THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

REPORT FOR THE YEAR 1946

TABLE OF CONTENTS

I. TRUSTEES

To serve until 1950

CHARLES FRANCIS ADAMS, 15 State Street, Boston, Mass.
JNO. A. FLEMING, 1530 P Street, Washington 5, D. C.
FRANK B. JEWETT, 195 Broadway, New York, N. Y.
ALBERT E. PARR, American Museum of Natural History, New York, N. Y.
ELIHU ROOT, JR., 31 Nassau Street, New York, N. Y.
SELMAN A. WAKSMAN, New Jersey Agricultural Experiment Station, New Brunswick, New Jersey.

To serve until 1949

OLIVER AMES, III, North Easton, Mass.
THE COMMANDANT (Admiral J. F. Farley), U. S. Coast Guard, Washington, D. C.
MARION EPPLEY, Eastover, Newport, R. I.
LAMAR R. LEAHY, 910 Park Avenue, New York, N. Y.
THE DIRECTOR (Admiral L. O. Colbert), U. S. Coast & Geodetic Survey, Washington, D. C.
EDWARD H. SMITH, Third Coast Guard District Headquarters, 42 Broadway, New York, New York.

To serve until 1948

HENRY B. BIGELOW, Museum of Comparative Zoology, Cambridge, Mass.
A. G. HUNTSMAN, University of Toronto, Toronto, Canada.
DANIEL MERRIMAN, Bingham Oceanographic Laboratory, Yale University, New Haven, Connecticut.
ALFRED C. REDFIELD, Woods Hole Oceanographic Institution, Woods Hole, Mass.
HENRY L. SHATTUCK, 50 Federal Street, Boston, Mass.
LYMAN SPITZER, JR., Yale Observatory, New Haven, Conn.

To serve until 1947

ISAIAH BOWMAN, Johns Hopkins University, Baltimore, Md.
E. G. CONKLIN, Princeton University, Princeton, N. J.
ALEXANDER FORBES, 610 Harland Street, Milton, Mass.
ROSS G. HARRISON, Yale University, New Haven, Conn.
FRANK R. LILLIE, 5801 Kenwood Avenue, Chicago, Ill.
HARLOW SHAPLEY, Harvard University, Cambridge, Mass.

Ex. Officio

COLUMBUS O'D. ISELIN, Woods Hole Oceanographic Institution, Woods Hole, Mass.
LAWRASON RIGGS, 120 Broadway, New York, N. Y.

OFFICERS

HENRY B. BIGELOW, President of the Corporation, Museum of Comparative Zoology, Cambridge, Mass.
LAWRASON RIGGS, Treasurer, 120 Broadway, New York, N. Y.
COLUMBUS O'D. ISELIN, Clerk of the Corporation, Woods Hole Oceanographic Institution, Woods Hole, Mass.

II. MEMBERS OF THE CORPORATION

CHARLES FRANCIS ADAMS, 15 State Street, Boston, Mass.
OLIVER AMES, III, North Easton, Mass.
HENRY B. BIGELOW, Museum of Comparative Zoology, Cambridge, Mass.
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FRANK R. LILLIE, 5801 Kenwood Avenue, Chicago, Ill.
ALFRED L. LOOMIS, Tuxedo Park, N. Y.
DANIEL MERRIMAN, Bingham Oceanographic Laboratory, Yale University, New Haven, Connecticut.
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SELMAN A. WAKSMAN, New Jersey Agricultural Experiment Station, New Brunswick, New Jersey.

III. REPORT OF THE TREASURER

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

GENTLEMEN:

The Accounts for the year 1946 have been audited by Messrs. Seamans, Stetson & Tuttle, certified public accountants of Boston.

During the year bonds costing $106,878.90 were redeemed at a net profit of $4,669.85 to which must be added $285.09, the applicable reserve for amortization, and stocks costing $97,614.92 were sold at a loss of $13,-169.74, making a total realized loss for the year in the Endowment Fund of $8,214.80. The accumulated net gain on securities sold or redeemed is $95,443.53.

During the year $205,542.20 was invested in bonds and $95,395.70 in stocks, leaving $5,283.29 uninvested at the end of the year.

The amount due from General Funds to Special Income Account rose during the year from $37,094.76 to $44,113.51. The continued withholding of these funds due Special Income Account is due to the continued use of all available funds to finance Government contracts.

The net amount due from the Government including some items not invoiced and less excess allowance for overhead amounted to $393,484.26.

There was spent directly for the Government $793,899.92 in addition to which there was allowed for overhead including fixed allowances $207,758.76.

The fund for Periodic Replacements at the beginning of the year stood at $40,200.00 in book value of securities and cash of $24,548.26 (including $14,400.00 due from Current Funds Cash), or a total of $64,748.26. During the year the cost of the installation of the new engine on "Atlantis" amounting to $39,212.22 was charged to this fund, which with the other credits and debits reduced the fund to $31,483.94, consisting of bonds of the book value of $49,863.12 (market $50,727.50) and a cash deficit of $18,379.18, leaving the fund with a book value of $31,483.94.

The total income of the Institution from its Endowment Fund including special income, after the payment of Custodian Fees was $121,482.89. This is over $4,500.00 more than in 1945 and over $10,000.00 more than in 1944. This increase is due to greater return from some 28 stocks, and the collection of arrears on Commonwealth & Southern Preferred.

The net Institutional expenses amounted to $116,209.76, leaving a balance of $5,273.13 before transfer of special income of $7,018.75 to the Special Income Account.

Our cash position has improved slightly. Bank loans have been decreased from $360,000.00 to $330,000.00 and accounts payable from $53,-310.80 to $47,613.45, and our current cash funds have risen from a deficit of $4,075.57 to a net balance of $27,319.03.

The additions to Plant Account more than offset the decrease in Current Surplus.

Our entire surplus and $330,000.00 of bank loans are still involved in the financing of the Government contracts.

The return on the investments held at the end of the year was at the rate of 4.52%. This is the rate after excluding dividends paid in stock and after taking into account the amortization of the premiums paid on bonds purchased above par.

At the end of the year the securities in the Endowment Fund had a market value of $2,826,349.07 which is $316,768.87 in excess of cost.

The Balance Sheet and the Statement of Income and Expenses are appended.

Respectfully submitted,

LAWRASON RIGGS

Treasurer

BALANCE — SHEET

As of December 31, 1946

ENDOWMENT FUND ASSETS

	Quoted Market Value		
Endowment Fund Assets:			
Bonds (less reserve for amortization of bond premiums, $3,631.47)	$1,084,311.57	$1,072,392.80	
Stocks	1,742,037.50	1,437,187.40	
Cash		5,283.29	$2,514,863.49
Note: Bonds having a book value of $483,145.17, are specificially allocated as collateral on the Institution's indebtedness to the Bankers Trust Company.			
Reserve Fund Assets:			
Bonds	$14,225.00	$14,032.75	
Stocks	14,295.75	19,099.02	
Cash		1,234.87	34,366.64
			$2,549,230.13

PLANT ASSETS

Laboratory Plant:			
Land		$27,072.32	
Buildings		332,202.26	
Laboratory equipment		21,361.93	
Library		16,700.00	$397,336.51
Ketch "Atlantis":			
Construction		$218,674.47	
Equipment		27,298.50	
		$245,972.97	
Power Boat "Balanus"		46,043.29	
Power Boat "Anton Dohrn"		17,145.67	
Small Boats and Equipment		10,028.85	319,190.78
Hall Property, Land and Buildings			26,500.00
			$743,027.29
Depreciation Fund Assets (for Periodic Replacements):			
Bonds	$50,727.50	$49,863.12	
Cash (including $20,012.22 due Current Funds cash)		(18,379.18)	31,483.94
			$774,511.23

BALANCE — SHEET

As of December 31, 1946

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		95,443.53	$2,514,863.49
RESERVE FUND		$23,658.07	
Add accumulated Reserve Fund Income		10,708.57	34,366.64
			$2,549,230.13

PLANT FUNDS

PLANT FUND — GENERAL			$607,642.13	
PLANT FUND RESERVE — Transferred in prior years from Current Surplus		$ 88,949.87		
Add appropriation from Current Funds, Hall Property	$26,500.00			
Power Boat "Balanus"	46,043.29			
Library Additions	800.00	73,343.29		
		$162,293.16		
Deduct				
Sale of "Physalia"	23,408.00			
Sale of "Little Reliance"	3,500.00	26,908.00	135,385.16	$743.027.29
RESERVE FOR PERIODIC REPLACEMENTS				31,483.94
				$774,511.23

BALANCE — SHEET

As of December 31, 1946

(Concluded)

CURRENT ASSETS

CURRENT FUNDS CASH:			
Main Account	$32,645.33		
Operating Accounts	16,860.52		
Petty Cash Funds	1,914,47	$51,420.32	
Less,			
Amount due Special Income Fund	$44,113.51		
Amount due from Depreciation Fund	(20,012.22)	24,101.29	$27,319.03
SPECIAL INCOME ASSETS:			
Investments			
Bonds (quoted market value $9,728.75)	$9,739,31		
Stocks (quoted market value $7,741.75)	6,196.60	$15,935.91	
Cash (including $44,113.51 due from Current Funds Cash)		44,568.21	60,504.12
ACCOUNTS — RECEIVABLE:			
United States Government Contracts,			
Invoiced on public vouchers	$169,060.53		
Invoiced after December 31, 1946	182,749.70		
Expenditures not invoiced	58,635.57	$410,445.80	
Less allowance for Overhead and Boat Costs collected in excess of charges		16,961.54	
		$393,484.26	
Advances to be repaid		7,650.89	
Sundry		4,204.23	405,339.38
SUPPLIES IN STOCK			10,186.40
DEFERRED CHARGES TO GOVERNMENT ALLOWANCE			1,117.97
			$504,466.90

BALANCE — SHEET

As of December 31, 1946

(Concluded)

CURRENT LIABILITIES AND SURPLUS

ACCOUNTS — PAYABLE:			
Institution		$2,082.51	
United States Government contracts		39,529.24	
Income Taxes withheld		6,001.70	$47,613.45
NOTES — PAYABLE (secured by bonds having a book value of $485,145.17)			330,000.00
UNEXPENDED GRANTS:			
Wallace and Tiernan Gift			1,199.36
SURPLUS:			
Balance at December 31, 1945		$163,424.20	
Add			
Excess of Income over Expenditures for the year ended December 31, 1946		5,273.13	
Book Value "Physalia" sold	$23,408.00		
Gain on sale	2,842.00	26,250.00	
Book Value "Little Reliance" sold	$3,500.00		
Gain on sale	500.00	4,000.00	
Gain on sale Special Income Investment.		50.05	
		$198,997.38	
Deduct cost of Plant Assets purchased from Current Funds,			
Hall Property	$26,500.00		
Power Boat "Balanus"	46,043.29		
Additions to Library	800.00	73,343.29	125,654.09
			$504,466.90

Income from Endowment Fund and Special Income Investments and Expenditures Applicable Thereto

Year ended December 31, 1946

INCOME:			
From Endowment Funds,			
Interest	$40,400.42		
Dividends	82,390.77		
From Special Income Securities	516.39	$123,307.58	
Less Custodian Fees and Expense		1,824.69	
Total Income			$121,482.89
INSTITUTION EXPENSES:			
Upkeep of Plant,			
Depreciation	$4,800.00		
Buildings and Grounds	1,361.69	$6,161.69	
Operating Expenses,			
Scientific Salaries	$44,466.62		
Scientific Projects	30,947.49		
Scientific Supplies and Expense	3,772.04		
Publications	2,069.26		
Contributions to Retirement Fund	1,763.26		
Travelling Expense	1,650.69		
Amortization of Bond Premiums	1,358.68		
Grants and Fellowships	210.79		
Administration	738.69		
Expenses of Hall Property	142.32		
	$87,119.84		
Less Sundry Credits	2,352.72	84,767.12	
Institution Overhead		25,280.95	
Total Expenditures			116,209.76
Excess of Income			$5,273.13

IV. REPORT OF THE DIRECTOR

By C. O'D. ISELIN

Introduction

During 1946 the activity, both in the laboratory and at sea, remained at a high level. The Government requests for oceanographic information, personnel and equipment were undiminished and at the same time a small beginning was made on the part of our permanent staff to develop the Institution's own post-war program. It was possible to operate on this expanded scale because several former members of our staff returned from serving in the Armed Forces and also we were able to find a number of new people who in one way or another were qualified to take part in the program required by the various contracts with the Government.

The chief reason for this rather unexpected, continuing activity was the opportunity afforded by the atomic bomb tests at Bikini Atoll for conducting various types of oceanographic investigations. More than 40 members of our staff took part in the many phases of this unique experiment.

Although much equipment and a considerable fraction of our staff were in this way diverted to the middle of the Pacific Ocean, field work was also active in the Atlantic. This was made possible through two new contracts with the Government, both of which required the use of our vessels in surveys of the distribution of temperature and salinity over considerable areas. As a result of these operations it has become evident that postwar costs of oceanographic field work have more than doubled as compared with the period just before the war. This is perhaps the most serious problem facing the Institution today. The costs of operating our own vessels have become so high that without Government subsidy we could not hope to undertake offshore observations. For the time being, at any rate, the Government is able to support science at private laboratories on an unprecedented scale, but should we have to return to operating solely on income from endowment, we could no longer afford more than a small program of field observations in local waters.

This unhappy situation has very much influenced the operations of the past year and has delayed the resumption of a balanced research program in which the analysis and publication of results keeps pace with the collection of new data. Facing the prospects of a greatly reduced field program within the next year or two, we have deliberately exerted every effort to keep our vessels busy accumulating observations. As a result, we have only a relatively small output of scientific publications to point to after an extremely busy year.

The Facilities at Woods Hole

A serious limiting factor during the past year has been the shortage of housing and laboratory space at Woods Hole. During the winter months, as in the past several years, we were able to expand into the Marine Biological Laboratory, but when summer came and an unexpected number of biologists returned to Woods Hole the situation became acute. It was not until autumn, when several members of our staff left to take up university positions, that the pressure was relieved. Although our administration staff, in cooperation with the Marine Biological Laboratory, had made every effort to provide accommodations for the expected number of summer visitors, the carefully laid plans were upset when late in the spring more and more people decided to come to Woods Hole. As far as laboratory space is concerned, it will be an easy matter in the future to avoid the mistakes of the past summer. We will not again plan on using any of the facilities of the Marine Biological Laboratory during the summer, but it will be some time before the living accommodations at Woods Hole can equal the combined demands of both laboratories.

Through the cooperation of the U. S. Fish and Wild Life Service, the housing shortage has been somewhat lessened during the past year, for the former residence building has provided accommodations for about 35 people. Nevertheless, it is evident that much new construction will be required.

The Marine Biological Laboratory has continued to make available to us the former Penzance Garage. Thus wharfage, storage space, machine shop space and the parking of automobiles have been no serious problem. However, this is a commercially valuable piece of property and commands a high rental. If oceanography is to be continued on anything like the present scale at Woods Hole, in the long run a less expensive solution to the storage problem will have to be found.

As a step in this direction in October the Executive Committee authorized the purchase of some property almost directly across the street from our main building. The tract has a street frontage of 42 feet and extends back to the Eel Pond for approximately 117 feet. Due to irregular widening along the northwestern property line, the Eel Pond frontage is about 50 feet. The land now has three small buildings on it which are fully rented and therefore it can be carried without loss of income. However, before undertaking any new construction, either for living accommodations, laboratory space, or storage, it will be wise to wait until the future activity can be gauged with some assurance.

Vessels

The following is a summary of the cruises made by "Atlantis" during the past year:

Cruise No.	Date	Region
138	Jan. 3–6, 1946	South of No Mans Land.
139	Jan. 30–31,	New London to Woods Hole.
140	Feb. 6–May 9	Woods Hole to Guantanamo to Miami to Woods Hole.
141	May 22–30	Woods Hole to Gulf Stream off Hatteras to 64° W.
142	June 3–7	Woods Hole to south off continental shelf.
143	Sept. 16–Nov. 16	Woods Hole to Bermuda, two runs south to Antilles and return to Woods Hole.

During the winter months, while operating off Guantanamo, it became evident that the main engine should soon be either replaced or completely rebuilt. After 15 years of hard service, this was, of course, no great surprise. The various alternatives were carefully considered in consultation with representatives of the Bureau of Ships of the Navy Department. Since "Atlantis" is the only vessel in this country which from the outset was designed with oceanography as the primary purpose, the Navy has a special interest in her continued efficient operation. Thus it was decided to make available a surplus engine of far greater horsepower and quality than the Institution itself could ever have considered. With the Government furnishing the machinery, the funds which the Institution had been accumulating for the expected rebuilding of the original engines could be used for a complete rearrangement of the engine room, including a new forced hot water heating system. The new installations were made by the Electric Boat Company of Groton, Connecticut, during July and August. As a result the "Atlantis" is now far better equipped with propelling and generating machinery than when she was new. The main engine can deliver 350 horsepower to the original feathering propeller. Thus we have retained the important feature of being able to tow nets at very low speeds. Cruising speed has been increased from about 7 knots to 9 knots without any serious loss in cruising radius. At the same time, we have ample reserve power to maintain speed when bucking a head sea. Two separate generating sets of 30 and 35 K.W. capacity provide ample direct current. The relatively small amount of alternating current required is supplied by converters.

In September, Captain Adrian K. Lane took over command of "Atlantis" from Captain Gilbert Oakley, Jr. The latter then assumed responsibility for the operation and maintenance of all our vessels, as well as the other duties which had been so ably carried out by Mr. John D. W. Churchill during the war period.

In July the opportunity arose to sell the "Physalia" which was somewhat light for offshore work, having been originally designed as a yacht. At the same time and at very nearly the same price, we were able to purchase a fishing type vessel originally built in 1942 but turned over to the Army before she was outfitted for fishing. The new vessel has been named "Balanus". Following use during the summer in geophysical work, we have begun to fit her out for general oceanography. The "Balanus," of 42 net tons, has a heavily constructed wooden hull, 72 feet in length. A heavy duty diesel engine of 155 horsepower enables her to cruise at 8.5 knots. She carries a crew of 8 and has additional accommodations for a scientific party of 5.

The smaller vessels owned by the Institution are now the "Asterias" and the "Mytilus," the "Little Reliance" having been sold last spring.

The remainder of the fleet are the "Mentor," which we now maintain and will later operate for the Bureau of Ships, and the Schooner "Reliance" and the "Claire," which are also Government owned and which are used for the work being carried out under contract with the Bureau of Ordnance.

The "Mentor," a 127 foot converted yacht which has been especially fitted out for acoustical research, was operated until July by a Navy crew. Because of greater horsepower and much more elaborate electronics installations, she will require a slightly larger civilian crew than "Atlantis." In assuming the responsibility for the maintenance and operation of the "Mentor," we have taken a new step which constitutes a rather crucial experiment for oceanography. More and more the facilities and instrumentation needed in the earth sciences are owned by the Government. Does this mean that the private laboratories will gradually give way to the Government laboratories because they cannot afford the elaborate new equipment? I believe that so specialized a vessel as the "Mentor" can be more efficiently operated by a civilian crew than by a Navy crew and events seem to indicate that the Navy has sufficient confidence in the Institution to give this plan a try. Should we fail in this responsibility, then it seems likely that the Government will of necessity seek other means of developing the earth sciences. Surely the Government as the only agency now capable financially, must encourage, in one way or another, continued development of the earth sciences. Unless man continues to broaden his knowledge of the earth, including the oceans, he will not be able to develop fully the potential resources of his environment.

Personnel

There have been many changes in personnel during the past year. This was to be expected as people were released by the Armed Services and as the universities resumed full scale operations. It will be only possible to

record a few of these changes here which for one reason or another seem particularly notable.

Former staff members and scientific workers returning from the Armed Services include: Mr. Gilbert Oakley, Jr., Dr. H. R. Seiwell, Dr. Mary Sears, Mr. L. Valentine Worthington, and Mr. Martin J. Pollak.

Scientists and technicians who have for the first time been employed here and who served in the Army or Navy during the war are: Dr. J. Brackett Hersey, Mr. John F. Holmes, Mr. Leslie Carter and Mr. Andrew F. Bunker.

In July Dr. Jeffries Wyman returned to Harvard University to resume full time duty in the Department of Biology. Mr. David M. Pratt and Dr. W. T. Edmondson also now have teaching positions in biology at Harvard.

Early in the year Dr. Paul C. Cross left to become Chairman of the Department of Chemistry at Brown University. In the autumn, Dr. J. S. Coles became Assistant Professor in his Department. On the other hand, Dr. Norris W. Rakestraw left Brown University and his part time position on our staff for the Scripps Institution of Oceanography. His title there is Professor of Oceanography, University of California at Los Angeles.

Last winter Dr. Wm. M. Ewing took up his new duties in the Geological Department of Columbia University. Mr. J. Lamar Worzel and Mr. Nelson C. Steenland are at present doing graduate work under his supervision.

Dr. Edward S. Deevey, Jr., returned to Yale University as Lecturer in Biology. Dr. Gordon A. Riley has been appointed Assistant Professor, a part time position, at Bingham Oceanographic Laboratory, Yale University.

Dr. Robert H. Cole has gone to the University of Missouri and Dr. Leonard L. Liebermann to the Marine Physical Laboratory at San Diego. Mr. Thomas S. Austin and Dr. Clifford A. Barnes have taken positions in the Division of Oceanography, Hydrographic Office.

Mr. Henry C. Stetson and Mr. William E. Schevill have resumed half time duty at the Museum of Comparative Zoology. Mr. Gardner Emmons has likewise returned to New York University.

Fellowships

The following were awarded fellowships by the Institution during the past year: Miss Margaret Briggs, Mr. William S. Butcher, Dr. Shu-ping Chu, Dr. James Lackey, Dr. Hans A. Panofsky, Mr. George Whiteley, Jr., and Mr. Nelson C. Steenland.

Visiting Investigators

Dr. Hilary B. Moore, Resident Naturalist at the Bermuda Biological Station, came to Woods Hole in October for an extended visit. Somewhat

shorter visits were made by Dr. Walter Munk and Mr. Walter Champion of the Scripps Institution of Oceanography.

Visitors from abroad who spent some time at the Laboratory included the following: Dr. J. N. Carruthers of the British Hydrographic Office, Oceanographic Section; Dr. Johan Ruud, Professor of Marine Biology at the University of Oslo and Dr. Hamed Abdul Fattah Gohar, Director of the Marine Biological Station at Ghardaqa, Egypt.

Library

Our contribution towards the purchase of new books and periodicals at the Library of the Marine Biological Laboratory has continued to be at the rate of $800.00 per year. However, by mutual agreement, our contribution towards the operating expenses of the Library has been substantially increased.

Publications

One number of Papers in Physical Oceanography and Meteorology, Vol. 10, No. 1, appeared before the end of the year.

Dr. Sears has spent considerable time reorganizing the mailing list for Institution publications and reestablishing contact with exchanges abroad from whom we have been cut off during the war years.

The complete list of numbered contributions for the year [redacted] is as follows:

No. 301. F. G. Walton Smith. Effect of Water Currents upon the Attachment and Growth of Barnacles. *Biol. Bull.* Vol. 90, No. 1, pp. 51–70.

No. 341. Nelson Marshall. Observations on the Comparative Ecology and Life History of two Sea Robins, *Prionotus carolinus* and *Prionotus evolans strigatus*. *Copeia* No. 3, pp. 118–144.

No. 342. John D. Ferry and Dayton E. Carritt. Action of Antifouling Paints: I. Solubility and Rate of Solution of Cuprous Oxide in Sea Water. *Industrial and Engineering Chemistry* Vol. 38, pp. 612–617.

No. 343. M. Juul Hvorslev and Henry C. Stetson. Free-Fall Coring Tube: A New Type of Gravity Bottom Sampler. *Bull. Geol. Soc. Amer.* Vol. 57, pp. 935–950.

No. 344. Fred B Phleger, Jr., and Walter A. Hamilton. Foraminifera of two Submarine Cores from the North Atlantic Basin. *Bull. Geol. Soc. Amer.* Vol. 57, pp. 951–966.

No. 345. John D. Ferry and Gordon A. Riley. Action of Antifouling Paints: II. Solubilities of Antifouling Toxics in Sea Water. *Industrial and Engineering Chemistry.* Vol. 38, pp. 699–701.

No. 346. John D. Ferry and Bostwick H. Ketchum. Action of Antifouling Paints: III. Maintenance of the Leaching Rate of Antifouling Paints Formulated with Insoluble, Impermeable Matrices. *Industrial and Engineering Chemistry.* Vol. 38, pp. 806–810.

No. 347. BOSTWICK H. KETCHUM, JOHN D. FERRY and ARTHUR E. BURNS, JR., Action of Antifouling Paints: IV. Maintenance of Leaching Rate of Antifouling Paints Formulated with Soluble Matrices. *Industrial and Engineering Chemistry*, Vol. 38, pp. 931–936.

No. 348. MAURICE EWING, ALLYN VINE and J. L. WORZEL. Photography of the Ocean Bottom. *Journ. Optical Soc. Amer.*, Vol. 36, No. 6, pp. 307–321.

No. 349. C. M. POMERAT and C. M. WEISS. The Influence of Texture and Composition of Surface on the Attachment of Sedentary Marine Organisms. *Biol. Bull.*, Vol. 91, No. 1, pp. 57–65.

No. 350. MARSHALL SCHALK. A Study of Textural Changes in a Beach by repeated Samplings. *Journ. Sedimentary Petrology*, Vol. 16, No. 2, pp. 43–51.

No. 351. MAURICE EWING, G. P. WOOLLARD, A. C. VINE and J. L. WORZEL. Recent Results in Submarine Geophysics. *Bull. Geol. Soc. Amer.*, Vol. 57, pp. 909–934.

No. 352. G. A. RILEY and D. F. BUMPUS. Phytoplankton-Zooplankton Relationships on Georges Bank. *Sears Found. Journ. Marine Res.*, Vol. 6, No. 1, pp. 33–47.

No. 353. G. A. RILEY. Factors Controlling Phytoplankton Populations on Georges Bank. *Sears Found. Journ. Marine Res.*, Vol. 6, No. 1, pp. 54–73.

No. 354. H. R. SEIWELL. Military Oceanography in Tactical Operations of World War II. *Trans. Amer. Geophysical Union*, Vol. 27, No. 5, pp. 677–681.

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Scientific Program

Under the present circumstances when so large a percentage of the activity of the laboratory is being financed under contract with the Government, it is most difficult to separate the investigations for which the Institution is primarily responsible from those which are largely or entirely undertaken at the request of the Government. Although we have set up an accounting system which permits the costs to be rather rigidly separated, the two programs are in many cases so closely integrated that it is difficult to describe them separately. In the following list, the emphasis gradually changes from studies which are entirely our own to those which are entirely for the Government. However, applications of oceanography developed for the Government will not be stressed. It will be seen that as time goes on our definition of oceanography is gradually being expanded to include almost all that goes on in, under, and above the sea.

1. The Productivity of the Sea.

Prior to the war, this was the central subject of investigation by the biologists and chemists of the Institution. The recent advances in the subject have been summarized by Dr. H. W. Harvey of the Plymouth Laboratory in a small book published in 1945. It is gratifying to see from this review what a substantial contribution to the subject as a whole has come from Woods Hole.

In resuming studies of the productivity of the sea, the chief objective will be the measurement of the factors underlying the productivity of coastal waters. Drs. George L. Clarke and W. T. Edmondson have undertaken, with the collaboration of others, the investigation of semi-enclosed arms of the sea and salt ponds where more detailed and precise measurements can be conducted than offshore and where changes in the physical and biological components can be followed closely.

Systematic studies have been made during the year in Tisbury Great Pond, (Marthas Vineyard), Rand Harbor at Megansett and Little Harbor, Cohassett, (Massachusetts). These have included tests of the addition of chemical fertilizer to the water in situations where the exchange of water could be controlled or limited. Results showed that biological activity could be greatly increased by such treatments.

To facilitate further studies on productivity, two concrete tanks supplied with sea water from the harbor were constructed outside the laboratory building. The tanks are 9 by 18 by 5 feet deep and protected by a glass roof. Tests in these tanks may be conducted efficiently under more natural conditions than exist in the laboratory but without the complicating effect of interchange with bottom muds. Large populations of phytoplankton were readily produced in the tanks when fertilizers were added.

Dr. H. H. Haskin, now of Rutgers University, conducted a number of surveys of the chemical conditions in the sea water overlying the oyster beds of Gardiners Bay, (Long Island, New York). His object is to determine the nutritional conditions responsible for the unusual value of this area for the cultivation of oysters.

2. Studies of the Pollution of Sea Water.

The distribution and extent of bacterial pollution of sea water depends upon the source and method of disposal of sewage, the local hydrographic conditions and the viability of the bacteria involved. Several aspects of a complete investigation of these problems have been initiated.

Several trips were made to Mount Hope Bay, where the hydrographic conditions were being explored. The distribution of pollution bacteria was closely correlated with the water circulation at various stages of the tide. With the aid of Mr. Amos Hopkins, a survey of pollution of Woods Hole was

made. Continuation of these studies as the local sewerage system is installed will demonstrate the effectiveness of the system.

Dr. Cornelia Carey and Miss Margaret Briggs have started an investigation into the factors controlling the viability of coliform bacteria in the sea. Sea water has been found to contain a substance destroyed by autoclaving, but not by boiling for a few minutes. This substance is lethal for the strain of *Escherichia coli* used. The seasonal variation in the potency of this substance and its distribution in water collected from various locations is being studied along with the effect of aging the water in the laboratory. In addition, it has been observed that certain bacteria in raw sea water are able to prevent the development of coliforms on nutrient agar plates in their immediate vicinity. It seems probable that these forms are secreting an antibiotic substance which may be important in the rapid reduction of the bacterial pollution of sea water.

3. The Biology of Fouling Organisms.

The group of biologists who were engaged in work on the prevention of fouling during the war have been winding up that work and continuing parts which have more general scientific interest. The final assignment from the Bureau of Ships was to prepare a comprehensive book reviewing all existing knowledge of fouling. The parts of this book dealing with the general biology of fouling organisms have been completed, and the chapters covering the practical methods of preventing fouling, previously issued, have been revised, so that the final manuscript will soon be ready for the press.

A very extensive collection of samples of fouling from navigation buoys from all parts of the coast of the United States was made during the war. The immediate study of this material was directed toward obtaining the answers of certain special questions of interest in mine warfare. The material, however, is of unique interest in connection with the geographical distribution of marine organisms along the coasts. The collections have been sorted with reference to the several different classes of animals or plants, and have been submitted to specialists on the various groups for identification and study. This work involves cooperation with experts connected with Yale University, the Bingham Oceanographic Laboratory, the Museum of Comparative Zoology, the University of California, the University of Oregon, Rhode Island State College and the Texas Game, Fish and Oyster Commission.

Six papers dealing with special aspects of the fouling problem were published during the year and a number of others were prepared for publication. Dr. Alfred C. Redfield was asked to organize a Symposium on Marine Ecology, which was presented before the Ecological and Limnological Socie-

ties at the Boston Meeting of the A.A.A.S. Two members of our staff, Drs. Bostwick H. Ketchum and Louis W. Hutchins, took part in the program

4. Geophysics of the Continental Shelves.

During the summer, Dr. Maurice Ewing, Dr. George P. Woollard, Mr. J. Frank Press, Mr. Nelson Steenland and Mr. J. Lamar Worzel continued their work on the geophysics of the continental shelves under a Geological Society of America grant. Using improved technique and instrumentation as compared with their pre-war work, they occupied 15 stations between the Gulf of Maine and the region off Cape May, New Jersey. On three lines the seaward slope of the older crystalline rocks was mapped beneath the veneer of younger (Cretaceous and Tertiary) sediments. Work in the Gulf of Maine was discontinued when these younger beds were found extremely thin or entirely lacking. To the south, with some local reversals, the wedge of sediments was found to thicken markedly, the maximum thickness reached exceeding 17,000 feet. The southern-most line indicated that their original work off Norfolk, generally discredited at the time it was made, was reasonable in showing a thickness of some 12,000 feet of sediments. The oil test well drilled during the year on Cape Hatteras further substantiated their original conclusions.

5. Distribution of Marine Sediments.

During 1946 sedimentary work was continued by a study for the Navy of that part of the Gulf of Maine lying immediately off Portsmouth. Under the direction of Mr. H. C. Stetson, Dr. Fred B Phleger and Mr. David B. Ericson, about 700 bottom samples including several hundred short cores were taken. Most of the samples were taken by Mr. Ericson who also did the major part of the laboratory analysis. From study of these samples, charts have been made showing various characteristics of the sediments of the area.

Study of the cores proved that in the deeper parts of the Portsmouth basin, three distinct layers of sediments occur. The oldest, glacial till devoid of organic remains, is overlaid by mud and silt containing sponge spicules, diatoms and calcareous foraminifera, which distinguish it from the third and uppermost layer of mud and silt containing the arenaceous foraminiferal fauna now living on the bottom of the basin.

Preliminary mechanical analyses of the post-glacial beds show that the average particle diameter of the older layer is about twenty percent finer than that of the material being deposited at present. That the older bed with its calcareous fauna is the seaward extension of the post-glacial marine clays of Maine, New Hampshire and northern Massachusetts, appears to be well established by its stratigraphic position directly above the till and by its smaller particle diameter implying deposition in deeper water.

From the degree of tilting of the land mass as determined by present elevations of deltas built into the marine clays, it is inferred that the uplift of the floor of the Portsmouth basin must have been in the order of 50 meters. Depth of water over Jeffreys Ledge before tilting would then have been about 70 percent deeper than now. A connection between the faunal change and the shoaling of water over Jeffreys Ledge appears probable since the ecological conditions in the Portsmouth basin must in large measure be determined by the extent to which the ledge acts as a barrier to the circulation of water in and out of the basin. The problem deserves further study, particularly investigation of the foraminiferal faunas occurring in deeper water seaward from Jeffreys Ledge.

6. Hydrography of the Western North Atlantic.

During the past year a good beginning was made in a broad new attack on the problems of circulation, and of the distribution of temperature and salinity in the Western North Atlantic. Such studies constituted the major effort of the Institution before the war, and it is now clear that because of new instrumentation and methods, the work can be resumed with excellent prospects of success. Adequate facilities for analyzing large numbers of observations and financial support for a continuing field program have been assured through a new contract with the Office of Naval Research. This contract is under the technical supervision of the Division of Oceanography of the Hydrographic Office.

The field program consisted of monthly surveys of two selected areas near the coast, and of less frequent surveys of the waters over the continental shelf and along the northern edge of the Gulf Stream. Beginning in September, the "Atlantis" began a systematic survey of the whole, roughly triangular, area between Cape Hatteras, Bermuda and Puerto Rico. By the end of the year, four north-south profiles of deep hydrographic stations had been completed in the eastern part of this area.

Mr. Frederick Fuglister has been in charge of the routine processing and analysis of the very large number of bathythermograph observations secured in the course of this work. Mr. Dean Bumpus directed the field work in the coastal waters, while Mr. Fuglister and Mr. Valentine Worthington alternated as scientist in charge of the off-shore surveys of "Atlantis". Mr. Martin J. Pollak, who like Mr. Worthington has recently returned from service in the Navy, has had the responsibility of working up the deep hydrographic material.

The chief technical advance at sea has been the use of Loran. This new navigational method is of great importance to oceanography. Not only does it increase the accuracy of the location of stations, but it also makes it possible

to obtain continuous information on the direction and velocity of the surface currents. Although an individual Loran fix may be in error by as much as a mile or two, when frequent fixes are obtained, for example, every half hour, the drift of the vessel due to currents can be determined with very satisfactory accuracy. By combining Loran with frequent bathythermograph lowerings, the "Atlantis" has also been able to track the northern edge of the Gulf Stream with most illuminating results.

In shallow waters, the new salinity recorder has likewise proved to be a very powerful tool. In this instrument, measurements of electrical conductivity and temperature are combined to produce a continuous record of salinity with an accuracy of about ± 0.1 parts per thousand. While underway, the surface water can be circulated through the conductivity cell. On station, the cell can be lowered so as to produce a salinity-depth curve. In areas where relatively large changes in salinity are found, as off the mouth of a river, the salinity recorder is invaluable.

The fact that oceanographic vessels can now accumulate temperature and salinity observations, as well as surface current observations, without stopping not only greatly increases the volume of data to be analyzed in the laboratory, but also makes it advisable to institute new methods of analysis and new means of presenting the data for publication. Although the work has been pushed vigorously in the laboratory, the combining of the new observations with those accumulated before the war is by no means an easy task. Most of the recent observations are relatively shallow ones and show that the surface layer of the ocean has a complex and rapidly changing structure. To reconcile this complicated superficial layer with the rather simple permanent current patterns indicated by the pre-war, widely separated, deep hydrographic stations, one needs to have a much more detailed understanding of the eddy structure, both large and small, and of the local wind currents than is yet available. To resolve some of the problems may require the sort of three dimensional picture that can only be built up from the observations of several ships operating simultaneously in a relatively small area. In the meanwhile, from the relatively simple area south of the Gulf Stream, we are accumulating excellent statistical data on the seasonal and diurnal temperature cycles. The time is approaching when from this area, at least, we can begin to study annual variations in the temperature of the water column.

7. Marine Meteorology.

In the spring of 1946, an Institution group led by Dr. Jeffries Wyman and including Mr. Alfred H. Woodcock worked in the Trade Wind area on the exchanges of heat and water vapor between air and sea. The contract

for this work was with the Bureau of Ships. Most of the observations were made about 100 miles northeast of San Juan, Puerto Rico, but in an area believed typical of the Trades. Observations were made by a relatively slow flying plane and included wet and dry bulb temperatures at accurately known heights, direct (although approximate) measurements of vertical velocities and high altitude photogrammetric study of cloud distribution. Ample bathythermograph observations gave information on the temperature structure of the surface waters. The trade wind air was found to consist of 3 distinct layers — the sub-cloud, cloud, and super-cloud. Except in the clouds, the roughest air, as shown by horizontal accelerometer traverses within each layer, was in the sub-cloud layer where it decreased with height. Temperature, humidity and lack of increase in roughness or turbulence directly beneath a cloud indicated that, unlike convective clouds over land, trade wind clouds originate primarily within the cloud layer rather than from surface warming of the air. Departure of the actual lapse rate within a cloud from the ideal moist adiabat served to indicate the amount of "outside" air entrained by the rising cloud. Surface solar measurements were analyzed with respect to bathythermograph data to calculate the total energy return from the sea.

Observations made during the war by the Radiation Laboratory (Massachusetts Institute of Technology) with Army and Navy cooperation were analyzed for the Bureau of Ships by Mr. Richard A. Craig and Mr. Gardner Emmons under the supervision of Dr. R. B. Montgomery. The observations consist primarily of vertical sounding through the lowest 500 meters of air over the ocean and are unique in regard to accuracy and detail. They reveal for the first time the types of vertical structure that occur in this part of the atmosphere. One group of 51 analyzed soundings was published, and a second group is in preparation.

Mr. Craig initiated a study to determine the distribution of eddy diffusivity on vertical atmospheric cross sections based on the soundings described above and he and Dr. Montgomery contributed to a conference on "Convection layers in the atmosphere and ocean" at The New York Academy of Sciences.

A study of the meteorological conditions leading to fog information is being carried out by Dr. Montgomery. The plan is to bring this subject up to date by applying the present knowledge regarding turbulent transfer and by incorporating results from the soundings described above.

A compilation of the latest determinations of the viscosity and other physical properties of air has been completed in preliminary form.

A study of the construction and use of the "Taylor characteristic diagram" in problems concerning the measurement and distribution of temperature and humidity at low levels was initiated.

Summer visitors included Dr. B. Haurwitz. Mr. H. A. Panofsky worked on an Institution Fellowship. During the fall, Mr. Woodcock spent some time in Florida measuring the amount and size of the salt particles in the air. In collaboration with Mr. Henry M. Stommel, he prepared a short paper on temperature gradients close to the surface of a small fresh water pond.

8. Development of Oceanographic Instruments.

During the past year, progress has been made mainly in two directions: wave recorder and wave period analyzer under the supervision of Mr. Arthur Klebba, and salinity-temperature-depth recorder under the supervision of Mr. Allyn Vine. Both of these developments have been financed through a contract with the Bureau of Ships, Navy Department.

With only minor interruptions, a bottom mounted, pressure type wave meter has been in operation off Cuttyhunk Island since early in 1946. Through the experience gained in operating at this station, the design was gradually improved and a second set of equipment built for installation at Bermuda. The "Atlantis" delivered the cable and the instruments to the Bermuda Biological Station in October and Mr. Frank Mather completed the installation about two weeks later. Unfortunately, the first cable used, which was light rubber covered cable known as demolition cable, soon developed leaks. In attempting to mend these, the cable was further damaged by the coral and the whole off-shore end finally had to be abandoned.

Mr. Mather returned to Woods Hole and made ready a slightly better quality cable which he laid from a small launch early in January 1947. The wave recorder has been operating successfully at Bermuda for over six months. Through these experiences, we have found that when proper precautions are taken, even on a rough and exposed coral bottom, inexpensive, small diameter, rubber covered cables will suffice. Thus the chief drawback of the pressure type wave meter, namely the expense of laying an armored cable, seems to have been overcome.

At Woods Hole, the records from both Cuttyhunk and Bermuda have been run through the wave period analyzer and Dr. H. R. Seiwell has undertaken the study of these data. It should perhaps be pointed out that the Bermuda records are unique in that the pressure unit is at the edge of the reef and records long period waves that have not yet been modified by moving across a continental shelf.

The salinity-temperature-depth recorder gives promise of becoming a relatively simple and inexpensive oceanographic instrument, although in its present form these virtues have clearly not yet been achieved. The sensitive element consists of a conductivity cell, a resistance type thermal unit and a pressure measuring device. These may be lowered on a multi-conductor

cable connected to the recorder which is on board the vessel. Conductivity and temperature are combined electrically to give salinity. A study of how these circuits might be simplified is in progress; meanwhile, as mentioned above, the preliminary model has been undergoing tests at sea. An important feature of this instrument is that when used as a surface salinity recorder it enables the research vessel to track any given surface isohaline.

Mr. J. Lamar Worzel has been studying possible means of increasing the depth range of the bathythermograph. The practical depth limit of the present type of pressure element is about 300 meters. Two instruments, which have tested satisfactorily in the laboratory under pressures equivalent to 2000 meters, have been constructed, but it is too early to report on the success of repeated use at sea. In any such instrument, corrosion problems can be critical.

9. Pacific Ocean Biology.

A new project, "Pacific Ocean Biology", which started September 1, 1946 under contract with the Office of Naval Research, is a departure from the usual types of investigations conducted at the Institution. Admittedly, the need for increased knowledge of the Pacific area is great. At the same time, it is highly desirable that some central headquarters for information be established. The reasons for locating the project at Woods Hole include the excellence of the Marine Biological Laboratory library and the availability and interest in the project of a former Institution worker, Dr. Charles J. Fish. The latter's experience with the Navy in the Pacific and elsewhere plus his previous training makes him a logical person to supervise the work.

The objectives may be divided into two parts. The first is to assemble and analyze all available data on the zoöplankton, reef building corals, fouling organisms, phosphorescence and sound-producing marine animals. Material published in foreign languages is being carded, abstracted and translated as necessary and a complete bibliography assembled. Unpublished findings of various U. S. Government agencies and similar materials from other governments as available also serve as source material. The second part of the project, on completion of the analysis and survey of the field, is to prepare recommendations for such new work as may be necessary. Thus the Institution is for the first time directly concerning itself with a phase of oceanography definitely beyond the confines of the North Atlantic Ocean.

10. Underwater Acoustics.

Studies of the environmental factors influencing the transmission of sound in seawater have been continued throughout the year under a contract with the Bureau of Ships, Navy Department.

Transmission measurements at the higher frequencies were carried out

from the USS "Mentor", a converted yacht acquired by the Navy and especially equipped for acoustical research. Dr. George P. Woollard directed the analyses of these data. A series of smaller scaled, and therefore more easily controlled, experiments were carried out in local waters under the supervision of Dr. Leonard Liebermann. Measurements of the reflectivity of the bottom and of the sea surface under a variety of conditions were obtained, as well as some determinations of the attenuation of sound by the decay method. Frequent breakdown and acute shortages of Navy personnel so hampered the operations of the "Mentor" that in August she was decommissioned. However, Dr. J. B. Hersey was able to carry out some much needed calibration studies while the ship was in operation.

The observations at much lower frequencies, secured during the previous year in the course of the experiments with Sofar, continued to be studied. Four men were trained in this new and most promising method of locating survivors at sea, and were sent out to the Pacific to help the Navy install receiving stations, two in California and two in the Hawaiian Islands. Additional low frequency transmission observations from the permanent sound channel at mid-depths will not be available until these installations have been completed.

Under Dr. Hersey's direction "Atlantis" has undertaken a systematic program of measuring the acoustical reflectivity of the bottom in deep water. Such measurements can be obtained at each hydrographic station without delaying the progress of the cruise. A most interesting development is that at many of the stations reflections have been obtained from considerable distances below the bottom. Thus it seems possible that through further studies of the velocity of sound in bottom deposits and through some additional refinements in instrumentation it may soon become possible to map stratification in the sedimentary material which has been so long accumulating. Dr. Ewing is much interested in this phase of the program.

Another acoustical development of great biological interest is that systematic observations on the depth of the so-called scattering layer, obtained through the new recording sonic sounder on "Atlantis", are beginning to show that the diurnal migration of this layer occurs with great regularity and consistency. Everywhere "Atlantis" has cruised during recent months the layer has been located, by day at about 300 fathoms and by night at about 50 fathoms. It is clear that we are here dealing with the vertical migration of plankton organisms, perhaps mainly euphausids, but whether the backward scattering of sound, which in some instances is at least as strong as the echo from the bottom, comes from such small animals or from the fish which may be feeding on them, has yet to be shown. Sonic echoes from schools of fish have, of course, frequently been observed in shallow water. If the scattering

layer in the deep ocean is also due to fish, our estimates of the total population will have to be greatly revised.

11. Underwater Explosive Phenomena.

The work of the Underwater Explosive Research Laboratory, directed by Dr. Paul M. Fye, continued under contract with the Bureau of Ordnance, Navy Department, throughout the year. Although originally the group working at Woods Hole on explosive phenomena had been thought of as a laboratory within a laboratory, this distinction has gradually almost completely disappeared. Not only have explosives become an important tool in oceanography, but also the specialist in underwater explosive phenomena has found that the environment plays an important part in the success of his experiments. However, it has become clear that there are too many people living in and near Woods Hole to make it practical to continue experimentation with explosives in local waters in peacetime. Thus the present plan is to terminate this project during the next year. Many of the results of this work are beginning to appear in the appropriate physical journals.

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(As of December 31, 1946)

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