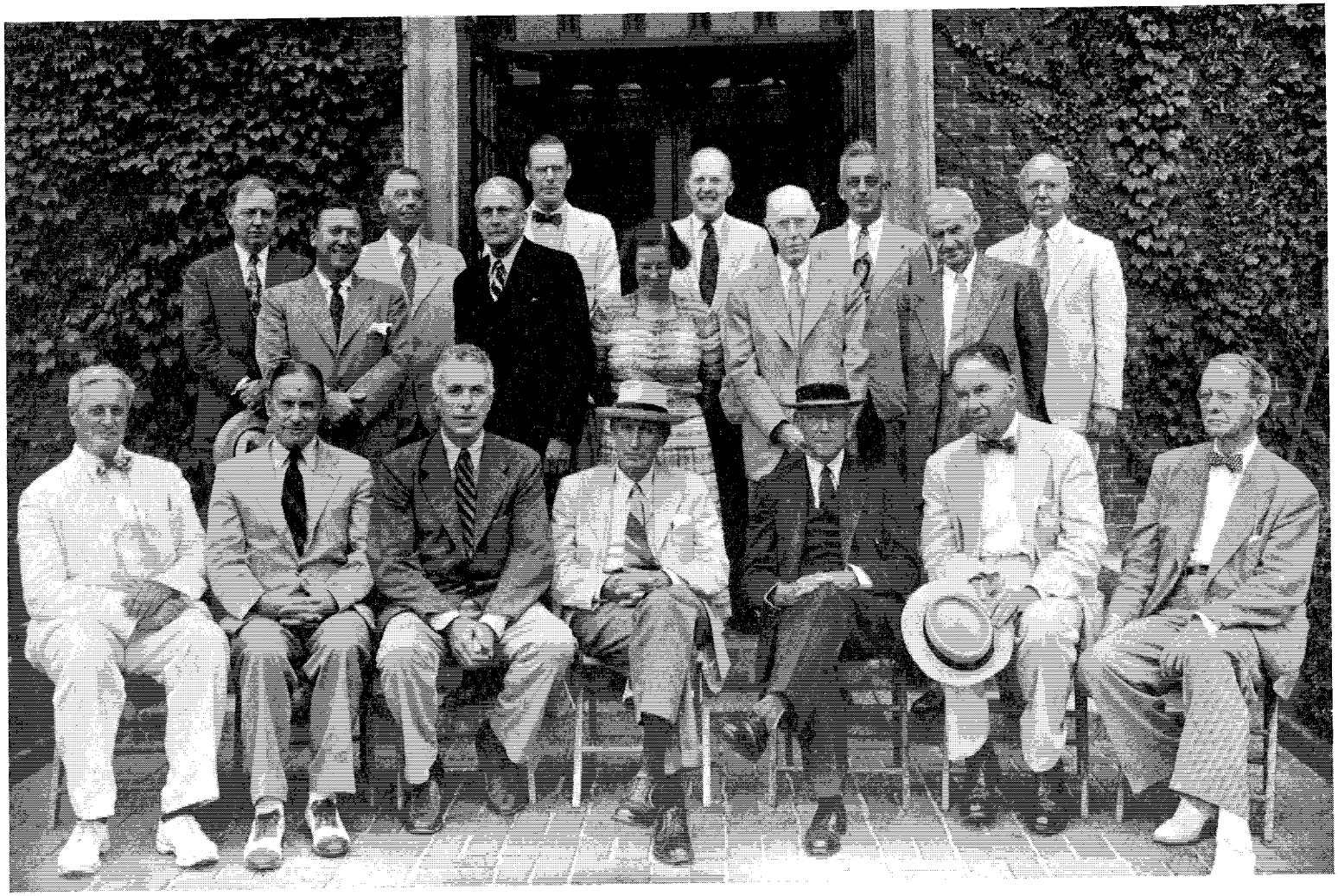
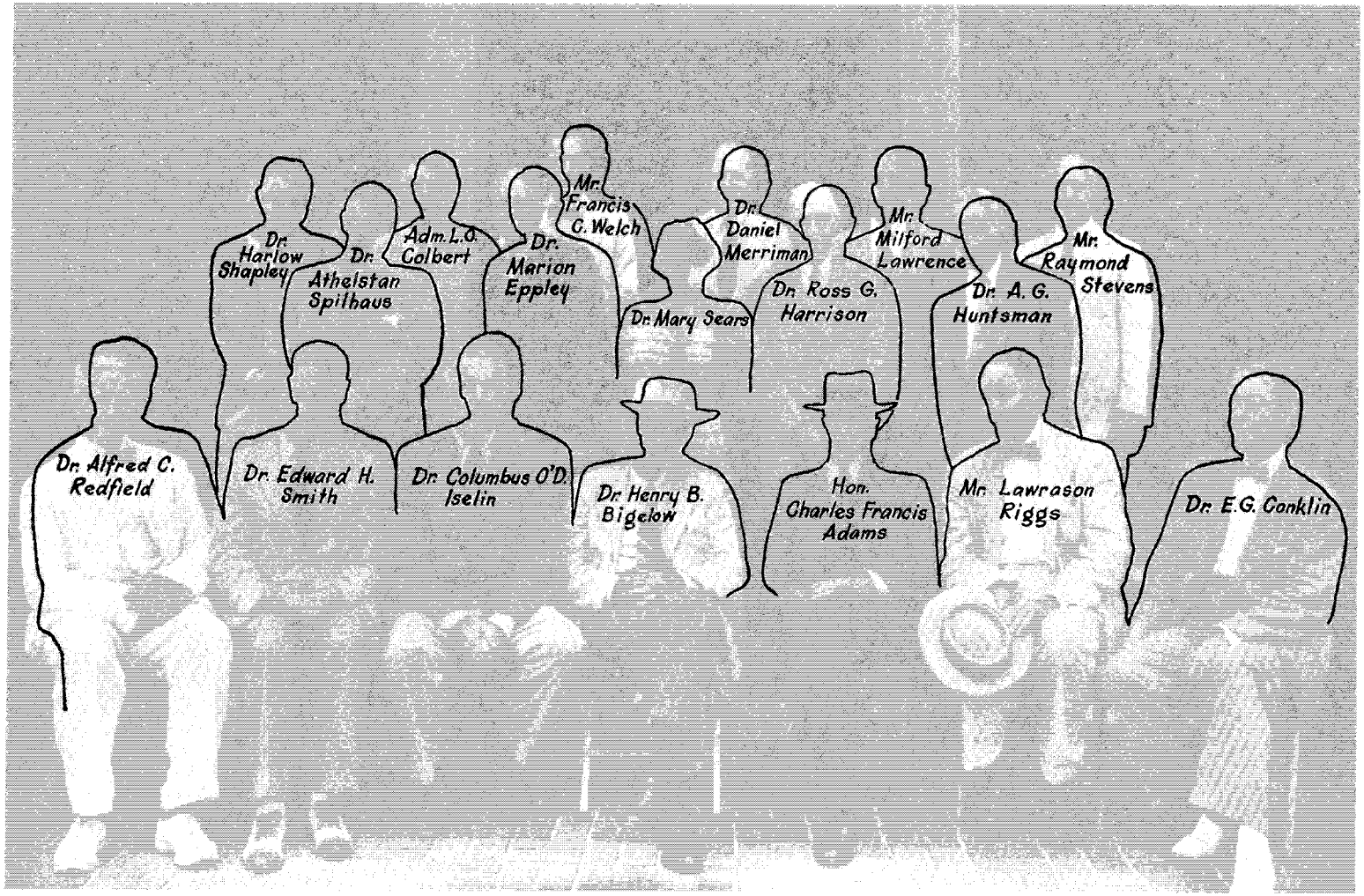
THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

REPORT FOR THE YEAR 1951

1952



Trustees and members of the Woods Hole Oceanographic Institution at the annual meeting, August 16, 1951



Trustees and members of the Woods Hole Oceanographic Institution at the annual meeting, August 16, 1951

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I. TRUSTEES

(As of December 31, 1951)

To serve until 1955

E. G. Conklin, Princeton University, Princeton, N. J.
Alexander Forbes, 610 Harland Street, Milton, Mass.
Ross G. Harrison, Osborn Zoological Laboratory, Yale University, New Haven, Conn.
Milford R. Lawrence, Siders Pond Road, Falmouth, Mass.
Harlow Shapley, Harvard College Observatory, Cambridge, Mass.
Francis C. Welch, 73 Tremont Street, Boston, Mass.

To serve until 1954

Charles Francis Adams, 15 State Street, Boston, Mass.
Horace S. Ford, 77 Massachusetts Avenue, Cambridge 39, Mass.
Arnaud C. Marts, 521 Fifth Avenue, New York, N. Y.
Albert E. Parr, American Museum of Natural History, Central Park West at 79th Street, New York, N. Y.
Athelstan F. Spilhaus, Institute of Technology, University of Minnesota, Minneapolis, Minnesota.
Selman A. Waksman, New Jersey Agricultural Experiment Station, New Brunswick, N. J.

To serve until 1953

L. O. Colbert, 4408 29th Street, N. W., Washington, D. C.
Marion Eppley, Eastover, Newport, R. I.
Frank A. Howard, 30 Rockefeller Plaza, New York, N. Y.
The Commandant (Vice Admiral Merlin O'Neill), U. S. Coast Guard, 1300 E Street N. W., Washington, D. C.
Columbus O'D. Iselin, Woods Hole Oceanographic Institution, Woods Hole, Mass.
Raymond Stevens, c/o Arthur D. Little, Inc., 30 Memorial Drive, Cambridge, Mass.

To serve until 1952

Henry B. Bigelow, Museum of Comparative Zoology, Cambridge, Mass.
Detlev W. Bronk, Johns Hopkins University, Baltimore, Md.
Daniel Merriman, Bingham Oceanographic Laboratory, Yale University, New Haven, Connecticut.
Alfred C. Redfield, Woods Hole Oceanographic Institution, Woods Hole, Mass.
Lawrason Riggs, Room 1722, 120 Broadway, New York, N. Y.
Henry L. Shattuck, 10 Milk Street, Boston, Mass.

Ex. Officio

Edwin D. Brooks, Jr., P. O. Box 135, Boston 3, Mass.
Edward H. Smith, Woods Hole Oceanographic Institution, Woods Hole, Mass.

OFFICERS

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II. MEMBERS OF THE CORPORATION

CHARLES FRANCIS ADAMS, 15 State Street, Boston, Mass.
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COLUMBUS O'D. ISELIN, Woods Hole Oceanographic Institution, Woods Hole, Mass.
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DANIEL MERRIMAN, Bingham Oceanographic Laboratory, Yale University, New Haven, Connecticut.
HENRY S. MORGAN, 2 Wall Street, New York, N. Y.
ALBERT E. PARR, American Museum of Natural History, Central Park West at 79th Street, New York, N. Y.
ALFRED C. REDFIELD, Woods Hole Oceanographic Institution, Woods Hole, Mass.
LAWRASON RIGGS, Room 1722, 120 Broadway, New York, N. Y.
GEORGE H. RICHARDS, 68 William Street, New York, N. Y.
MARY SEARS, Woods Hole Oceanographic Institution, Woods Hole, Mass.
ATHELSTAN F. SPILHAUS, Institute of Technology, University of Minnesota, Minneapolis, Minnesota.
LYMAN SPITZER, JR., Princeton University Observatory, 14 Prospect Avenue, Princeton, New Jersey.
HARLOW SHAPLEY, Harvard College Observatory, Cambridge, Mass.
HENRY L. SHATTUCK, 10 Milk Street, Boston, Mass.
EDWARD H. SMITH, Woods Hole Oceanographic Institution, Woods Hole, Mass.
RAYMOND STEVENS, c/o Arthur D. Little, Inc., 30 Memorial Drive, Cambridge, Mass.
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FRANCIS C. WELCH, 73 Tremont Street, Boston, Mass.
WM. D. WINTER, Atlantic Mutual Insurance Co., 49 Wall Street, New York 5, N. Y.

III. STAFF

(As of December 31, 1951)

Director

EDWARD H. SMITH, Oceanographer

Senior Scientists

COLUMBUS O'D. ISELIN, Associate Professor of Physical Oceanography, Harvard University and Research Oceanographer, Museum of Comparative Zoology; Senior Oceanographer.

ALFRED C. REDFIELD, Professor of Physiology, Harvard University; Senior Biologist.

Scientists

ARNOLD B. ARONS, Associate Professor of Physics, Stevens Institute of Technology; Associate in Physics.

JOHN C. AYERS, Assistant Professor of Oceanography, Department of Conservation, Cornell University; Associate in Biology.

DAVID L. BELDING, Professor of Bacteriology and Experimental Pathology (Emeritus), Boston University; Consultant, U.S. Fish and Wildlife Service; Associate in Marine Biology.

HENRY B. BIGELOW, Professor of Zoology (Emeritus), Harvard University; Associate in Oceanography.

DEAN F. BUMPUS, Oceanographer.

ANDREW F. BUNKER, Marine Meteorologist.

CORNELIA L. CAREY, Associate Professor Emeritus, Barnard College; Associate in Marine Bacteriology.

GEORGE L. CLARKE, Associate Professor of Zoology, Harvard University; Marine Biologist.

WILLARD Dow, Engineer.

WILLIAM MAURICE EWING, Professor of Geology, Columbia University; Director, Lamont Geological Observatory; Associate in Geophysics.

CHARLES J. FISH, Professor of Marine Biology, University of Rhode Island and Director, Narragansett Marine Laboratory; Associate in Marine Biology.

FREDERICK C. FUGLISTER, Physical Oceanographer.

BERNARD HAURWITZ, Professor of Meteorology and Chairman of the Department of Meteorology, New York University; Associate in Meteorology.

JOHN B. HERSEY, Physical Oceanographer.

LOUIS W. HUTCHINS, Director, Bermuda Biological Station for Research, Inc.; Marine Biologist.

CHARLES H. KEITH, Physical Chemist.

BOSTWICK H. KETCHUM, Marine Microbiologist.

JOANNE S. MALKUS, Meteorologist.

RAYMOND B. MONTGOMERY, Visiting Professor of Oceanography, Brown University; Physical Oceanographer.

HILARY B. MOORE, Associate Professor of Marine Biology, and Assistant Director, Marine Laboratory, University of Miami; Associate in Marine Biology.

ROBERT C. MOSES, Engineer.

ROY L. RATHER, JR., Engineer.

FRANCIS A. RICHARDS, Chemical Oceanographer.
GORDON A. RILEY, Associate Professor of Marine Biology, Yale University; Marine Physiologist.
CARL-G. ROSSBY, Professor of Meteorology, University of Stockholm; Visiting Professor, University of Chicago; Associate in Meteorology.
IRVING I. SCHELL, Marine Meteorologist.
WILLIAM E. SCHEVILL, Associate Curator of Invertebrate Paleontology, Museum of Comparative Zoology, Harvard University; Associate in Physical Oceanography.
WILLIAM C. SCHROEDER, Associate Curator of Fishes, Museum of Comparative Zoology, Harvard University; Ichthyologist.
MARY SEARS, Planktonologist.
FLOYD M. SOULE, Principal Senior Oceanographer, U. S. Coast Guard; Associate in Physical Oceanography.
ATHELSTAN F. SPILHAUS, Dean, Institute of Technology, University of Minnesota; Associate in Physical Oceanography.
HENRY C. STETSON, Research Oceanographer and Alexander Agassiz Fellow in Oceanography, Museum of Comparative Zoology, Harvard University; Submarine Geologist.
HENRY M. STOMMEL, Physical Oceanographer.
PARKER D. TRASK, Research Engineer, University of California; Associate in Submarine Geology.
HARRY J. TURNER, Marine Biologist.
ALLYN C. VINE, Physical Oceanographer.
WILLIAM S. VON ARX, Physical Oceanographer.
EDMOND E. WATSON, Professor of Physics, Queen's University, Kingston, Ontario; Associate in Physical Oceanography.
ALFRED H. WOODCOCK, Oceanographer.
GEORGE P. WOOLLARD, Professor of Engineering Geology and Geophysics, University of Wisconsin; Associate in Geophysics.

Research Associates

DUNCAN C. BLANCHARD, Research Associate in Meteorology.
WILLIAM S. BUTCHER, Research Associate in Geology.
HARLOW G. FARMER, JR., Research Associate in Engineering.
LLOYD D. HOADLEY, Research Associate in Engineering.
JOHN F. HOLMES, Research Associate in Engineering.
HENRY R. JOHNSON, Research Associate in Engineering.
WILLEM V. R. MALKUS, Research Associate in Physics.
FRANK J. MATHER, III, Research Associate in Oceanography.
WILLIAM G. METCALF, Research Associate in Oceanography.
ARTHUR R. MILLER, Research Associate in Oceanography.
FREDERICK DEW. PINGREE, Research Associate in Engineering.
HAROLD E. SAWYER, Research Associate in Engineering.
ARTHUR D. VOORHIS, Research Associate in Physics.
L. VALENTINE WORTHINGTON, Research Associate in Oceanography.
RALPH L. WYRICK, Research Associate in Engineering.

EDWARD H. SMITH, Director.
ALFRED C. REDFIELD, Associate Director.
RONALD A. VEEDER, Assistant to the Director.
HELEN F. PHILLIPS, Secretary to the Director.
JOHN MCGILVRAY, Business Manager.
NORMAN T. ALLEN, Administrator.
HARVEY MACKILLOP, Controller.

IV. TREASURER'S REPORT

THE accounts for the year 1951 have been audited by Messrs. Seamans, Stetson & Tuttle, Certified Public Accountants of Boston.

ENDOWMENT FUND ASSETS AND ENDOWMENT FUND

The Endowment Fund cash plus the quoted market value of the investments in bonds and stocks at December 31, 1951 totaled $3,365,727.94, an increase of $192,193.71 over the December 31, 1950 total. Of the total amount, $1,265.94 was in cash, $1,056,022.00 in bonds, a decrease of $33,768.28 over the book value, and $2,308,440.00 in stocks, an increase of $846,241.42 over the book value.

During the year bonds costing $113,182.71 were sold or redeemed for $112,271.95 which, after adding applicable amortization of bond premiums in the amount of $485.89, resulted in a realized loss of $424.87. Stocks and rights with book or assigned values of $173,882.50 were sold for $163,810.70, resulting in a net loss of $10,071.80. The total net loss from all sales or exchanges amounted to $10,496.67, thus bringing the accumulated net realized gain to the Endowment Fund to $133,834.84.

During the year, from the proceeds of the above sales and cash, $156,780.00 was invested in bonds and $122,343.76 in stocks, leaving $1,265.94 uninvested at the year-end.

PLANT ASSETS AND PLANT FUNDS

Plant Assets increased $33,853.85 during the year. The increase resulted from the following additions to Plant: Laboratory Equipment, $18,622.01; Library Books, $1,200.00; Buildings, $4,362.60; and improvements to the Homestead property $9,669.24. The Depreciation Fund assets, consisting of cash and advances for current funds, were consolidated with current funds, to assist in reducing our borrowing. The accumulated net amount of the Depreciation Fund is ear-marked in the Current Surplus account under "Periodic Replacements," totaling $14,322.82 on December 31, 1951.

CURRENT ASSETS AND CURRENT LIABILITIES

Accounts and Notes Payable, plus Unexpended Grants, exceeded Cash and Receivables by $45,447.17, against a similar figure for last year of $72,350.24, an improvement of $26,903.07. The Notes Payable were reduced $10,000.00 during the year.

Deferred Boat Costs increased from $66,628.04 at the end of 1950 to $70,528.69 at the end of 1951. The benefit of these expenses extends over

several years, and each year a proportionate part is added to Boat Costs. During the year $28,298.83 was thus charged to Current Boat Costs, and $32,199.48 was added to Deferred Boat Costs, primarily due to replacement and repair of deck and hull plates, new batteries and two life boats on the ATLANTIS, and batteries on the CARYN.

The Surplus Account increased from $43,025.93 to $71,190.34. This increase, of $28,164.41, is shown in detail on the Balance Sheet.

The Housing and Mess were operated at losses of $4,067.63 and $2,975.60 respectively, which losses were included in overhead costs. The Hall property produced a net income of $2,072.26. The three comparable figures for the previous year were: Housing, loss of $4,207.49; Mess, loss of $4,955.07; and Hall property, net income of $888.18.

The total income of the Institution from investments after deducting custodian fees and amortization of bond premiums, amounts to $157,333.69, compared to $155,234.84 for the previous year. Other income, including grants and fees, brought our total Institution income to $211,456.94. Institution charges against income, including our share of cooperative projects, totaled $205,702.70, resulting in an excess of Income carried to Surplus of $5,754.24.

The Institution does contract work for various governmental agencies on a cost reimbursement basis, and during 1951 received a fee for work under one of these contracts, amounting to $941.56, which amount is included in the Institution income.

The return on the investments held at the year-end was at the rate of 4.67% on the market value, 6.16% on the book value, and 6.51% on the original book value of the Endowment.

The Balance Sheets and Statement of Income and Expenses are appended.

BALANCE SHEET

As of December 31, 1951

ENDOWMENT FUND ASSETS

BONDS (LESS RESERVE FOR AMORTIZATION OF BOND PREMIUMS $1,914.18)		$1,089,790.28
Quoted Market Value	$1,056,022.00	
STOCKS		1,462,198.58
Quoted Market Value	2,308,440.00	
	$3,364,462.00	
CASH		1,265.94
		$2,553,254.80

Note: Bonds having a book value of $400,455.00 are specifically allocated as collateral on the Institution's indebtedness to the New England Trust Company.

PLANT ASSETS

LABORATORY PLANT:			
Land		$27,072.32	
Buildings		336,564.86	
Laboratory Equipment		50,741.63	
Library		22,000.00	$436,378.81
KETCH "ATLANTIS":			
Construction	$218,674.47		
Equipment	41,462.50	$260,136.97	
KETCH "CARYN"		98,275.43	
SMALL BOATS AND EQUIPMENT		10,578.85	368,991.25
HALL PROPERTY			26,500.00
HOMESTEAD			110,611.58
			$942,481.64

BALANCE SHEET

As of December 31, 1951

ENDOWMENT FUNDS

ENDOWMENT FUND — GENERAL	$2,000,000.00	
ENDOWMENT FUND — FOR UPKEEP OF PLANT	419,419.96	$2,419,419.96
Add accumulated net gain on securities called or sold		133,834.84
		$2,553,254.80

PLANT FUNDS

PLANT FUND — GENERAL			$640,328.79
PLANT FUND RESERVE — TRANSFERRED IN PRIOR YEARS FROM CURRENT SURPLUS	$250,299.00		
Add appropriation from Current Funds:			
"Caryn" One-fifth Purchase price	$18,000.00		
Laboratory Equipment	18,622.01		
Improvements to Homestead	9,669.24		
Temporary Building	4,362.60		
Library — Book Purchases	1,200.00	51,853.85	$302,152.85
			$942,481.64

BALANCE SHEET

As of December 31, 1951

(Concluded)

CURRENT ASSETS

CASH:			
Main Accounts		$7,421.84	
Operating Accounts		21,024.40	
Office and Boat Funds		1,110.87	$29,557.11
ACCOUNTS — RECEIVABLE:			
Governmental Agencies:			
Invoiced		$86,418.57	
Expenditures Not Invoiced	$144,625.29		
Use of Boats Not Invoiced	86,465.08	231,090.37	
		$317,508.94	
Co-operating Institutions		25,928.47	
Other Accounts Receivable		14,314.32	357,751.73
SUPPLIES AND WORK-IN-PROCESS			35,502.80
PREPAID EXPENSES			9,203.38
DEFERRED EXPENSES:			
Boat Expense		$70,528.69	
Maintenance of Homestead		1,402.64	71,931.33
			$503,946.35

BALANCE SHEET

As of December 31, 1951

(Concluded)

CURRENT LIABILITIES

ACCOUNTS — PAYABLE:			
Sundry Creditors		$41,618.30	
Withheld from Employees for Taxes, Insurance, etc.		10,246.21	
Sundry Accrued Expense		3,829.59	$55,694.10
NOTE — PAYABLE (SECURED BY BONDS HAVING A BOOK VALUE OF $400,455.00)			$360,000.00
UNEXPENDED GRANTS:			
Commonwealth of Massachusetts (Shellfish Propagation)		$6,089.28	
United States Public Health Service (Bacteriology of Polluted Waters)		7,127.96	
Research Corporation Instrument Fund		2,315.27	
Barataria Bay Model		988.37	
Wallace and Tiernan Gift		541.03	17,061.91
SURPLUS:			
Periodic Replacement Fund:			
Balance, January 1, 1951	$5,322.82		
Additions for the Year	9,000.00	$14,322.82	
General Surplus:			
Balance, January 1, 1951	$43,025.93		
Add:			
Gift $18,000.00			
Book Value of Plant Items Charged to Boat Expense 8,087.35			
Excess of Income for the Year 5,754.24	31,841.59		
	$74,867.52		
Deduct:			
Payment of "Caryn" Note — Payable	18,000.00	56,867.52	
Balance, December 31, 1951			$71,190.34
			$503,946.35

INCOME AND EXPENSE STATEMENT

Year Ended December 31, 1951

INCOME:			
Investments:			
Interest	$33,530.60		
Dividends	124,691.91	$158,222.51	
Less Amortization of Bond Premiums and Custodian Fees		888.82	$157,333.69
Grants:			
Commonwealth of Massachusetts (Shellfish Propagation)		$17,278.26	
United States Public Health Service (Bacteriology of Polluted Waters)		12,192.55	
Great South Bay Survey		4,000.00	33,470.81
Recovery of Depreciation through Charges to Overhead			16,694.25
Hall Property (Net Operating Income)			2,072.26
Fees			941.56
Sundry			944.37
Total Income			$211,456.94
EXPENSES:			
Operating		$79,587.69	
Co-operative Projects		40,508.87	
Institution Projects		20,594.14	
Interest Paid		8,933.75	
Additional Charge for Overhead, 1951		6,920.15	
Prior Year Adjustments:			
Unrecovered Overhead, 1950	$11,695.98		
Unrecovered Contract and Accounts — Receivable Balances	5,026.56		
Sundry Credits	*1,418.29*	15,304.25	171,848.85
			$39,608.09
PLANT ITEMS PURCHASED FROM CURRENT FUNDS:			
Laboratory Equipment		$18,622.01	
Improvements to Homestead		9,669.24	
Building		4,362.60	
Library Books		1,200.00	33,853.85
Excess of Income to Surplus			$5,754.24

V. DIRECTOR'S REPORT

Introduction

The year has witnessed one of the most productive periods in the history of the Institution. This feeling is verified, not only by the variety of subjects dealt with at the laboratory, but likewise by the wide range of the field investigations. Offshore cruises kept the ocean-going vessels underway, in several instances for months at a time, while inshore waters also received a measurable share of attention.

To understand current phenomena, both on a large scale and also in detail, is one of the important tasks of physical oceanography. In this respect the Institution, since its founding, has consistently focused an appreciable portion of its field work on the Gulf Stream, in the belief that eventually we will be able to contribute a reliable picture of the patterns of motion of a stratified fluid medium. The application of such investigations to many of the problems of oceanography and meteorology is quite obvious.

The year's work in biology was directed mainly toward inshore waters where opportunity seemed to offer the most profitable results, considering the modest funds which were available. Pollution caused by waste materials and abnormal concentrations of plant growth in certain coastal areas, has been the subject of continuing study. Improved techniques in the determination of trace elements of sea-water, and the ecological studies of the Massachusetts' shell fishery, were other features of the 1951 program.

Our marine geology received added interest from a bottom survey of the eastern half of the Gulf of Mexico.

Due acknowledgment should be made in the record of the generous support accorded the oceanographic research by the U. S. Navy Department's Bureau of Ships, Office of Naval Research, and the Bureau of Aeronautics.

No marked changes occurred in the administration of the Institution. The activities for the year, and other items worthy of record, are reported in more detail under appropriate headings which follow.

Floating Facilities

The sea-going research vessels ATLANTIS and CARYN in 1951 were augmented by the addition to the fleet, during March, of the U. S. Fish and Wildlife Service Vessel, ALBATROSS III, a steel trawler which with slight alterations served well as an oceanographic vessel. These three vessels, in order named, spent 206, 199, and 161 days respectively at sea during the year; a table summarizing their operations is contained in the Appendix.

ATLANTIS sailed from Woods Hole in January and returned in early June. During the first leg of the cruise she carried out a survey of the sediments of the eastern part of the Gulf of Mexico under the direction of Mr. Henry C. Stetson. Later under Mr. Martin Pollak's supervision a restricted bottom area in the west gulf was surveyed in considerable detail. The ATLANTIS then cruised first on the Blake Plateau with Dr. J. B. Hersey, and later to the vicinity of Guantanamo, Cuba, where she was joined by CARYN. In company, until they arrived at Woods Hole the first week in June, the two vessels were engaged in seismic refraction studies directed by Dr. Maurice Ewing. This work was a cooperation between the Institution and Lamont Geological Observatory.

The CARYN spent the winter months operating out of Bermuda on Sofar studies. Later in April she joined the ATLANTIS in southern waters.

ATLANTIS (after a thorough yard overhaul), and CARYN in company, departed in July on another geological cruise which occupied the remainder of the summer, the vessels covering a rather wide offshore area. Short cruises completed what was quite an active year of sea operations.

The ALBATROSS III departed from Woods Hole in early June on a current survey of the higher latitudes of the North Atlantic making port in Ireland, England, the Azores, and Bermuda. Messrs. Fuglister and Worthington were in charge of the scientific observations, the ship returning to her home port early in November.

A former naval supply craft named BEAR, which was chartered from a commercial dredging concern for the period July 1 to December 31, was employed on local cruises by several members of the scientific staff, carrying out sea investigations in the field of their particular interest. A smaller vessel of some fifty-foot length named the HAZEL III was chartered to carry out oceanographic observations in harbor waters.

The Institution's vessels consisting of ATLANTIS, CARYN, ASTERIAS, and CLAIRE have been maintained in good operating conditions throughout the year. The ATLANTIS underwent a thorough overhaul during June at the Electric Boat Company's yard at New London, Connecticut. A total of eleven plates were found excessively corroded. It was necessary to weld new plates over those which were weakest.

The CARYN has had its copper sheathing removed, and has had a new mizzen mast stepped in place of the old one which was weakened by dry rot. With the exception of certain fairing of the underwater planking, and new gearing of the steering quadrant, she is in good condition, although of course limited in sea endurance when compared with ATLANTIS. The final payment on CARYN in accordance with arrangements made with her former owner, Mrs. Caroline Ryan Foulke, was made in February.

The RELIANCE which the Navy had kept in our custody in a laid up status, was finally auctioned off during the early Fall, and departed from Woods Hole in the charge of her new owner.

Shore Facilities

Considerable thought and time has been given during the year to additional laboratory space which, as stated in the last annual report, was being projected due to the overcrowded condition of the main building which was erected more than twenty years ago.

Early in May the matter culminated in an offer by the Navy to provide a building of approximately 28,000 square feet area, including shops to be used in conjunction with the Institution's existing plant.

In accepting the proposal, the Trustees were careful to stipulate that the Institution accepted in principle the offer of the facility to be used primarily in carrying out basic oceanographic research. In reply to the Navy's request to recommend several sites, the one preferred was that adjacently east of the Institution's property, now under lease and occupancy from the Marine Biological Laboratory. At year's end plans were being drawn by the architect on the assumption that the laboratory would be separated only by a driveway from our own building, and to front likewise along Main Street. Furthermore, that the building now leased from the Marine Biological Laboratory and used as a machine shop, carpenter shop, and storage house, would be renovated and enlarged but retain its present utilitarian character.

The change in ownership of the so-called Norman House, rented during the summers of 1950 and 1951 for the convenience of summer workers at the Institution, necessitated taking steps either to lease other space, or to provide dormitory facilities of our own. The small village of Woods Hole is crowded every summer, as those who have visited the Institution at that time well know, and prices of rented apartments and rooms are at a premium. It has been the practice of the Institution to underwrite suitable housing space, and provide it at low cost to those of our summer-time workers who can least afford higher priced quarters.

The renovation of the large barn, therefore, on the Institution's residential tract, to provide a summer dormitory, was begun in the Fall. When completed in the Spring of 1952 it will contain three small apartments, and eight double room dormitories. A relatively large storage space in the basement will assist to relieve present storage congestion at the main plant.

The scarcity of adequate houses in Woods Hole and the vicinity for

rent or for sale, which was remarked upon in the last annual report, still exists, but the shortage apparently is not quite so acute as in 1950.

The Institution's buildings on the former Fay tract, number five residences, all of which are occupied by Institution personnel, and are now in excellent appearance and preservation. Other necessary maintenance of the ex-Fay estate has been the hard surfacing of a road leading from Main Street and connecting with Maury Lane, a private way, which runs to School Street.

Personnel

Our staff has (in addition to its primary work at the laboratory and at sea) found opportunity to present numerous technical papers during the past year at scientific meetings, and to professional societies, and it participated in seminar discussions, all in the promotion of oceanography. Several members of the Institution serve on standing committees, or act as consultants to government agencies. For example, Dr. Iselin is an active member of the Undersea Warfare Committee of the National Research Council; also a member of the panel on acoustics of the Research and Development Board, and serves too as a consultant to the Earth Sciences and the Physics Divisions of the Office of Naval Research. Dr. Redfield is president of the Oceanographic Section of the American Geophysical Union, and also served as chairman of the Oceanographic Panel of the Research and Development Board. He has represented the Institution at several dedicatory ceremonies, and has participated in university symposia. Admiral Smith serves as a board member of the Arctic Institute of North America, and as a deputy member of the Committee of Geography and Geophysics of the Research and Development Board. Dr. Iselin taught a term course in oceanography at Harvard; Dr. Montgomery at Brown, and Mr. Stommel did likewise at Yale. Others of the staff, such as Dr. Clarke and Mr. Stetson at Harvard, Dr. Riley at Yale, and Dr. Ayers at Cornell, are similarly identified with collateral assignments which keep the Institution in close liaison with developments in fields of common interest.

We regretted to lose through resignation Messrs. Martin J. Pollak and Arthur A. Klebba, both of whom had been with the Institution for several years, and had contributed materially to progress in their particular fields.

The Institution suffered the loss of one of the earliest members of its scientific staff in the tragic death on March 7th of Dr. Richard H. Seiwell. He, his wife, and two children were killed instantly in an automobile accident. An appropriate commemorative resolution was recorded at the annual meeting of the Board of Trustees.

If one compares the records of mid-year 1950 with those of 1951, it will be noted from the following tabulation that an increase of 51 employees,

or approximately 20 per cent of the force, occurred in 1951. About half of the rise was due to the ALBATROSS III, and BEAR, which joined our fleet, as already mentioned.

SCIENTIFIC AND TECHNICAL STAFF	*1950*	*1951*
Full time:		
At Woods Hole	82	70
On field trips	5	12
Summers only:		
At Woods Hole	29	40
On field trips	10	12
Working at other institutions	18	4
Fellowship holders	12	14
Visiting investigators	7	9
SECRETARIES AND CLERKS	17	24
ADMINISTRATION	9	11
GENERAL MAINTENANCE AND SERVICE		
Projects	25	31
Overhead	11	20
CREWS OF VESSELS	32	61
	257	308

It is with pleasure that we record the appointment to the staff of the following: Mr. Charles H. Keith, Physical Chemist; Dr. Joanne Starr Malkus, Meteorologist; and Mr. Robert C. Moses, Engineer; also Dr. Willem V. R. Malkus and Mr. Arthur D. Voorhis, Research Associates in Physics; Dr. William S. Butcher, Research Associate in Geology; Mr. Duncan C. Blanchard, Research Associate in Meteorology; Mr. Harlow G. Farmer, Jr., Mr. Henry R. Johnson, Mr. Frederick deW. Pingree, and Mr. Harold E. Sawyer, Research Associates in Engineering.

Dr. George L. Clarke traveled in Europe during the summer, visiting marine biological institutions, and representing the Institution at the Meeting of the International Union of Geodesy and Geophysics at Brussels.

The following persons were awarded honoraria, or fellowships, during the year:

HONORARIA

AYERS, JOHN C.
EWING, WILLIAM M.
FJELDSTAD, JONAS J.
HIDAKA, KOJI
MUNK, WALTER H.
NORTON, DANIEL R.
RILEY, GORDON A.
VAN DAM, LEONARD

FELLOWSHIPS

BARLOW, JOHN P.
FELSENFELD, GARY
GEALY, BETTY L.
HOLMES, ROBERT W.
MILLER, ARTHUR R.
MOSKOVITS, GEORGE
PLUNKETT, MARY A.
RYTHER, JOHN H.
SAID, RUSHDI
SEAL, MORGAN S.
SMITH, JOAN
WATSON, STANLEY W.

The Institution was visited by many scientists from this country and abroad. Such an exchange of information by personal visit is deemed highly beneficial, and the travel and visits of our own staff members to other seats of oceanographic activity has been encouraged.

The Social Security Act of 1950, the privileges of which were offered to employees of non-profit organizations (mentioned in last year's report) was accepted by a majority vote, and became effective as of January 1, 1951. This federal statute provides certain retirement benefits in which both the Institution and the employee contribute during the term of employment.

For the past few years the advantages of devoting greater efforts to the public relations of the Institution has been receiving increasing consideration. More and more attention has been given to news reports to the local Press, magazines and popular periodicals. It has come to be acknowledged at the Institution that public relations is an important but neglected field, in which we should strive to make the work of the Institution better known.

Scientific Program

Major advances have been achieved during the past year in our ability to describe the shallow distributions of temperature and salinity that exist in the sea at any one time and to relate these to the surface currents. At long last the observational approach, the theoretical approach and the experimental approach are all beginning to yield similar results. Not only can the Institution point to a beginning in the publication of these new results, but also we have been able to formulate and initiate a promising program of continuing investigations, both in the field and in the laboratory. No other period at Woods Hole has been more fruitful in physical oceanography.

As the result of the CABOT operation in the Spring of 1950, and as substantiated by the ALBATROSS' cruise across the North Atlantic this year, it has become evident that there are many similarities between the Gulf Stream System northeastward of Cape Hatteras and the recently discovered atmospheric jet streams at high altitudes in the belts of prevailing westerly winds. Both phenomena are in all probability dependent on the same fundamental laws of large scale motions in thin fluid envelopes on a rotating globe. Since the velocities and the time scale are much more favorable for detailed investigations in the case of oceanic jets, the theoretical meteorologists are finding our Gulf Stream surveys of increasing interest.

Mr. Wm. S. von Arx early in the year set up a small rotating model of the North Atlantic circulation. The optical system through which this

could be conveniently viewed was contributed by Mr. Arthur A. Klebba. Although the model was a relatively crude one, being little more than two feet in diameter, it reproduced several of the distinctive characteristics of the Gulf Stream that we have come to recognize only during the last few years, namely the concentrations of the flow in very narrow bands, the meandering, the formation of eddies, and the counter currents. Encouraged by these preliminary results Mr. von Arx has proceeded to design a much more elaborate, six foot, rotating model which is now operating in the fish tank room in the basement. It is evident that this model will at least be of the greatest help to theoreticians, for it can reproduce the sorts of simplified conditions that can be handled mathematically. Until now few checks on the theoretical reasoning have been possible.

In preparation for the past summer's ALBATROSS III cruise to England Mr. Fuglister prepared a chart showing temperature at 200 meters over the whole North Atlantic. The best previous such chart was published in the "Meteor Atlas" just before World War II, and depended on only a few thousand points of observation. Because of our rapidly gowing file of bathythermograms, Mr. Fuglister could use nearly 60,000 observations. Even when these are averaged by one degree squares it is evident that on a statistical basis a new Gulf Stream begins to form north of the old one off Georges Bank and off the Nova Scotian continental shelf, so that there are two distinct currents passing the tail of the Grand Banks, as was indeed found during operation CABOT. There is also a hint in this new chart that a third jet develops east of the Grand Banks. The same multiple jet phenomena have been found in the atmosphere and have been called "jetlets" by Dr. Rossby. The primary mission of the ALBATROSS III during the past summer was a survey of these new subdivisions of the Gulf Stream System. They found that at least as far as Flemish Cap the 200 meter average temperature chart provides a fairly good, although simplified, picture of the actual current system. It is already clear why statistical charts of surface currents seem to show that the Gulf Stream branches east of the Grand Banks. It is simply that in the averaging process these charts are not able to separate the several overlapping jetlets that exist at any given time.

Mr. Fuglister's new chart also indicates that the currents in trade wind latitudes may also be streaky and this is something that we hope to be able to examine at first hand next winter. Although we do not yet fully understand these unexpected phenomena, it is probable that we have been mistaken in thinking that the wind stress on the surface almost alone determines the characteristics of the major ocean currents. The present indication is that density differences due to heating, cooling, evaporation

and precipitation are able to modify to a considerable degree the circulation that would be expected to result from the winds alone.

In considering the wind stress on the sea surface it has only been practical up to now to think in terms of the average wind distribution. Mr. Joseph Chase, a meteorologist who joined our staff in the autumn of 1950, has been making a most interesting study of the typical wind patterns that occur over the North Atlantic month by month. These tend to persist for several weeks at a time and may be significantly different from the mean monthly winds. He is also beginning a study of the differences which occur from year to year.

The old problem of how velocity changes with depth continues to be nearly as much of a mystery as ever. Mr. von Arx has uncovered some important clues in the large number of geomagnetic electric kinetograph observations secured on operation CABOT. He finds that the effective electrical thickness of the current increases gradually in the down stream direction and very rapidly as one proceeds across the stream in the offshore direction. He also finds differences between the seaward and landward meanders. When the geomagnetic electric kinetograph was towed at 100 meters it yielded higher velocities than when towed at the surface.

Dr. Edmond E. Watson has been attacking the velocity-depth problem more directly. The last two summers he has made a series of current meter observations in the Gulf Stream. About all that can be said at present is that the velocity-depth distribution changes markedly as one proceeds across the current and is by no means simple in character.

Various means of overcoming the deficiencies of conventional current meters when used in the deep ocean are being actively explored. Dr. Willem V. R. Malkus has developed a sort of diving current meter which has considerable promise. Three such instruments have been built and will be thoroughly field-tested during the winter of 1952. The instrument records velocity against pressure as it is towed slowly through the water. At each depth to which the instrument is lowered and allowed to come to equilibrium a measure can be obtained of the influence of the velocity-depth profile on the steady forward speed of the ship. For example, if the ship is moving down current and the velocity decreases with depth, the Pitot tube in the instrument will record increasing velocity at each successively deeper level. By making a second cast after a 90° change in course the velocity-depth profile can be calculated. What this instrument chiefly exploits is the fact that a wire being towed through the water rather quickly comes into equilibrium with the forces acting on it. Thus in lowering the instrument only a short pause is needed at each level of observation before the Pitot tube begins to record a steady velocity and the pressure element a steady depth.

Much thought has been given to designing a deep sea pressure recorder that could remain on bottom for considerable periods of time. Mr. David H. Frantz, Jr., has begun building such a device, after studying the problem of giving it sufficient sensitivity to record not only the passage of the tidal wave, but also of standing waves. In addition, means will be incorporated for recording bottom temperature and bottom velocity. Several means have also been devised to insure recovery of the instrument.

Another general class of much needed instruments has advanced beyond the talking stage. These are drifting buoys which would report their positions by radio day by day. The receiver element of the buoys will be tuned to the Loran stations. For a short while each day, when the sending element is activated by the coming of daylight, the buoys will re-transmit these Loran signals at a different frequency to the monitoring ship or plane. Thus in effect the proposed design should achieve a drift bottle which day by day reports its position. The principal difficulty is to secure permission to use suitable frequencies for re-transmitting the Loran signals. It is hoped that by limiting the power output of the buoys so that their signals cannot be picked up on shore this permission can be obtained. Electronically the system has been demonstrated to be feasible.

Sound as a tool for exploring submarine geology has become the specialty of Dr. Maurice Ewing's new laboratory at Columbia University. He and his staff continue to work side by side with our people at sea to the great advantage of both groups.

Sound as a means for exploring the ocean waters is a goal towards which we are only gradually working. Dr. Hersey's paper on the frequency dependence of sound returned from the scattering layer at mid-depths is undergoing final revision. This suggests that sound may become a most useful tool in marine biology. By turning an echo sounding transducer on its side and mounting it in a crude "fish" so that it can be conveniently towed, Mr. Vine has shown of what the basic elements of an effective fish locator should consist. What is still missing is the time and funds to use these systems to advance a specific biological problem.

Mr. Paul F. Smith has continued his investigation of underwater sound scattering by various forms of marine life using a short-range echo ranging technique and variable frequency to evaluate the biological interpretation of the deep scattering layer. A comparison of the results with reported extreme values of volume scattering coefficients at the depth of the deep scattering layer is made which indicates that the observed scattered sound can be accounted for by a population of from 10 to 120 palaemonetes shrimp per cubic yard. These inshore shrimp are a reasonable substitute for the larger euphausids and were chosen as an initial physical test of H. B. Moore's

hypothesis that the scattering layer is predominantly composed of euphausids. The lower figure is in good agreement with Moore's estimate of euphausid density but the higher is too large. These measurements show that small shrimp are sufficiently effective sound scatterers to warrant serious consideration on physical, as well as on biological grounds, as part of the scatterers composing the deep scattering layer.

Various theoretical studies of refraction, defraction and focusing in underwater acoustics are under way through the help of several graduate students in physics who can come to the Institution during the summer months. Dr. Hersey and Mr. Vine have a common interest in this field and advances are being made steadily, if somewhat slowly. However, this is a valuable means of interesting students having the right sort of background in mathematics in some of the special problems of underwater acoustics.

Support for work in Marine Meteorology has been roughly doubled during the past year and the indications are that a continuing expansion will be justified, as we can find interested and qualified investigators.

Mr. Alfred H. Woodcock's studies of the role of sea salt nuclei in the formation of rain has been split off from the original project directed by Dr. Haurwitz. Mr. Woodcock has recruited two advanced students trained in physical chemistry to assist him in the enlarged program. In June at the request of meteorologists employed by the fruit growers of the Hawaiian Islands, Mr. Woodcock carried out a number of nuclei sampling flights in the clouds forming on the mountains of the islands. His preliminary results indicate, as was expected, that there is a good correlation between the number of larger salt nuclei present near the base of the cloud and the subsequent rainfall. He and Mr. Duncan C. Blanchard returned there in November for a continuing program of observation and because the islands are a convenient base from which to make exploratory observations on other phenomena over the ocean. There is much evidence in the recent meteorological journals that the full significance of Mr. Woodcock's investigations is finally becoming recognized.

We are fortunate that beginning in July Dr. Joanne S. Malkus could secure a 15-month leave of absence from her university and can thus join Mr. Andrew F. Bunker and Dr. Bernhard Haurwitz for an extended period in their studies of convection and turbulence over the ocean. It has been the fashion for some time now in meteorology to ignore the fact that theirs is a thermally driven system and that for much of the time air is flowing over the ocean rather than over the land. Thus the rather complicated processes whereby heat and water vapor are exchanged at the sea surface are of fundamental importance to both oceanography and meteorology.

Mr. Donald Parson, Jr., and Mr. Kenneth G. McCasland have been gradually much improving the instrumentation for these studies.

Our program in submarine geology at present essentially has three parts: the support we are giving to Dr. Ewing's group at Columbia, Mr. H. C. Stetson's continuing studies of the sediments of the Gulf of Mexico, and further studies of submarine geology in Massachusetts Bay.

Dr. Ewing's group at Columbia has become much more firmly established. A good fraction of his program comes under the heading of submarine geology, rather than submarine geophysics. The primary tool for the deep sea geology continues to be the ATLANTIS' trawl winch on which we spent nearly $20,000 two years ago. Dr. Ewing's collection of long, deep sea cores from the North Atlantic now numbers roughly 345.

Mr. Stetson's program deals systematically with an area of great interest to petroleum geology. Several years ago, with the help of a grant from the Geological Society of America, he and Dr. Phleger surveyed the western half of the Gulf of Mexico. The working up of this material is nearing completion. Last winter, therefore, a month was spent on ATLANTIS securing the corresponding samples from the eastern half. Perhaps the most spectacular find was a huge cliff paralleling the western coast of Florida for hundreds of miles. This rises almost vertically 5000 feet or more from the floor of the Gulf.

Dr. William S. Butcher, who has recently completed his formal training as a submarine geologist, has returned to Woods Hole and is in charge of new sedimentary studies in Massachusetts Bay. The sedimentary processes operating in harbors and estuaries are only understood in broad outline. Several of Mr. Stetson's students at Harvard assisted in the field work during the summer. The sedimentary studies are being conducted simultaneously with an oceanographic survey for which Mr. Dean F. Bumpus is directly responsible.

The special opportunity which oceanography offers to the biologist is to understand the conditions of life in an environment which differs markedly from the more familiar situations found on shore. So it is that the marine biologist is primarily an ecologist and is concerned in correlating physical and chemical phenomena of the sea with the characteristics of its populations. For this reason also, our biologists have trespassed into the field of physical oceanography and are doing pioneer work in exploring the conditions in coastal waters and embayments. Such waters are of great interest in relation to fisheries and because of the practical problems arising from industrial and domestic pollution, yet they have been largely neglected heretofore by the physical oceanographer.

An investigation which has been conducted during recent years on

the effects of the discharge of wastes from the titanium plant of the National Lead Company off New York Harbor has now been completed. A report entitled "The Disposal of Industrial Wastes at Sea" which is to be published by the National Research Council will emphasize the great potential of coastal waters for dispersing industrial pollutants. The scientific pay-off of this investigation is a monograph on the hydrography of the New York Bight by Drs. Ketchum, Redfield, and Ayers which appeared in *Papers in Physical Oceanography and Meteorology*.

In order to extend the detailed knowledge of such conditions as obtain off the Hudson River more widely, a survey was made in May from the ALBATROSS III of the entire coastal belt extending from Woods Hole to Cape Hatteras, thus including the outflow of the Delaware River and Chesapeake Bay along with that of the Hudson. As knowledge of the coastwise circulation increases in detail, it becomes apparent that the southerly longshore drift is continuous and rapid. The pattern of flow, however, is broken by large eddies and fluctuates rapidly with conditions of wind and season. Mixing is sufficiently intense so that the influence of one river system has disappeared before the drifting water has reached the next river mouth. As in the case of the Gulf Stream, increasingly detailed observations are showing that earlier concepts of the coastal circulation are vastly over-simplified.

Dr. B. H. Ketchum has described a method for estimating the rate of flushing of an estuary under the combined influence of the tidal currents and the discharge of tributary rivers. The great virtue of this procedure is that it yields useful results based on the analysis of information which may be obtained from charts, tide tables, and hydrological data and is thus available to engineers concerned with pollution problems. Dr. Ketchum's ideas, which grew out of studies of the circulation of Raritan Bay, where a trunk sewer outfall is under consideration, have had a stimulating effect on our theoretical oceanographers. Dr. Arnold B. Arons and Mr. Henry M. Stommel have recently attempted to translate his fundamental idea, that the element of mixing volume is bounded by the length of the tidal excursion, into the language of the physics of continua. They found that an *a priori* calculation of the flushing number was not feasible without a thorough study of the sorts of simplified conditions that could be set up in model studies. Mr. Harlow G. Farmer, Jr., a graduate in hydraulic engineering at M.I.T., was interested and qualified in just such work. He has set up a most versatile hydraulic flume which is now in operation in the back yard. Thus, again in a most fruitful manner field observations, pure theory, and model studies are proceeding hand in hand. While the theoretical approach in oceanography has on the whole been rather barren,

during the last few years the theoreticians have been catching up rapidly and it may be that before long they will actually begin to predict phenomena for the field observers to go out to look for.

Dr. Ketchum's method of analysis has found immediate application to biological problems. For some years a group directed by him has been studying the antibiotic effect of sea water upon colon bacteria and has determined the rates at which the bacterial populations are killed off on exposure to sea water. Since the analysis of the flushing permits one to estimate the age of the river water found in any part of its estuary, it is possible to determine how long the bacteria of a polluted river have been exposed to the antibiotic action of sea water and thus to estimate the relative importance of this action and the effect of dilution in reducing their numbers. In the case of the Raritan River, it may be shown that the antibiotic action of sea water is the major factor in reducing the bacterial pollution of the water of the estuary.

At the instigation of local oyster interests, the Town of Islip, Long Island, has engaged the Institution to make a survey of the waters of Great South Bay. This bay is the traditional source of the Blue Point Oyster and formerly produced an annual crop valued at more than $1,500,000. During the past twenty years, the crop has declined progressively owing to failure of the oysters to grow and fatten properly, and the oyster industry has now ceased to exist. An intensive survey made last summer indicated that the trouble is not due to hydrographic factors arising from changes in Fire Island Inlet and other openings to the sea, as was locally claimed, but pointed rather to pollution arising from the duck farms which occur along the tributaries of the bay. The Town of Islip has asked us to continue these studies and has been joined by the Town of Brookhaven in supporting the work. The damage to oysters appears to be due, not to the immediate effects of pollution, but to an intense bloom of algae which is stimulated to grow by the pollutants. Finally, Moriches Inlet, a critically placed opening to the sea, has closed since last summer's studies were made, so we are in a position to observe first hand the effects of this change on the circulation of the bay.

Ever since Dr. Rakestraw left our staff to join the faculty of the Scripps Institution of Oceanography, there has been no one in the laboratory concerned primarily with chemical oceanography. Somewhat over a year ago this weakness was corrected by the appointment as Chemical Oceanographer of Dr. Francis A. Richards, a chemist trained in the Oceanographic Laboratory at the University of Washington. Dr. Richards arrived in time to take over the development of special methods required for the work in Great South Bay. During last summer, Dr. Daniel R. Norton, Assistant

Professor of Chemistry at George Washington University, worked at the Institution and became interested in finding better methods of detecting the various metals present in sea water in traces. Such substances are known to be essential in the nutrition of animals and plants on land but relatively little is known of their relation to marine animals because of present difficulties in analysis. Dr. Norton and a graduate student assistant were at the laboratory throughout the summer. The chemical group was also strengthened by the presence of Dr. Mary A. Plunkett, Assistant Professor of Chemistry at Vassar College, a skilled analytical chemist. Finally, after many years, studies are being resumed on the biochemistry of marine animals. Mr. Gary Felsenfeld worked on the mechanism by which copper is bound in the molecule of hemocyanin. This is a problem which has become of interest recently because of the discovery that many important enzymes are copper-protein compounds analogous to hemocyanin.

These associations have gone a long way toward restoring chemistry to its proportionate place in the Institution, and in widening our relations with the universities.

The Institution has continued to work on shellfish for the Department of Conservation of the Commonwealth of Massachusetts. The primary object was to develop means of improving the production of clams by introducing farming methods. It must be admitted that our experience has been discouraging, it having been found that natural enemies are fatally destructive of the plantings. A great deal has been learned, however, about these predators, the horseshoe crab and the snail, Polynices. Perhaps the most valuable lesson is that clam farming should not be undertaken lightly. Mr. H. J. Turner and Dr. D. L. Belding are now turning their attention to studies in other areas where clams appear to grow naturally with greater success than on Cape Cod.

Other activities undertaken under this contract are more encouraging. Pacific oysters, a Japanese species grown commercially in Puget Sound, were introduced into Barnstable Harbor in 1949 and have survived and grown prodigiously. If this oyster will reproduce in our waters, it may form the basis for an oyster industry in the colder waters north of Cape Cod, where the Virginia oyster does not survive. Earlier surveys showed that the beds of the black quahogs, which occur in Cape Cod Bay and off Cuttyhunk, are sufficiently extensive to supply a fishery for the small-boat draggers if a market could be developed. During 1950, we supplied a food technology laboratory and several commercial dealers with small quantities of black quahogs for experimental purposes and there is now a good possibility that the industry will develop methods of processing this shellfish in a manner that will appeal to the consumer. Finally, studies are being con-

ducted on the natural history of the sea scallop, a species which has attained great commercial importance without benefit of scientific study.

Turning to the fin fish, Mr. William C. Schroeder has continued exploratory fishing for ground fish on the nearby continental shelf. The objectives have been to assay the possibilities of profitable fishing in the deep waters of the continental slope which are not regularly fished, to study the on and offshore migration of the fluke which are now taken just south of Woods Hole, and to secure an accurate census of all the kinds of fish living on the grounds where commercial fishing is conducted. Mr. Frank J. Mather III has been collecting information on the growth and migration of the tuna, which has become a popular sport fish. He is persuading the fishermen to use numbered hooks, which will serve to tag such fish as "get away" and thus show the extent of their migrations when they are recaptured.

Among our invertebrate zoologists, Dr. Mary Sears has continued her studies of the Siphonophores collected by the Danish ship DANA in an ocean-wide cruise. During the year, she has found it necessary to make a drastic revision of the classification of this group of animals, a task which has required the comparison of her specimens with those from the principal museums of Europe. Mr. John P. Barlow has been making a careful year-round study of the zooplankton of Great Pond, Falmouth. This is a small estuary tributary to Vineyard Sound. The problem has been to learn to what extent the pelagic population of a salt pond depends upon recruitment from the open sea with which the pond connects. It has become clear that the pond population maintains itself as a distinct entity, in spite of the continuous exchanges of water due to the tides.

At the present time, there is no one on the staff concerned primarily with the marine plants. Some work on the culture of marine phytoplankton is being done in connection with the Great South Bay studies, and Dr. Gordon A. Riley is paying particular attention to the contributions of the phytoplankton to the general economy of the sea. Mr. E. M. Hulburt, a visiting investigator, is studying the phytoplankton of Great Pond in a way complementary to Mr. Barlow's work on the zooplankton. It is important that we have someone available who knows the marine plants from the taxonomic as well as the ecological viewpoint. During the past year, we have given Fellowship aid to Mr. Robert W. Holmes, a student of Dr. Riley, to enable him to spend a year in Norway to obtain training in the taxonomy of the photyplankton.

A review of the year's work in marine biology would be incomplete without mention of a paper published by Dr. Gordon A. Riley on Oxygen, Phosphate, and Nitrate in the Atlantic Ocean. In this paper, Dr. Riley has

gathered together the pertinent data on the circulation, the chemistry and the biology of the North Atlantic and by use of bold methods has attempted to draw a picture of the system as a whole as a mechanism productive of life. This paper is undoubtedly the most original and ambitious contribution to marine biology which has appeared since the end of the war.

Among the distinguished visitors who were welcomed at the Institution for from one to several days, or weeks, to consult on scientific matters in their particular fields, were the following. Several, on invitation, gave lectures of their work.

Dr. Paul Vigoureux, Admiralty Research Laboratory, Teddington, England.
Dr. Svend E. Saxov, Danish Geodetic Commission, Denmark.
Mr. D. Rochford, C.S.I.R.O. Fisheries, Cronulla, Australia.
Dr. Abdel-Fattah Mohamed, Farouk I University, Alexandria, Egypt.
Prof. J. Fjeldstad, Geografisk Institutt, Oslo, Norway.
Dr. G. E. R. Deacon, Admiralty Research Laboratory, Teddington, England.
Dr. Koji Hidaka, Tokyo University, Tokyo, Japan.
Prof. Hilding Koehler, University of Uppsala, Sweden.
Mr. M. S. Longuet-Higgins, Trinity College, Cambridge, England.
Dr. H. Munro Fox, London University, England.
Dr. P. Karapiperis, National Observatory, Athens, Greece.
Dr. Wendell Mordy, Pineapple Research Institute, Honolulu, T.H.
Dr. Edwin Oswald Cook, Naval Research Establishment, Halifax, N. S.
Dr. Ken Sugawara, University of Nagoya, Japan.
Dr. Ivan Hessland, University of Uppsala, Sweden.

The persons whose names are listed below were members of the Institution (exclusive of Staff Members) for a period of six months or more during the calendar year 1951.

RESEARCH ASSISTANTS, ENGINEERS AND TECHNICIANS

Barbour, L. Hilliard
Bergstrom, Stanley W.
Bunce, Elizabeth T.
Cain, Henry A.
Campbell, Robert
Chase, Joseph
Clarke, Arnold H.
Corwin, Nathaniel
Davis, Lee C.
Denman, Nathaniel A.
Duys, Gerrit, Jr.
Edwards, Melville E.
Foster, Donald B.
Hall, Henry B. S.
Hammond, Willis T.
Hodgson, Sloat F.
Hunt, Otis E.
Iselin, Columbus O'D., Jr.
Keen, D. Jean
Kemp, James M.
Kittredge, Caroline F.
Klebba, Arthur
Knott, Sydney T., Jr.
Larson, Edward H.
McCasland, Kenneth G.
McLeod, Jean
Owen, David M.
Parson, Donald, Jr.
Pasley, Gale G., Jr.
Poole, Stanley E.
Schleicher, Karl E.
Shelnut, Eva M.
Shultz, William S.
Stern, Melvin
Stilwell, Jean
Wagner, Lansing P.

JUNIOR TECHNICIANS AND LABORATORY ASSISTANTS

Anderson, Nellie E.
Ash, Adelma A.
Atwood, Barbara
Brown, Joan A.
Childs, Shirley A.
Cobb, Mary C.
Crandall, Harriet
Davis, Priscilla A.
Diaco, Elizabeth S.
English, Jean
Farnan, Marjorie A.
Gallagher, Gloria
Holmes, Doris M.
Klebba, Constance F.
Mason, Barbara H.
Moskovits, Lillian D.
Scharff, Eileen J.
Scharff, Margaret
Silva, Alberta B.
Tollios, Evangeline P.

ADMINISTRATIVE AND SECRETARIAL

Backus, Jeanne M.
Broadbent, Madeline P.
Bryant, Edwin T.
Conlan, Marcus J.
Craig, Margaret W.
Dingwell, Eva Z.
Donald, Mary
Ferris, Alice H.
Griffin, T. S. Perry
Hahn, Jan
Hatzikon, Kaleroy L.
Malloy, Thomas C.
Mellor, Florence K.
Oakley, Gilbert, Jr.
Ortolani, Mary
Ostiguy, Betty P.
Parker, Evelyn M.
Schnabel, Dorothy L.
Souza, Jane C.
Wilson, Esther N.
Young, Anita M.

TECHNICAL SERVICES

Bailey, Frank A.
Blake, Forrest W.
Bodman, Ralph H.
Bowman, Warren O.
Condon, J. William
Dingwell, Paul E.
Eldridge, Stanley N.
Fisher, Stanley O.
Gallagher, William F.
Gaskell, Fred
Gifford, James E.
Hodgkins, Harry L.
Howland, Myron P., Jr.
Lane, Marian O'D.
Morrison, Kenneth
Rennie, Thomas D.
Ronne, F. Claude
Spencer, Allard T.
Stimpson, John W.
Thayer, Lawrence A.
Vail, Phyllis F.
Walden, Robert G.
Weeks, Doris May
Weeks, Robert G.
Whitney, G. G., Jr.
Whittemore, Eugene H.
Wing, Carleton R.

MAINTENANCE AND HOUSING

Backus, Harold
Christian, John A.
Handy, Harry H.
Howes, Elijah S.
Nickelson, Ellen T.
Rose, Manuel W.
Salthouse, James
Soderland, Ida S.
Solberg, Otto
Sparks, Elizabeth C.
Stansfield, Richard
Turner, Catherine
Wilde, Phillips B.
Wing, Nathaniel R.
Woodward, Fred C., Jr.
Wright, Carleton B.

OFFICERS, CREW MEMBERS AND VESSELS

ADDY, JOHN A.
BACKUS, CYRIL
BAHMER, ERNEST F.
BAILEY, JAMES S.
BALDWIN, JAMES F.
BARON, NORMAN
BARSTOW, ELMER M.
BEARSE, FRANCIS A. T.
BOSWORTH, RUSSELL E.
CAVANAUGH, JAMES J.
CLARKIN, JAMES J.
COLBURN, ARTHUR D., JR.
COLLINS, JOHN S.
CONLEY, WILLIAM J.
COOK, HANS
FAY, DONALD H.
FOSTER, HOWARD C.
FRICK, GEORGE P.
GRINNELL, RUSSELL, JR.
GROHT, RICHARD W.
HAZELL, RAYMOND
HEMPSTEAD, ROBERT L.
HERMANSEN, GEORG
KARLSON, ARVID
LAFFORD, GILBERT R.
LANE, ADRIAN K.
LAVITA, ANTHONY P., JR.
LINCOLN, VERNON R.
LINDSEY, ARNOLD M.
LITTLEJOHN, ROBERT E.
MACAULEY, FRANKLIN A.
MERCHANT, FLOYD L.
MYSONA, EUGENE J.
ORSER, DAVID A.
PARKER, CLIFTON V.
PEARSON, ROWLAND
PIERCE, SAMUEL F.
PIKE, JOHN F.
POOLE, MATHEW A.
RICHARD, MATHIEW
RODERICK, MILTON
SCHROEDER, JOHN J.
SPALDING, OAKES
STARRETT, DONALD A.
STEWART, ROBERT J.
VANZANDT, CLAIBORNE C., JR.

VI. PUBLICATIONS

The following forty-one papers were published during 1951:

	Contr. No.
ARONS, A. B., and HENRY STOMMEL. A mixing-length theory of tidal flushing. *Trans. Amer. Geophys. Union*, 32 (3): 419–421, 1 text fig. 1951	544
BIGELOW, H. B., and W. C. SCHROEDER. A new genus and species of anacanthobatid skate from the Gulf of Mexico. *J. Washington Acad. Sci.*, 41 (3): 110–113, 1 text fig. 1951	554
BIGELOW, H. B., and W. C. SCHROEDER. Three new skates and a new chimaerid fish from the Gulf of Mexico. *J. Washington Acad. Sci.*, 41 (12): 383–392, 4 text figs. 1951	555
CASTLE, E. S. Electrical control of marine fouling. *Indust. Eng. Chem.*, 43 (4): 901–904, 2 text figs. 1951	539
ERICSON, D. B., MAURICE EWING, and B. C. HEEZEN. Deep-sea sands and submarine canyons. *Bull. Geol. Soc. Amer.*, 62 (8): 961–965, 1 text fig. 1951	575
FUGLISTER, F. C. Annual variations in current speeds in the Gulf Stream system. *J. Mar. Res.*, 10 (1): 119–127, 6 text figs. 1951	557
FUGLISTER, F. C. Multiple currents in the Gulf Stream system. *Tellus*, 3 (4): 230–233, 2 text figs. 1951	584
FUGLISTER, F. C., and L. V. WORTHINGTON. Some results of a multiple ship survey of the Gulf Stream. *Tellus*, 3 (1): 1–14, 11 text figs. 1951	548
KETCHUM, B. H. Plankton algae and their biological significance. In: Manual of Phycology, Chronica Botanica Co., Waltham, Ch. 17: 335–346. 1951	366
KETCHUM, B. H. The exchanges of fresh and salt waters in tidal estuaries. *J. Mar. Res.*, 10 (1): 18–38, 5 text figs. 1951	516
KETCHUM, B. H. The flushing of tidal estuaries. *Sewage and Industrial Wastes*, 23 (2): 198–209, 7 text figs. 1951	536
KETCHUM, B. H., A. C. REDFIELD, and J. C. AYERS. The oceanography of the New York Bight. *Pap. Phys. Oceanogr. Meterol.*, 12 (1): 46 pp., 20 text figs. 1951	549
KLEBBA, A. A., and HENRY STOMMEL. A simple demonstration of Coriolis force. *Amer. J. Physics*, 19 (4): 247, 1 text fig. 1951	545
LANGWELL, P. A. Forced convection cell circulation in clear air. *Trans. Amer. Geophys. Union*, 32 (1): 7–14, 1951	527
LANGWELL, P. A. The onset of rain from cumuli. *J. Meteorol.*, 8 (5): 354–356. 1951	568
MALKUS, J. S., A. F. BUNKER, and KENNETH MCCASLAND. A formation of pileus-like veil clouds over Cape Cod, Massachusetts. *Bull. Amer. Meteorol. Soc.*, 32 (2): 61–66, 4 text figs. 1951	534
MENARD, H. W., and A. J. BOUCOT. Experiments on the movement of shells by water. *Amer. J. Sci.*, 249: 131–151, 4 text figs. 1951	546
MOORE, H. B. The seasonal distribution of oceanic birds in the western North Atlantic. *Bull. Mar. Sci., Gulf and Caribbean*, 1 (1): 1–14, 10 text figs. 1951	560
NORTHROP, JOHN. Ocean-bottom photographs of the neritic and bathyal environment south of Cape Cod, Massachusetts. *Bull. Geol. Soc. Amer.*, 62 (12): 1381–1384, 3 pls.	573
NORTHROP, JOHN, and B. C. HEEZEN. An outcrop of Eocene sediment on the continental slope. *J. Geol.*, 59 (4): 396–399, 1 text fig., 1 pl. 1951	523
PHLEGER, F. B., Ecology of Foraminifera, northwest Gulf of Mexico. Pt. 1. Foraminifera distribution. *Mem. Geol. Soc. Amer.*, No. 46: 88 pp., 33 text figs., 37 loose tables. 1951	565

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PHLEGER, F. B., and F. L. PARKER. Ecology of Foraminifera, northwest Gulf of Mexico. Pt. 2. Foraminifera species. *Mem. Geol. Soc. Amer.*, No. 46: 64 pp., 20 pls. 1951 566

POLLAK, M. J. The sources of the deep water of the eastern Mediterranean Sea. *J. Mar. Res.*, 10 (1): 128–152, 14 text figs. 1951 556

REDFIELD, A. C., and L. A. WALFORD. A study of the disposal of chemical waste at sea. Report of the Committee for Investigation of Waste Disposal. *Nat. Res. Council*, Publ. 201: 49 pp., 29 text figs. 1951 586

RILEY, G. A. Oxygen, phosphate, and nitrate in the Atlantic Ocean. *Bull. Bingham Oceanogr. Coll.*, 13 (1): 1–126, 33 text figs. 1951 542

RILEY, G. A. Parameters of turbulence in the sea. *J. Mar. Res.*, 10 (3): 247–256, 2 text figs. 577

SAID, RUSHDI. Foraminifera of Narragansett Bay. *Contr. Cushman Found., Foram. Res.*, 2 (3): 75–86, 4 text figs. 1951 491

SAID, RUSHDI. Organic origin of some calcareous sediments from the Red Sea. *Science*, 113 (2940): 517–518. 1951 540

SAID, RUSHDI. Preliminary note on the spectroscopic distribution of elements in the shells of some recent calcareous Foraminifera. *Contr. Cushman Found., Foram. Res.*, 2 (1): 11–13. 1951 541

SEIWELL, H. R. Experimental correlogram correlation analyses of artificial time series (with special reference to analyses of oceanographic data). In: Proc. Second Berkeley Symposium on Mathematical Statistics and Probability, Univ. Calif. Press: 639–666, 27 text figs. 1951. (published posthumously) . 531

SOULE, F. M. Physical oceanography of the Grand Banks region, the Labrador Sea and Davis Strait in 1949. *U.S.C.G. Bull.*, No. 35: 49–116, text figs. 12–33. 1951 550

SOULE, F. M. Physical oceanography of the Grand Banks region and the Labrador Sea in 1950. *U.S.C.G. Bull.*, No. 36: 61–127, text figs. 16–29. 1951 . . . 551

STOMMEL, HENRY. An elementary explanation of why ocean currents are strongest in the west. *Bull. Amer. Meteorol. Soc.*, 32 (1): 21–23, 2 text figs. 1951 . . 532

STOMMEL, HENRY. Entrainment of air into a cumulus cloud. II. *J. Meteorol*, 8 (2): 127–129, 5 text figs. 1951 533

STOMMEL, HENRY. Streaks on natural water surfaces. *Weather*, 6 (3): 72–74, pls. 9–10. 1951 538

STOMMEL, HENRY. Determination of the lateral eddy diffusivity in the climatological mean Gulf Stream. *Tellus*, 3 (1): 43. 1951 552

STOMMEL, HENRY, and A. H. WOODCOCK. Diurnal heating of the surface of the Gulf of Mexico in the spring of 1942. *Trans. Amer. Geophys. Union.*, 32 (4): 565–571, 5 text figs. 1951 553

TOLSTOY, IVAN. Submarine topography in the North Atlantic. *Bull. Geol. Soc. Amer.*, 62 (5): 441–450, 3 text figs., 6 pls. 1951 559

TURNER, H. J., JR., ET AL. Third report on investigations of methods of improving the shellfish resources of Massachusetts. Comm. Mass., Dept. Conserv., Div. Mar. Fish., 31 pp., 3 text figs. 1951 564

VON ARX, W. S. Dead reckoning by surface current observation. *J. Inst. Navigation*, London, 4 (2): 9 pp., 2 text figs. 526

WOODCOCK, A. H., and A. F. MCBRIDE. Wave-riding dolphins. *J. Exp. Biol.*, 28 (2): 215–217. 1951 522

APPENDIX

January–December 1951

ATLANTIS

Cruise No.	Departure and Return	Days Duration	Ports of Call	Scientist in Charge
167	4 Jan. 23 ~~22~~ Jan.	18	Woods Hole to Bermuda, to Miami.	Mr. B. H. Heezen
168	28 ~~23~~ Jan. 30 ~~29~~ Jan.	6	Miami to Straits of Florida and return.	Dr. H. B. Moore
169	2 Feb ~~31 Jan.~~ 11 ~~10~~ Feb.	10	Miami to Mobile.	Mr. C. R. Hayes
170	16 Feb. 19 Mar.	31	Mobile to Miami.	Mr. M. J. Pollak
171	21 Mar. 24 Apr.	34	Miami to Nassau, Blake Plateau, Guantanamo.	Dr. J. B. Hersey
172	26 Apr. 6 June	41	Nassau to Guantanamo, San Juan, Bermuda, Woods Hole.	Dr. J. B. Hersey Dr. W. M. Ewing
173	7 Aug. 19 Sept.	44	Woods Hole to Bermuda to Argentia, Newfoundland and return.	Dr. J. L. Worzel
174	1 Oct. 4 Oct.	3	To sea.	Mr. R. F. Wyrick
175	14 Oct. 19 Oct.	5	Woods Hole to south of Block Island and return.	Mr. H. R. Johnson
176	24 Oct. 26 Oct.	2	To sea.	Mr. H. R. Johnson
177	Nov. Dec.	12	To sea — short trips.	Dr. J. B. Hersey

CARYN

C–20	3 Feb. 21 Mar.	46	Woods Hole to Bermuda, to Nassau.	Mr. B. H. Heezen
C–21	23 Mar. 26 Apr.	34	Miami to Guantanamo.	Mr. S. W. Bergstrom
C–22	26 Apr. 6 June	41	Nassau to Guantanamo, San Juan, Bermuda, Woods Hole.	Mr. S. W. Bergstrom Dr. W. M. Ewing
C–23	25 June 29 June	4	To sea.	Dr. J. B. Hersey
C–24	5 July 19 July	14	Woods Hole to Cape Sable to Georges Bank and return.	Dr. J. L. Worzel
C–25	7 Aug. 20 Sept.	44	Woods Hole to Bermuda, Argentia, Grand Banks and return.	Dr. J. L. Worzel
C–26	23 Oct. 27 Oct.	4	Woods Hole to Georges Bank and Southward to 1000 fathom curve and return.	Dr. B. H. Ketchum
C–27	13 Nov. 14 Nov.	2	To sea.	Dr. W. V. R. Malkus
C–28	Dec.	10	To sea—short trips.	Mr. A. C. Vine

ALBATROSS III

A–40	8 May 22 May	14	Woods Hole to Cape Hatteras and return.	Mr. A. R. Miller
A–41	6 June 31 Oct.	147	Woods Hole to St. Johns to Londonderry, No. Ireland, to Plymouth, England, to Azores to Bermuda, to Woods Hole.	Mr. F. C. Fuglister Mr. L. V. Worthington