sample is introduced into the column by rotation of a disk upon which was placed 2 - 10 gm of sample which has been dampened. A timer is used since the chart speed is decreased at specified times. A size time overlay aids in reading the chart which is produced. The cumulative percent is read using a Gerber variable scale.

To determine percent organic matter, a small amount of sample was placed in a crucible, dried, weighed, and heated to 500-600° C in order to combust the organic matter. It was reweighed and a percent was obtained.

Calculations

The percent of gravel is obtained directly. The percentages in the sand fraction were determined by multiplying the percentage the phi unit is of the sand portion times the percentage the sand sample is of the total sample. In the silt-clay range the weight of the 50 ml sample is multiplied by 20 to give the amount per 1000 ml. Percent can then be obtained. Cummulative percents vs phi graphs are plotted and necessary values are read from these graphs. The median is the 50% value, Q_1 75% and Q_3 25%.

Results

The data are summarized in the Table. Large amounts of fine organic matter were found in samples located close to the outfall. The samples were black, gelatinous and contained much H_2S. They also contained foil, glass, and shredded paper. The divers observed "patches of fine soft silt, often with patches of white sulfate reducing bacteria on it, toilet paper, cigarette butts, etc." This suggests that the material flowing from the effluent pipe is settling and being decomposed in the area around the outfall. In general the smaller grain sizes were associated with the larger percents of organic matter. In some areas Zostera was present. This may have accounted for the high organic values, even surpassing the effect of the outfall in some areas. The amount of organic matter present was also directly proportional to the distance from the outfall with extremely high organic values found in the samples immediately surrounding the effluent pipe.

When depth vs mean phi was plotted no correlations could be found. Current studies may prove useful and correlations between current velocity and grain size may be observed.

The results of the biological aspects of the study are included in "The Bottom Fauna of Great Harbor" by Camille Hyde and Andrew Schaedel.

Conclusions

The collection and analysis of sediment samples was part of a larger study to determine the effect of effluent on Great Harbor and to interrelate effluent, fauna, and sediment type. Since sediment data were gathered for the use of the biologists many of the stations were located near the outfall and relatively few stations were located in other areas of the harbor.* Thus it is impossible to draw a detailed map of the sediment distribution in Great Harbor. The chart of Great Harbor includes the station numbers and mean phi of the samples. These results compare quite favorably with the study conducted by Manheim, et. al., (1964). However the area in the northwest portion of the harbor appears to be decreasing in depth suggesting a filling in of the area. To obtain a more detailed chart many more samples located throughout the harbor must be analyzed. Current measurements could be made at various locations and some correlation between grain size and current velocities might be possible. More samples on transects at various directions from the outfall could be taken.

*See p. 90

The grain size and percent organic material may be correlated with direction from the outfall and current direction.

Although care was taken in the pipette analysis, limitations in the procedure exist. Since the method is based upon settling velocities and depths at which samples were taken, errors result. The clay and organic particles float and undulate instead of settling steadily down the tube as to larger spherical particles do. In addition, shaking the table affects the settling and location of the pipette in the sample has also been found to affect results. Care was taken to place the pipette in the middle of the 1000 ml cylinder.

Sorting and skewness could be calculated; however, this information did not appear necessary in the studies conducted. Many of the samples were so fine that no Q_1 value could be determined from the cumulative graphs. Extrapolation is possible but would add little information. In the future a computer program could be implemented to analyze the data.

The effluent seems to be affecting the sediments of the area. An anerobic area, rich in H_2S and high in organic matter, was seen around the outfall. The sediments were gelatinous and mixed with various artifacts. Further investigation including dye studies to determine where the effluent goes must be conducted to determine the complete effect of the effluent. Hopefully in the future a new method of waste disposal will be implemented which will minimize any effects on the environment.

Bibliography

Bagge, Pauli. "Effects of Pollution on Estuarine Ecosystems." Merentutkimuslait Julk./Hausforsknings Inst. Skr. No. 228.

Chen, Carl W. "Effects of San Diego's Wastewater Discharge on Ocean Environemnt." Ocean Environment, Vol 42 #8, Pt 1 (1969), pp. 1458-1467.

Driscoll, Egbert G. "Attached Epifauna-Substrate Relations." Limnology and Oceanography, 12 (#4 Oct, 1967) pp. 633-641.

Dugdale, R. C. and Whitledge, T. "Computer Simulation of Phytoplankton Growth near a Marine Sewage Outfall." Rev. Intern. Oceanog. Med., Tome XVII (1970), pp. 201-210.

Emery, K. O. "Rapid Method of Mechanical Analysis of Sands", Journal of Sedimentary Petrology, Vol * #3 (Dec. 1938), pp. 105-111.

Ewing, Maurice, Crary, A.P., and Rutherford, A.M. "Geophysical Investigations in the Emerged and Submerged Atlantic Coastal Plain, Part I: Methods and Results." Bulletin of the Geological Society of America, Vol 48, (June 1, 1937).

Ewing, Maurice, Worzel, J.L., Steenland, N.C., and Press, Frank, "Geophysical Investigations in the Emerged and Submerged Cape May Sections", Bulletin of the Geological Society of America, Vol. 61, (Sept. 1950), pp. 877-892.

Hough, J.L., "Sediments of Cape Cod Bay, Mass." Journal of Sedimentary Petrology, Vol. 12, #1, (April 1942) pp. 10-30.

Krumbein, W.C. and Pettijohn, F.J., Manual of Sedimentary Petrography, New York: Appleton-Century-Crofts, Inc., 1938.

Manheim, F.T., Trumbull, J.V.A., Tagg, A.R., and Hulsemann, J., "Bottom Sediments of Woods Hole Great Harbor", Unpublished, #64-38, (August 1964).

McGawan, John A., Enright, James T., and Fager, E.W., "Ecology and Oceanography of Sewer Outfalls: A Seminar Held at Scripps Institute of Oceanography", SIO Ref. #70-18, (Spring, 1969).

Moore, J. Robert III, "Bottom Sediment Studies, Buzzards Bay, Mass.," Journal of Sedimentary Petrology, Vol. 33, #33, (Sept. 1963), pp. 511-558.

Murray, Stephen Patrick, "Control of Grain Dispersion by Particle Size and Wave State," Journal of Geology, Vol. 75, #5, (1967), pp. 612-634.

Olson, Theodore A., and Burgess, Frederick J. (Eds.), Pollution and Marine Ecology, New York: Interscience Publications, 1967.

Purdy, Edward G., "Sediments as Substrates," in Approaches to Paleoecology, New York: John Wiley and Sons, Inc., 1964, pp. 238-271.

Sanders, Howard L., "Benthic Studies in Buzzards Bay: I. Animal-Sediment Relationships," Liminology and Oceanography, Vol. 3, #3, (July 1958), pp. 245-258.

"Benthic Studies in Buzzards Bay: III. The Structure of the Soft-Bottom Community," Limnology and Oceanography, Vol. 7, #1, (Jan. 1962), pp. 63-79.

Sanders, Howard L., Goudsmit, E.M., Mills, E.L., and Hempson, G.E., "A study of the Intertidal Fauna of Barnstable Harbor, Mass.," Limnology and Oceanography, Vol. 7, #1, (Jan. 1962), pp. 63-79.

Schlee, John, "A Modified Woods Hole Rapid Sediment Analyzer," Journal of Sedimentary Petrology, Vol. 36, #2, (June 1966) pp. 403-413.

Shepard, Francis P. Submarine Geology, New York: Harpers and Row, Pub., 1963.

Whitney, G.G., Jr., "The Woods Hole Rapid Analyzer for Sands," Unpublished, #60-36.

Zeigler, John M. "Beach Studies in the Cape Cod Area Conducted during the Period August 1, 1953-December 31, 1953." Unpublished Ref. No. 54-3.

"Beach Studies in the Cape Cod Area Conducted during the Period July 1, 1956 - December 31, 1956," Unpublished Ref. No. 57-4.

Zeigler, John M. and Gill, Barbara, "Tables and Graphs for the Settling Velocity of Quartz in Water, Above the Range of Stokes' Law," Unpublished Ref. No. 59-36.

Zeigler, John M., "Beach Studies in the Cape Cod Area Conducted During the Period August 1953 - April, 1960," Unpublished Ref. No. 60-20.

Zeigler, John M. Whitney, Geoffrey G., Jr., and Hays, Carlyle R., "Woods Hole Rapid Sediment Analyzer," Journal of Sedimentary Petrology, Vol. 30, #3, (Sept. 1960) pp. 490-495.

CHART I -- RESULTS

Sample no.	Gravel %	Sand %	Silt %	Clay %	Mean Ø	Organic Matter %	Depth Ft.	Dist. from Outfall Yds.
1-1	0.0	12.41	22.79	64.57	10.0	8.47	40	508
2-4	0.46	62.61	10.74	26.64	3.5	3.35	60	35
3-7	0.0	66.94	5.60	27.45	3.0	1.54	42	143
4-10	9.32	54.35	2.00	34.34	2.5	1.37	43	203
5-13	0.26	68.33	3.32	28.10	3.0	1.60	15	821
6-16	7.16	65.83	1.76	25.23	1.5	0.92	59	351
7-18	0.0	46.80	20.48	32.68	4.5	3.75	8	854
7-20	0.0	9.60	32.52	57.86	9.0	7.30	8	821
8-21	0.0	42.07	2.31	5.48	1.0	1.00	28	531
9-23	2.26	53.00	14.84	29.89	3.75	3.51	34	466
10-25	0.08	79.08	5.76	14.32	2.5	3.27	44	175
11-27	0.0	83.32	9.11	7.56	3.0	2.70	34	157
19-40	39.10	33.14	20-51	7.24	1.25	3.54	20	360
20-41	1.71	83.34	7.35	8.59	2.25	1.85	30	406
21-42	1.78	81.14	6.73	10.34	2.25	1.81	42	369
22-43	2.03	94.88	0.81	2.26	1.25	0.61	54	305
23-44	45.00	35.24	7.05	12.69	1.0	7.11	66	291
R-1	3.46	58.98	16.83	20.71	3.5	4.17	42	0
R-2	0.10	68.52	15.02	16.12	3.0	16.33	44	0
R-3	13.11	66.53	7.91	12.44	2.0	8.76	46	0
R-4	0.0	7.50	29.43	63.06	10.0	12.22	44	0
R-5	0.0	12.41	38.71	48.87	8.0	12.83	44	5.45
R-6	0.54	26.14	35.35	37.97	7.0	9.15	44	15.26
R-7	0.0	57.97	20.64	21.37	3.7	3.09	44	54.50
R-8	0.0	29.18	36.17	34.64	6.5	8.99	28	226
R-11	0.0	83.86	6.58	9.55	2.75			92
R-12	4.31	89.61	1.05	5.01	1.75			111
R-14	0.44	51.16	22.66	25.73	4.0			102

Sample No.	Description
A-1	36'-silt-much H_2S, few shells and cobbles, grass
A-2	10'-fine sand-light brown layer on top, no shells or coarse material, homogeneous.
A-3	35'-mostly fine sand (some medium sand), grass, shells, much partly decaying organics, sticks.
A-4	49'-silt (almost clay), much organics, grass, shells.

A Study of Nutrients in Vineyard Sound

by Douglas C. Takacs

A study was made of Vineyard Sound in late Spring, 1971, by a group of University of Michigan students. The following paper reports the results of the chemical parameters from the hydrographic stations.

Colorimetric techniques were used to measure nitrates, phosphates and silicates. Nitrates were measured by the Wood-Armstrong-Richards method; phosphates by the Murphy-Riley method; and silicates by the Grasshoff method. All three methods are reviewed and summarized herein.

Tidal currents seemed to have a pronounced effect on the measured parameters. The water in Vineyard Sound may possibly be derived from three different sources.

A separate study of the effects of a raw sewage outfall in Great Harbor was also begun by members of this same group. High nitrate, phosphate, and urea concentrations were found in the plume of this outfall as were expected.