

THE
WOODS HOLE OCEANOGRAPHIC
INSTITUTION

REPORT FOR THE YEAR
1938

I. TRUSTEES

(As of December 31, 1938)

To serve until 1942

CHARLES FRANCIS ADAMS, Boston, Mass.
THOMAS BARBOUR, Museum of Comparative Zoölogy, Cambridge, Mass.
JOHN A. FLEMING, Carnegie Institution, Washington, D.C.
FRANK B. JEWETT, New York, N.Y.
ALBERT EIDE PARR, Bingham Oceanographic Foundation, New Haven, Conn.
ELIHU ROOT, JR., New York, N.Y.

To serve until 1941

THE COMMANDANT (Admiral R. R. Waesche), U. S. Coast Guard, for the time being,
Washington, D.C.
MARION EPPLEY, Newport, R.I.
LAMAR R. LEAHY, U. S. Navy, Washington, D.C.
T. H. MORGAN, California Institute of Technology, Pasadena, Calif.
THE DIRECTOR (Admiral L. O. Colbert), U. S. Coast & Geodetic Survey, for the time
being, Washington, D.C.
B. W. ST. CLAIR, Cambridge, Mass.

To serve until 1940

WILLIAM BOWIE, Washington, D.C.
A. G. HUNTSMAN, University of Toronto, Toronto, Canada.
COLUMBUS O'D. ISELIN, Woods Hole Oceanographic Institution, Woods Hole, Mass.
ALFRED C. REDFIELD, Harvard University, Cambridge, Mass.
HENRY L. SHATTUCK, Boston, Mass.
T. WAYLAND VAUGHAN, Washington, D.C.

To serve until 1939

ISAIAH BOWMAN, Johns Hopkins University, Baltimore, Md.
E. G. CONKLIN, Princeton University, Princeton, N.J.
ALEXANDER FORBES, Harvard Medical School, Boston, Mass.
ROSS G. HARRISON, Yale University, New Haven, Conn.
FRANK R. LILLIE, University of Chicago, Chicago, Ill.
HARLOW SHAPLEY, Harvard University, Cambridge, Mass.

Ex Officio

HENRY B. BIGELOW, Museum of Comparative Zoölogy, Cambridge, Mass.
LAWRASON RIGGS, JR., New York, N.Y.

OFFICERS

FRANK R. LILLIE, President of the Corporation, University of Chicago, Chicago, Ill.
LAWRASON RIGGS, JR., Treasurer, 120 Broadway, New York, N.Y.
HENRY B. BIGELOW, Clerk of the Corporation, Museum of Comparative Zoölogy,
Cambridge, Mass.

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II. MEMBERS OF THE CORPORATION

(As of December 31, 1938)

CHARLES FRANCIS ADAMS, Boston, Mass.
THOMAS BARBOUR, Museum of Comparative Zoölogy, Cambridge, Mass.
HENRY B. BIGELOW, Museum of Comparative Zoölogy, Cambridge, Mass.
WILLIAM BOWIE, Washington, D.C.
ISAIAH BOWMAN, Johns Hopkins University, Baltimore, Md.
THE COMMANDANT (Admiral R. R. Waesche), U. S. Coast Guard, for the time being,
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being, Washington, D.C.
BENJAMIN M. DUGGAR, University of Wisconsin, Madison, Wis.
MARION EPPLEY, Newport, R.I.
JOHN A. FLEMING, Carnegie Institution, Washington, D.C.
ROSS G. HARRISON, Yale University, New Haven, Conn.
A. G. HUNTSMAN, University of Toronto, Toronto, Canada.
COLUMBUS O'D. ISELIN, Woods Hole Oceanographic Institution, Woods Hole, Mass.
FRANK B. JEWETT, New York, N.Y.
LAMAR R. LEAHY, U. S. Navy, Washington, D.C.
FRANK R. LILLIE, University of Chicago, Chicago, Ill.
ALFRED L. LOOMIS, Tuxedo Park, N.Y.
T. H. MORGAN, California Institute of Technology, Pasadena, Calif.
ALBERT E. PARR, Bingham Oceanographic Foundation, New Haven, Conn.
ALFRED C. REDFIELD, Harvard University, Cambridge, Mass.
LAWRASON RIGGS, JR., New York, N.Y.
ELIHU ROOT, JR., New York, N.Y.
B. W. ST. CLAIR, Cambridge, Mass.
HARLOW SHAPLEY, Harvard University, Cambridge, Mass.
HENRY L. SHATTUCK, Boston, Mass.
T. WAYLAND VAUGHAN, Washington, D.C.

III. REPORT OF THE TREASURER

TO THE MEMBERS AND TRUSTEES OF THE
WOODS HOLE OCEANOGRAPHIC INSTITUTION:
GENTLEMEN:

The accounts for the year 1938 have been audited by Messrs. Stagg, Mather & Hough, public accountants.

During the year bonds costing \$196,779.20 were sold or redeemed at a profit of \$6,087.38, to which must be added \$2,494.81 the reserve for amortization of bond premiums applicable to these bonds, making a total profit of \$8,582.19. There was invested \$177,486.75 from endowment cash in securities.

There was added to special income account, extra dividends on endowment fund stocks amounting to \$1,487.50 and \$306.75 dividends in stock and \$436. income on the securities of the fund itself.

The gross income received during the year on the securities held at the end of the year in the endowment fund was .0420 of the cost of those securities, and .0435 of their then market value.

A grant of \$1,000. was received from the Carnegie Corporation for operating expenses.

The operating expenses were under the budget by about \$1,000. The expenses of upkeep of plant exceeded the budget by \$5,746.68. Of this about \$1,500. is due to repairs and improvement of the grounds after the hurricane (which considerably damaged the driveway and parking space) and the rest of the excess is due to the fact that replacements on the ship were made from current funds.

Summaries of the various accounts appear on pages 6, 7, and 8.

Respectfully submitted,

LAWRASON RIGGS, JR.,

Treasurer

BALANCE SHEET

ENDOWMENT FUND ASSETS

	QUOTED MAR- KET VALUE		
Endowment Fund assets:			
Bonds.....	<u>\$1,364,345.00</u>	\$1,438,299.51	
Stocks.....	<u>\$ 967,027.50</u>	974,914.86	
Cash (including \$553.25 due from current funds—Cash).....		31,878.00	\$2,445,092.37
Reserve fund assets:			
Bonds.....	<u>\$ 4,720.00</u>	\$ 5,470.00	
Stocks.....	<u>\$ 16,172.00</u>	19,098.99	
Cash.....		2,275.65	26,844.64
			<u>\$2,471,937.01</u>

PLANT ASSETS

<i>Laboratory plant:</i>			
Land.....	\$ 27,072.32		
Buildings.....	323,213.12		
Laboratory equipment.....	21,361.93		
Crew room equipment.....	557.95		
Library.....	10,700.00	\$ 382,905.32	
<i>Ship "Atlantis":</i>			
Construction.....	\$ 218,674.47		
Equipment.....	27,298.50	245,972.97	
Small boat and equipment.....		6,570.55	
			\$ 635,448.84
Depreciation fund assets (for periodic replacements):			
Bonds (quoted market value \$21,412.00).....	\$ 21,000.00		
Cash.....	12,648.02	33,648.02	
			\$ 669,096.86

CURRENT ASSETS

Current funds—Cash.....	\$ 14,670.13		
Less—Due to Endowment fund cash.....	553.25	\$ 14,116.88	
Special income account:			
Investments:			
Bonds (quoted market value \$12,780.00)....	\$ 12,375.00		
Stocks (quoted market value \$ 1,946.25)....	1,950.25		
Cash.....	6,020.61	20,345.86	
Interest receivable.....		348.35	
			<u>\$ 34,811.09</u>

DECEMBER 31, 1938

ENDOWMENT FUND RESERVES

Endowment fund reserve—General.....	\$2,000,000.00		
Endowment fund reserve—For upkeep of plant...	419,419.96		
			<u>\$2,419,419.96</u>
<i>Add:</i>			
Realized net gain on securities called or sold.....	\$19,406.44		
Reserve for amortization of bond premiums.....	6,265.97	25,672.41	\$2,445,092.37
Reserve Fund.....	\$30,000.00		
<i>Less:</i>			
Adjustment occasioned by sale of Imco Participating Certifi- cates.....	6,604.43	\$ 23,395.57	
<i>Add</i> —Reserve fund income.....		3,449.07	26,844.64
			<u>\$2,471,937.01</u>

PLANT FUND RESERVES

Plant fund reserve—General.....	\$ 607,642.13		
Plant fund reserve—From current account.....	27,806.71	\$ 635,448.84	
Reserve for depreciation (reserve for periodic replacements).....			33,648.02
			<u>\$ 669,096.86</u>

CURRENT LIABILITIES AND SURPLUS

Accounts payable.....	\$	8,110.44	
Reserve for "working balance".....		5,000.00	
Current surplus:			
Balance at December 31, 1937.....	\$24,592.26		
<i>Less</i> —Excess of expenses over income for the year ended December 31, 1938.....	2,891.61		21,700.65
			<u>\$ 34,811.09</u>

STATEMENTS OF INCOME FROM ENDOWMENT FUND INVESTMENTS AND
CURRENT ASSETS, AND EXPENSES APPLICABLE THERETO, INCLUDING
EXPENDITURES FOR PERMANENT PLANT ADDITIONS

FOR THE YEAR ENDED DECEMBER 31, 1938 AND FOR THE YEAR ENDED DECEMBER 31, 1937

	YEAR ENDED DECEMBER 31, 1938	YEAR ENDED DECEMBER 31, 1937
Income:		
Income from endowment funds:		
Interest.....	\$63,530.07	\$64,696.11
Dividends.....	46,154.77	56,317.01
	\$109,684.84	\$121,013.12
Less—Custodian fees and expenses.....	1,490.73	1,468.73
	\$108,194.11	\$119,544.39
Carnegie Corporation grant for operating expenses.....	1,000.00	—
Total income.....	\$109,194.11	\$119,544.39
	<i>Budget</i>	
Expenses:		
Upkeep of plant:		
Upkeep of buildings and grounds \$	6,425.00	\$ 8,116.00
Upkeep of "Atlantis".....	9,000.00	12,978.78
Upkeep of "Asterias".....	150.00	52.62
Insurance.....	6,155.99	5,816.74
Depreciation.....	4,800.00	4,800.00
	\$ 26,530.99	\$ 31,764.14
Operating Expenses:		
Operation of "Atlantis".....	\$ 29,350.00	\$28,901.55
Operation of "Asterias".....	900.00	900.58
Scientists' salaries.....	28,679.00	27,200.14
Scientific supplies and equipment	4,500.00	4,516.44
Traveling expenses.....	565.00	424.56
Publications.....	3,500.00	2,327.72
Administration.....	8,825.00	7,098.19
Amortization of bond premiums.	2,000.00	1,800.63
Contribution to retirement fund.	1,784.60	1,771.19
Not allocated.....	265.41	—
	\$ 80,369.01	74,941.00
	\$106,900.00	\$106,705.14
Total expenses.....	\$107,900.00	107,305.14
Expenditures for permanent plant additions:		
Additions to library.....	600.00	600.00
	112,085.72	107,905.14
Excess of expenses over income for 1938.....	\$ 2,891.61	\$ 12,239.25
Excess of income over expenses for 1937.....	\$ 2,891.61	\$ 12,239.25

IV. NINTH ANNUAL REPORT OF THE DIRECTOR FOR THE YEAR 1938

BY HENRY B. BIGELOW

Equipment

New shelving for the storage of publications was installed; a room has been set apart for the storage of plankton samples which are now beginning to assume formidable proportions; and the U. S. Coast and Geodetic Survey has reconstructed the tide gauge house on the dock under a grant from the Public Works Administration.

Our work in physical oceanography has now reached a point where it is necessary to anchor "Atlantis" in deep water with our trawling wire, and after some experiment, a gallows has been installed at the bow for this purpose.

While "Atlantis" was in the shipyard last November and December, the ballast was removed in the after hold, the skin cleaned and covered with bitumastic before restowing; the port anchor chain was regalvanized; the linoleum in two cabins was replaced and wooden gratings were substituted for the lineoleum in the deck laboratory; and a new battery set was installed.

The engine of "Asterias" was thoroughly overhauled and certain repairs made to the hull.

The most important additions to our scientific equipment during the past year have been 30,000 feet of new $\frac{1}{2}$ inch steel trawling wire and 22,000 feet of hydrographic wire; several "Otter" and "Blake" trawls; two Monaco deep sea fish traps; a "Hjort" bottom sampler and two other similar, but simpler, bottom samplers; a set of bolting silk plankton nets; 5 flow meters for plankton nets; ten new deep sea thermometers; a microscope; and a drill press for the machine shop. The recording current meter, on the development of which Professor Watson has been employed, has received a first successful trial on "Atlantis."

Library

Our contribution of \$600. to the library of the Marine Biological Laboratory allowed subscription to 41 current journals and monographs, the completion of two back sets, purchase of six books, and the binding of 45 volumes. Seven current journals were received as gifts, while 70 current journals were added by exchange, and about 390 other reprints and pamphlets were placed in the library.

Personnel

The only changes in the scientific staff have been the appointments of Dr. Raymond B. Montgomery as Junior Oceanographer, Mr. D. Q. Anderson as Bacteriological Technician and Dr. Sidney Hsiao as Technician in Physical Oceanography; and the resignation of Mr. Dayton E. Carritt as Chemical Technician.

The following have worked at the laboratory during the past summer under fellowships: David D. Bonnet, Edward M. Brooks, Coit M. Coker, Robert H. Hay, Clifford E. Herrick, Jr., Charles W. Hock, Lois C. Lillick, Frances L. Parker, Robert C. Stauffer, Harold A. Thomas, Jr., Th. von Brand and Talbot H. Waterman, the latter carrying on his work at the Bermuda Biological Station. Twelve assistants have worked for various members of the staff during part of the year. There have been three volunteer workers.

The following visiting investigators have worked at the Laboratory during the year: Dr. A. A. Abramowitz, Mr. Gardner Emmons, Dr. Maurice Ewing, Dr. Stina Gripenberg, Dr. Frederick L. Hisaw, Dr. B. H. Ketchum, Dr. Clinton M. Osborn, Dr. G. H. Parker, Mr. Charles L. Schneider, Mr. A. F. Spilhaus, Dr. K. V. Thimann, Dr. George Wald, Dr. C. P. Winsor, Dr. E. F. Thompson and Mr. Herman Yagoda:

Through the generosity of a friend, the salary was supplied for the services of a skilled mechanic for the months of July and August.

The following institutions were represented during the year in the laboratory or on cruises of "Atlantis": Barat College, Barnard College, Bermuda Biological Station for Research, Harvard University, Lehigh University, Massachusetts Institute of Technology, New York University, Princeton University, Queen's University, Rutgers University, U. S. Coast Guard, U. S. Navy, U. S. Weather Bureau, University of North Carolina and University of Pennsylvania.

There have been no changes in the officers of "Atlantis." "Asturias" was in charge of Captain Norman Cleaves, assisted by William Butcher, William Glidden and Charles Taylor.

Travel

Professor Iselin visited the Bermuda Biological Station in April; Dr. Seiwel spent most of the winter working at Scripps Institution of Oceanography; Dr. Clarke spent the summer at the Trout Lake Laboratory of the University of Wisconsin; Professor Waksman attended a soil science congress in Finland, afterwards making other European visits in connection with his researches. And Dr. Montgomery went to Europe, in September, under a National Research

Council Fellowship, to work first with Professor Defant, at the Institut für Meereskunde, in Berlin, and later to visit other oceanographic laboratories.

Publications

Volume V, No. 4, and Volume VI, Nos. 1 and 2, of Papers in Physical Oceanography and Meteorology were printed.

The following contributions were published during the year:

- No. 136. Schalk, Marshall. A Textural Study of the Outer Beach of Cape Cod, Massachusetts. *Jour. Sedimentary Petrology*, Vol. 8, No. 2, pp. 41-54. 1938.
- No. 147. Bigelow, Henry B. Plankton of the Bermuda Oceanographic Expeditions. VIII. Medusae taken during the Years 1929 and 1930. *Zoologica*, Vol. XXIII, Part 2. No. 5, pp. 99-189. 1938.
- No. 152. Seiwel, H. R. and Gladys Eddy Seiwel. The Sinking of Decomposing Plankton in Sea Water and its Relationship to Oxygen Consumption and Phosphorus Liberation. *Proc. Am. Philos. Soc.*, Vol. 78, No. 3, pp. 465-481. 1938.
- No. 154. Soule, Floyd M. Oceanography. Excerpt from International Ice Observation and Ice Patrol Service in the North Atlantic Ocean, Season of 1936. *U. S. Coast Guard Bull.*, No. 26, pp. 33-82. 1938.
- No. 159. Redfield, Alfred C. and Ancel B. Keys. The Distribution of Ammonia in the Waters of the Gulf of Maine. *Biol. Bull.*, Vol. LXXIV, No. 1, pp. 83-92. 1938.
- No. 160. Waksman, Selman A., Margaret Hotchkiss, Cornelia L. Carey and Y. Hardman. Decomposition of Nitrogenous Substances in Sea Water by Bacteria. *Jour. Bacteriology*, Vol. 35, No. 5, pp. 477-486. 1938.
- No. 161. Waksman, Selman A. and Unto Vartiovaara. The Adsorption of Bacteria by Marine Bottom. *Biol. Bull.*, Vol. LXXIV, No. 1, pp. 56-63. 1938.
- No. 162. Seiwel, H. R. Application of the Distribution of Oxygen to the Physical Oceanography of the Caribbean Sea Region. *Papers in Physical Oceanography and Meteorology*, Vol. VI, No. 1, pp. 1-60. 1938.
- No. 163. Von Brand, Theodor. Quantitative Determination of the Nitrogen in the Particulate Matter of the Sea. *Jour. d. Conseil*, Vol. XII, No. 2, pp. 187-196. 1938.
- No. 165. Waksman, Selman A. and Margaret Hotchkiss. On the Oxidation of Organic Matter in Marine Sediments by Bacteria. *Sears Found. Jour. Mar. Res.*, Vol. I, No. 2, pp. 101-118. 1938.
- No. 166. Clarke, George L. Seasonal Changes in the Intensity of Submarine Illumination off Woods Hole. *Ecology*, Vol. 19, No. 1, pp. 89-106. 1938.
- No. 167. Spilhaus, Athelstan F. A Bathythermograph. *Sears Found. Jour. Mar. Res.*, Vol. I, No. 2, pp. 95-100. 1938.
- No. 168. Clarke, George L. Light Penetration in the Caribbean Sea and in the Gulf of Mexico. *Sears Found. Jour. Mar. Res.*, Vol. I, No. 2, pp. 85-94. 1938.
- No. 169. Stetson, Henry C. Present Status of the Problem of Submarine Canyons. *Proc. Amer. Philos. Soc.*, Vol. 79, No. 1, pp. 27-33. 1938.
- No. 170. Montgomery, R. B. Fluctuations in Monthly Sea Level on Eastern U. S. Coast as Related to Dynamics of Western North Atlantic Ocean. *Sears Found. Jour. Mar. Res.*, Vol. I, No. 2, pp. 165-185. 1938.

- No. 171. Iselin, C. O'D. The Influence of Fluctuations in the Major Ocean Current on the Climate and the Fisheries. The Collecting Net, Vol. XIII, No. 7, pp. 1-4. 1938.
- No. 172. Ketchum, Bostwick H. and Alfred C. Redfield. A Method for Maintaining a Continuous Supply of Marine Diatoms by Culture. Biol. Bull., Vol. LXXV, No. 1, pp. 165-169. 1938.
- No. 174. Leavitt, Benjamin B. The Quantitative Vertical Distribution of Macrozoöplankton in the Atlantic Ocean Basin. Biol. Bull., Vol. LXXIV, No. 3, pp. 376-394. 1938.
- No. 175. Rakestraw, Norris W. and Victor M. Emmel. The Solubility of Nitrogen and Argon in Sea Water. Jour. Phys. Chem., Vol. 42, No. 9, pp. 1211-1215. 1938.
- No. 176. Welsh, J. H. and F. A. Chace, Jr. Eyes of Deep-Sea Crustaceans II. Sergestidae. Biol. Bull., Vol. LXXIV, No. 3, pp. 364-375. 1938.
- No. 177. Seiwel, H. R. Eddy Diffusion at Mid-Depths in the Caribbean Sea Region. Jour. d. Conseil, Vol. XIII, No. 2, pp. 155-162. 1938.
- No. 178. Stetson, H. C. The Sediments of the Continental Shelf off the Eastern Coast of the United States. Papers in Physical Oceanography and Meteorology, Vol. V, No. 4, pp. 1-48. 1938.
- No. 179. Parr, Albert Eide. Further Observations on the Hydrography of the Eastern Caribbean and Adjacent Atlantic Waters. Bull. Bingham Oceanographic Coll., Vol. 6, Art. 4, pp. 1-29. 1938.
- No. 180. Iselin, C. O'D. A Promising Theory Concerning the Causes and Results of Long-Period Variations in the Strength of the Gulf Stream System. Trans. Am. Geophys. Union, Nineteenth Annual Meeting, pp. 243-244. 1938.
- No. 181. Seiwel, H. R. Use of Non-Conservative Properties of Sea Water to Physical Oceanographical Problems. Nature, Vol. 142, p. 164. 1938.
- No. 182. Rakestraw Norris W. and Victor M. Emmel. The Relation of Dissolved Oxygen to Nitrogen in Some Atlantic Waters. Sears Found. Jour. Mar. Res., Vol. I, No. 3, pp. 207-216. 1938.
- No. 183. Johnson, W. H. The Effect of Light on the Vertical Movements of *Acartia clausi* (Giesbrecht). Biol. Bull., Vol. LXXV, No. 1, pp. 106-118. 1938.
- No. 185. Rossby, C.-G. On the Mutual Adjustment of Pressure and Velocity Distributions in Certain Simple Current Systems, II. Sears Found. Jour. Mar. Res., Vol. I, No. 3, pp. 239-263. 1938.
- No. 186. Seiwel, H. R. Über die ganz- und halbtägige Mondkomponente der internen Wellen im westlichen Nordatlantischen Ozean. Annalen der Hydrographie u. maritimen Meteorologie, Heft X, pp. 485-487. 1938.
- No. 188. Carey, Cornelia L. The Occurrence and Distribution of Nitrifying Bacteria in the Sea. Sears Found. Jour. Mar. Res., Vol. I, No. 4, pp. 291-304. 1938.
- No. 189. Lillick, Lois C. Preliminary Report of the Phytoplankton of the Gulf of Maine. The Amer. Midland Nat., Vol. 20, No. 3, pp. 624-640. 1938.
- No. 190. Montgomery, R. B. Circulation in Upper Layers of Southern North Atlantic Deduced with Use of Isentropic Analysis. Papers in Physical Oceanography and Meteorology, Vol. VI, No. 2, pp. 1-55. 1938.
- No. 198. Clench, W. J. and C. G. Aguayo. Notes and Descriptions of New Species of Calliostoma, Gaza and Columbarium (Mollusca); Obtained by the Harvard-Havana Expedition off the Coast of Cuba. Mem. Soc. Cub. Hist. Nat., Vol. 12, No. 5, pp. 375-384. 1938.
- No. 200. Bermúdez, Pedro J. Resultados de la Primera Expedicion en las Antillas del Ketch Atlantis bajo los Auspicios de las Universidades de Harvard y Habana. Mem. Soc. Cub. Hist. Nat., Vol. 12, No. 5, pp. 385-388. 1938.

Coöperation

The physical investigations from the coast out to Bermuda, in coöperation with Bermuda Biological Station, have now fallen in place as one of the regular items of our activities and seven profiles were run during the past year, in one of which Dr. E. F. Thompson, hydrologist of the Bermuda Station, participated. "Atlantis" was also able to take Drs. Garstang and Gurney from Bermuda for some deep sea towing and occupied a line of stations to obtain data for Dr. Thompson around the islands. The possibility that mutual shifts in mean sea level on the two sides of an ocean current may give a measure of the velocity of the latter, has recently received considerable attention. In the hope of reaching a solution, a tide gauge, supplied by the U. S. Coast and Geodetic Survey, was installed by Mr. Woodcock at Cat Cay in the Bahamas last winter, to allow comparison of the marigrams obtained there with those from Miami on the opposite side of the Straits of Florida. Mr. Woodcock also assisted in setting up a tide gauge at Bermuda.

In September "Atlantis" took Dr. Ewing on another cruise for further tests of his seismic apparatus in connection with the investigations mentioned in earlier reports, in which we have coöperated with Lehigh University and the Geological Society of America. Cores, in localities where the bottom deposits are not stratified, were also obtained for the Carnegie Institution, for studies in magnetism.

During the winter "Atlantis" in charge of Mr. William C. Schroeder, accompanied by Drs. Luis Howell Rivero, Pedro J. Bermúdez and Carlos Guillermo Aguayo from the University of Havana, carried out a biological survey of the mid-depth bottoms around Cuba in coöperation with Harvard University and the University of Havana, the collecting gear being provided by the two institutions. We have to thank the University of Havana for courtesies extended while in Cuba, and the U. S. Navy for assistance while the ship was in Guantanamo.

While it is still too early for accurate appraisal of the results, we can say that in spite of much difficulty with bad bottom, an astonishingly large collection was secured, especially of fishes, crustacea, echinoderms and mollusks, including a large number of new species. Reports on the various groups are now in preparation by several specialists with a view to publication.

In April and May "Atlantis" made a cruise to Georges Bank, for haddock investigations for the U. S. Bureau of Fisheries, in charge of Mr. John Webster of the Bureau.

Finally "Asterias" collected diatoms in large quantity (about 12

liters of diatom sludge), near Gloucester, during April, under a grant from the Carnegie Corporation, for use by Professor Hans Clarke in investigations which have already revealed an unusual biochemical composition, possibly explaining reactions of great theoretic and economic importance.

Field Work

Operations of "Atlantis" for the year 1938:

Cruise 74: January-April; circumnavigation of Cuba.

Cruise 75: April-May; Georges Bank.

Cruise 76: May; off Montauk Point.

Cruise 77: May-July; Bermuda.

Cruise 78: July-August; south of Montauk Point.

Cruise 79: August; Gulf of Maine.

Cruise 80: August-September; across the Gulf Stream on the Montauk Point-Bermuda line.

Cruise 81: September; south of Woods Hole

Cruise 82: September-October; Bermuda

Summary of observations:

Total distance sailed, miles.....	14,763
Number of days at sea.....	246
Deep hydrological stations.....	164
Shallow hydrological stations.....	42
Serial temperature lowerings for internal waves....	272
Plankton hauls.....	391
Bottom trawl hauls.....	204
Bottom samples.....	37

"Asterias" was in commission from early April when she spent six weeks collecting diatoms near Gloucester, to September. During the summer she was employed as usual, on short trips near shore and in the Gulf of Maine.

Staff Meetings

Nine staff meetings were held at which the speakers were Norris W. Rakestraw, Clifford E. Herrick, Jr., Cornelia L. Carey, Mary Sears, Charles E. Renn, C.-G. Rossby, Columbus O'D. Iselin, G. H. Parker, A. Abramowitz, C. M. Osborn, D. Q. Anderson, Wm. C. Schroeder, Stina Gripenberg and E. E. Watson.

A seminar was also held weekly by the various workers in physical oceanography.

Scientific Program

The chief lines of investigation in which the Institution is engaged may be summarized as follows:

Physical oceanography and meteorology

Internal waves. The subject of internal waves has been much to the fore of late. In June Dr. Seiwel occupied a fourteen-day station, between Bermuda and the Gulf Stream, on "Atlantis," taking repeated observations on temperature and salinity at close vertical intervals.

An analysis of the effect of vertical movements on temperature, salinity, dynamic topography, and related characteristics is under way, together with a theoretical investigation of the mechanism involved. And a preliminary report on the 12 and 24 lunar hour components of vertical motion, as shown at an eight day "Atlantis" station in 1937 has been published by Dr. Seiwel. Examination of the effect of submarine waves on calculations of dynamic topography is also in progress.

Synoptic studies. Two reports have been published, one by Dr. Montgomery on the circulation of the upper sub-surface layers of the southern North Atlantic deduced chiefly by the use of isentropic analysis, the other by Dr. Seiwel on the distribution of oxygen in the Caribbean sea region. Dr. Seiwel is also extending his studies of the minimum oxygen layer to a consideration of its relation to a nearly constant density surface to the South Atlantic, Eastern Pacific, and Indian Oceans. And one of our fellowship holders, Mr. Coit M. Coker, has nearly completed a report on the relation of the minimum concentration of oxygen in the Caribbean to other chemical and physical properties of the water.

Professor Iselin has made good progress in his studies of the scheme of circulation in the waters along the continental slope of Northeastern America, especially of the mixing processes along the northern edge of the Gulf Stream; also of the diurnal and seasonal thermal cycle in the surface layer. And a large body of data has been accumulated as to the seasonal and annual changes in strength of the Gulf Stream System, on the cruises of "Atlantis," in coöperation with the Bermuda Laboratory.

Mr. Soule's work on the Ice Patrol, including 4 current surveys of this critical region, yielded valuable evidence as to the depth of the most nearly motionless level beneath the Atlantic current and as to the direction of flow of the deep counter current.

Professor Watson's calculations of dynamic conditions in the

Gulf of Maine at all seasons of the year have yielded a series of pictures showing the seasonal changes and the interchanges of water at certain times with the neighboring Scotian banks and with the slope water beyond Georges Bank. With the calculations completed, it is hoped that it will soon be possible to publish an account of the most recent ideas about the circulation in the Gulf of Maine and of coastal waters in general.

Theoretical studies. Professor Rossby completed the second part of his theoretical study of the adjustment of the internal mass distribution in the ocean to changes in the current distribution caused by changes in the wind distribution at the sea surface, indicating that dynamic changes in the interior of the ocean, that accompany large scale changes in the currents at the sea surface, must be felt all the way down to the bottom, as very slow turbulent horizontal motions. This tentative conclusion is now being tested on oxygen, and if verified is likely to have a profound influence on present views as to circulation in the deep oceans.

Professor Spilhaus investigated the origin of the apparently retrograde eddies observed on the edge of the Gulf Stream by a study of frictionally driven eddies in the air, also by comparison of observed motion with geostrophic potential gradient on isentropic surfaces. And he has continued his examination of circulatory patterns set up in a rotating tank.

Instrumental. The recording current meter which was built last summer under Professor Watson's supervision was tested, successfully, on "Atlantis" to a depth of 250 meters. And the automatic recording apparatus, which goes on the ship, was perfected.

Professor Spilhaus has likewise developed two instruments for the purpose of speeding up observations in the surface layers of the ocean; namely a Bathythermograph, and a pressure operated Multiple Sea Sampler. The rapid technique made possible by these instruments will, it is hoped, make a closer approach to synoptic observations practicable.

Biological-chemistry of sea water

The more strictly chemical division of the Institution has carried on four lines of work during the last year:

1. A seasonal survey of the waters between Woods Hole and Bermuda, in coöperation with the hydrographic and biological work on this line of stations, the goal being a complete chemical picture for the annual cycle.

2. A study of dissolved gaseous nitrogen and argon in sea water. Two papers on this subject were published.

3. A study of dissolved helium and neon in sea water, to determine whether, indeed, the distribution of these gases is irregular, as has been previously reported.

4. Continued experimental decomposition and regeneration of nitrogenous organic matter in the sea.

Professor Redfield and Dr. Keys have also published an account of the ammonia content of the waters of the Gulf of Maine; Professor Redfield of the phosphorus. Professor von Brand made analyses of the nitrogen content of the particulate matter in samples secured at six stations during the Bermuda program, also of decomposing diatoms. And Dr. and Mrs. Seiwel continued their study of the settling velocities of decomposing particles in sea water, using an apparatus designed to measure the effects of compression and of stratification of the water column.

Marine bacteriology

Most of the projects in bacteriology have a common goal, namely the investigation of the decomposition of organic matter in the sea.

In connection with Mr. Anderson's studies on organic matter in the various strata of marine sediments and its availability for bacterial decomposition, cores were collected with a newly devised sampler at various stations in the Gulf of Maine and in the vicinity of Woods Hole. Professor Carey investigated the distance, down into the mud, to which nitrifying organisms exist, while Dr. Hock studied the rate of decomposition of chitin in mud, in sand, and in sea water, as well as the morphological and physiological characteristics of pure cultures of chitin-attacking bacteria.

Dr. Renn continued his studies of the availability of nitrogen in the sea, in conjunction with Professors Rakestraw and von Brand, and is engaged on the development of a respirometer for measuring the rate of oxygen utilization by bottom sediments.

Professor Thimann began a study of the conditions governing the precipitation of calcium carbonate from sea water, and of the rôle of bacteria in promoting such precipitation.

Dr. H. A. Thomas tested the applicability, to salt water, of the methods in use for the detection of sewage pollution in fresh water, using mud and water samples collected at several stations along a line beginning in New Bedford harbor, and extending about 15 miles into Buzzards Bay.

Physiology of marine organisms

Physiological work, of the more strictly oceanographic sort, was devoted, as usual, to the conditions of life of copepods and diatoms.

Mr. Bonnet measured the oxygen consumption of copepods, particularly *Calanus finmarchicus*, using a Dixon constant-pressure respirator adapted for use with small animals, with parallel measurements by the Winkler method for comparison with previous work upon the oxygen consumption of copepods.

Under Professor Redfield's direction, Dr. Ketchum developed a method for growing pure cultures of the marine diatom *Nitzschia Closterium* in large quantities on which the formation of various organic compounds of phosphorus in the cell was studied, the investigation also including analyses of fat, of sugar and of protein formation by cells grown under various environmental conditions.

Mr. Stauffer determined, for this same diatom, the intensity of illumination at which photosynthesis just balances respiration, an important point in diatom economy because light intensity is the principle factor determining the greatest depth to which diatoms can grow and contribute to the economy of the sea.

Dr. Osborn, under Professor G. H. Parker's supervision, studied the physiological mechanism involved in the color adaptation of several species of local flat fishes to black and white backgrounds, and to light and dark, the behavior of innervated and denervated areas of their skins, and their responses to a variety of drugs and hormones.

Professor Hisaw and Dr. Abramowitz completed the investigation, which was begun last summer, of the normal reproductive cycle of the smooth dogfish, *Mustelis canis*; continued their observations on the more complicated reproductive cycle of the spiny dogfish, *Squalus acanthius*; and studied the seasonal distribution of estrogenic hormone in the latter species.

Dr. George Wald, on a short visit, continued his work on the distribution of vitamins A₁ and A₂ among liver oils and eye tissues of various local fishes.

Plankton studies

Dr. Lillick worked on a general account of the phytoplankton of the Gulf of Maine, based on all available information, of which her own investigations of collections made on "Atlantis" cruises form the chief item; and Professor Redfield completed a study of the distribution of the pteropod, *Limacina*, in relation to the circulation of the Gulf of Maine.

Mr. Coker made a quantitative analysis of the vertical distribution of the chaetognaths previously collected by the "Atlantis" in deep water at stations along the profile between Woods Hole and Bermuda. Dr. Winsor continued his statistical examination of the

results of simultaneous and successive hauls of plankton nets of various types, with a view to establishing and evaluating the variability arising from different causes. And Dr. Sears and I completed our report on quantitative distribution of the zoöplankton of the continental shelf between Cape Cod and Chesapeake Bay.

Finally, in connection with Dr. Clarke's studies of planktonic production in different ocean waters, 7 surveys were made on the Montauk-Bermuda line, including 371 hauls of various kinds at 60 stations. Analysis of the catches is now in progress.

Fisheries biology

Besides the Fisheries cruise mentioned elsewhere (p. 13), Mr. William Gosline studied the abundance of different year classes, and the growth types, among Canadian herring, in relation to the problem of local races, under Mr. Schroeder's supervision.

Submarine geology

Mr. Stetson, in continuation of his studies on marine sediments, obtained 23 additional long cores with the Piggot gun, from "Atlantis" at representative localities along the continental slope, between the offings of New York and of Chesapeake Bay, both in the valley-bottoms, and on the intervening ridges. And Dr. Joseph A. Cushman and Miss Frances L. Parker, in their study of the faunal ranges of the foraminifera along the eastern coast of the United States, have practically completed the mechanical work of sorting the samples from the seven northern traverses, while the species of two of these have been studied in detail.

V. STAFF

(As of December 31, 1938)

- HENRY B. BIGELOW, Professor of Zoölogy, Harvard University, Director
CORNELIA L. CAREY, Assistant Professor of Botany, Barnard College, Research Associate in Marine Bacteriology
GEORGE L. CLARKE, Tutor and Instructor in Biology, Harvard University, Junior Biologist
COLUMBUS O'D. ISELIN, Assistant Professor of Physical Oceanography, Harvard University, and Assistant Curator of Oceanography, Museum of Comparative Zoölogy, Research Associate in Physical Oceanography
RAYMOND B. MONTGOMERY, Junior Oceanographer
A. E. PARR, Director of Peabody Museum and Curator of the Bingham Oceanographic Collection, Yale University, Research Associate in Oceanography
NORRIS W. RAKESTRAW, Associate Professor of Chemistry, Brown University, Research Associate in Physical Chemistry
ALFRED C. REDFIELD, Professor of Physiology, Harvard University, Research Associate in Biology
C. E. RENN, Tutor in Biology and Instructor in Sanitary Engineering, Harvard University, Junior Marine Bacteriologist
C.-G. ROSSBY, Professor of Meteorology, Massachusetts Institute of Technology, Oceanographer
H. R. SEIWELL, Investigator in Oceanography
FLOYD M. SOULE, Senior Physical Oceanographer, U. S. Coast Guard, Research Associate in Oceanography
ATHELSTAN F. SPILHAUS, Assistant Professor of Meteorology, New York University, Investigator in Physical Oceanography
HENRY C. STETSON, Research Associate in Paleontology, Museum of Comparative Zoölogy, Research Associate in Submarine Geology
SELMAN A. WAKSMAN, Microbiologist, New Jersey Agricultural Experiment Station, Marine Bacteriologist
E. E. WATSON, Assistant Professor of Physics, Queen's University, Research Associate in Physical Oceanography
CAPTAIN SIR HUBERT WILKINS, Honorary Research Associate in Oceanography
DAVID Q. ANDERSON, Bacteriological Technician
DEAN F. BUMPUS, Biological Technician
SIDNEY T. C. HSIAO, Technician in Physical Oceanography
ALFRED WOODCOCK, Oceanographic Technician
-
- WILLIAM C. SCHROEDER, Business Manager
MRS. VIRGINIA WALKER SMITH, Secretary and Administrative Assistant
WILLIAM SCHROEDER, Superintendent of Buildings and Grounds

APPENDIX

Reports of progress by investigators working at the Institution during 1938.

ZOÖPLANKTON STUDIES

HENRY B. BIGELOW AND MARY SEARS

Our report on the quantitative distribution of the Zoöplankton of the continental shelf waters, Cape Cod to Chesapeake Bay, was completed for publication.

THE RESPIRATION OF *CALANUS FINMARCHICUS*

DAVID D. BONNET

A study of the respiration of *Calanus finmarchicus* at different temperatures was made, using a manometric respirometer of the Dixon-Haldane constant pressure type. It was found that the oxygen consumption of this copepod from local waters was of the same order of magnitude as that of copepods from European waters as determined by Marshall, Nicholls, & Orr at Plymouth, in 1935, with values ranging from 0.32 at 5° C. to 0.91 at 17° C. (expressed in cc. O₂/hour/1000 animals).

LIGHT PENETRATION AND TRANSPARENCY OF SEA WATER; ZOÖPLANKTON STUDIES

GEORGE L. CLARKE

1. Measurements of light penetration were made at intervals at standard stations in coastal water, in continental slope water, and in Sargasso water using instruments sensitive respectively to the whole visible spectrum and to the green wave lengths only. The three localities differed sharply in transparency, but the water at each was found to be optically homogeneous. Seasonal differences were greatest in the coastal water. Samples of water from these three stations and from three others near Woods Hole were also analyzed in the monochromator at the University of Wisconsin both before and after Berkefeld filtering. The absorption of filtered sea water from the off-shore stations was found to be practically identical with distilled water. Coastal water was shown to contain a filter-passing material which exerts a highly selective action on light and which is not present in off-shore waters.

2. The influence of temperature and of food on the survival and growth of the copepod *Calanus finmarchicus* was investigated in a series of laboratory experiments. At 3° C. survival was good, but the

growth of the animals was retarded regardless of the amount of food provided. At 6° C. and 9° C. survival was inferior, but a larger amount of successful moulting occurred, and both were directly influenced by food.

3. A plankton sampler has been developed, in which a precise measure of the amount of water strained by the net is given by a volume meter, and five have been put into operation. The samplers have proven useful for quantitative zoöplankton studies, particularly in coastal water where animals are abundant, and also for detecting differential currents in subsurface strata.

4. The zoöplankton of three typical areas of the ocean was studied throughout the year by means of net hauls and collections made with the plankton sampler from the "Atlantis" on her sections from Montauk Point toward Bermuda. Standard stations were made in the center of the coastal water, in the continental slope water, and in the Sargasso water and six subsidiary stations were interposed. Qualitative and quantitative analysis of the material has been commenced. Since the section was traversed nine times, it should be possible to detect the seasonal variations in each area as well as the particular differences between the areas.

PHYSIOLOGY OF REPRODUCTION IN THE DOGFISHES, *MUSTELIS CANIS* AND *SQUALUS ACANTHIUS*

F. L. HISAW AND A. A. ABRAMOWITZ

The account, presented in our last report, of the normal reproductive cycle of the smooth dogfish was fully confirmed. One event—that concerning ovulation—which had not been studied was worked out. Ovulation does not occur completely without copulation.

Data were accumulated on the normal cycle of the spiny dogfish, dealing chiefly with the growth of the embryo and ovogenesis. The data we have at present indicate a gestation period of 22 months.

Considerable more tissue for chemical work on the naturally occurring hormones in the gonads of both the spiny and the smooth dogfishes was accumulated.

In the smooth dogfish, attempts made the previous summer to stimulate the reproductive tract of immature specimens by injections of pure sex hormones were unsuccessful. We tried again with an improved technique and obtained very successful results. In male yearlings, male hormone accelerated the growth of the claspers while in female yearlings, female sex hormone produced a maturation of the genital tract equivalent to that seen in a normal three year old specimen.

HYDROLOGICAL INVESTIGATIONS

C. O'D. ISELIN

In preparing a report on the "Atlantis" surveys of the eastern slope water area, it has become necessary to examine critically the various indirect methods of determining subsurface current direction. This has led to some clarification of the basic assumptions on which these methods depend and to a better understanding of their reliability. It has also led to the conclusion that as soon as possible a new instrumental technique must be developed, for it has become evident that the ordinary water-bottle observations are not capable of explaining the large scale mixing processes along the borders of such a current as the Gulf Stream. Besides new instruments, it will probably become necessary to enlist the cooperation of at least one additional ship, for it is probable that the "Atlantis," working alone, will not be able to adequately survey the frictionally-driven eddies which often are met with north of the Gulf Stream.

The routine observations on the Montauk Point-Bermuda line now provide 16 sections for a study of the variability of the Gulf Stream. A preliminary report on this material was sent to the Bermuda Oceanographical Committee of the Royal Society of London in December. Dr. Thompson has spent a good deal of time at Woods Hole during the past year and has made considerable progress with the accumulated observations from the neighborhood of Bermuda. In recent months the "Culver" has been able to take over the local routine observations.

During the past summer Mr. E. M. Brooks made a computation of the surface transport resulting under certain assumptions from the mean winter winds over the North Atlantic. He also drew up a report on the instrumental requirements of the proposed program for measuring the friction between the winds and the sea surface. This information, along with other suggestions, has been forwarded to the Committee on Questions of the Interaction between the Sea and the Atmosphere of the International Union of Geodesy and Geophysics.

PHYTOPLANKTON INVESTIGATIONS

LOIS C. LILLICK

Large-scale culturing of the diatom *Nitzschia Closterium* was carried on under Professor Redfield's supervision, and experiments were made with Professor Rakestraw on the growth of diatoms in recrystallized sea salts. A preliminary examination was made of recently collected phytoplankton from the continental slope and Gulf

Stream. Tables of the phytoplankton collected in past years by "Atlantis" in the Gulf of Maine were published. And a general report on the seasonal and regional distribution of pelagic plants, in the Gulf, was brought nearly to completion.

STUDIES OF OCEANIC CIRCULATION BASED ON ISENTROPIC ANALYSIS

RAYMOND B. MONTGOMERY

A study of the circulation in the upper strata of the North Tropical Atlantic based on isentropic analysis was completed and published. This work was continued in Berlin, with Professor Defant, at the Institut für Meereskunde.

THE PHYSIOLOGY OF COLOR CHANGE IN FLATFISHES

CLINTON M. OSBORN

Experiments on the mechanisms of color change were made on the winter flounder, *Pseudopleuronectes americanus*, on the sand dab, *Lophopsetta maculata*, and on the summer flounder, *Paralichthys dentatus*. All of these species adapt markedly in shade to black or white illuminated backgrounds. Spots of contrasting shade characteristic of each species exhibit specific background responses.

Blinding in *Pseudopleuronectes* and *Lophopsetta* results in an intermediate brown shade quite free from spots.

Denervated areas darken in pale animals but subsequently fade if constantly illuminated. Vigorous excitement causes marked pallor in denervated areas due presumably to an adrenalin-like substance in the blood. Adrenalin injections produce a similar pallor. Innervated areas in black-adapted fishes also pale temporarily following excitement and characteristic "spotting" responses are elicited. White-adapted fishes darken to excitement and exhibit dark local spots.

Extracts of the pituitary of *Paralichthys dentatus* contain melanophore-dispersing materials as evidenced by their darkening effects in test frogs and catfishes. Nevertheless, injections of relatively high doses of four different pituitary preparations failed to darken pale *Pseudopleuronectes*.

CHEMICAL INVESTIGATIONS

NORRIS W. RAKESTRAW

1. The data accumulated along the Montauk-Bermuda profile, mainly by the chemical technician, Mr. D. E. Carritt, on seven

cruises, now covers a full year's cycle, and provides material for a fairly comprehensive picture of the chemical changes in the three principal water masses between Woods Hole and Bermuda during the year.

2. The study of the decomposition and regeneration of nitrogenous organic matter, begun in 1936 in collaboration with Professor von Brand and Dr. Renn, has been considerably extended, and a paper combining results of 1937 with those of 1938 is now in preparation. In fifteen months' time it has been possible to carry out three successive cycles of decomposition and regeneration in the same water and to observe, both qualitatively and quantitatively, a number of factors influencing these changes. The influence of anaerobic conditions has been studied and the groundwork laid for a more thorough study of the rates at which the various changes take place under different conditions.

3. An investigation of the helium content of sea water, carried out principally by Mr. C. E. Herrick, has been practically finished. We were unable to confirm the earlier reports of a correlation between the oxygen minimum and a supposed helium minimum, and believe we can trace the earlier results to the technique used in carrying out the difficult and laborious analysis. Samples from two stations, both showing a very distinct oxygen minimum, indicated a practically constant helium distribution at all depths. Samples from the Pacific, which we had obtained for this work, had apparently stood too long before use, but we hope to get another set with which to corroborate the data from the Atlantic.

STUDIES ON THE BIOLOGY OF THE GULF OF MAINE, AND OF THE PHYSIOLOGY OF DIATOMS

ALFRED C. REDFIELD

The growing of diatoms and certain other algae in mass cultures at a rate sufficient to make possible a variety of studies on the biochemical processes of these forms was successful and was continued during the summer in collaboration with Drs. B. H. Ketchum and Lois Lillick.

Dr. Ketchum completed a study of the conditions controlling the removal of phosphate and nitrate from sea water by marine diatoms which is being prepared for publication.

A paper showing the important rôle which the drift water plays in the distribution of plankton in the Gulf of Maine, based on collections made by the "Atlantis" in 1933-34 was published.

Dr. Sidney Hsiao published two papers which constitute the first

detailed studies of the phenomena of sex reversal in an oceanic pteropod.

THEORETICAL ANALYSIS

C.-G. ROSSBY

The theoretical work on the relation between velocity distribution and mass distribution was continued during the year and the second part of the report of this general investigation was published. The investigation continues.

STUDIES ON FISHES

WILLIAM C. SCHROEDER

1. *The Deep Water Fauna around Cuba.* During February and March "Atlantis" made a deep sea bottom trawling cruise around the island of Cuba to collect fishes and any other animals that could be obtained. A total of 103 hauls were made in depths ranging from 200 to 3886 meters. Of these 76 were successful. The gear consisted of 35 and 60-foot otter trawls, and 10 and 14 foot "Blake" trawls with rigid frame.

Particularly good catches were made between depths of 300 and 1500 meters. Estimates of the total catch include about 250 species of fishes together with about 800 species of invertebrates, exclusive of foraminifera and, of these thousand-odd species, about 100 are believed to be new.

The fishes are being studied by Dr. Luis Howell Rivero of Havana University, and myself, while the various other groups are in the hands of specialists.

2. *Migrations of Gulf of Maine Cod.* Studies of cod scales were made from time to time. This material was collected during the period 1924-1931 in the course of cod marking experiments and analyses thus far made indicate that stocks of fish such as those living on Georges Bank, Nantucket Shoals or along the coast of Maine have distinct types of scales. The Nantucket cod, for example, have an average of about 20 circuli in the first zone of growth whereas Georges cod may have an average of 18 and Maine cod only 15 or 16. If this difference of circulus count proves constant from year to year for various regions within the Gulf of Maine, it will provide a useful means for studying the migrations of the local stocks of cod.

3. *Herring.* Studies of herring scales were made during the summer by Mr. William Gosline who utilized material chiefly from Nova Scotia. Analyses were made of age classes and possible racial

groups but the results have not yet progressed far enough to yield definite results.

PROBLEMS OF OCEANIC CIRCULATION

H. R. SEIWELL

1. *Caribbean Sea*. Results of the reduction and study of oxygen data (obtained by "Atlantis" in 1933 and 1934) with reference to the circulation of this region, were published.

2. *Internal Waves*. Between January 1 and May 1, I was at the Scripps Institution of Oceanography to consult with Professors Sverdrup and McEwen on various theoretical and practical aspects of this problem. The continuous series of internal wave measurements obtained in 1937 have been partially analyzed, and a resumé of the harmonic constants for 24 and 12 lunar hour waves published. In June, two weeks of continuous observations were obtained from "Atlantis" in the same locality (northwest of Bermuda) as the 1936 and 1937 observations. In October the American Philosophical Society granted sufficient funds to employ a full time technician to assist with the problems. During the summer (assisted by Gladys Eddy Seiwell and later, by Andrew Stergion) research on the internal wave phenomenon was confined principally to practical aspects, with the object of estimating the significance of short period vertical oscillations of the water column in hydrostatic problems in the North Atlantic.

3. *Sinking of Organic Particles in Sea Water*. Results of laboratory studies on settling rates of decomposing organic matter in sea water were published in collaboration with Gladys Eddy Seiwell. During the summer technique was improved and measurements on the sinking of organic matter through a sea-water column of approximately six meters were continued.

4. *Origin of the Minimum Oxygen Concentration*. During the year progress was made on the problem, with the assistance of Coit M. Coker, by the investigation of density surfaces along which the principle minimum oxygen concentration has been observed.

5. *Applications of Methods of Mathematical Statistics to Oceanographic Data*. Systematic inquiry into methods adaptable for precise analysis of oceanographic field data was continued, in collaboration with Dr. George P. Wadsworth. Progress has been made chiefly in problems involving frequency distributions and correlation—a resumé of which was presented to the Statistical Congress in the autumn.

PHYSICAL OCEANOGRAPHY OF THE GRAND BANKS
REGION AND LABRADOR SEA

FLOYD M. SOULE

The oceanographic section of U. S. Coast Guard Bulletin No. 27 (season of 1937) was completed for publication, with the development of evidence that a most nearly motionless level beneath the Atlantic Current east of the Grand Banks exists at a depth of about 2000 or 2500 meters and that below this level the deep water is in motion in a direction counter to the overlying Atlantic Current. The months of April, May, June and the first part of July were spent on the oceanographic vessel of the International Ice Patrol Force, the U.S.C.G. Patrol Boat *General Greene*, in the region of the Grand Banks, supplying topographic dynamic charts of the region to the Ice Patrol cutters *Tahoe* and *Pontchartrain*. During this period four current surveys of the critical area were made, the resulting charts being referred to the 1000-decibar surface although at most of the oceanographic stations the temperature and salinity measurements extended to a depth of 1400 meters where the depth of water permitted. In this work 268 oceanographic stations were occupied. Early in June a section was run from the Tail of the Grand Banks across both the Labrador and Atlantic Currents as far south as latitude 39° N. On this section temperature and salinity measurements extended to a depth of between 2000 and 2500 meters. From July 22 to August 17 serial observations of temperature and salinity were made at 39 oceanographic stations during a post-season cruise in the Labrador Sea, along sections (1) South Wolf Island, Labrador, to Cape Farewell, Greenland, (2) Longitudinal section from section (1) to Davis Strait Ridge, (3) On Davis Strait Ridge from the "West Ice" to Holsteinsborg, Greenland. Most of these stations were occupied from the surface to as near bottom as was practical.

In addition to the temperature and salinity observations, samples were collected for the determination of dissolved helium and oxygen from section (2) and from three stations in the middle of section (1); and 451 fathometer soundings were taken along these sections. These soundings have been corrected and tabulated and supplied to the U. S. Hydrographic Office and to the International Hydrographic Bureau. A continuous sonic sounding section was made along the continental shelf from Davis Strait to the Strait of Belle Isle to obtain information regarding the existence or non-existence of submarine canyons in this region.

FRICTIONALLY DRIVEN EDDIES

ATHELSTAN F. SPILHAUS

The attempt to obtain a representation and explanation of some impermanent current systems in the ocean (eddies in the neighborhood of the Gulf Stream) has proceeded along the following lines.

1. A detailed investigation of a large anticyclonic eddy in the atmosphere and its development under the influence of a frictional "drive," provided by the semipermanent stream of westerlies to the north, has been completed. This analysis in the atmosphere is of oceanographic interest in view of the implications it has regarding the possibility of a similar mechanism existing in the ocean in the neighborhood of a well developed permanent current. If such a mechanism exists it may provide some explanation for "retrograde" eddies in the vicinity of the Gulf Stream and further it means that the eddies will be temporary and that the main stream will suffer lateral displacements for comparatively short periods in accordance with their growth and decay. Patterns exhibiting some of the principal characteristics of the above system have been reproduced in the rotating tank.

2. The temporary nature of these eddies, which has of course been realized before, but which is emphasized by this work has created a need for a new instrumental technique in the form of rapid measuring instruments which will provide observations approximating more closely to synchronous conditions. Two instruments have been developed to this end: first, the Bathythermograph, for obtaining a continuous record of temperature and depth in the ocean and secondly, a companion instrument which may be described as a Pressure Operated Multiple Sea Sampler, for taking samples rapidly at various predetermined depths (pressures) for salinity and oxygen determinations. Preliminary tests of the Sea Sampler indicate that it will be ready in the near future for routine use. Further development of the Bathythermograph is proceeding. By the use of these instruments the time involved in the collection of data will be greatly reduced. Of particular significance in this connection is the fact that the use of these instruments will not require a hydrographic winch nor is it necessary to completely stop the vessel.

PHOTOSYNTHESIS OF ALGAE

ROBERT C. STAUFFER

Studies of the relation between the rate of photosynthesis and intensity of illumination were made on the diatom *Nitzschia Closterium*

either grown in bacteria-free cultures in 500 cc. Erlenmeyer flasks, or in species-pure mass cultures in large glass cylinders. An attempt was made to obtain fresh diatoms from Vineyard Sound, but it did not prove possible to separate the phytoplankton from zoöplankton and bacteria in a state pure enough for experiment. For comparison with the cultured diatoms, two wild fixed algae were also used, one red, *Porphyra umbicalis*, and one green, *Ulva lactuca*. All experiments were carried out with Warburg manometers, using as a medium sea water saturated by an atmosphere with 5% CO₂.

For all three forms the compensation intensity at which oxygen production and respiration just balance fell within a narrow range not varying more than 40%. It was found that the cell concentrations affected the rate of photosynthesis noticeably when they ranged between 5.5×10^6 to 3.6×10^7 cells per cc.; the higher concentration naturally showed the lower rate per million cells. Under mass culture the one diatom species showed far greater variation in photosynthesis at different times, than did wild forms as widely separated as red and green algae. On the other hand, diatoms cultured in flasks under uniform conditions showed reasonably uniform behavior.

STUDIES IN SEDIMENTATION AND ON THE GEOLOGY OF THE CONTINENTAL SHELF

H. C. STETSON

In collaboration with Dr. J. A. Cushman, Miss Frances L. Parker and Dr. Fred B. Phleger, work on the sediments of the continental slope and of the nearby Atlantic Basin, as described in the last report is progressing satisfactorily; Dr. Phleger's report is finished and Dr. Cushman's and Miss Parker's is well advanced. My own section necessarily has to depend on the paleontological evidence supplied by the reports of the others and has just been started.

Through the kindness of Dr. A. C. Veatch his new charts of the continental slope, shortly to be published by the Geological Society of America, were made available for last summer's cruise. Cores were taken at topographically significant points in the canyons and on the slope from the Hudson Gorge to the latitude of Chesapeake Bay. The mechanical analyses have been completed.

The report on the sediments of the continental shelf was completed and published, and the chapter on the development of Oceanography, particularly along geological lines, was completed for the Geological Society of America's forthcoming anniversary volume. A short report was also prepared for a symposium on the Coastal Plain held at the Richmond meeting of the American Association for the Advancement of Science.

Dr. Maurice Ewing conducted further tests with his deep sea seismograph, and also experimented with an apparatus for retrieving instruments from the bottom without a wire, the lifting force being supplied by oil-filled containers.

THE PRECIPITATION OF CALCIUM CARBONATE

KENNETH V. THIMANN

Experiments were made on the conditions governing the precipitation of CaCO_3 from waters, and the effect of the presence of excess CaCO_3 on the process, phenomena of importance for the understanding of the formation and dissolution of chalk banks, shells, etc.

Fresh sea water (Vineyard Sound) precipitates no CaCO_3 on standing, up to 15 days, but the addition of calcite causes a steady precipitation which reaches a maximum (at room temperature) of about 10 mg. per liter in 200 hours. Vigorous shaking has little effect on the rate of precipitation. Since the amounts of precipitate are so small, experiments were extended to distilled water saturated with calcium bicarbonate. This material precipitated CaCO_3 steadily on standing. Vigorous shaking hastens the precipitation but does not change the final value, which is reached in about ten days. The addition of calcite promotes the precipitation, but the same effect is exerted, though to a less extent, by powdered MnO_2 or by sugar charcoal. Thus the reaction is partially due to the provision of a large surface.

According to the literature, Woods Hole sea water should be strongly supersaturated with CaCO_3 ; on the other hand our data above show that precipitation is extremely slow, does not take place unless calcite is added, and in any event does not reach the expected values. This could be explained by the binding of the calcium carbonate by organic matter. Experiments on the addition of bacteria isolated from sea water on asparagine media, or of *b. coli* and some other organisms, showed no effect either on sea water or on the calcium bicarbonate solutions. Indeed, in several cases the precipitation was inhibited. The addition of gelatine or peptone at a concentration of 5 mgs. per liter, or of certain enzyme preparations, strongly inhibits the precipitation.

The tentative conclusion from these experiments is that small amounts of organic matter in some way interfere with the precipitation of CaCO_3 , while even in the absence of organic matter solutions of calcium bicarbonate reach equilibrium only with extreme slowness.

LACTOSE-FERMENTING BACTERIA IN
THE OCEAN

HAROLD A. THOMAS

The prevalence of lactose-fermenting bacteria in the ocean was studied, with particular regard to the determination of the proportion of these bacteria that would be indicative of human or land pollution. Of primary interest was the analysis of the value of simple lactose fermentation as an index of the intensity of pollution.

Fourteen stations in a line from New Bedford Harbor toward Robinson's Hole were sampled. The research was directed to determine (a) the number of samples containing lactose-fermenters; and (b) the number of lactose fermenting samples containing members of the coli-aerogenes group, indicating human or land pollution.

It was found that 29% of the water samples and 100% of the mud samples contained lactose-fermenting organisms. Of these samples only 54% contained members of the coli-aerogenes group of bacteria. Almost without exception the coli-aerogenes positive samples were obtained from stations located nearest to the pollution emanating from New Bedford Harbor.

The results show the presence of large numbers of bacteria in the ocean capable of fermenting lactose that bear no apparent relation to human or land pollution. Therefore, the Standard Presumptive test for intestinal bacteria, predicated upon the fermentation of lactose, is of little value as a criterion of pollution in salt water.

NITROGEN OF THE PARTICULATE MATTER
IN THE SEA

THEODOR VON BRAND

Fourteen stations, all from the Montauk-Bermuda line, have been analyzed. The highest values were found at the shallow stations. The nitrogen values in the upper layers of the shelf stations were lower than these, but a little higher than those of the Sargasso Sea stations. In the deeper layers no significant difference could be found between these two latter localities. Distinct seasonal variations in the particulate nitrogen were seen only at the shallow localities, inshore.

STUDIES IN MARINE MICROBIOLOGY

SELMAN A. WAKSMAN, NORRIS W. RAKESTRAW, CORNELIA L. CAREY,
C. E. RENN, C. W. HOCK AND D. Q. ANDERSON

1. Chemical and Biological Oxidation of Organic Matter in the Sea Bottom and Associated Bacterial Processes—S. A. Waksman and D. Q. Anderson.

Previous studies of the oxidation of organic matter in marine bottoms have been continued. The new investigations concern the distribution and nature of organic matter in a large number of cores and bottom samples taken from sites near land, at distances from land in the Gulf of Maine, from the floor of the shelf, and from the deeps. The carbon and nitrogen contents of samples from various core profiles have been determined by chemical methods, and the oxygen consumptions of suspensions of mud incubated under controlled conditions applied as a biological method of measuring quantities of available organic matter in the same samples. The effect of immediate chemical absorption of oxygen by natural muds upon this procedure was also examined.

2. Occurrence of Nitrite and Nitrate Forming Bacteria in Sea Water—C. L. Carey.

Studies on the numbers and distribution of nitrifying bacteria in the sea, the work of several summers, were completed, and a summary of results published. Waters from various sources produce nitrite and nitrate at different rates; the processes go on more rapidly in muds than in water. Ammonia liberation, nitrite formation, and nitrate production take place in a fixed sequence and at widely varying rates which are determined by the source of the water and mud and the nature and quantity of enriching materials used.

3. Decomposition of Chitin by Marine Bacteria—C. W. Hock.

The quantitative breakdown of *Limulus* chitin was studied in various natural media. In sea water alone the rate is immeasurable, but in mud and sand the chitin is readily attacked. A number of pure cultures of chitin-destroying bacteria were isolated from different sources. The morphology and growth characteristics of these organisms were determined.

4. Regeneration of Nitrogen from Decomposing Plankton—N. W. Rakestraw, C. E. Renn and Th. von Brand.

The changes in the various nitrogenous fractions assimilated by diatoms during growth, and those liberated by them on decomposition were studied by refined micro-methods in laboratory systems involving concentrations of pure strains of diatoms comparable to

those found in the sea. Under these conditions plankton nitrogen is converted to inorganic nitrogen completely, and the various forms of the latter are reassimilated without loss to the system when the diatoms are permitted to grow. The several stages of nitrogen regeneration: organic nitrogen to ammonia to nitrite, and nitrite to nitrate, proceed in a fixed order and separately.

5. Regeneration of Nitrogen from Organic Matter of Marine Muds; Studies of Biological Oxygen demand, and Review of Literature of Marine Bacteriology—C. E. Renn.

The rate at which ammonia develops in stored mud indicates that inorganic nitrogen is regenerated from organic nitrogen in marine muds much more slowly than from plankton material. This low rate is determined by the biological stability of materials reaching the mud, by low temperatures and limited oxygen, and by decreased exchange with the overlying water. But it also appears that the inorganic constituents of the mud itself absorb bacteria and organic matter in such a way as to depress biological activity.

The amounts of oxygen consumed by biological activity in stored samples from stations in the Western Basin of the North Atlantic vary with the depth from which the samples are taken. More oxygen is consumed by superficial and by deep water than by water from the "intermediate oxygen-minimum" layer. Within limits this indicates a relatively small amount of biologically available material in the zone of the oxygen minimum concentrations.

A review of the work in marine bacteriology since 1925 is in preparation.

THE DISTRIBUTION OF VITAMINS A₁ AND A₂ IN FISHES

GEORGE WALD

The distribution of vitamins A₁ and A₂ has been determined in eye tissues and livers of a number of fishes. The eye tissues of all permanently fresh-water fishes examined contain vitamin A₂ alone. Those of all permanently marine fishes except the tautog contain only vitamin A₁. Those of all euryhaline (potentially migratory) fishes contain either predominantly or exclusively the vitamin A ordinarily associated with the environment in which the fish is spawned. The tautog is exceptional in possessing a typically anadromous vitamin A configuration, though it is a permanently marine fish.

These correlations extend in part to the liver oils, but most livers contain mixtures of both vitamins A, occasionally in proportions the reverse of those in the eye tissues.

MARINE BIOLOGY

TALBOT H. WATERMAN

During the summer of 1938 work was continued on the study of the bathyplankton, as well as on the taxonomy and comparative anatomy of the deep-sea angler-fishes (Ceratioidea), and experimental studies on the neuro-muscular mechanism in Crustacea were begun at the Bermuda Biological Station.

DIRECT MEASUREMENT OF CURRENTS

E. E. WATSON

The electrically recording current meter has been altered so as to remove most of the sources of trouble indicated by the preliminary trials in 1937, and the automatic recording apparatus for the meter was built, with the assistance of Mr. R. H. Hay. In August, the meter and recording apparatus were taken out on "Atlantis" for tests. After adjustments, the operation of both meter and recorder proved satisfactory, though a few minor improvements were indicated. At 250 meters, there was no indication of any trouble from pressure, and the design of the meter is such that it should function at any depth. For the electrical connection from meter to ship a 3/16 inch insulated cable was used. The meter was carried by the hydrographic cable and the electrical cable was lashed to this at intervals of about 30 meters or less. This method is not satisfactory for depths exceeding 200 meters. For deeper work it is planned to use a single insulated steel cable to support the meter and also to furnish the electrical circuit.