Yours, H B Bigelow;

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LVIII. No. 2.

EXPLORATIONS IN THE GULF OF MAINE, JULY AND AUGUST, 1912, BY THE U. S. FISHERIES SCHOONER GRAMPUS. OCEANOGRAPHY AND NOTES ON THE PLANKTON.

By Henry B. Bigelow.

With Nine Plates

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Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905, Lieutenant Commander L. M. Garrett, U. S. N. Commanding, published or in preparation:—

A. AGASSIZ. V.[5] General Report on the Expedition.

A. AGASSIZ. I.[1] Three Letters to Geo. M. Bowers, U. S. Fish Com.

A. AGASSIZ and H. L. CLARK. The Echini.

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H. B. BIGELOW. XXIII.[23] The Siphonophores.

H. B. BIGELOW. XXVI.[26] The Ctenophores.

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O. CARLGREN. The Actinaria.

R. V. CHAMBERLIN. The Annelids.

S. F. CLARKE. VIII.[8] The Hydroids.

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W. E. HOYLE. The Cephalopods.

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B. L. ROBINSON. The Plants.

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[1] Bull. M. C. Z., Vol. XLVI., No. 4, April, 1905, 22 pp.
[2] Bull. M. C. Z., Vol. XLVI., No. 6, July, 1905, 4 pp., 1 pl.
[3] Bull. M. C. Z., Vol. XLVI., No. 9, September, 1905, 5 pp., 1 pl.
[4] Bull. M. C. Z., Vol. XLVI., No. 13, January, 1906, 22 pp., 3 pls.
[5] Mem. M. C. Z., Vol. XXXIII., January, 1906, 90 pp., 96 pls.
[6] Bull. M. C. Z., Vol. L., No. 3, August, 1906, 14 pp., 10 pls.
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[9] Bull M. C. Z., Vol. L., No. 6, February, 1907, 48 pp., 18 pls.
[10] Mem. M. C. Z., Vol. XXXV, No. 2, August, 1907, 56 pp., 9 pls.
[11] Bull. M. C. Z., Vol. LI., No. 6, November, 1907, 22 pp., 1 pl.
[12] Bull. M. C. Z., Vol. LII., No. 1, June, 1908, 14 pp., 1 pl.
[13] Bull. M. C. Z., Vol. LII., No. 2, July, 1908, 8 pp., 5 pls.
[14] Bull. M. C. Z., Vol. XLIII., No. 6, October, 190[illegible], 285 pp., 22 pls.
[15] Bull. M. C. Z., Vol. LII., No. 5, October, 1908, [illegible]1 pp., 2 pls.
[16] Mem. M. C. Z., Vol. XXXVII., February, 1909, 243 pp., 48 pls.
[17] Mem. M. C. Z., Vol. XXXVIII., No. 1, June, 1909, 172 pp., 5 pls., 3 maps.
[18] Bull. M. C. Z., Vol. LII., No. 9, June, 1909, 26 pp., 8 pls.
[19] Bull. M. C. Z., Vol. LII., No. 11, August, 1909, 10 pp., 3 pls.
[20] Bull. M. C. Z., Vol. LII., No. 13, September, 1909, 48 pp., 4 pls.
[21] Mem. M. C. Z., Vol. XLI., August, September, 1910, 323 pp., 56 pls.
[22] Bull. M. C. Z., Vol. LIV., No. 7, August, 1911, 38 pp.
[23] Mem. M. C. Z., Vol. XXXVIII., No. 2, December, 1911, 232 pp., 32 pls.
[24] Bull. M. C. Z., Vol. LIV., No. 10, February, 1912, 16 pp., 2 pls.
[25] Mem. M. C. Z., Vol. XXXV., No. 3, April, 1912, 98 pp., 8 pls.
[26] Bull. M. C. Z., Vol. LIV., No. 12, April, 1912, 38 pp., 2 pls.
[27] Mem. M. C. Z., Vol. XXXV, No. 4, July, 1912, 124 pp., 12 pls.

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EXPLORATIONS IN THE GULF OF MAINE, JULY AND AUGUST, 1912, BY THE U. S. FISHERIES SCHOONER GRAMPUS. OCEANOGRAPHY AND NOTES ON THE PLANKTON.

BY HENRY B. BIGELOW.

WITH NINE PLATES.

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No. 2.— *Explorations in the Gulf of Maine, July and August, 1912, by the U. S. Fisheries Schooner Grampus. Oceanography and Notes on the Plankton.*

By Henry B. Bigelow.

CONTENTS.

The cruise.

During July and August 1912 the U. S. Fisheries Schooner Grampus was detailed for an oceanographic cruise in the Gulf of Maine, under my direction, the purpose being to make as nearly complete a survey of the temperatures, salinities, currents, and plankton, of the waters of the Gulf as the brief time at our disposal, and the limitations incident to the use of a sailing vessel would allow, (Bigelow, 1913). It was also planned to do some systematic trawling in the neighborhood of Casco Bay, in cooperation with the Harpswell Marine Laboratory. During the cruise I was accompanied by Messrs. W. W. Welsh and Herbert E. Metcalf as assistants. It is a pleasure to acknowledge the assistance which Dr. C. O. Esterly has afforded in the preparation of this report, by identifying the copepods in more than 60 samples of plankton, no small task. And the value of the discussion of the plankton (p. 98) is largely due to his efforts, for copepods were altogether its most important constituent. A like debt of thanks is due to Mr. E. L. Michael, who has identified many of the Sagittae (p. 121), and to Mr. W. W. Welsh, who supplied the lists of fish fry and adult fishes (p. 107). I am also indebted to Capt. John W. McFarland, of Gloucester, who made several "tows" from his Schooner Victor.

Up to the present time, very little attention has been paid to the oceanography of the Gulf of Maine. But the fact that waters of diametrically opposed origins, *i. e.* Gulf Stream water and cold coast water, have long been known to meet each other here, gives reason to expect that an examination by modern methods will be of general oceanographic interest, and may be expected to have a practical bearing on the extensive fisheries of which it is the seat.

It is obvious that observations restricted to two months in mid-summer can not afford a picture of the regular series of changes which its waters undergo during the year, or of the sporadic variations which may be expected from the geographic position of the region in question, and from its relation to the Gulf Stream. Consequently the following report is to be regarded only as the beginning of a survey which, it is hoped, will be continued at other seasons in ensuing years.

The preparations for the cruise were made in Gloucester, and our first station, some five miles off that harbor, was occupied on July 9th, when we made a trial of the winches, trawl, deep-sea thermometers, water-bottles, and of the current-meter. The current measurements must, of course, be made from a boat at anchor; and we found that time was economized by taking them, and the serial temperatures and water samples as well, from a dory, which we could easily anchor in any depth of water down to 150 fathoms.

Our first field of work was the northern part of Massachusetts Bay. We then ran out to the 100 fathom basin, some 35 miles east of Cape Ann, where we made Station 7; but unfortunately the sea was so rough that it was impossible to make a quantitative haul, although the other work, including the hydrographic observations from the dory, was successfully performed. The nature of the hauls and other observations made at this and the other stations is tabulated below (p. 135).

From the 100 fathom basin we ran in toward Ipswich Bay, where the plankton is proverbially rich, making a rich trawl-haul of fishes at Station 8, and taking observations in the deep trough between Jeffrey's Ledge and the coast. At Station 10, off Portsmouth, our trawl fouled in some obstruction, and the winch failed to pay out the wire rope, with the result that we lost the trawl with 150 fathoms of wire rope, broke the dredging boom, and did so much damage that we were forced to return to Gloucester to refit.

After the damage was repaired, heavy weather delayed us until July 22d, when we ran northerly to Casco Bay, touching at Portsmouth, and occupying Stations 12–14, to develop the hydrographic conditions along the coast and in the trough west of Jeffrey's Ledge.

According to previous agreement Casco Bay was made our headquarters until July 31st (Stations 15–20), the vessel being engaged in dredging and trawling in the Bay and off its mouth, in coöperation with the South Harpswell Marine Laboratory.

On the completion of this work, July 31st, the vessel proceeded along the coast as far as the mouth of Penobscot Bay, making one offshore Station (21), and numerous hauls in the coastal waters and among the islands, while I remained at the South Harpswell Laboratory and titrated all the water samples collected up to that date, a room being placed at my disposal by the Director, Dr. J. S. Kingsley. I rejoined the Grampus at Portland; but owing to heavy weather and thick fog, it was not until August 7th that we were able to resume work.

We now ran a triangle to Platt's Bank and Jeffrey's Bank, likewise making a station off Cape Elizabeth, one in the deep trough between Platt's and Cash's Ledge, and one between Jeffrey's and the mouth of Penobscot Bay; but on the evening of August 8th, we were driven to refuge in Boothbay by thick fog, and lay storm-bound there and in Portland Harbor for a week. Leaving the latter port on August 13th, we commenced a section toward Cape Sable, following the parallel of 48° 25′, making Stations 27 and 28 in the eastern part of the 100 fathom basin, and Stations 29 and 30 on German Bank off the Nova Scotia Coast on the evening of August 14th in thick fog. The following day Station 31 was occupied off Lurcher Shoal, the exact position doubtful because of the fog. That afternoon we spoke a fishing vessel lying at anchor on the Grand Manan Bank and making a good fare of cod; during the night the fog lifted, allowing us to pick up the light house on Petit Manan Island.

At daylight, August 16th, the weather having cleared, we occupied Station 32, some ten miles off Mt. Desert Rock, and then turned northeasterly along the coast, making a station off Moose Peak. That night we made Station 34 in the Grand Manan Channel, and anchored in Eastport the following morning. On our passage through the channel we had found almost no plankton, a result in very marked contrast to the hauls which we had made off shore and further to the west (p. 104); and our run homeward was planned to develop the limits of this barren area as well as to trace the breadth of the band of cold water which lies close to the coast of Maine. Consequently on leaving the Grand Manan Channel, August 20, we ran off shore once more to the 100 fathom basin (Station 36) where we found an abundant plankton, and then turned northward again, reaching the coast near

Mt. Desert, whence we followed the outer islands (Stations 37–39) to the mouth of Penobscot Bay. On August 21st heavy fog once more set in, and on the 22nd we were driven to refuge until the 24th, in the Kennebec River, whence we ran direct for Cape Ann. We had planned several stations for this run, but heavy sea so interfered with our work, that only surface and intermediate hauls, bottom temperature, and water sample were taken at one station.

Up to this time we had been covering fresh ground constantly, thus having little chance to trace the changes in hydrographic conditions consequent on the advance of the season. But we were now able to repeat in Massachusetts Bay some of the stations which we had occupied six weeks earlier. One Station (43) was likewise occupied off Cape Cod, and on August 31st the Grampus returned to Gloucester.

Equipment and methods.

The money available for fitting the Grampus for the cruise was limited, and we were therefore unable to provide ourselves with various pieces of apparatus which would have been desirable. The Grampus has no dredging engine, to remedy which deficiency a gasoline winch, built for her on a previous occasion (Bigelow, 1909), was installed on deck just forward of the mainmast. But as this machine has a cargo-drum only, it was necessary to wind the wire rope from it by hand on a second winch. The reeling drum carried 300 fathoms of plough-steel rope, $\frac{3}{8}$ in. in diameter, with which all the trawling, dredging, and towing with the large horizontal and vertical nets was done, the length of wire outboard being measured by a fathom recording sheave. A small hand winch with divided barrel carrying 300 fathoms of soft iron rope $\frac{1}{8}$ in. in diameter with breaking strain of 500 lbs., and 400 fathoms of malleable steel sounding wire was also used.

The little winch was used in the dory, for serial temperatures, serial water samples, and current measurements; and occasionally on the vessel for similar purposes.

Soundings were usually made by hand with cod-line and 30 lb. lead, a method sufficiently accurate for depths of less than 150 fathoms; but occasionally with the $\frac{1}{8}$ in. wire, or with the sounding wire.

The surface thermometers were of two kinds; the ordinary "Bureau of Fisheries" type (Tanner, 1897) graduated to 1° F, and a set of six extremely accurate chemical thermometers provided by R. Goertze, Leipzig, graduated to .1°C. Most of the observations were made with the former, as the readings are sufficiently accurate for the purpose, and they are much more convenient in actual use. Two of them were used, their rating being so close that there was no appreciable difference between them.

We carried four Negretti and Zambra reversing deep-sea thermometers, unfortunately without auxiliary thermometers for taking the temperatures of the detached thread at the moment of reading, such as are provided in their latest pattern and in the Richter thermometer. Two of these were rated in the U. S. Bureau of Standards at Washington, two in the Chemical Laboratory at Harvard University, with the following results:—

Negretti and Zambra Thermometer, U. S. B. F., No. 7,277.

Reading, °F	Correction, °F when *T.* of detached thread is 32°	60°	90°
32°	−.3°	−.5°	− .6°
60°	−.6°	−.9°	−1.1°
90°	0	+.3°	+ .6°

Negretti and Zambra Thermometer, U. S. B. F., No. 7,259.

32°	−.5°	−.8°	−1.1°
60°	−.2°	−.5°	− .9°
90°	+.4°	0	− .5°

It is fortunate that the changes in reading consequent on change of temperature of the detached thread are so small, for without the use of a water-bath, which was not available, the temperature of the detached thread could be obtained only by allowing the instrument to come to the temperature of the air before reading.

The corrections for Nos. 84,036 and 49,648 were noted with the temperature of the detached thread the same as that of the readings; *i. e.*, the freezing point reading was taken at an air temperature of 32°, the 68.5° reading at an air temperature of 68.5°. They are as follows:—

84,036, 32°, correction −.2°; at 68.5°, −.55°; at 77.13°, −.82°.
49,648, 32°, correction −.5°; at 68.5°, −.16°; at 77.13°, −.37°.

With both these thermometers the requisite correction at readings between 40° and 50° is about −.3°: and though this is not exact, variations from it, within this range, are less than the probable error of the observations (p. 40). The thermometers were used in reversing cases of the Tanner type (Tanner, 1897, pl. 21) actuated by a propeller; and these worked very well.

Two water-bottles were taken for collecting samples, a "Sigsbee" (Tanner, 1897, pl. 24): and a stop-cock bottle; but as the first trial of the "Sigsbee" showed that it could not be relied upon, all subsequent samples were obtained with the stop-cock bottle. This apparatus is a modification of the stop-cock bottle used on the MICHAEL SARS and highly recommended by Helland-Hansen and Nansen, (1909) the chief difference being that it is single instead of double, and actuated by a messenger instead of by a propeller. In its essentials (fig. 1) it consists of a brass tube, tinned on the inside, with a stop-cock at either end, the openings of the latter being only slightly smaller than the inside diameter of the tube. The mouth of the lower one carries a large copper funnel, which hastens the flow through the tube as it is being lowered and prevents water being carried downward in the bottle. Each stop-cock is hinged by a rod to the brass plate which carries the tripping gear, in such a way that when the bottle is raised both stop-cocks are open. When the bottle is tripped, the tube falls of its own weight, the hinge-rods turning the cocks in their barrels, and closing them.

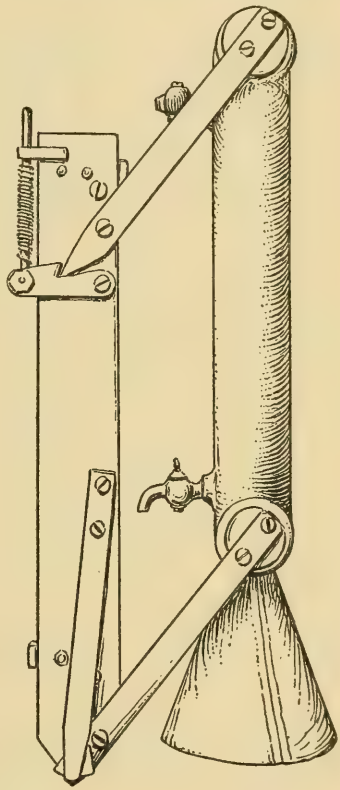

FIG. 1.— Stop-cock water bottle.

The tripping gear consists of a scear which engages the end of the upper hinge-rod when the tube is raised, and of a trigger which trips the scear when pushed downward against its spring by the messenger which is sent down along the wire rope. The dog, or ratchet engages the lower hinge-rod when the bottle falls and is closed, to prevent accidental opening. There is a small stop-cock near the upper end to admit air, and another near the lower end to discharge the water.

The apparatus proved entirely reliable, perfectly water tight, and it has the great advantage that it can be made by any skilled machinist at small expense. The most important precautions in its manufacture are to provide tight stop-cocks: and to make the diameter of the tube as nearly the same as that of the latter as possible.

The water samples were preserved in "citrate of magnesia" bottles, made of lead glass by the Whitall Tatum Co., with patent stoppers consisting of a porcelain disc forced by a spring against a rubber ring. The joint thus formed is so nearly air tight, that the danger of evaporation is negligible. As pointed out (p. 62) tests show no appreciable alteration of the samples after prolonged storage. The only drawback to these bottles is that they are fragile and occasionally break spontaneously as a result of sudden change of temperature.

Current measurements were taken with an Ekman current meter.

Salinity was determined by titration with nitrate of silver, the index being chromate of potassium. The burette and "Knudsen" 3-way pipette were supplied by Robert Goertze of Leipzig, the standard water by the International Committee for the exploration of the sea. This, of course, is the method almost universally employed; and the principle on which it depends has been explained by Murray and Hjort, (1912) as well as by various other writers.

The color of the sea is usually recorded by the "Forel" scale based on a combination of blue and yellow, the former being .5 gram copper-sulphate + 5 cc. ammonia in 95 cc. water, the latter .5 gram potassium chromate in 100 cc. water. The combinations used are: —

	1	2	3	4	5	6	7	8	9	10	11	12	13
blue	100	98	95	91	86	80	73	65	56	46	35	23	10
yellow	0	2	5	9	14	20	27	35	44	54	65	77	90

In practical use a scale consisting of a series of glass tubes is unsatisfactory because of surface reflections. But these are entirely avoided if the tubes be mounted in a frame above a white mirror of porcelain at 45°, being thus seen by transmitted light against a white background. The color of the sea water is observed by means of an ordinary plate-glass mirror mounted at 45° at the end of a pole and held a foot or two below the surface on the shady side of the ship. With this device, our home waters change from apparent blue to light bottle-green.

Transparency measurements were made with the ordinary white disc fourteen inches in diameter, and we likewise used a four candle-power electric light with storage battery, in a water-tight brass case with glass window at the top.

The following nets were used: —

1. Four foot open net for horizontal towing, of the ALBATROSS pattern; ten ft. long, the upper five ft. with $\frac{1}{8}$ in. mesh, the lower five ft. lined with silk, 38 meshes to an inch. A glass bucket was sometimes used with this net, and a 70 lb. weight attached to the wire rope.
2. Quantitative nets of the Hensen type, the opening of the net 36 cm. in diameter, with glass collecting-bucket, and a 70 lb. weight attached to the latter. Nets of two grades were used, the silk of one being 74 meshes to the inch, the other 144 to the inch.
3. Ordinary open net of no. 20 bolting silk, 18 inches in diameter.
4. Open net 12 inches in diameter, silk 38 meshes to the inch.
5. A scrim net 18 inches in diameter.
6. A closing net for horizontal towing.

This net, described in Int. rev. hydriob., 1913, **5**, p. 576, is a combination of the Chun-Petersen-Nansen principles, *i. e.*, it has a hinged ring which is sent down closed, to be opened by a spring released by

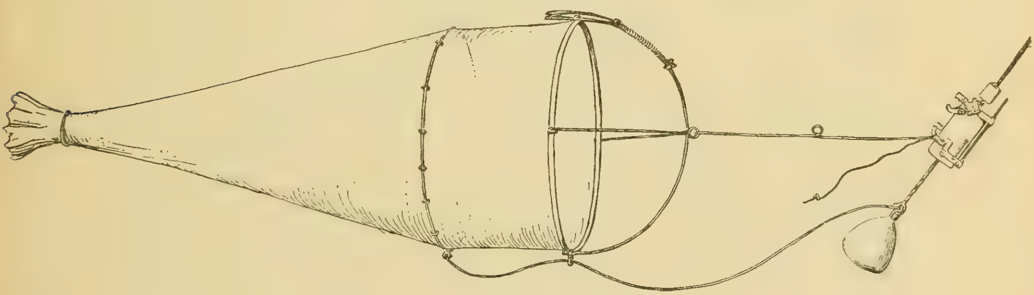

FIG. 2.— Closing net in operation.

a messenger; and it is closed by a draw-string about the net bag, likewise operated by messenger (fig. 2).

Trawling and dredging were a minor part of our program; for this work we carried ordinary dredges, and eight-ft. beam trawls.

The four-ft. and closing nets were towed horizontally, sometimes separately, sometimes simultaneously on the wire rope. In the latter case, the former was necessarily used at the deepest, the latter at the intermediate horizon. In the shallow waters in which we worked the catenary of the rope is so small as to be practically negligible;

and the depth can be calculated from the angle of the rope as observed by the dredging quadrant (Tanner, 1897) and the length outboard.

The need for a high degree of accuracy in oceanographic research has been emphasized by Helland-Hansen and Nansen, (1909) who have shown that in waters as comparatively well known as those of the North Sea and the Norwegian Sea, inaccurate salinity observations are worse than none, as they give a wholly misleading idea of the water-circulation. The same is true also of temperature readings, especially at great depths. But in a preliminary survey of a field, so little known as the Gulf of Maine, the same high degree of accuracy is not so essential, for any information which can be relied on as approximately correct is of value. Nevertheless, the more accurate the determinations the better, for the sake of future comparisons. In any case, it is essential that the probable limits of error of the observations for both salinity and temperature should be clearly stated, and constantly borne in mind in all discussions.

In the determinations for salinity we are provided with a perfectly satisfactory water-bottle; the storage of the samples is not open to any apparent criticism, and our burette and pipette are of the best. The instrumental error, therefore, must be very small indeed; and there remains only what we call the personal error of the observer. Unfortunately no trained chemist was available for the titrations; and I must confess that I have found the determination of the precise point at which the color changes from yellow to orange a difficult one. Nevertheless, as every sample was titrated twice, some of them three or four times, as the standard water could be relied upon, and as an actual test (p. 62) has shown that repeated tests of the same samples did not differ by more than .01 of salinity, I believe that the results arrived at are reliable considerably within the requirements of the International Committee for the exploration of the sea, *i. e.*, ±.05 of salinity, probably to ±.02 of salinity.

In the case of temperature, a very high standard of accuracy could not be expected from the instruments which we used. Our deep-sea thermometers were graduated only to 1.°F; and the graduations are so rough that we found it impossible to rely on estimation closer than .2°F, though the readings were taken with a reading lens, and estimation to .1°F was constantly attempted. We must also consider the possibility of error resulting from not knowing precisely the temperature of the detached mercury thread when read, though the table of correction shows that an error here of 5°F, at the usual air temperature of 55°–70°F would make a difference of only about .1°F in the reading, and this may be considered the extreme. There is one other source of error in any reversing thermometer actuated by a propeller; *i. e.*, uncertainty at what precise level the instrument reverses, with possibility of change in reading during its passage upward through the column of water necessary to reverse it. But we so often used two thermometers at each level, and so often repeated the entire series, that I do not believe this possible error is of any practical importance in the present case. On the whole, then, it is better not to claim accuracy closer than ±.3°F; *i. e.*, roughly, .15°C. And it is certainly much better to set these limits wide, rather than to claim a higher degree of accuracy than can be relied upon.

The surface thermometers were extremely reliable, and so far as the instruments themselves are concerned very little error is to be expected. But the readings were taken by various persons, often under difficult conditions, therefore accuracy is not claimed beyond ±.5°F.

FIG. 3.— Bathymetic chart of the Gulf of Maine.

Oceanography.

Up to the present time no systematic studies of the oceanography of the Gulf of Maine have been undertaken. The surface temperatures have, of course, been known in a general way for many years, as has the existence of a cold band of water close to the coast of Maine and in the Bay of Fundy; and thanks to Dickson's, (1901) researches we have a fairly satisfactory idea of the seasonal range of surface temperature for two years, 1896 and 1897. But his records were far too few to delimit the distribution of slightly differing temperatures within the Gulf.

Almost all the knowledge we possess as to the bottom temperatures dates back to 1872, 1873, and 1874 when a series of dredgings was carried out by the U. S. Fish Commission and the U. S. Coast Survey on George's Bank, in the Bay of Fundy, off Cape Elizabeth, and at various other localities in the Gulf. The bottom temperature was recorded at each station, and the records have been published by Verrill, (1873–1875); but unfortunately, as he himself points out, the Miller-Casella thermometers which were used proved unreliable, two instruments often differing by several degrees when used simultaneously. Nevertheless the results were valuable as showing in a general way the low bottom temperature of the Gulf (p. 93). So far as I can learn, no intermediate temperatures have ever been taken in the Gulf, except a few which I obtained during the summer of 1911 between Cape Ann and Casco Bay.

The salinity records for the Gulf are even more scanty than those for temperature. A considerable number of hydrometer readings for the surface have been taken by the Bureau of Fisheries; but most of them were made with unstandardized instruments, and under circumstances precluding any approach to accuracy. The only reliable salinity records from the surface are three titrations by Dickson, (1901), of samples collected off Cape Cod, April, 1896; off Cape Sable, April, 1896; and northeast of George's Bank, April, 1896. And there are no records whatever of the salinity on the bottom, or at intermediate depths.

For George's Bank and the Eastern Channel, the data is rather more extensive, there being eighteen titrations (Dickson, 1901); and a considerable series of temperatures were taken by the Albatross in 1883 in the channel with Negretti and Zambra reversing thermometers. There is one titration from Brown's Bank and a considerable number southeast of Nova Scotia (Dickson, 1901) besides a series of surface and bottom temperatures by the ALBATROSS (Townsend, 1901).

Surface temperature, July–August, 1912.— The surface temperature was taken hourly, day and night, throughout the cruise; and the readings are plotted on the chart (Plate 1). When I came to check up the results, one interesting anomaly became apparent, namely, that the surface temperature at each station is from .5° to 1° lower than the next reading on either side of it. This discrepancy is probably due to the method of observation, the readings at the stations being taken with the thermometer hanging a foot or so below the surface, whereas the instrument dragged on the actual surface when the vessel was under way.

The chart shows that so far as surface temperature is concerned the Gulf of Maine can be divided into two general regions, one with temperatures of 60° F or over, both day and night, in July and August, the other with temperatures below 60°. In a general way the first includes the whole of the southern and central parts of the Gulf, *i. e.*, Massachusetts Bay, and the off-shore waters south of 43° 21′ N. Lat., as far east as 66° 45′ W. Long., but it does not reach the Nova Scotia coast. Over all this area the daily average of the surface water was about 61° and the diurnal warming, touched on below, considerable. But though Massachusetts Bay as a whole belongs to the warm division, lower temperatures were observed along the northeast coast of the Bay, near Eastern Point, off Race Point (Station 44, 58°); off Baker's Island, and notably near Boston Light-ship (July 15, 58°) where two days before a temperature of 63° was observed. And on July 23 a band of water of only 56° was found extending from Gloucester around Cape Ann for some ten miles northeasterly, *i. e.*, covering a region where a few days before temperatures above 60° were found.

The temperature was above 60° in Ipswich Bay, north of Cape Ann. But when we entered the passage between the Isles of Shoals and the mainland, the surface temperature dropped several degrees, the readings here being 55°–57°, and working northeastward, a continuous belt of this cold water was found lying next the coast. From the Isles of Shoals nearly to Cape Elizabeth this cold band was about 15 miles broad; south of the Isles of Shoals it narrowed suddenly, the 60° curve touching the coast somewhere between Station 10 and the mouth of the Piscataqua River. The cold water does not reach Cape Ann except sporadically, an instance, as noted above, being July 24th, when, strong northerly gales for the three preceding days had driven the warm surface water to the south. And even in this case it is probable that the cold water which took its place welled up from below, rather than that it was an extension of the cold zone normally encountered some 15 miles further north. At 43° 27′ N. Lat., *i. e.*, a few miles south of Cape Elizabeth, the cold band suddenly became broader, the 60° curve bending eastward almost at a right angle, and roughly following the parallel of 43° 27′, to within about 35 miles of Seal Island, Nova Scotia (*i. e.*, 66° 49′ W.) where it turned southward and passed out of the area covered by the cruise of 1912. The cold water thus expands from a narrow band to a triangular area which is about 45 miles broad opposite Grand Manan. It is continuous thence along the western coast of Nova Scotia, becoming narrower again (25 miles broad) off Yarmouth. Throughout this triangle the temperatures, day and night, were everywhere 59° or below, except for one sporadic reading of 60° off the Grand Manan Bank, probably explicable by diurnal warming on a very calm day; and the diurnal range very small. From Portland eastward to Mt. Desert the temperature range was from 56°–58°, a very small variation when we remember the strong tides of this region. Northeastward from Mt. Desert the temperature close to the coast dropped below 55°; and from Moose Peak to and through the Grand Manan Channel, as well as in Passamaquoddy Bay and Eastport Harbor the temperature on the surface was 50°–52°.

Unfortunately we did not enter the Bay of Fundy proper, and it is therefore impossible to draw the curve of 55° accurately. But so far as our observations show, it touched the outer islands at Mt. Desert; ran easterly for about 25 miles, and then turned southeasterly, enclosing the Bay of Fundy and a band along the west coast of Nova Scotia. On our run from Station 28 to Station 29, the drop in temperature was very sudden, from 60° at 60° 49′ W to 50.5° at Station 29, 20 miles further east. The area of water colder than 55°, is then roughly comparable in outline to that between 55° and 60°, though much smaller in extent. And this cold water was below 55°, usually below 53°, by day as well as by night. The lowest surface temperatures encountered were on German Bank (50.5°) off Grand Manan Bank (50°), and in the Grand Manan Channel (50°).

Our only example of seasonal change is in Massachusetts Bay, which we studied at the beginning and again at the end of our cruise. From July 9–15 the temperatures in the northern half of the Bay during the day time were usually 63°–65° (60°–65°) except for the occasional cold bands mentioned (p. 43) to which we will have occasion to return in our discussion of vertical circulation; and off Cape Ann the temperature during this same period ranged from 60°–66° (day and night); usually 63°–65° in the day time. On our return we crossed Massachusetts Bay twice (August 28th–31st). On the first passage the surface temperature ranged from 60°–62°, the mean being about 61°; on the second, two days later, from 59°–61°, the mean being nearly 61°; and on August 29th, off Cape Cod, the temperature range was from 60° to 62°, with a mean of 61°. These observations show that by the end of August an appreciable cooling of the surface water had taken place in and near Massachusetts Bay, from the annual maximum, which must be reached about the first of August.

Satisfactory data as to diurnal warming can be obtained only when the vessel lies at one spot for considerable periods, so our information on this point is not very extensive. But we made some observations which suggest an unusually great diurnal warming under certain con-

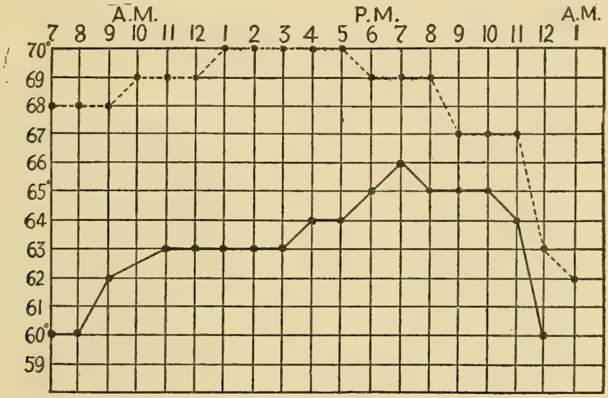

Fig. 4.— Air and surface temperatures, off Cape Ann, July 15, 1912.

ditions. On July 15th we ran eastward from Massachusetts Bay to Station 7, and then westward again in the evening, being continuously within an area of weak tides, with clear sky and moderate breezes. Surface and air temperatures for each hour from 7 A. M. to 12 midnight are shown (fig. 4). The surface temperature, which was 60°, near Boston Light-ship, rose rapidly to 63° at 10 A. M. It then remained constant until 2 P. M., when there was an irregular rise, culminating, at 7 P. M., with 66°. After this the temperature fell reaching 60° once more at midnight. Observations made during the rest of the night are not comparable with the foregoing, because we were then within a few miles of the coast; but they show that the temperature remained 60°–61° until 8 A. M., then rose gradually to 67° at 1 P. M., July 16, at which time we were in Ipswich Bay. In the afternoon we passed into the cold coast water off Portsmouth. The air temperature for July 15th shows a rise and fall roughly parallel to that of the water, the latter, however lagging far behind the former. On the 16th the air temperature rose from 64° at 6 A. M. to 76° at 11 A. M., *i. e.*, it was roughly parallel to the rise of the water.

On August 7th we had a second opportunity to observe diurnal warming of the surface. This day was flat calm, with a bright sun, but slightly hazy. We ran all day southeastward from Cape Elizabeth. Close to the coast, of course, we passed through the cold band; but at 9 A. M. we had run into the warm off-shore water, some fifteen miles from the Cape; and air and water temperatures for every hour from this point on until midnight are plotted (fig. 5). The surface

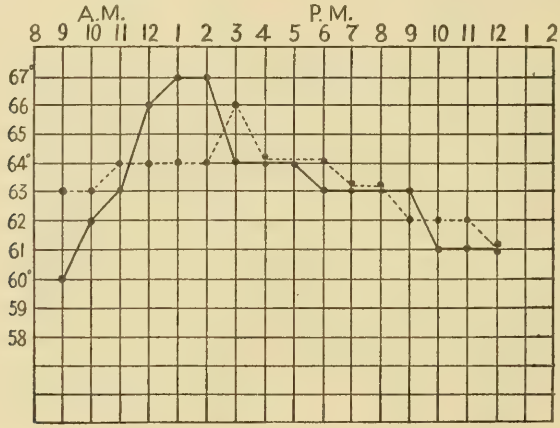

FIG. 5.— Air and surface temperatures, August 7, 1912.

temperature rose steadily from 60°, until at 1 P. M. the maximum, 67°, was reached. By this time the air temperature had risen only 1° (from 63°–64°); but by 3 P. M., when the water had fallen to 64°, the air reached its maximum for the day, 66°. From this time onward both air and water cooled, until at midnight both were 61°. This case is especially interesting, because the warming of the water preceded that of the air, and reached a higher degree. So far as they go, these observations show that diurnal warming in the region in question is very considerable in clear, calm weather, even as much as 6° or 7°, but it is usually much less, *i. e.*, 2° to 3°.

One day, August 21st, throws light on the diurnal warming of the cold coast water between Mt. Desert and the mouth of Penobscot Bay. The hourly diagram (fig. 6) shows that there was only about 2°

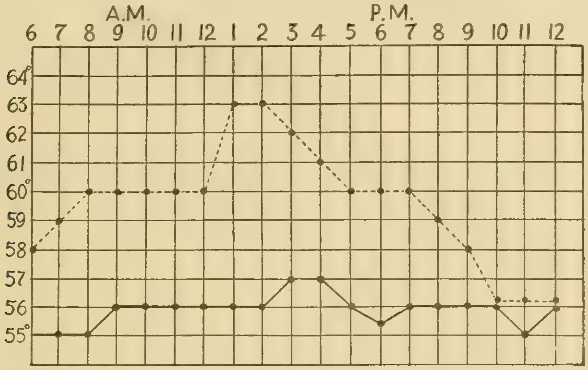

FIG. 6.— Air and surface temperatures, August 21, 1912.

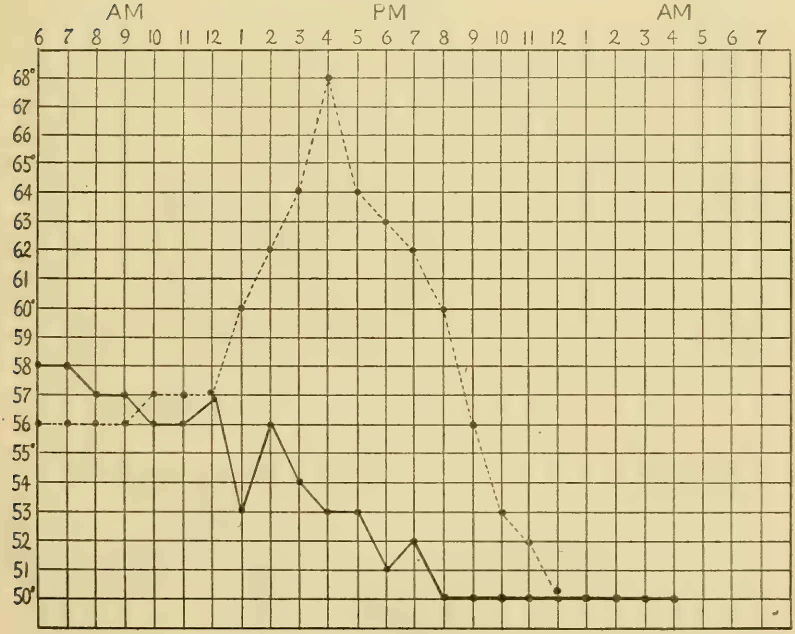

FIG. 7.— Air and surface temperatures, August 6, 1912.

rise in the surface temperature readings (55°–57°) although the air rose from 58°–63°, and the temperature readings taken on various days show that diurnal warming is very much less in this region than it is in the warmer off-shore waters. So far as our observations go, they suggest that in the cold coast water northeast of Mt. Desert diurnal warming is not usually observable; thus the diagram for August 6th (fig. 7) shows a slight fall (56°–57°) from 6 A. M. until

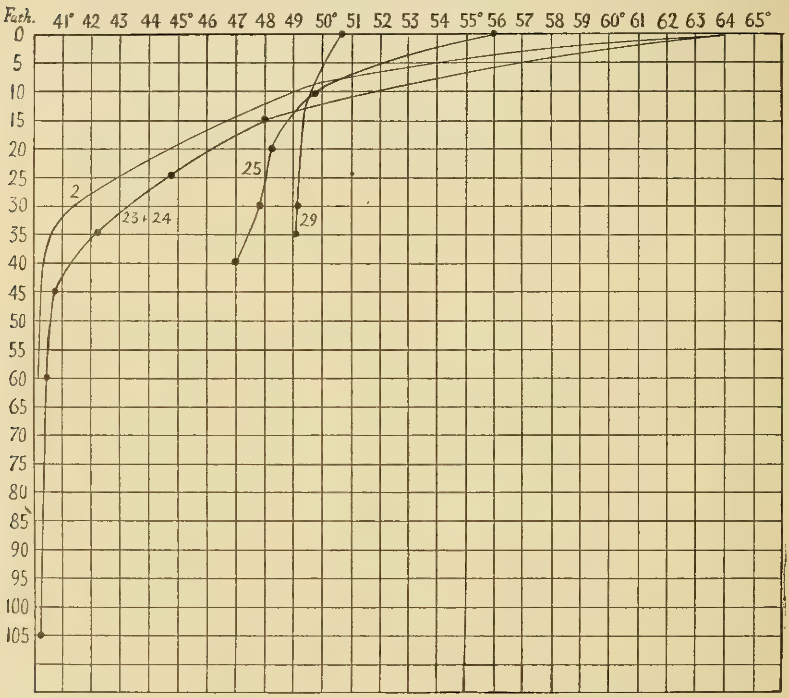

FIG. 8.— Temperature sections at Stations 2, 23, 24, 25, 29.

noon; although between 9 A. M. and 4 P. M. the air temperature rose from 56° to 68°.

To explain the distribution of the surface temperatures of the Gulf of Maine, just outlined, requires a knowledge of the temperatures in the underlying water layers at the same season, which is afforded for the first time by the Cruise of 1912.

Temperature sections.— The section made off the mouth of Massa-

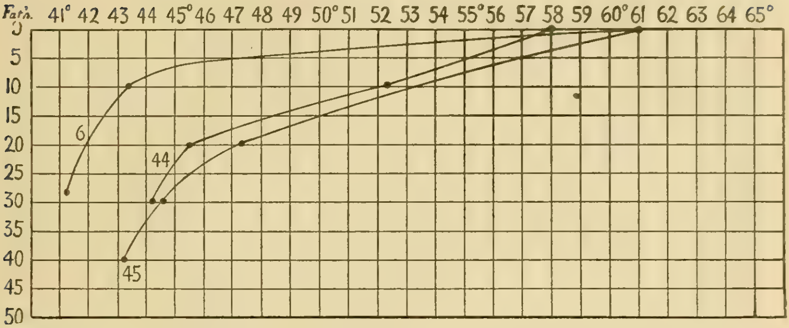

FIG. 9.— Temperature sections in Massachusetts Bay, Stations 6, 44, 45.

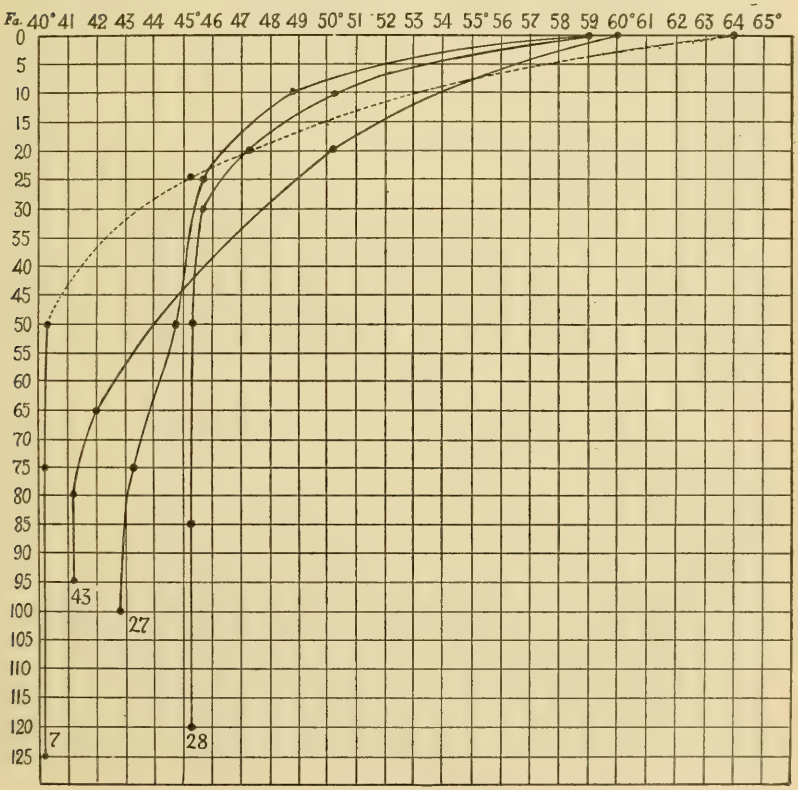

FIG. 10.— Temperature sections in the western and eastern parts of the Gulf Stations 7, 27, 28, 43.

chusetts Bay in the first half of July, (Station 2 [1]) shows (fig. 8, 11) that there is a very rapid decline in temperature from the surface where it is about 65°, to 49° at about ten fathoms, followed by a rather slower decrease to 40.3° at about thirty-five fathoms, from which point downward to the bottom there is no further change. In the shallower parts of Massachusetts Bay in July, Stations 5 and 6 (fig. 9) the cooling between the surface and ten fathoms is even more rapid, the drop being from 61° to 43.4°; and it then declines less rapidly just as at Station 2, to the bottom in twenty–thirty fathoms, at which point the lowest temperature, 41.3° is reached, the temperature at this level

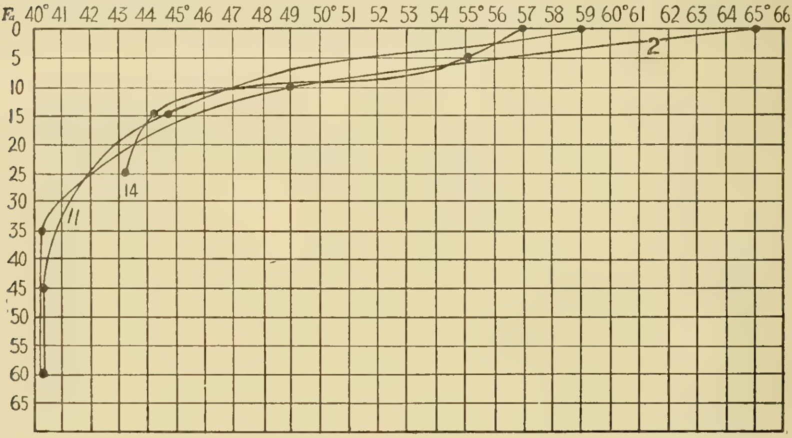

Fig. 11.— Temperature sections in the mouth of Massachusetts Bay (Station 2), and west of Jeffrey's Ledge (Stations 11, 14).

being the same as it was at Station 2. In the Bay at the end of August conditions are different, as pointed out below. At Station 1 the temperature curve is practically the same as at Stations 5 and 6, the temperature at the bottom in thirty-five fathoms being 40.6°, very nearly what it is at Station 2 at a corresponding depth.

The section in the 100 fathom basin off Cape Ann, Station 7, (fig. 10) shows that the surface layer of warm water was slightly thicker here, the drop from the surface to 10 fathoms being only from 64° to about 53°; and the rate of decrease diminishing slowly until the minimum of 40.3° is reached at fifty fathoms, instead of at thirty-

[1] To agree with the station numbers of the U. S. Bureau of Fisheries 10000 should be added to the numbers given in this report, *e. g.* 10002.

five as at Station 2. Below this level there was no further change of temperature to 125 fathoms.

At Stations 9, 11, and 14, (fig. 11) west of Jeffrey's Ledge, the curves agree very well with those for Massachusetts Bay, except that the surface temperature of the last two is several degrees lower, and that at one Station (12b) in the trench, a lower bottom temperature, 39.2°, was recorded. But as this was the only instance of a reading below 40.3°, it is possible that the thermometer recorded incorrectly. Off Cape Cod at Station 43, late in August, the bottom temperature was higher, in this case, 41.3° instead of 40.3°; and as at Staton 2, the uniform bottom water was met at 50 fathoms (fig. 10).

In all the western part of the Gulf, there was a bottom layer, of varying thickness, and reaching to within varying distances of the surface of the water, the temperature of which was practically uniform, 40.3°. In the western 100 fathom basin, it was seventy fathoms or more in thickness, and it filled the deep circumscribed basin at the mouth of Massachusetts Bay, as well as the bottom of the deep trough west of Jeffrey's Ledge. But the differences in the temperature in Massachusetts Bay in early July and late August (p. 58) show that it is only below fifty fathoms or so that the bottom temperature may be expected to remain fairly constant throughout the year. Above that level, the whole water mass is subject to summer warming and winter cooling.

If we compare the temperature sections at successive stations from Cape Ann toward Nova Scotia (Stations 2, 7, 23, 24, 27, 28, 29, figs. 8, 10) we find that the curves, which are nearly uniform from the Cape to Station 24, grow progressively straighter from that point eastward, the temperatures being higher and higher on the bottom, lower and lower on the surface. And while the curves for Stations 27 and 28 show that the lower seventy to eighty fathoms of the eastern arm of the 100 fathom basin, like that of the western one, was filled with a layer of water which shows very little decrease in temperature downward below thirty-five fathoms, the bottom water differed from that of the western basin in being decidedly warmer than in the latter, a difference which can not be laid to advance of the season, because on our return (Station 41) we once more encountered bottom water of 40.3°, west of Jeffrey's Ledge; and in being less uniform, for it was slightly warmer at all depths at Station 28 than at Station 27. And while at Station 28 the temperature of the whole mass below thirty fathoms was 45.3°, at Station 27 there was a slow, but constant decrease all the way to the bottom, where the temperature in 100 fathoms was about 43°. On reaching German Bank, we found that the surface temperature had dropped from 59° to 50.5°; the bottom water on the contrary, had risen to 49.2°, the entire drop taking place within ten fathoms of the surface.

Temperature sections from Cape Ann toward the Bay of Fundy, (Stations 11, 19, 39, and 35, fig. 12, and Stations 8, 14, 15, 21, fig. 13), exhibit a gradation similar to that seen on the line Cape Ann–Nova Scotia, the curves growing progressively straighter and straighter

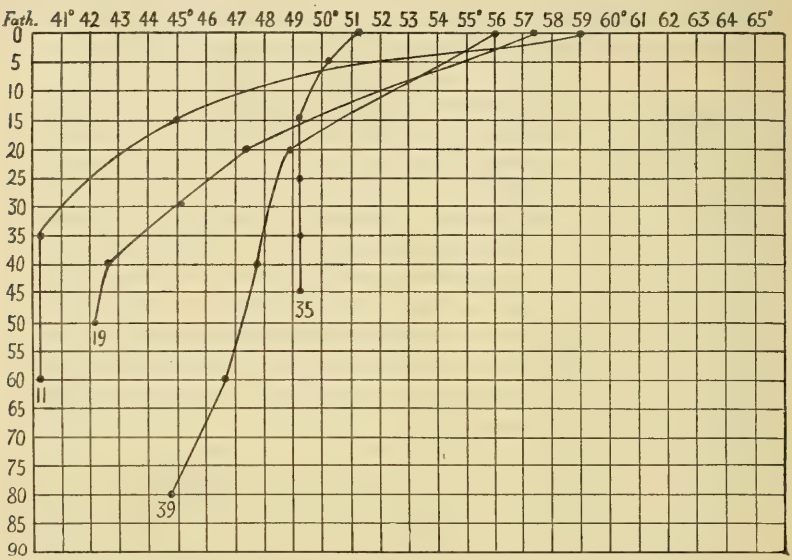

FIG. 12.— Temperature sections, Cape Ann to the Bay of Fundy, Stations 11, 19, 39, 35.

toward the northeast. Station 11 is practically identical with Stations 2, 23, and 24; Stations 33, and 35 with Station 29; Station 39 is intermediate.

It is interesting to compare the temperature conditions over the three off-shore banks which we visited, Platt's, Jeffrey's, and German, (fig. 14) with one another and with those of the deep basins. The first is about fifty miles northeast of Cape Ann. The surface temperature here was 64°, the bottom reading in 45 fathoms, 40.8°, and its temperature curve (fig. 14) is almost precisely identical with that of Stations 2 and 11. This, of course, shows that the bank had no disturbing effect on the water above it. On Jeffrey's Bank, some thirty-five miles south of the mouth of Penobscot Bay, the surface temperature was distinctly colder than we found it on Platt's the day before, *i. e.*, 57°; but the bottom, in 60 fathoms, was much warmer, 47.3°

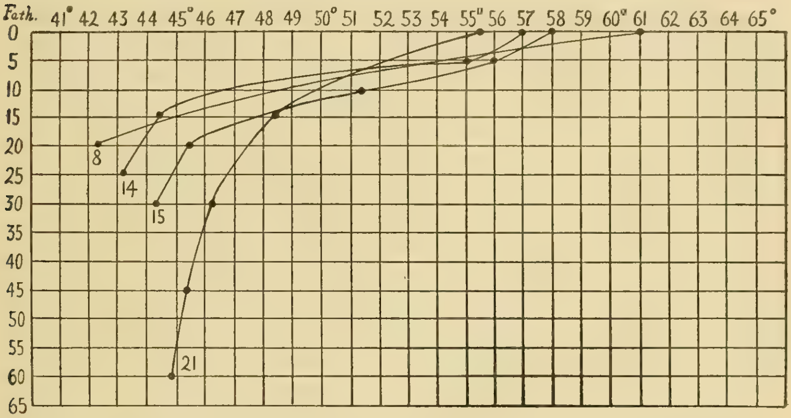

Fig. 13.—Temperature sections in Ipswich Bay (Station 8), off Cape Porpoise (Station 14); off the mouth of Casco Bay (Station 15), and off Monhegan (Station 21).

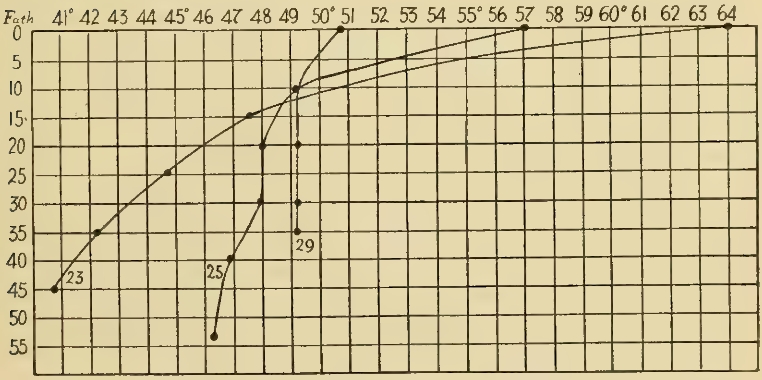

Fig. 14.— Temperature sections on Platt's Bank (Station 23), Jeffrey's Bank (Station 25) and German Bank (Station 29).

instead of 40.8°. The curve for Station 25 shows a rapid decline from the surface down to ten fathoms, in which distance there was a drop of nearly 8°, while from that point downward the decline was slow and irregular. On German Bank, some fifteen miles off Seal Island, Nova Scotia, the surface reading was 50.5°, the bottom 49.3°, the entire drop taking place in the upper ten fathoms, below which point the temperature was uniform to the bottom. These three banks, then, taken in a series, illustrate precisely the same kind of temperature relation as was exhibited by the coast waters passing eastward and northeastward from Cape Ann, but to a more pronounced degree.

The serial temperatures at Station 31 (Fig. 15) are especially in-

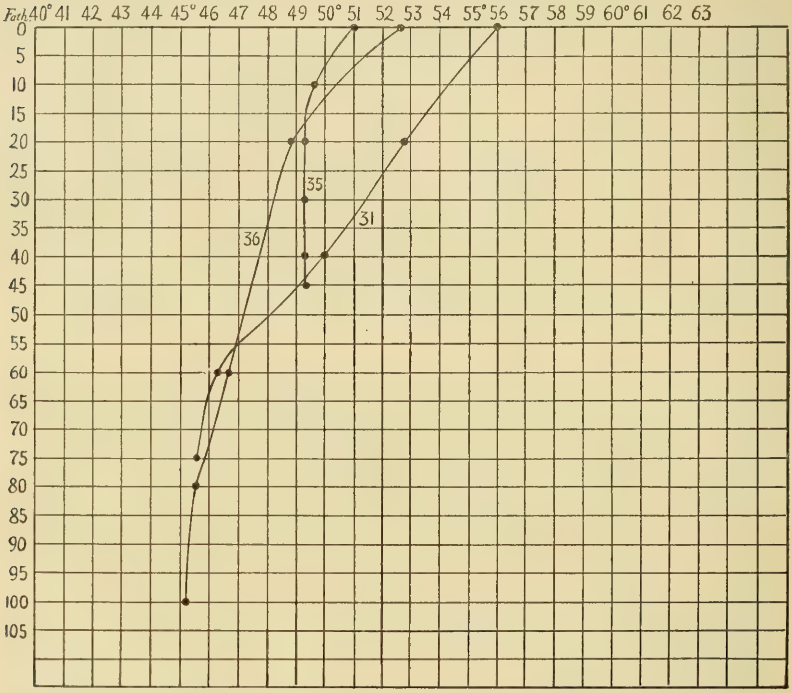

FIG. 15.— Temperature sections in the Grand Manan Channel (Station 35); in the northeast end of the Deep basin (Station 36), and near Lurcher Shoal (Station 31).

teresting because of nonconformity with those at neighboring stations, *i. e.* they are warmer at all depths above fifty fathoms, a phenomenon best discussed in connection with the temperature profiles.

Temperature at twenty-five fathoms.— The curves for temperature at twenty-five fathoms (Plate 1) reconstructed from the temperature sections, show that the relative distribution of temperatures at this depth was in a general way the opposite of what it was on the surface, the lowest temperatures being encountered in the west, in Massachusetts Bay, off Cape Ann, and in the trough west of Jeffrey's Ledge, the highest in the east, off the coast of Nova Scotia (Stations 29 and 31), and in the Grand Manan Channel. The extreme range, at this depth, was from about 42° to about 51°, the former characterizing the cold area delimited above, the latter encountered only at Station 31. In general the twenty-five fathom temperature in the northeastern part of the Gulf was between 48° and 49°. The curve for 48° runs southerly from the mouth of Penobscot Bay far enough to include Jeffrey's Bank, then turns northward again toward the coast, which it parallels at a distance of about twenty miles, until the meridian of 67° 25′ is reached, when it once more bends to the southward. Off the mouth of Casco Bay there was an isolated area where the twenty-five fathom temperature was 48° or higher. And off Cape Cod, Station 43, the temperature at twenty-five fathoms was likewise above 48°. The chart for this level is constructed only for July and early August, and our observations show that at least in the western part of the Gulf there is a decided rise in temperature at twenty-five fathoms from July 9 to August 31, the water shown on the chart as 42° warming to 45°–46°.

Bottom temperatures.— The curves for the temperatures at the bottom (Plate 1) show that, like those for twenty-five fathoms, there was a regular rise, both at corresponding depths and absolutely, passing northeastward from Cape Ann to Nova Scotia. Thus at Stations 2, 3, 5, 6, 7, 12b, and 24, the bottom temperatures in depths of from 40 to 120 fathoms were constantly below 42°, the minimum being 39.2 at Station 12b in the trench between Jeffrey's Ledge and the mainland. That is to say, in July, the bottom temperature over the western arm of the 100 fathom basin, in the deeper parts of Massachusetts Bay, below say forty-five fathoms in the trench west of Jeffrey's Ledge, and over Platt's Bank was extremely uniform, usually 40.3°. But as we ran eastward we found higher and higher bottom temperatures, irrespective of depth. Thus, at Station 27, on the western edge of the eastern arm of the 100 fathom basin, in 100 fathoms, the bottom reading was 43°; at Station 28, thirty-five miles further northeast, in 120 fathoms, it was 45.5°; at Station 29, on German Bank, in thirty-five fathoms, between 48° and 49°, *i. e.*, only about 1.5° below the surface reading; and some 7° or 8° warmer than the bottom temperature at a corresponding depth in Massachusetts Bay, 6° warmer than at thirty-five fathoms over Platt's Bank. Successive stations passing northeasterly along the coast from Cape Ann toward the Bay of Fundy show a similar rise of bottom temperature, irrespective of depth. Thus at Station 11, in sixty fathoms, abreast of Portsmouth, the bottom reading was about 40.3°; at Station 19, abreast of Cape Elizabeth, in fifty fathoms, 42.3°; Station 39, off the mouth of Penobscot Bay, eighty fathoms, 46°; Station 35, in the mouth of the Grand Manan Channel, forty-five fathoms, 49.3°; which was only about 1° lower than the surface temperature.

Temperature profiles.— The first profile (fig. 16) constructed from the temperature curves, shows the distribution of temperature for July and early August from Boston to Station 29, on German Bank, passing through Jeffrey's Bank, (Stations 6, 2, 7, 24, 25, 27, 28, 29). At the western end of the profile, there is a very thin surface layer of warm water with temperatures above 46° overlying the cold bottom water with a temperature of 40.3°–41°, which fills all the eastern basin below about forty fathoms. Passing eastward the lower limit of the warm layer, which may be established arbitrarily by the isothermobath of 46°, dips from about five fathoms at Station 6 to fifteen fathoms at Station 2; and in the trough west of Jeffrey's Ledge, it lies at about that same depth. From Station 2 to Station 7 it dips to about twenty fathoms, which level it follows to Stations 23 and 24.

At Station 25 a very interesting phenomenon is seen, for here the curves for temperatures above 48° rise nearly to the surface, while that of 46° touches the slope of Jeffrey's Bank at about seventy fathoms. East of the bank the reverse occurs, the curve of 48° rising to about fifteen fathoms at Stations 27 and 28, the curve of 46° to twenty – twenty-five fathoms at these same stations. At Station 29 there is a distortion of the curves parallel to that on Jeffrey's Bank (Station 25); the temperature of the entire water-mass being between 49.1° and 50.6°.

Over the eastern part of the profile, the bottom water is less uniform in temperature than it is in the western, the coldest water (about 43°) being met on the eastern face of the slope of Jeffrey's Bank, while the easterly part of the basin below thirty fathoms is filled with water of about 45.3°.

A profile from the basin (Station 28) to German Bank (Station 29) passing through Station 31 (fig. 17) reveals the presence of a mass of warm water on the surface at the latter. Over the first part of this line the curves for temperatures between 46° and 54° dip sharply, the former descending from about twenty-two fathoms at Station 28 to about sixty-five fathoms at Station 31. The curve for 50° dips from

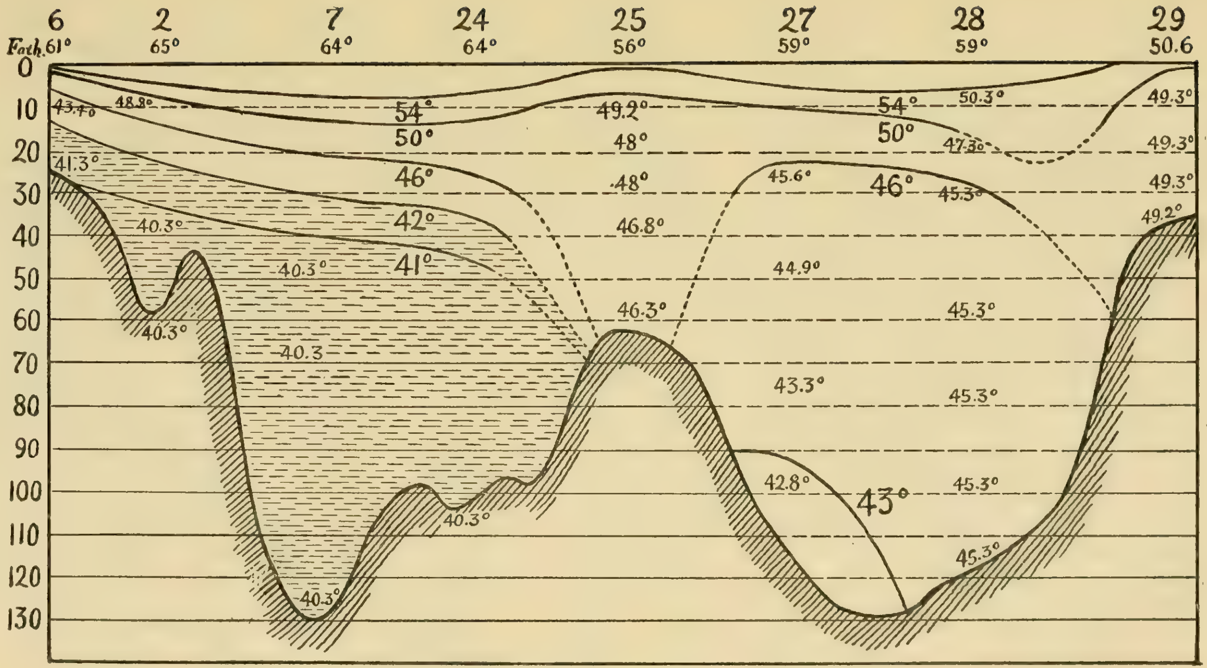

FIG. 16.— Temperature profile from Boston to German Bank, via Jeffrey Bank. Horizontal scale, 33 miles to the inch.

twelve to forty-two fathoms; that for 52° from about five to about twenty-five fathoms. The curve for 54°, however, runs parallel with the surface. But the course of the curves eastward from Station 31 shows that the warm water does not extend to the coast bank. On the contrary, the curve of 50° rises sharply until at Station 29 our serial observations locate it at a depth of only about three fathoms. The warm water at Station 31 can be further delimited by a profile across the mouth of the Bay of Fundy (Stations 33, 36, 31, 29, fig. 18) which shows that Station 31 is warmer at corresponding depths than either of the other three, Station 33 practically reproducing Station 29, except that the immediate surface was about .5° warmer. Evidently then there was a mass of water lenticular in section, several degrees warmer, at all depths, than the water either east, north, or west of it, at Station 31. Whether this warm area was circumscribed on the south also, or whether it was continuous with the warm off-shore water, possibly even with the Gulf Stream water, which washes the continental slope, is doubtful.

The profiles show that the temperature conditions over Jeffrey's Bank, on German Bank, and off the mouth of the Grand Manan Channel are closely related to one another, differing correspondingly from the deeper adjacent waters, in being colder at the surface, warmer at the bottom. The three differ from each other, it is true, in degree, but not in kind. But a profile running southeasterly from Mt. Desert for about fifty miles to Station 28 (Stations 37, 32, 28, fig. 19) shows that there is no spreading of the curves on the slope here, which is probably due to the fact that Station 37 lay in the shallow, partially enclosed waters of Frenchman's Bay, where local seasonal warming no doubt played a greater part than it does further off shore. But a profile running off shore from the mouth of Casco Bay (Station 15) to Station 24 shows a spreading of the curves at the shore end (fig. 20) and a profile from Swan Island (Station 38) to the deep basin near Platt's Bank roughly parallel in direction to the above, shows much the same temperature conditions, with the difference that at the northerly end, which lies just east of the main entrance to Penobscot Bay, the spreading of the curves is more extreme than it is further west.

Seasonal changes in Massachusetts Bay.— Our work over the central and northeastern parts of the Gulf did not last long enough to show anything about seasonal changes, further than that the bottom temperature at Station 41 (40.3°) compared with what we found off Cape Ann and in the trench west of Jeffrey's Ledge at the beginning of the trip,

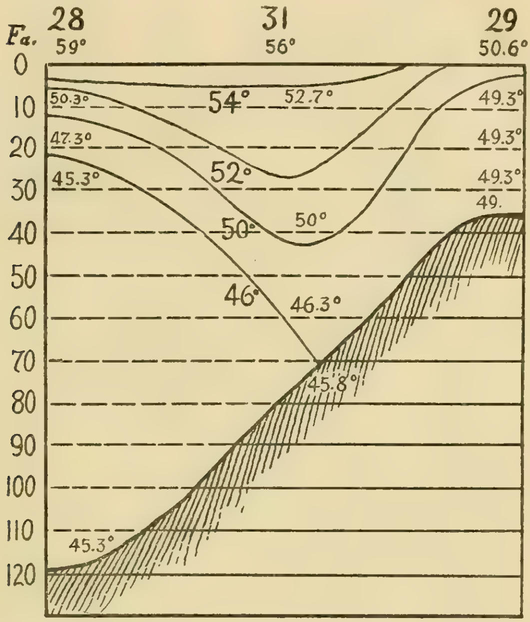

FIG. 17.— Temperature profile from the eastern basin (Station 28) to German Bank (Station 29) passing through Station 31.

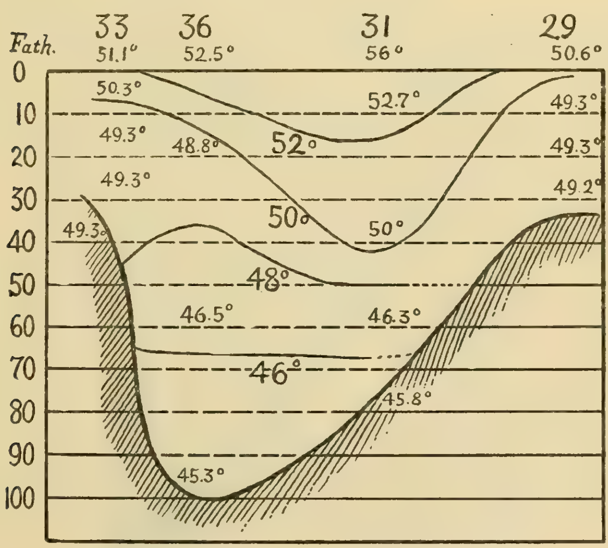

FIG. 18.— Temperature profile across the mouth of the Bay of Fundy to German Bank.

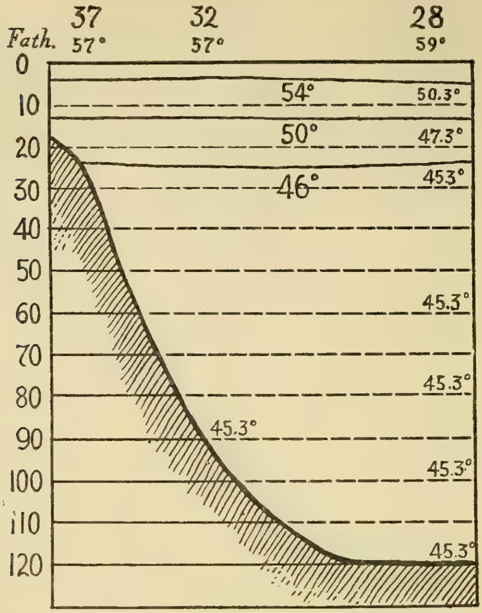

Fig. 19.— Temperature profile running southeasterly from Mt. Desert to Station 28.

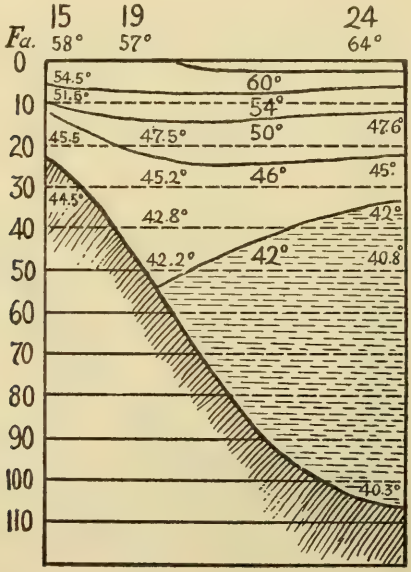

Fig. 20.— Temperature profile from the mouth of Casco Bay (Station 15) to Station 24.

revealed no appreciable change in temperature of the bottom water in that region from the middle of July to the 25th of August. But comparison between the serial temperatures in Massachusetts Bay July 9–13 (Stations 1, 5, 6) and those on August 31 (Stations 44, 45, 46) shows a marked warming of the bottom water down to forty fathoms, though, as pointed out above (p. 44), the surface water had cooled appreciably during the interval between our two visits. Stations 6 and 45 are especially instructive because made within a few miles of each other. The surface temperatures (fig. 9) were 61° at both; but whereas on July 14 the temperature was 43° at ten fathoms, and 41.3° at twenty-seven fathoms, on August 31 the ten fathom temperature had risen about 10°, *i. e.*, to nearly 53°. At thirty fathoms there was also a rise; but of only 3°, *i. e.*, to 44.7° the bottom temperature, in forty fathoms, being 43.1°. And the curves for Station 45, if continued downward, suggest that 40.3° would not have been met until a depth of about sixty-five fathoms was reached instead of at forty to forty-five fathoms as in early July. But as we were unable to make stations in the deep parts of the Bay on our second visit, it is impossible to state how far such a reconstruction would be correct, though we can safely say that the whole water-mass over the shallower parts of the Bay down to at least forty fathoms was several degrees warmer at the end of August, than it had been the beginning of July, except for the surface, which was slightly colder.

One Station, (43), some twelve miles off Cape Cod, over the inner edge of the deep basin, in ninety-five fathoms, remains to complete our survey of the temperatures. With a surface reading of 60°, the intermediate temperatures at Station 43 below five fathoms were from 1°–3° warmer at all depths than they were in Massachusetts Bay two days later (Stations 45 and 46). The temperature curve (fig. 10) is a regular one, without sudden angles. Comparison with the curve at Station 7 (fig. 10) shows that the bottom water at Station 43 was 1° warmer, 41.3° instead of 40.3°; and that it was not encountered until a depth of eighty fathoms was reached, instead of at fifty fathoms, *i. e.*, it was only fifteen instead of seventy-five fathoms thick. Station 43 was colder at all depths above seven fathoms, warmer at all depths below that level.

In considering the differences between Station 43 on the one hand, and Stations 2 and 7 on the other, the advance of the season and consequent cooling of the surface must be borne in mind. And this no doubt accounts for the lower temperature down to seven fathoms at the former. But the fact that Station 43 was warmer at all depths than Stations 45 and 46, made almost simultaneously, shows that the discrepancy below seven fathoms between it, and Stations 2 and 7, can not be wholly the result of seasonal change, in the sense of solar warming. Hence it seems safe to say that at Station 43 we encountered a water mass distinctly warmer than the waters west, north, or northeast of it. But of course it is impossible to know whether this warm water would have been encountered off Cape Cod earlier in the season, or whether it had moved thither between the times of our two visits to Massachusetts Bay.

Salinity.

As pointed out above, titration is, on the whole, the most satisfactory method for determining salinity, (the term salinity meaning the number of grams of solids per kilogram of water); and the following account of the salinities of the Gulf of Maine is based entirely on the values arrived at by this method.

Every water sample was titrated twice, some of them three or four times, and to test the possibility that some evaporation or other alteration in the salinity of the samples might have taken place between collection and titration, the titrations for four samples, chosen at random, were repeated after an interval of two months, with the following results:—

Station		Trial A	Trial B
27,	surface	32.66	32.66
43	95 fathoms	33.69	33.70
22	45 "	32.74	32.75
2	60 "	32.92	32.91

The pairs of salinities agree so closely that there was evidently no appreciable change as a result of storage.

Surface salinity.— The chart of surface conditions in July and August, 1912 (Plate **2**) shows that the salinity was lowest close to the coast, there being a band five to twenty miles broad reaching from Cape Ann northward nearly to Cape Elizabeth where the salinity was below 31.4, while it was highest along the western edge of the Gulf, over the Nova Scotia Coastal Bank (Station 31), where water of 32.84 was encountered. The curves clearly show two distinct masses of water of low salinity intruding into the comparatively salt waters of the central part of the Gulf. One of these was off Cape Ann, where the curves of 31.4, 31.8 and 32, swing far to the eastward. The curve of 31.8 divides Massachusetts Bay lengthwise, reaches eastward as far as longitude 69° 61′ W, thus including Station 7, then curves back abruptly to within fifteen miles of Cape Neddick, whence it runs northeasterly roughly parallel to the coast, as far as the mouth of Penobscot Bay, and the curves for values below 31.8 show a similar swing. In this region the lowest off-shore salinities observed were 31.08, at Station 14 abreast of Cape Porpoise, 31.2 off the mouth of Casco Bay, and 31.2 at Station 16, near Seguin. But even lower salinities were found at the mouths of the large rivers, *i. e.* 30.6 at Station 21a in Penobscot Bay. The second intrusion of comparatively fresh water was encountered off the mouth of Penobscot Bay, where the curve of 32.4 swings off shore southward for some twenty-five miles; but though relatively fresh, this mass of water was absolutely less so than the waters off Cape Ann, its salinity lying between 32 and 32.4, instead of below 32.

The conditions in Massachusetts Bay are complex. Both in July and in August the surface salinities of its central portion were between 31.8 and 32; but along the north shore from Nahant to Cape Ann, much higher salinities were occasionally noted, *i. e.*, 32.14 six miles southeast of Baker's Island on July 15th, while a few miles away (Station 6) the salinity was 31.9 two days previous. At Station 1, off Eastern Point, the salinity was 32.07, while at Station 2 it was only 31.7. At Station 44, the only one in the southern half of the Bay, it was likewise higher (32.03) than at the stations made on the same day in the central and northern part of the Bay, the salinity at Station 45 being 31.9, at Station 46 only 31.6. The curves show, furthermore, that while the comparatively saline water of the southern half of the Bay may have been directly continuous, on the surface, with the salt off-shore waters, the high salinities noted along the north shore were isolated patches enclosed by fresher water, *i. e.*, by the curve of 31.8. This phenomenon is important in connection with the fact that it was at just these same localities that abnormally low temperatures were recorded (p. 43). Its significance will be discussed later (p. 90). The salinity of the surface waters of the greater part of the Gulf, in July and August, was 32.4 or more. Off Cape Cod the curve for this value lies about twenty miles off shore; but abreast of Cape Ann it swings eastward toward Cashe's Ledge, corresponding to the intrusion of fresh water in that region. It then curves toward the coast once more, enclosing Platt's Bank, whence it runs northeastward almost to Monhegan Island, enclosing Stations 21 and 26. Off the mouth of Penobscot Bay, as already noted, it is forced far off shore (Plate 3); but it then approaches the coast once more, water of this or higher salinity washing the outer islands from Mt. Desert to the Grand Manan Channel. The salinity of the whole of the Gulf to the south and east of this curve was probably above 32.4; but we have no data on the salinity in the head of the Bay of Fundy.

It is probable that the curve of 32.6 enclosed Cashe's Bank, where the violent tides must cause an active vertical mixing of water, and the GRAMPUS crossed it about half-way between Stations 25 and 27, whence it runs in a direct line northeastward, coming close to the coast at Moose Peak. But the water in the Grand Manan Channel was not so salt as this. Whether or not this curve entered the Bay of Fundy is not known; nor can we absolutely establish the occurrence of water with salinities between 32.4 and 32.6 along the west coast of Nova Scotia; but the facts that water only slightly more saline was found at Station 29 on German Bank, and that there is a considerable discharge of fresh water from the numerous small rivers along this coast suggest that the coast water was fresher than 32.6. Surface salinities above 32.6 were encountered generally over the eastern arm of the deep basin, the value at Station 27 being 32.6; Station 28, 32.75; Station 29, 32.7; and Station 31, 32.84. Unfortunately no sample was collected at Station 30.

Salinity at intermediate depths.— The table of salinities (p. 139) shows that in no case was the water saltest on the surface; while at most of the stations there was a rapid increase in salinity from the surface downward, though the rate varied in different localities, as shown by the sections (fig. 21–28). At five Stations, 2, 7, 11, 27, 43, samples were taken at three or more levels, thus allowing a satisfactory plotting of curves for the mouth of Massachusetts Bay, off Cape Cod, the western and eastern arms of the 100-fathom basin, and the trench west of Jeffrey's Ledge. At the other stations only surface and bottom salinities are known; consequently the curves are only approximate. But inasmuch as the known curves are all practically parallel down to fifty fathoms or so, they give a guide for reconstructing the others. The type of curve is strikingly different from the temperature curves, being regular and gradual, without the sudden dislocations which characterize the latter, though the increase in salinity is usually most rapid between the surface and fifty fathoms. They show, furthermore, that over the deeper parts of the Gulf the increase in salinity noted on the surface as we go eastward from Cape Ann, extended to the intermediate depths and to the bottom as well. Thus, taking successively Stations 7, 23, 27, 28, (figs. 21, 22) the curves show that each was salter than its predecessor at all depths. The bottom salinity at Station 24 is an apparent exception to this generalization; but this Station, like Station 2, lies in a circumscribed trough of the sea bottom, and it is probable that the salinity at the level of the enclosing sill, eighty fathoms, was almost as high as it was at the bottom, just as it was at Station 2. At Stations 8, 9 and 16 (fig. 23, 26) *i. e.*,

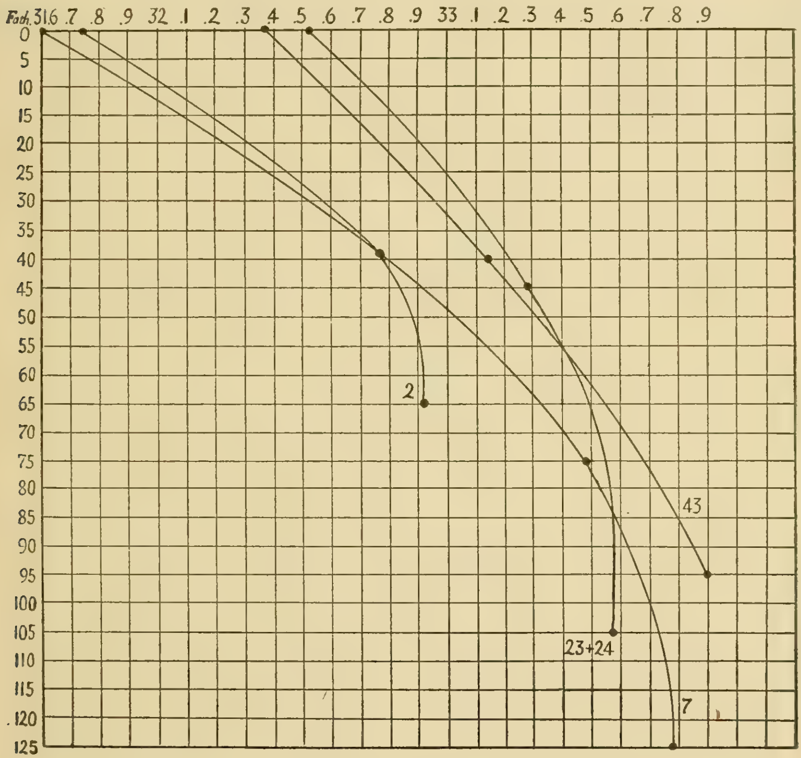

Fig. 21.— Salinity sections at Stations 2, 7, 23, 24, 43.

in the coastal band of low surface salinity, the rate of increase with depth was much more rapid than at the off-shore stations, which shows of course that the effect of the fresh drainage from the land is greatest at the surface; and the same is true of Stations 25 and 38 off the mouth of Penobscot Bay. The curves on the off-shore banks, Platt's, Jeffrey's and German, and in the Grand Manan Channel (fig. 24) are especially important, because of the peculiar temperature conditions which characterized the last two. German Bank and Platt's Bank bear the same relation to each other in salinity that they do in temperature, the former being colder and salter at the surface, warmer and fresher at the bottom, than the latter. But while Jeffrey's Bank was inter-

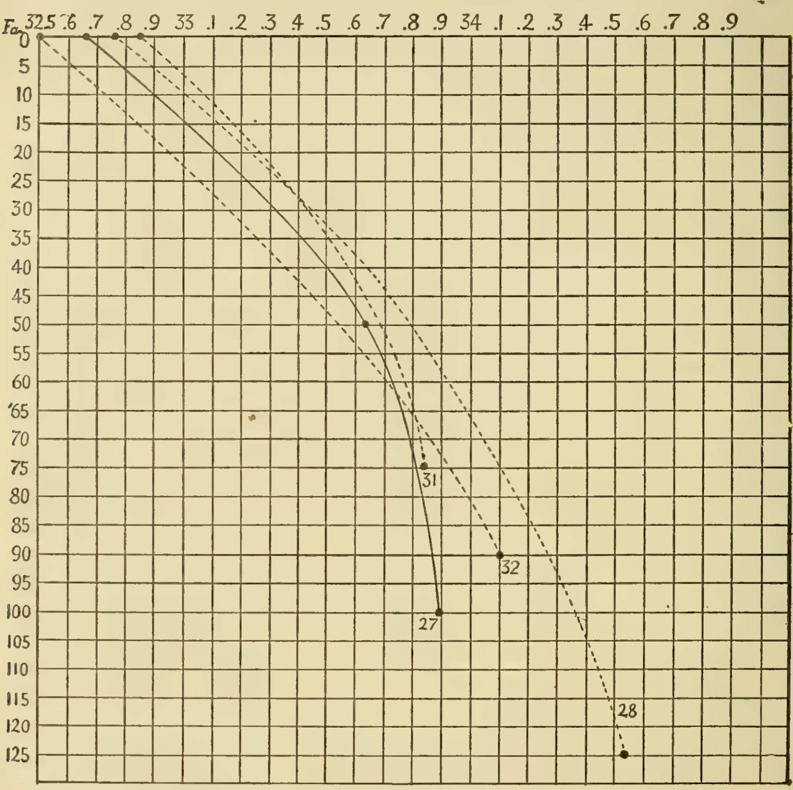

FIG. 22.— Salinity sections at Stations 27, 28, 31, 32. Curves are dotted when the surface and bottom salinities alone are known.

mediate between the two in temperature, it had a lower salinity at all depths than Platt's Bank and it was fresher down to about thirty fathoms than German Bank, showing the influence of fresh water from the Penobscot. The increase in salinity with depth was very slight on German Bank, the difference between surface and bottom

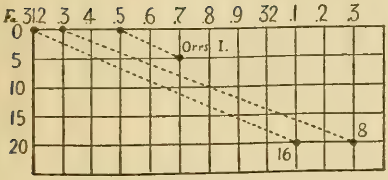

Fig. 23.

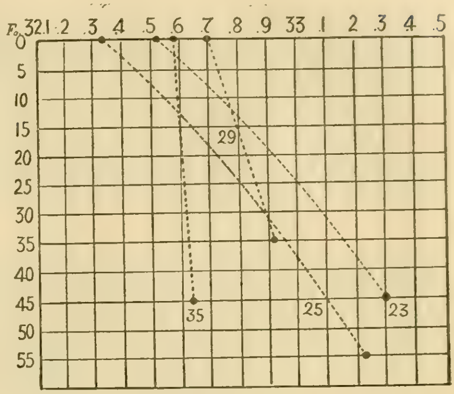

Fig. 24.

Fig. 23.— Salinity sections in the coast water, Stations 8, 16, and Orr's Island.

Fig. 24.— Salinity sections on Platt's Bank (Station 25), Jeffrey's Bank, (Station 23); German Bank (Station 29), and in the Grand Manan Channel (Station 35).

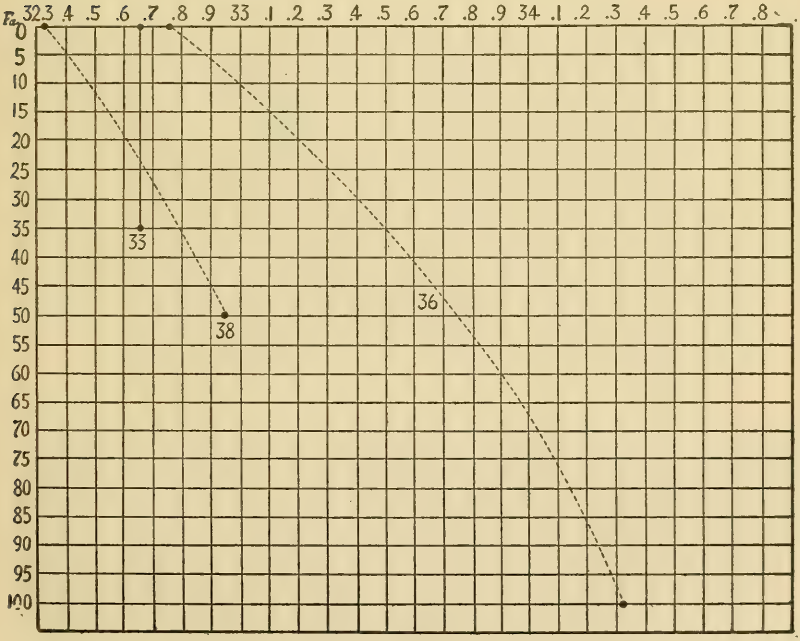

Fig. 25.— Salinity sections at Stations 33, 36, and 38.

being only .2‰; and in the Grand Manan Channel (Station 33) there was virtually no difference in salinity at different depths, *i. e.*, we find a reproduction of the temperature curve, though at all depths it was somewhat fresher than the water over German Bank.

Salinity at twenty-five fathoms (Plate **2**).— We have only a few samples at precisely this depth; but the salinity sections, and samples taken at several stations a little deeper or a little shallower than

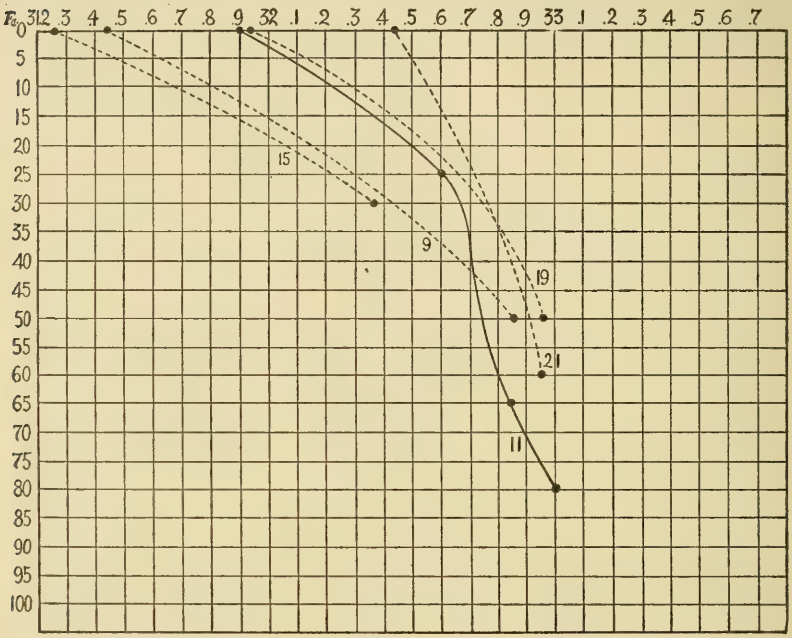

FIG. 26.— Salinity sections at Stations 9, 11, 15, 19, 21, from Ipswich Bay to Monhegan.

twenty-five fathoms, afford sufficient data for tentative mapping of the curves for the various values at this level. It must be remembered, however, that it, and the following charts, are not offered as final. At twenty-five fathoms the salinity for the whole of Massachusetts Bay, and for an area extending eastward some thirty miles over part of the deep basin was between 32.5 and 32.6. And comparison with the chart of surface salinity (Plate **1**) shows that the curve of 32.6 in this region reproduces the eastward swing of the curves of 31.8 and

32.4 on the surface. North of Cape Ann there was a band of comparatively fresh water, of 32.2 to 32.3, washing the coast along the twenty-five fathom curve, extending northeastward as far as Monhegan Island, some ten miles broad, *i. e.*, roughly corresponding to the fresh coast water noted on the surface in this same region. But it did not pass around Cape Ann into Massachusetts Bay. The band of water with salinities between 32.4 and 32.6, which was from thirty to fifty

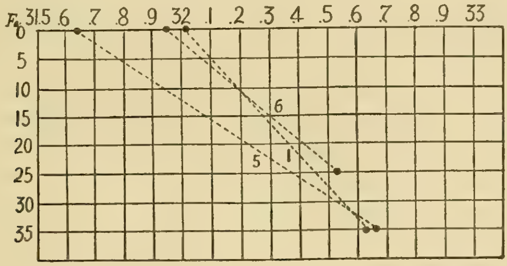

FIG. 27.— Salinity sections in Massachusetts Bay, Stations 1, 5, 6.

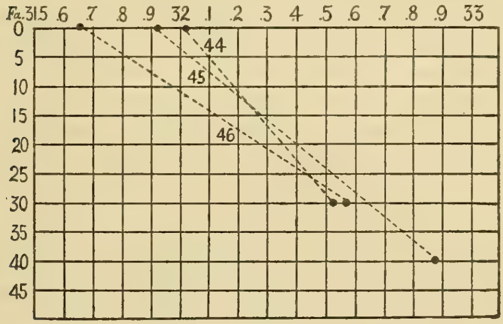

FIG. 28.— Salinity sections in Massachusetts Bay, Stations 44, 45, 46.

miles broad abreast of Massachusetts Bay, became very narrow north of Cape Ann, the two curves lying close together as far as Monhegan. Beyond this point, *i. e.*, in the mouth of Penobscot Bay, we have no data on the coast water from depths as great as twenty-five fathoms, or until Petit Manan is reached. But at Station 33 the twenty-five fathom salinity was 32.68, and judging from temperature and tidal currents, it is probable that the curve of 32.6 followed the twenty-five fathom curve from Mt. Desert Island to the southwestern end of the Grand Manan Channel.

Over the central part of the Gulf, including Platt's Bank as well as most of the 100-fathom basin, the salinity at twenty-five fathoms was above 33‰. But the curve for that value runs off shore far enough to exclude the whole of Jeffrey's Bank, thus suggesting the southerly swing of the curve of 32.4 on the surface, though not exactly duplicating it. It then turns northward toward the coast, including in its sweep the whole of the eastern branch of the deep basin, as well as part of the coastal bank off Nova Scotia. The saltest water found at this depth was not at Station 31, as was the case on the surface, but at Station 28 (33.4). In spite of this discrepancy, however, the twenty-five fathom level corresponds to the surface in the presence of intrusions of comparatively fresh water off Cape Ann and off the mouth of the Penobscot, and in the fact that the saltest water was over the eastern edge of the 100-fathom basin.

Salinity at fifty fathoms.— The curves at fifty fathoms (Plate 3) show the same influx of fresh water off Massachusetts Bay as do the charts for twenty-five fathoms and for the surface, though to a less degree. But I must point out that the charts for the different levels are not strictly comparable with one another in this region, because almost the whole of Massachusetts Bay, as well as the long ridge formed by Jeffrey's Ledge, running some forty-five miles northeasterly from Cape Ann, is shallower than fifty fathoms. The salinity over most of the Gulf at this level was above 33. But along the shore from Cape Ann northward, in the trough west of Jeffrey's Ledge and as far as Monhegan, the salinity was lower, between 32.8 and 33.; and in the isolated basin in the mouth of Massachusetts Bay (Station 2), the salinity at fifty fathoms was 32.8. The curves at this level hardly show the southerly swing off the mouth of Penobscot Bay so pronounced at higher levels, the curve for 33 running parallel to the coast, along the fifty fathom line, from Matinicus Rock eastward. This fact, of course, shows that the fresh water from the Penobscot had little or no influence at this depth, although its presence was evident nearer the surface. Over the eastern branch of the 100 fathom basin the fifty fathom salinity was above 33.6, the highest being 33.8 at Station 28, while at Station 31, so salt at the surface, the fifty fathom reading was only 33.5. The lowest salinity at this depth was in the Grand Manan Channel, 32.65, practically the same as at the surface.

Bottom salinity.— The bottom salinities of the Gulf of Maine (Plate 3) are largely dependent on depth, for, as we have seen, there was a steady rise in salinity from the surface downward, at all our stations except in the Grand Manan Channel and on German Bank. The bottom salinity below the 100-fathom curve varied from 33.5 to 34.54. There is little if any evidence that the wedge of fresh water abreast of Massachusetts Bay, so noticeable from the surface down to fifty fathoms, influenced the bottom water, for the salinity curves at the bottom show very little easterly swing in this region, and that little is probably the result of the bottom contour. The same is true also of the influx from the Penobscot, because the southerly swing of the curve of 33.8 agrees with the bottom contour, following the slope at about the hundred fathom line. It likewise crosses the mouth of Massachusetts Bay at one hundred and twenty fathoms, rising to about eighty-five fathoms off the northern end of Cape Cod. But it does not enter the trough west of Jeffrey's Ledge, for here the salinity of the bottom water in sixty to eighty fathoms is only 33 to 33.2. North-eastward from Jeffrey's Bank the 33 curve rises higher and higher on the coastal slope until finally water of this salinity was found at about fifty-five fathoms off Petit Manan. The curve must then turn off-shore, for the bottom water in the Grand Manan Channel was only about 32.5–32.6. No station was made on Grand Manan Bank; but judging from conditions on the other banks, it is not likely that the bottom water had a salinity as high as 33. The same is also true of Lurcher Shoal. On German Bank, also, the bottom water was fresher, only 32.9 in thirty-five fathoms; hence it is probable that the 32.6 curve came close to the surface along the west coast of Nova Scotia. The bottom salinity of Platt's Bank was above 32.5; and it is probable that this was the case on Cashe's Ledge likewise. On the other hand the circumscribed deep basin in the mouth of Massachusetts Bay (Station 2) had a considerably lower bottom salinity, 32.92, than the waters at corresponding depths further east. Over the eastern arm of the 100-fathom basin the bottom salinity was 34 or over, the highest values being at Station 28, 34.5; Station 32, 34.1; and Station 36, 34.3, in one hundred and twenty, ninety, and one hundred fathoms respectively. But at Station 27, only a few miles west of the saltest spot, the bottom salinity at 100 fathoms was only 33.9.

Salinity profiles. — The profiles (fig. 29–33) can not pretend to as great accuracy as those for temperature, because the number of observations is much smaller; and they are necessarily largely reconstructed from the salinity sections. But if regarded only as preliminary, they are useful as showing general distribution of salinity.

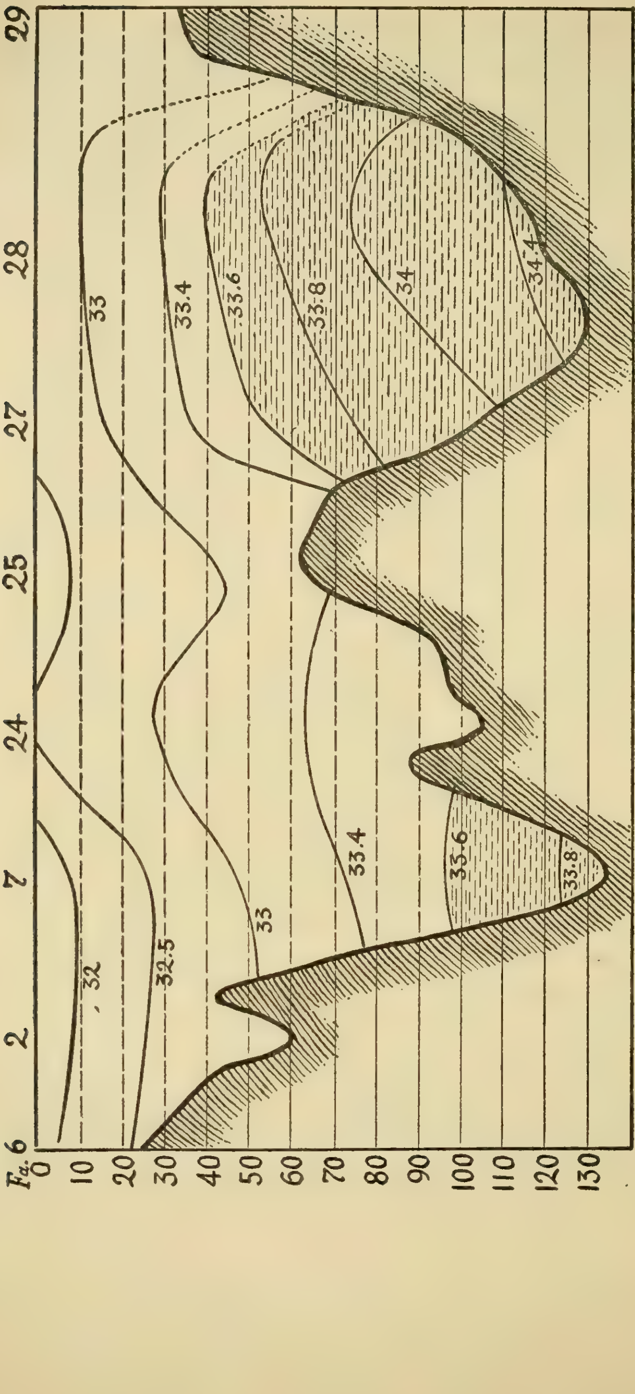

Fig. 29. — Salinity profile from Boston Light-ship (Station 6) to German Bank (Station 29), via Jeffrey Bank. Horizontal scale 33 miles per inch.

The profile from Boston Light-ship to German Bank (fig. 29) shows conditions in Massachusetts Bay, over both arms of the deep basin, on Jeffrey's Bank, and over the coast slope of Nova Scotia. From Station 6 to 7 salinities were very uniform at all depths, except for a slight upwelling of salt water above twenty fathoms at the westerly end, thus paralleling the temperature profile (fig. 16) and for the fact that there was no appreciable increase in salinity below forty fathoms in the isolated basin at Station 2, *i. e.* below the depth to which the enclosing sill rises. Passing easterly from Station 7, the entire mass of water above seventy fathoms becomes salter, all the curves approaching the surface, that for 32.5 rising from thirty fathoms to the surface, while the curve for 33 lies at about twenty-five fathoms at Station 24, instead of at fifty fathoms as at Station 7. Below seventy fathoms, however, there is very little difference between the two stations. Our profile thus shows that the wedge of comparatively fresh water off Massachusetts Bay was not traceable below about seventy fathoms.

Over Jeffrey's Bank the water was appreciably fresher at all depths than it was either west or east of it, the curve for 33 showing a pronounced downward swing from twenty-five fathoms at Stations 23 and 24 to fifty fathoms at Station 25. But its upper twenty fathoms, though fresher than at Station 24, had a higher salinity than in the region west of Station 7. The whole of the eastern basin was salter at all depths than the regions west of it, the curve of 33.6 rising to within about forty fathoms of the surface at Station 28, whereas in the western basin, water of this salinity was only found below ninety-five fathoms. At all depths down to about twenty-five fathoms salinities were highest at Station 31; but below that depth at Station 28; for example, the curve of 33.8 lies at sixty-five fathoms at Station 31, at fifty fathoms at Station 28; and the curve for 34 must show an even more pronounced rise, for water of that salinity or over was found at Station 28, from eighty fathoms down to 120 fathoms, whereas at Stations 27 and 31 the bottom water was only 33.9 and 33.8 respectively in 100 and in seventy-five fathoms.

Over German Bank, as already pointed out, the water was between 32.7 and 32.9 from surface to bottom.

The west to east extent of the fresh Penobscot water is shown by a profile running from Platt's Bank across Jeffrey's Bank to the neighborhood of Mt. Desert Rock (fig. 30) and the breadth of the coast-band of comparatively fresh water off the mouth of Casco Bay is illustrated by a profile from Station 15 to Station 24 (fig. 31). A similar profile

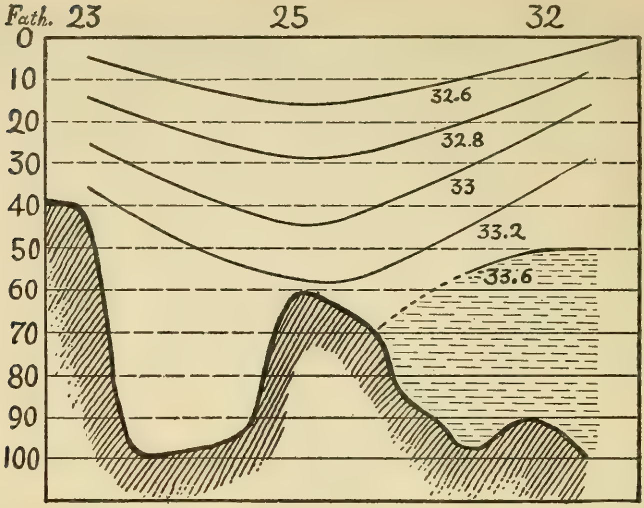

FIG. 30.— Salinity profile from Platt's Bank (Station 23) toward Mt. Desert Rock (Station 32) crossing Jeffrey's Bank (Station 25).

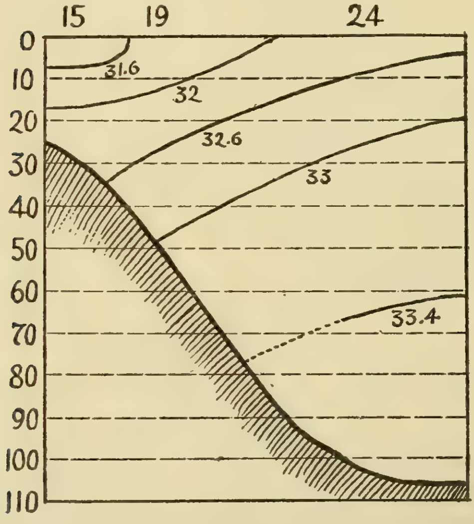

FIG. 31.— Salinity profile from the mouth of Casco Bay to Station 24.

running southeastward from Mt. Desert (Fig. 32) shows the increase in salinity passing off shore in that region.

In Massachusetts Bay two pairs of Stations, 6 and 45, and 5 and 46, (figs. 27, 28) were taken six weeks apart, purposely to show seasonal change, if any. But the sections show that at both 46 and 5 the salinity at the surface was 31.6, at 30 fathoms 32.5, and also that there was apparently nothing to separate Station 6 from Station 45, at both of which the surface salinity was 31.9; though as the depth at the former was twenty-five and at the latter forty fathoms, only two samples being taken at each, it is possible that there may be some slight divergence in the intermediate zone. In short, these four stations certainly do not suggest that there was any seasonal change in the salinity in Massachusetts Bay during our absence, although there was a very pronounced rise in temperature (p. 58) at all depths below five fathoms.

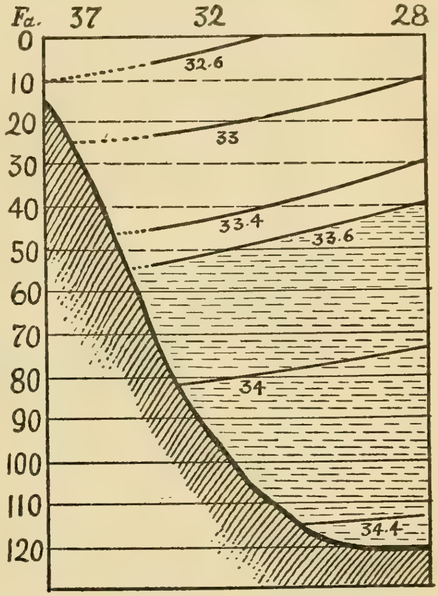

FIG. 32.— Salinity profile from near Mt. Desert (Station 37) to Station 28.

Stations 44, 45, 46, all taken on the same day, afford a profile across the Bay, from south to north (fig. 33). The curves show that the core of fresh surface water was thickest in the northern half of the Bay. And as Station 6 is, as we have just seen, interchangeable with 45, and 5 with 46, it is clear that this is the characteristic condition in midsummer. In the southern half of the Bay, the curve of 32.2, found at twenty fathoms at Station 46, rose to within eight fathoms of the surface; and the surface salinity was 32 instead of 31.9. But below twenty fathoms the salinities were slightly lower at Station 44 than in the centre of the Bay. Thus we find reproduced, but on a much smaller scale, the spreading of the salinity curves so pronounced on German Bank, and in the mouth of the Grand Manan Channel. And as pointed out (p. 56) the same thing was true of the temperatures.

In the northerly end of the profile Station 1 is introduced, to show how the cold salt bottom water wells up close to the shore. However, as pointed out in the discussion of temperatures, this phenomenon is

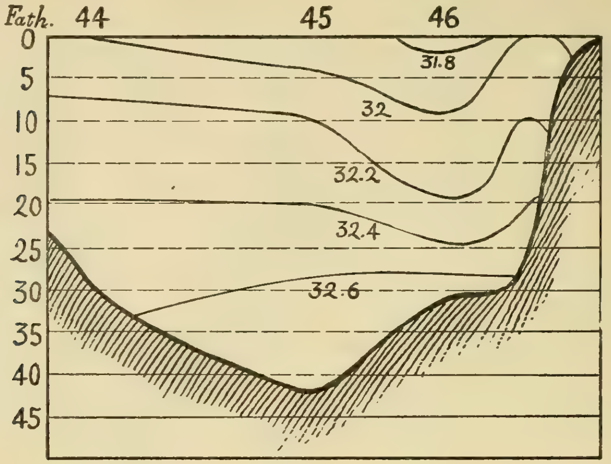

Fig. 33.— Salinity profile across Massachusetts Bay, August 13 (Stations 44, 45, 46).

sporadic, probably the result of offshore winds driving the surface water away from the coast, their place being taken by water from below. Conditions at Station 1 show that the effect may be felt to as great a depth as 20 fathoms.

Density.

The three features of sea water most interesting to the oceanographer are temperature, salinity, and density; the former because of its biological importance; the second because it is the only safe clue to the geographic origin of water-masses; and the third because of its importance as determining circulation, both vertical and horizontal. The last is a product of the first two and of a third factor, namely pressure. And we must never lose sight of the fact that as it is determined by temperature as well as by salinity, it is a temporary quality, changing as the water becomes colder or warmer. In the accompanying table (p. 141), the densities *in situ* are calculated from

Knudsen's (1901) tables and from Ekman's (1910) tables of sea water under pressure. Such calculations are approximately correct arithmatically, but notice must be called to the fact that the probable limits of error are the sum of the two observational errors, first for salinity, *i. e.*, ± .02 of salinity (p. 40), second for temperature, which is ± .3° F, approximately .15° C. Now the sum of these errors has a considerable effect on the calculated densities, and for this reason the fifth decimal point is disregarded in the table. Of course a much higher degree of accuracy could be, and is, obtained with improved instruments, for example, during the North Atlantic cruise of the Michael Sars in 1910 (Murray and Hjort, 1912). But it would be misleading to claim better results with our instruments.

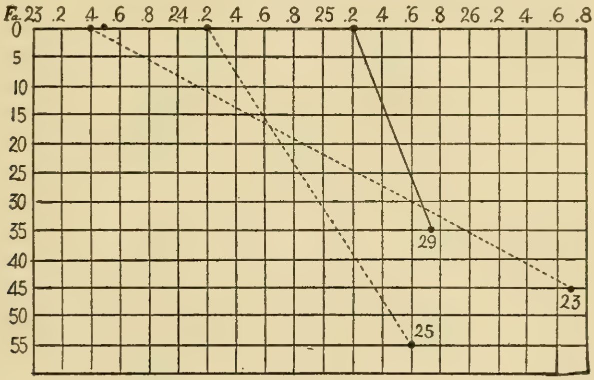

Fig. 34.— Curve of density *in situ* at Platt's Bank (Station 23); Jeffrey's Bank (Station 25) and German Bank (Station 29).

The correction for pressure has often been disregarded, especially in shallow water; but it can easily be applied from Ekman's tables. In depths less than fifty fathoms it is of little practical importance, but by the time 100 fathoms is reached it is by no means negligible. For example, at Station 28, 120 fathoms, the density at the temperature *in situ* without pressure correction, is 27.02; with pressure correction, 28.03. In the accompanying table the pressure correction for depths less than fifty fathoms is calculated by the use of Ekman's table IV alone, which is sufficiently accurate for our present purpose.

The most important thing which the table and curves (fig. 34–36) show is that there was a steady increase of density at every station from the surface down to the bottom, which, as we now know, is the normal condition in all ocean waters during the warm season, though there are temporal and local inversions due to temperature conditions in winter (Helland-Hansen and Nansen, 1909). But the rate of increase varies greatly in different regions, there being two very different types of vertical distribution in the Gulf. The first, exemplified over Jeffrey's and German Bank, and in the Grand Manan Channel, Station 25 (fig. 34), Station 29 (fig. 34), Station 35 (fig. 36), shows only a very slight increase from surface to bottom; but in the second, comprising practically all the other stations, there is a large rise, with slowly decreasing rate from the surface downward. The curves for

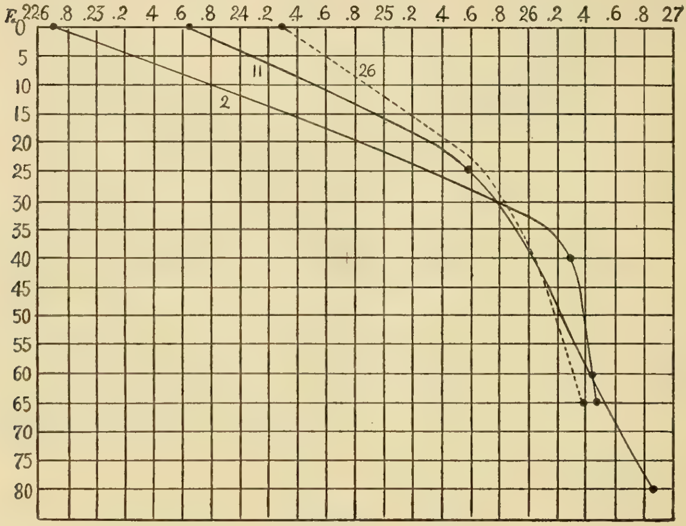

Fig. 35.— Curves of density *in situ* at Stations 2, 11, 26.

the last recall the salinity curves at corresponding stations; but the difference between surface and bottom was in every case considerably greater in the former than in the latter, at corresponding stations. The most important conclusion to be drawn from the density curves is that over the whole deep basin, in Massachusetts Bay, and along the coast from Cape Ann to the Penobscot, the water was in very stable vertical equilibrium during July and August; but that on Jeffrey's and German Banks and in the Grand Manan Channel the difference in density in different depths was so slight that it would offer very little resistance to vertical circulation. In comparing the densities for Stations 6 and 5 with those of 45 and 46 it is evident that vertical stability in Massachusetts Bay decreases with the advance of the season; pointing to the inversion which no doubt takes place there in winter.

A profile from Boston (Station 6) northeastward to German Bank, *via* Jeffrey's Bank (Station 25), and Station 31 (fig. 37) shows the

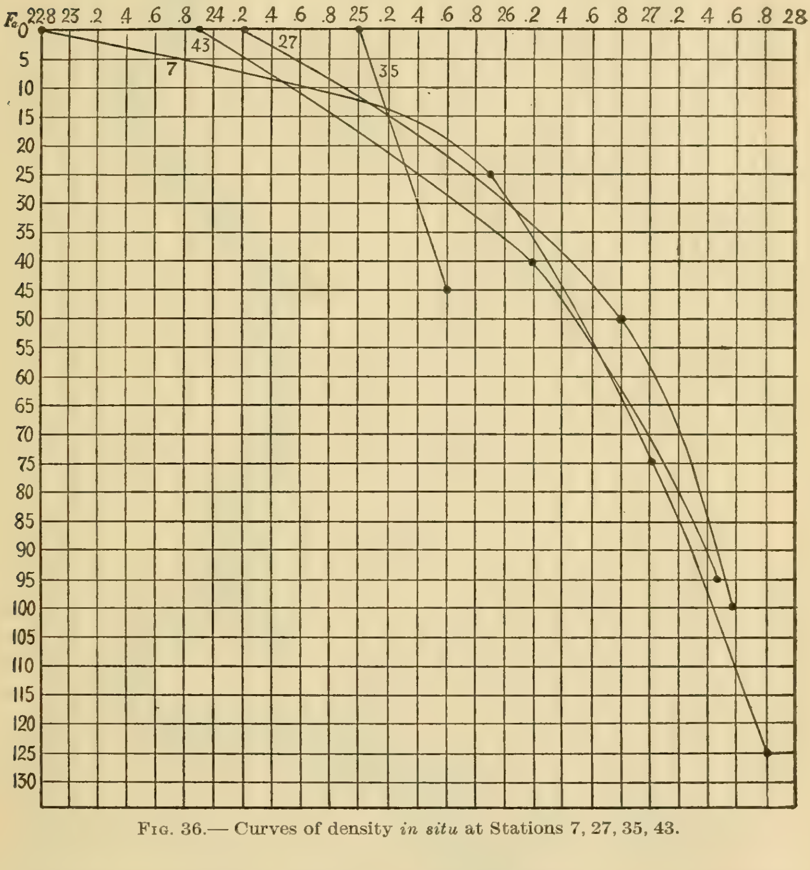

FIG. 36.— Curves of density *in situ* at Stations 7, 27, 35, 43.

relative distribution of lighter and heavier water over the northern part of the Gulf. Above the two deep basins heavy water, distinguished arbitrarily by the curve of .026, rose close to the surface, whereas over the two banks the whole column of water was of lower den-

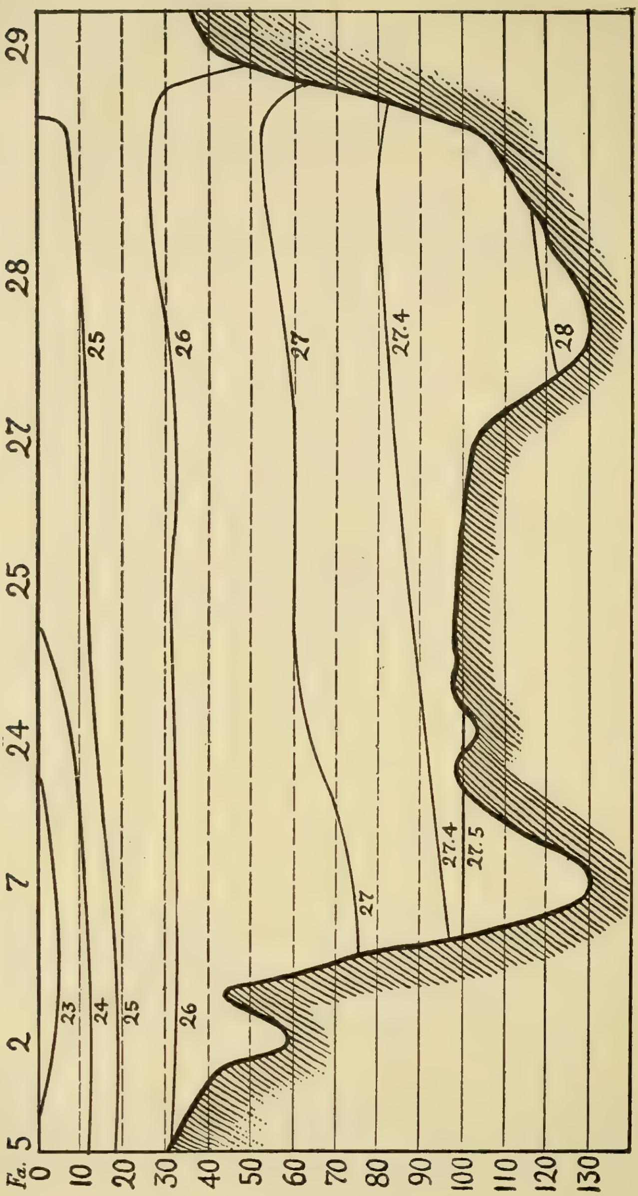

Fig. 37.— Profile from Massachusetts Bay to German Bank, passing between Platt's Bank and Cashe's Ledge, and south of Jeffrey's Bank, to show density *in situ*.

sity than this. But the water of the eastern basin was appreciably denser at all depths than that of the western, corresponding densities being about ten fathoms deeper in the latter than in the former. And corresponding densities were found twenty to thirty fathoms higher over German Bank than over Jeffrey's Bank. The profile shows also in a graphic way how much more rapid the downward increase was over the basins than over the banks, and consequently how much more stable, vertically, their waters must have been. At the western end of the profile there was again an increase in density as compared with the western half of the basin, a phenomenon consequent on the upwelling of cold, salt bottom water in this region, while at Stations 2 and 7 density near the surface was very low, corresponding to low surface salinity. In the trough between Jeffrey's Ledge and the coast the density agreed closely with that of the western basin, except that it was rather higher on the surface, corresponding to the low surface temperatures of this region. And passing northeastward along the coast we find the vertical range progressively less and less, until in the Grand Manan Channel the difference between surface and bottom was only .6 at 45 fathoms. The information our cruise afforded as to density is insufficient even for the northern half of the Gulf, but so far as it goes, it shows that two distinct water masses can be distinguished, a light over the western, a heavy over the eastern basin, partially separated by the disturbed conditions caused over Jeffrey's Bank by the influx of fresh water from the Penobscot.

Color.

The color of the sea is of minor importance in oceanography: but it can not be neglected, because it helps to form the physical complex, in which the plankton finds its biological environment. The color, described by percentages of yellow as indicated by the Forel scale, is given in the table (p. 82). At the off-shore stations it varied from 27% (Station 43) to 14% (Stations 7 and 23), usually being 20%: in Massachusetts Bay it was 20% at all stations at which a record was made (Stations 2, 4, 6, 44, 45). West of Jeffrey's Ledge the color was 14% at Station 9; but grew greener as we went north, being 20% at Station 11, 27% at Stations 13 and 14. Off the mouth of Casco Bay it was 27%, inside the Bay 27% and 35%. Over the northeastern part of the Gulf as a whole, the color was 20% yellow, except close to the shore (Stations 33, 37) where it was 35%. This distribution of waters of different colors does not correspond either to temperature or to salinity, for the bluest water was not the saltest, while the coldest water was neither bluest nor greenest. The plankton may give the necessary clue.

Color, in % of Yellow in the Forel scale.

Sta.	Color	Sta.		Sta.	Color	Sta.	Color	Sta.	Color
2	20	13	27	21[a]	27	29	20	39	20
4	20	14	27	22	27	31	20	40	20
6	20	15	27	23	14	32	27	41	20
7	14	16	27	25	20	33	35	43	27
8	20	17	35	26	20	35	20	44	20
9	14	Orr's I.	44	26[a]	20	36	20	45	20
10	20	19	20	27	20	37	35		
11	20	21	27	28	20	38	20		

The color of the Gulf of Maine agrees fairly well with that of the southern part of the North Sea, with the English Channel, and with the coast water of the Bay of Biscay (Schott, 1902, pl. 36). Up to the present time we have no records of the color of the water along the coast of the United States from Cape Cod south, or for the Gulf of St. Lawrence.

Transparency.

Measurements of transparency were taken with the disc (p. 00) at eighteen stations. In the clearest water (Station 23) it was visible at 8.2 fathoms; but it usually disappeared at from four to five fathoms. There was little, if any, correlation between color and transparency at these stations, for though the water was most transparent where bluest (Station 23), it was not least so where greenest, but where the percentage of yellow was only 20% (Station 38).

Transparency, in fathoms.

Sta.	Trans.	Sta.	Trans.
4	3.5	31	4
11	6	36	4
12b	6	37	4
14	6	38	3
15	4.5	39	4
16	3.5	40	6
22	7.2	41	5
23	8.2	43	5
25	6.5	44	5

Circulation in the Gulf of Maine.

Circulation in the Gulf may be expected to be of three types:— 1, tidal, which is proverbially violent in the northeastern part of this region; 2, the slower but more constant vertical or horizontal movement of water resulting from different density gradients at different regions, or from the presence of an actual ocean current, if there be one; and 3, sporadic movements of the water, due to prolonged or violent winds.

Tidal currents.— A considerable number of measurements of tidal movements have been made on the surface of the Gulf of Maine by the U. S. Coast and Geodetic Survey, by the British Admiralty, and by the Tidal Survey of Canada in charge of Dr. G. B. Dawson; but so far as I can learn, the only accurate records of bottom currents are the few taken on the Grampus last summer. The earlier surface records, for off shore stations, are limited to the east coast of Cape Cod, Stellwagen Bank and the channels north and south of it, George's Shoal, the Eastern Channel, Brown's Bank, the west coast of Nova Scotia, and the Bay of Fundy; these the 1912 cruise of the Grampus extends to the central part of the Gulf and to the coastal region between Cape Ann and the mouth of the Penobscot. Although our records are too few for a complete survey even at a given station, we always attempted to take them as close to the mid-period of flood or ebb as possible, so as to obtain the mean direction and velocity of the current for a given tide; but of course, this result could be expected only in regions where the current was fairly constant for the major part of each tide.

The sum of all available observations suggests that the violent surface currents of the Gulf, noticed by every navigator, are purely tidal, the mean flow of ebb and flood being in general about equally strong at a given locality; but the mean directions of the two are not always precisely opposite. The general rule is that "along the whole line between Nantucket shoal and Cape Sable Bank the ebb current runs southwardly.... the flood current northwardly...." (U. S. Coast Pilot), and along this whole line the currents are swift (1.1 to 1.6 knots at their height). The tidal wave divides over the basin south of Jeffrey's Bank and Cashe's Ledge, the flood currents west of here turning westward toward Massachusetts Bay, and toward the coast between Cape Ann and Portland. Abreast of Casco Bay (Stations 14, 40) the flood flows nearly due north; but east of Jeffrey's Bank the general direction of the flood near shore, is N. N. E. toward the Grand Manan Channel and the Bay of Fundy, and along this coast the velocity increases steadily from west to east, the rate in the channel being two knots. Along the west coast of Nova Scotia the mean direction of the flood-current is nearly north. The flood is weakest in the northern part of Massachusetts Bay, and along shore from Cape Ann to Portland, as shown in the Table (p. 143), though there are strong tidal currents off the mouths of large rivers, and tide rips off Portsmouth (Station 11). In the central part of the Gulf (Stations 7, 27) the current is about .5 knot; but along the Nova Scotian Coast and off the mouth of the Bay of Fundy it occasionally attains velocities of more than two knots, with extensive and dangerous tide-rips on the various shoals, for example the Grand Manan Bank.

In a general way the ebb is the reverse of the flood, flowing out of the Bay of Fundy in a generally S. W. to S. S. W. direction, and around the coast of Nova Scotia to the S. and S. E. Along the coast of Maine from the Grand Manan Channel to Mt. Desert the ebb flows about S. W. But the current in the central part of the Gulf is about S. by E. Off Casco Bay the ebb is southerly; along the coast from Portland to Cape Ann it sets in general toward the E. S. E. but there are various local currents here, yet to be explained. The strength of the ebb current is proportional to that of the flood, strongest off the mouth of the Bay of Fundy and along the coast of Nova Scotia; progressively weaker to the westward.

The data is insufficient to show whether the tidal currents result in any definite eddy movement of the waters of the Gulf, nor have I been able to find in them any evidence of an inflow, or alongshore flow within the Gulf, such as might be credited to a branch of any constant ocean current. This question was thoroughly studied by Dawson (1910) for the Bay of Fundy and for the Nova Scotian Coast, between the mouth of the St. John and Cape Sable, in 1904 and 1907. And his general conclusion is that ebb and flood are almost opposite, veering at slack water only, if at all; and that there is little indication of any movement of water in a dominant direction. The mean compass-bearings and strengths of the currents on Brown's and George's Banks as given on the U. S. Coast Survey charts suggest a drift from northeast to southwest. But the data on the tidal currents of George's Bank given by Mitchell (Rept. U. S. Coast and Geodetic Survey, 1881, p. 175) show that there is a slight easterly drift, and it is so represented on the current chart in the coast pilot. (U. S. Coast Pilot, part 3, 1912, chart facing p. 9). And although most of the current charts which have appeared show a southwest flow along the outer edge of George's Bank, next the Gulf Stream, it is a question whether this flow is a contant, or even a dominant one.

Surface and bottom currents.— To obtain a satisfactory knowledge of the tidal currents at any locality, it is necessary to make observations at intervals throughout a twelve-hour period, to insure readings for both flood and ebb, because the time of turning of the tide at the bottom often differs by a considerable period from the time of slack water on the surface. Nevertheless, our few isolated observations are worth passing notice because they are the first attempts to measure the bottom currents of the Gulf of Maine with modern instruments. The diagrams (fig. 38) illustrate the considerable strength of the bottom currents even in the western side of the Gulf; and in the northeastern part, for example over German Bank, they are even stronger.

The only region where enough observations were taken to allow a tentative statement of the relations of bottom to surface currents is the northern half of Massachusetts Bay (Stations 1, 2, 4, 5, 6). The surface current flows into this part of the Bay toward northwest and west at the height of the flood (Station 5) turning at least one half hour before the time of high water at Gloucester, and flowing easterly during the first half of the ebb (Stations 1 and 4). We made no records for the last three hours of the ebb. A few miles further off shore the direction at mid-ebb was southeast (Station 2); and in the centre of the Bay (Station 6) N. N. E. (all bearings being magnetic). In the southern half of the Bay the flood current ran toward the southwest, the ebb toward the northeast. These observations are not sufficiently extensive to show whether or not there is any dominant drift alongshore. But tidal records taken by the U. S. Coast Survey at the mouth of the Bay suggest that it may be occupied by an eddy-like circulation flowing slowly from north to south, there being a decided drift to the northwest near Cape Ann, with an easterly movement on Stellwagen bank and near Race Point (U. S. Coast Pilot, part 1 and 2, 1911, p. 151). The bottom currents in Massachusetts Bay differ very noticeably from the surface ones (fig. 38) not only in being as a rule weaker, but in flowing in a different direction. At all the stations in the central and northern part of the Bay, the bottom flow was easterly, the records being made a few minutes before high water (Station 1), two-hour ebb (Station 4), mid-ebb (Station 6), and early flood (Station 5). This data, so far as it goes, suggests that if there be any tidal flow to the west on the bottom it must be restricted to the last two hours of the flood, veering again to the eastward shortly before high water.

There was no bottom current at Station 2, and inasmuch as that station was occupied at the mid-ebb, when the bottom current further

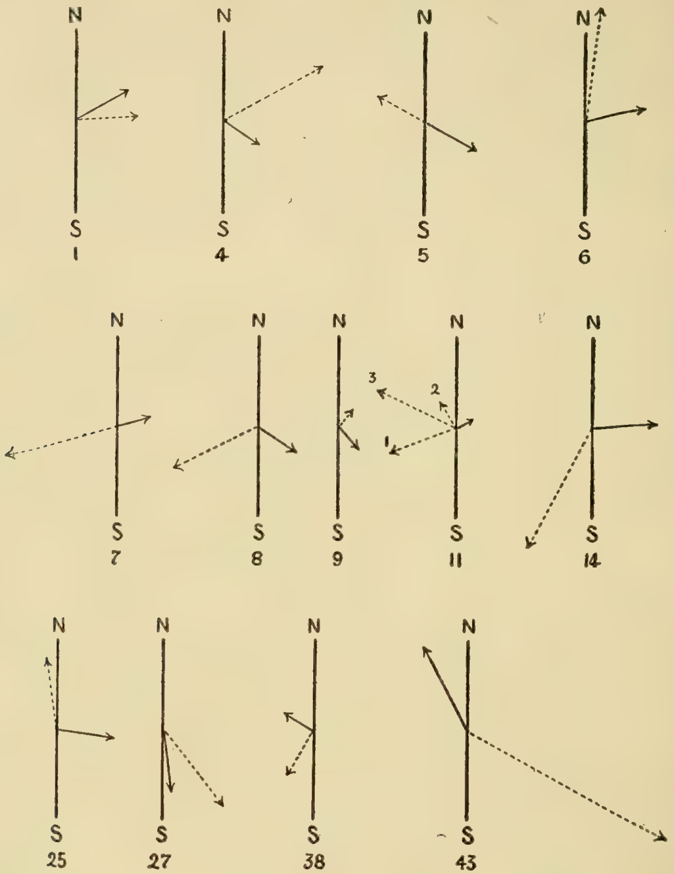

Fig. 38.— Currents, Stations 1, 4, 5, 6, 7, 8, 9, 11, 14, 25, 27, 38, 43. Surface current··········>; bottom current———>. The strength of the current is represented by the length of the arrows, 3 cm. = 1 knot per hour.

within the Bay attains considerable velocity, its absence is no doubt to be explained by the fact that the bottom here is an isolated pocket some twenty fathoms deeper than its enclosing sill, with a consequent separation from the general bottom circulation. The highest bottom velocity recorded in Massachusetts Bay was .25 knots per hour. The observations at Station 7 show that over the western basin opposite Cape Ann the surface current begins to flow westerly with the considerable velocity of .5 knot, at least two hours before it is low water at Cape Ann; but not the bottom current, for the latter, a few minutes later, was still flowing to the east, though slowly.

There are four stations between Jeffrey's Ledge and the mainland in depths from twenty-five to eighty fathoms, at which bottom as well as surface readings were taken, Stations 8, 11a, on the flood; Stations 9, 11b and c, 14, on the ebb. On the surface the flood current runs to the west (Station 8), or W. by S. (11a), velocity .3 to .4 knots per hour, and the three sets of observations at Station 11 show that the current was still running to the westward two hours after high water at Cape Ann and Cape Porpoise, though it had veered from west to north by west. But there were several active tide-rips in the vicinity, which were probably responsible for this apparent on-shore flow during the ebb. At Station 14, there was a strong current flowing southwest (.6 knot) two hours before low water at Cape Porpoise, only eight miles distant. But at Station 9 it had started to run slowly to the N. E. by E. one hour after high water. On the bottom the current was easterly in every case (Station 8, 9, 14, 11c) except at 11b, where there was a very slow movement to the N. N. W. One of these records (Station 8) is at four-hour flood, the others are at various stages of the ebb. At Station 11b, two-hour ebb, the bottom flow was toward the N. N. W.; but one half hour later it had veered to the E. by N., *i. e.*, toward the extremity of Jeffrey's Ledge. At Station 14 there was a .3 knot current on the bottom toward the E. by S. the surface flow being S. W.

On Jeffrey's Bank (Station 25) the bottom current was to the E. S. E. almost at right angles to the surface flow (N. by W.), three hours after high water at Portland and Rockland.

Our one bottom reading in the eastern basin (Station 27) revealed a quarter-knot current, running southerly, like the surface flow, on the early ebb.

Off Cape Cod, our single reading (Station 43) showed that the bottom flow was still toward the northwest, on the early ebb, although the surface current was already flowing to the southeast.

Circulation as shown by temperature and salinity.— Since we have seen that the surface currents of the Gulf, though often violent, do not demonstrate the existence of any circulation on broader lines than that caused by the tides, we must turn to salinities, temperatures, and densities in the attempt to reconstruct the movements of its waters the most important subject on which the cruise may throw light. Perhaps the most striking oceanographic feature of the Gulf of Maine in summer, certainly the one which has aroused the most speculation, is the existence of a cold band of surface water which bathes the coast from Portsmouth as far as the Penobscot, and extends thence across the mouth of the Bay of Fundy and along the western coast of Nova Scotia, gradually growing broader and broader to the eastward. If we were to judge from surface temperatures alone we would naturally assume that this cold water was evidence of a cold current following the coast; and it has often been referred to as an Arctic current solely on this ground. But, as we have seen, the surface currents, at least in summer, afford no support to such a view, while serial temperatures and salinities show that the phenomenon can be explained on very different grounds.

The coldest surface water was found over German Bank and in the Grand Manan Channel; but serial temperatures show that this low temperature, at these stations, was solely a surface phenomenon, the bottom waters being much warmer there than at corresponding depths in the basin or on the west coast of the Gulf. Furthermore the mean temperatures for the upper forty fathoms, *i. e.*, for the whole depth at Stations 29, 33, and 35, are no lower than they are in the western part of the Gulf; (Station 29, 49.8°; Station 33, 49.5°; Stations 27 and 28, 49°; Station 11, 45.7°; Station 7, 49.1°; Station 2, 46.4°: Station 43, 51.1°.) We find, too, that in the northeast part of the Gulf, there is much less change in salinity from surface to bottom than in the western half. And when we take into consideration the extraordinary violence of the tide, both on German Bank and in Grand Manan Channel, and the numerous tide-rips, with which everyone who has sailed these waters is familiar, it can hardly be doubted that the low surface and high bottom temperatures are merely the evidence of thorough mixing of surface and bottom waters, caused by the active vertical circulation which necessarily results from the strong currents. Verrill (1873, p. 438) explained the phenomenon correctly when he wrote "the constant mixture of the cold bottom water with the warmer surface waters by means of the strong tides and local wind currents, causes the remarkably low temperatures observed in the shallow waters of these shores." The temperature conditions on Jeffrey's Bank result from a similar phenomenon, though as tidal currents are less strong here than they are further to the eastward, the equalization of temperature from surface to bottom is less complete; and the diminishing range of temperature from surface to bottom at successive stations along the coast from the Penobscot to Grand Manan, the surface growing warmer, and the bottom colder at least at corresponding depths, is evidently due to the fact that the diminishing force of the tidal currents is less and less effective in causing vertical circulation, so that the waters retain more and more nearly their normal temperature gradient. Exactly the opposite takes place in passing off shore from the mouth of Grand Manan Channel, the temperature and salinity range growing progressively greater.

The mouth of Casco Bay, *i. e.*, the region where the general trend of the coast changes from northerly to northeasterly, is the dividing line between temperature sections of two types; for whereas the coast waters east of this point were about as much warmer than the off-shore stations on the bottom as they were colder on the surface, the coast water south and west of Portland was no warmer on the bottom than it was off Cape Ann or near Platt's Bank, though it was constantly several degrees colder on the surface. On the contrary, Station 11, close to the coast, was colder at all depths down to about sixty fathoms than the water east of Jeffrey's Ledge, and the curve at Station 14, off Cape Porpoise, was almost precisely like it, the same temperatures being found from five to ten fathoms nearer the surface at Station 11 than at Stations 23 and 24. Below fifty fathoms the temperatures were about equal. If temperature were the only clue to oceanic circulation, we would naturally assume that such a profile indicated an upwelling of cold bottom water. But the salinities of this region, forbid this explanation, because, as the salinity sections show, the in-shore stations were fresher at all depths, whereas, if the surface were cooled by water rising from below, the salinity would necessarily be raised by the same process, and we would expect to find the surface salter than, or at least as salt as it was at the stations further off shore. But although the temperature readings at Station 11 were lower at all depths down to fifty fathoms, than they were east of Jeffrey's Ledge, the curve for the former was almost precisely the same as it was at Station 2, in the mouth of Massachusetts Bay a few days earlier, except that the upper ten fathoms were cooler at Station 11; while the salinity curves (fig. 11) show that the latter was slightly salter than Station 2 at the surface, slightly fresher below thirty fathoms. It is evident that while vertical movements of such a column of water as was met at Station 24 could not reproduce the temperature and salinity conditions found at Station 11, a vertical mixing of the upper fifteen or twenty fathoms of the waters at Station 2 would cause results very similar to the conditions observed over the trench west of Jeffrey's Ledge. And this is probably the correct explanation. Further evidence in its favor is afforded by the fact that diurnal changes of surface temperature are not so great in this region as they are further off shore.

The profiles show that this mass of coast water is fairly sharply defined from the off shore water east of Jeffrey's Ledge in July and August, by low temperature and low salinity, in which it agrees with the water off the mouth of Massachusetts Bay. And no doubt the contour of the bottom is largely responsible for this fact by hindering free circulation of the water below thirty-five fathoms; because although the northern end of the trench is open, and the water there (Station 22) was salter than it was at Station 11, yet it was so much warmer at all depths that the density, depth for depth, was about the same at the two stations. Consequently there is no dynamic cause for an active flow of water of high salinity into the deep parts of the trench, and the latter retains more nearly the conditions of early summer than does the coast water further north and east.

Temperatures and salinities show that the cold bands of water so often observed along the north shore of Massachusetts Bay are evidence of upwelling of bottom water, probably due to off-shore winds. But in the southern half of Massachusetts Bay, the curves of both these factors, taken with the strong tides of this region, show that the cool surface water is the result of mixing, rather than of upwelling, two forms of vertical circulation which may be perfectly distinct, though they are often combined.

The existence of a band of coast water of very much lower salinity than the off-shore water is no doubt the direct result of the vast volume of fresh water poured into the Gulf by the large rivers which empty into it, chief of which are the Merrimac, Saco, Androscoggin, Kennebec, Penobscot, St. Croix and St. Johns, with a combined water-shed of about 45,550 square miles. Unfortunately we have very little data on the salinities of the Gulf at any season of the year except in midsummer, but the salinity curves for July and August show that at that season, at least, the fresh river water is localized along the coast, swinging off shore opposite the Penobscot and off Cape Ann. It is true that at that season there is little or no evidence afforded by the surface salinities of an influx of river water in the northeast corner of the Gulf, although it is there that the greatest volume enters, *i. e.*, from the St. Johns and St. Croix. And although this can be partly explained as due to the active vertical circulation in this region, which raises the surface salinity by mixing, virtually equalizing the physical properties of the water from surface to bottom, the mean salinities for the upper thirty fathoms show that the water off the Grand Manan Channel is absolutely, as well as apparently, salter than it is at Station 11, or off Massachusetts Bay; and that Jeffrey's Bank, off the Penobscot, is intermediate between the two extremes (the figures are:— Stations 33 and 35, 32.5‰; Station 25, 32.6‰; Station 11, 32.3‰; Station 19, 32.4‰; Station 2, 32.2‰). These facts must be amplified by records from other times of year; but so far as they go they point to the conclusion that the coast water flows southwesterly alongshore, with a branch turning southward off the mouth of the Penobscot; and that it swings eastward as a whole off Cape Ann. The fact that the St. Johns water is less evident, though much greater in amount, than the water from the Penobscot, Kennebec, and Merrimac, can be explained only on the assumption that it is more constantly mixed with salt off-shore water than are the latter; an assumption supported by our observation that oceanic salinities are most closely approximated both on the surface and in deeper layers in the eastern part of the Gulf. All this, of course, indicates an in-shore movement of water in this region in August, which mixes with the St. Johns water off the mouth of the Bay of Fundy, with consequent changes of salinity; while the occurrence of Salpae over the Eastern Basin is as good evidence, as is the high salinity, that at the time of our visit this oceanic water was an offshoot from the northern edge of the Gulf Stream, not of northern origin. Off the mouth of the Penobscot the salinity curves show that the flow is the reverse, *i. e.*, to the south; but off Casco Bay we once more find a tongue of comparatively salt water approaching the coast, and separating the Penobscot from the Cape Ann fresh wedge. Thus, although the actual movements of tidal currents do not reveal the existence of any general circulation in the Gulf (p. 84), salinity conditions show very clearly that there is an influx of ocean water on the east side of the Gulf; and a longshore movement of the fresh coast water, sending out a southerly tongue off the Penobscot, and swinging eastward off Cape Cod. In other words, the surface of the Gulf as a whole, at the time of our cruise, was probably occupied by two separate eddies, which are reconstructed here from the salinities (Plate **4**). The fact that the salinity is lower over the western than over the eastern side of the eastern basin, is due to the eddy, part of the fresh wedge off the Penobscot being drawn into its circulation on the west side. And the comparatively low salinity of the western basin, and the gradual rise of salinity from west to east is similarly explained by the indraught into the eddy of the comparatively fresh water off Cape Ann. Off Cape Cod (Station 43) the water was considerably salter than off Cape Ann, the mean for the upper fifty fathoms being about 32.7, instead of 32.4 as it was at Stations 2 and 7; *i. e.*, in this region the influence of the coast water was felt but little.

Unfortunately we yet have so little data for the salinities of the region south of a line from Cape Ann to Cape Sable, that an attempt to extend the chart of circulation over the southern half of the Gulf would be little better than guess work.

Comparison with previous records of temperature and salinity.

In July and August, 1873, Verrill found nearly the same surface temperature fifteen to twenty miles southeast of Cape Elizabeth as we did last summer, 62°–65°. Near Seguin Island, August 20, he records 59°; this is very close to our Station 40, where on August 22 our reading was 58°. But by September, 1873, the surface temperature had fallen several degrees below our August records, the surface temperature east of Jeffrey's Ledge, and generally over the western basin opposite Cape Ann being given by Verrill as 57°–58°, *i. e.*, autumn cooling had probably set in by that time. And his records near Monhegan and Matinicus Rock are from 2°–3° lower than ours a month earlier. But in Massachusetts Bay his records are 59°–64°, suggesting that seasonal cooling in that region was more rapid in 1912 than in 1873.

The temperature data obtained by the U. S. Coast Survey in 1874 is of slight value, because the surface readings are not reliable (Verrill, 1875, p. 413, footnote); and there is no way of estimating the probable error, which *may* be several degrees. But so far as they go they suggest that the surface of the Gulf was several degrees warmer in that year than in 1912, with surface temperatures of 60–69° in its southwestern part. On Cashe's Ledge, and on the northern part of Jeffrey's Ledge readings of 55–58° were obtained, probably an index of active vertical tidal circulation.

Dickson's (1901) charts for July and August, 1896, and July and August, 1897, show a very different distribution of surface temperatures in the Gulf from what we encountered: for they do not show the cold coast-band east and north of Cape Ann, while in July, 1897, the surface temperature of the whole of the Gulf east of about 69° W. Long. is given as below 59°; the smaller area west of 69° Long., 60°

or warmer: and in August of that year, he shows all of the Gulf, including the Bay of Fundy, 59° to 68°, Massachusetts Bay above 68°.

But without access to the vessels' logs, and other unpublished data from which these charts were compiled, it is useless to discuss them critically further than to point out that the distribution of temperatures within the Gulf represented on them does not accord with conditions in 1912, with Verrill's observations, or with the occasional surface readings which I have made in other years. The surface temperatures taken by the GRAMPUS in July, 1908, while crossing the mouth of Massachusetts Bay on her way to the Gulf Stream, (Bigelow, 1909) were 66° to 68°, *i. e.*, appreciably higher than they were in 1912. This fragmentary data suggests that the surface waters in the Bay and over the Gulf as a whole, were colder than usual during the summer of 1912; the result of abnormally low air temperatures during the preceding winter, the coldest in eastern Massachusetts for many years.

Unfortunately the only previous records of bottom temperatures within the Gulf, those recorded by Verrill, (1873–1875) are not reliable, as shown by the fact that when two thermometers were used simultaneously their readings occasionally differed by as much as 4.5°, frequently by 1° or 2°; indeed it was the exception that they registered alike, and as Verrill himself pointed out, they rated differently at successive standardizations. His records, taken at their face value, would indicate that the bottom temperatures were distinctly lower in the northeastern part of the Gulf in 1873 than they were in 1912; *i. e.*, the reading, with both thermometers, in 107 fathoms, in September, 1873, twenty-three miles southeast of Matinicus Rock, was 39.5°; in 105 fathoms just east of Jeffrey's Bank it was 40°, whereas it was 42.8° at Station 27, in 1912. Fifteen to twenty miles southeast of Cape Elizabeth, the discrepancy is still greater, for Verrill records bottom temperatures of from 36° to 39.5°. But these differ so much from those of the GRAMPUS (41° to about 45°) and are so much lower than he himself records from any other part of the Gulf, that it seems that the instrumental readings were too low. In the deep basin off Grand Manan, Verrill found the bottom temperature 37.5° in 106 fathoms in 1872, but we have no data to compare with his; and this basin is isolated from the exterior by a sill over which there is only about eighty fathoms of water.

Fifteen miles southeast of Boon Island, in the trench west of Jeffrey's Ledge, the older record is about 39° (37.5° and 40.5°) in ninety-five fathoms, instead of 40.3° which we found to be the general temperature at that level (Stations 11, 41), though at one Station near by (12b) we got a bottom reading of 39.2°. In the deep basin off Cape Ann, Verrill's readings, in ninety, one hundred and eighteen and one hundred and fourteen fathoms, are 40°, 43°, 39° and 39°, at three stations near together. But the fact that we found a thick layer of bottom water very uniform in temperature in this region, suggests that the discrepancy in his readings was due to the faulty instruments. And it is at least suggestive that the average of his four readings in the basin is 40.2°, *i. e.*, within .1° of our observations. Off Cape Cod, too, in 142 fathoms, close to Station 43, the bottom temperature in 1874 was 39° or 42°, agreeing fairly well with our record of 41.3° at Station 43. And the difference in depth is not significant in this case, because we encountered the uniform bottom water at 50 fathoms. On the other hand Verrill records a bottom temperature of 52° in 100 fathoms southwest of Jeffrey's Bank, where in 1912 the bottom reading, to judge from neighboring stations, must have been little, if any above 40.3°. And our entire experience makes it so improbable that the 100 fathom temperature is as high as 50° anywhere in the Gulf, that such a reading is best credited to the unreliability of the instrument with which it was taken. On the whole the bottom temperatures in Massachusetts Bay, in the western basin, and in the trough west of Jeffrey's Ledge were practically the same in 1873 as they were in 1912. But Verrill's readings for the northeast corner of the Gulf are so consistently lower than ours, that it is probable that the bottom water in that region actually was from 1° to 3° colder in 1873 and 1874 than it was in 1912. His records for 1874, (1875, p. 413) agree in a general way with our work in 1912, but as the same unreliable thermometers were used, and only one reading taken at each station, it is unwise to lay stress on them.

Dickson's, (1901) charts show the salinity of the eastern half of the Gulf as below 32‰ the Bay of Fundy 31‰ or lower, and Massachusetts Bay as below 32 for August, 1897 (no salinities are given for the remainder of the Gulf for these months). But on examining his tables, which give the tests of the water samples on which the charts are based, I did not find a single record from within the Gulf for either month, which suggests that the salinity credited in his charts to the eastern half of the Gulf was deduced from the low salinities revealed by several water samples taken in that month off the Nova Scotian Coast. But our own records show that his reconstruction of this region was probably incorrect, because it is certain that in August, 1912, there was an indraught of Atlantic water with salinities of 32.8 or more into the eastern part of the Gulf, and we have no actual data to disprove the supposition that this is an annual, if not a constant phenomenon. A similar indraught is shown by Schott, (1902) on his chart of the Atlantic.

Unfortunately salinities at other times of year do not aid as to whether or not the 1912 conditions were normal, for there are only two titration records from within the Gulf, north of George's Bank in Dickson's tables, one of 32.9 off Cape Cod, April, 1896, the other of 32.3 off Cape Sable in the same month. There are several records in his table from George's Bank, and I have received two samples from its northern edge, collected November, 1911, with salinities of 32.7 and 32.9 respectively.

General considerations.

Various explanations have been proposed to account for the band of cold water of low salinity which bathes the coastal slope from Newfoundland to Cape Hatteras, one of the earliest being that it is a branch of the Labrador Current flowing southerly along the shore. And although there is little actual evidence, other than low temperature, in its support, this is the one which has found its way most generally into literature, scientific as well as popular. Thus Libbey (1891), in his discussions of ocean temperatures south of Nantucket, constantly refers to the cold wall as the "Labrador Current." Of late years, however, practical oceanographers have found less to recommend it, and Verrill, (1874) long ago questioned whether the low bottom temperatures which he observed off Portland in 1873 were not really a part of the cold bottom water of the North Atlantic rather than evidence of Arctic water. The facts, according to Verrill, do not warrant the assumption that an Arctic Current, properly so called, as distinguished from tidal currents, enters the Gulf of Maine; but he qualifies this generalization by adding that the Gulf gets constant accessions by the tides of cold water which has primarily come from the north.

According to Schott, (1897) and Hautreux, (1910) the source of the cold water, as far south as New York, is not the Labrador Current, but the St. Lawrence. But Pettersson, (1907) discarding the idea of an Arctic Current, definitely classes the cold wall along the North American coast as "an updrift of the cold bottom water of the ocean when pushed against the coast banks," the motive force for this push being the "sinking cold water at Newfoundland," though, as he points out, "we know too little of the hydrography of the Gulf Stream and of the cold wall on the American side of the Atlantic to be able to trace with security the origin of its waters." Quite a different explanation for the cold wall is proposed by Tizard, (1907, p. 343) who believes that the chief factor in forming the cold coast water is the discharge of fresh water from the rivers along the American coast, by which means large quantities of cold fresh water and fresh ice are emptied over the coastal slope. And he argues that neither upwelling of oceanic bottom water, nor the Labrador Current, has anything to do with the formation of the cold wall.

The partial isolation of the Gulf of Maine from oceanic waters by the sill formed by George's and Brown's Banks, makes it possible that its cold waters need a different explanation from those of the "cold wall" west of Cape Cod; and the discussion of the latter is best postponed until we have a better knowledge of their salinity. But so far as the Gulf is concerned, we can safely say that the low salinities in July and August certainly show that its waters are not predominantly Atlantic abyssal water welling up over the continental slope, because the salinity of the bottom water over most of the North Atlantic is about 34.9 (Murray and Hjort, 1912).

The same index, salinity, shows that Tizard has suggested a factor of real importance, for besides the fresh water emptied into the Gulf of Maine annually by its rivers (p. 90) there is also the annual rainfall of about 40 inches, a total annual increment of fresh water, which would make a layer more than a fathom thick over the entire Gulf. To offset this, there is the annual evaporation; and while this is not exactly known for any off-shore station in the Gulf, conditions on the neighboring coasts indicate that it is probably less than the rainfall. Rainfall and inflow from rivers combined are likewise considerably in excess of the annual evaporation all along the coast of Nova Scotia where the salinity, according to both Dickson, (1901) and Schott, (1902) is 32‰ or less.

The Gulf of St. Lawrence, has, of course, been mentioned by previous authors as a source of fresh water, but its importance must be greater than has been usually recognized, because of the enormous extent of its watershed, including the St. Maurice, Saguenay, Humber, and other large rivers, besides the St. Lawrence itself. Its rainfall, too, exceeds evaporation. The little that is known about the currents in its two mouths (Dawson, 1910) shows that its main outlet must be through Cabot Straits, as Schott represents it in his chart of ocean currents, (1902, pl. 39) not through the Straits of Belle Isle. The comparatively fresh St. Lawrence water is continuous with the water with salinities of 32 or less, along the east coast of Nova Scotia. And if the Gulf of Maine receives any regular accessions of northern water of low salinity, it is probably from the Gulf of St. Lawrence, not from the Labrador Current.

The temperatures of the Gulf of Maine are, of course, very low in comparison with the Gulf Stream off shore; and its surface temperature, at least, is considerably lower than the average for its latitude, about 57°, as calculated by Krümmel, (1904) as against a probable yearly mean of about 48° for the Gulf. But we must remember in this connection that on the east coast of North America cyclonic atmospheric disturbances move as a whole from the land out over the sea, not from sea to land, as they do over Western Europe, and consequently, that the coastal waters may be expected to take their temperatures from the land climate instead of the latter being governed by oceanic temperatures, as is the case in Europe.

If the Gulf of Maine were an enclosed basin, we would expect its bottom temperature to be about the same as the mean annual temperature of the surrounding land-mass, just as Nordgaard, (1903) has found it for the Norwegian fjords. And as a matter of fact, the lowest temperatures which we encountered in the Gulf are practically the same as the mean annual for northern New England, *i. e.*, that portion of the land mass from which the chilling winds of autumn and winter blow. The considerable snowfall must likewise be an active factor in chilling the surface water in winter, while the inrush of fresh snow-water, only a few degrees above freezing point, in spring, may be expected to show its effect in retarding the warming of the coast water as the season advances. Furthermore, the considerable thickness of the bottom water of uniform temperature in the western part of the Gulf, is good evidence of winter cooling, while our observations show that the temperature was lowest in the western half, just where cooling land winds and snow are most active, instead of in the eastern, where a northern current might be expected to show itself most clearly. Thus Verrill was probably correct in his contention that the waters of the Gulf are not abnormally cold, considering their geographic location, and the climate of the neighboring land mass.

The possibility that cold northern water enters our Gulf in small amounts is not forbidden by the conclusion that the low temperature of the latter is chiefly due to winter cooling. On the contrary, the fact that the bottom temperatures on the coastal banks along the coast of Nova Scotia are much lower than at corresponding depths in the Gulf or further west, and that they decrease from southwest to northeast, as found by the Albatross in 1883 and 1885, together with the salinities, as pointed out above (p. 97) is good evidence that there is a flow of St. Lawrence water along the coast of Nova Scotia toward the southwest. And, finally, at least two wreck courses (Hautreux, 1910) have been recorded with a southerly drift near Nova Scotia. But there are no wreck tracks nor iceberg tracks leading from the grand banks of Newfoundland toward Nova Scotia, such as might be expected were there any pronounced westerly drift of the Labrador current. The occasional occurrence of Arctic pelagic organisms in Massachusetts Bay and the Bay of Fundy, such as the medusa Ptychogena and the ctenophore Mertensia, neither of which has been able to establish itself in the Gulf, shows that there are occasional indraughts of the St. Lawrence water into the latter. But the fact that last summer the indrift was of Atlantic not St. Lawrence origin (p. 94), and the occasional record of tropical organisms, *e. g.*, the siphonophore Physalia at Grand Manan, show that its influence is either sporadic, or seasonal, not constant.

If any general conclusion can be drawn from the scanty oceanographic data yet available, it is that the Gulf of Maine owes its low temperature and salinity largely to local causes; *i. e.*, to its geographic position and partial isolation by the sill formed by George's Bank; and that though there was an influx of ocean water in the summer of 1912 from the edge of the Gulf Stream, in other years, or at other seasons, there are more or less sporadic indraughts of cold water flowing from the northeast. This water, however, probably has no connection with the Labrador Current, but comes from the St. Lawrence.

Preliminary notes on the plankton.

The following notes on the macroplankton, preliminary to the special reports on the various groups, are offered because no attempt seems to have been made to study the pelagic fauna of the Gulf as a whole; and because the collections and oceanographic data of the Grampus allow a correlation between its plankton at a given time and the physical factors of the water, at the same time and place. With these ends in view, our main efforts were directed toward qualitative, rather than quantitative results, though we devoted as much attention to the latter as was practicable. The usual program of plankton work during the day time, was to use the no. 20 (bolting silk) net at or near the surface, and to tow the coarse four-foot net horizontal for half an hour at some intermediate depth. When stations were occupied after dark, we usually used the four-foot net within a fathom or so of the surface, in this way getting very rich tows. The data of the hauls is listed in the table of stations (p. 135). The hauls with the quantitative (Hensen) net are discussed separately (p. 127).

By far the most important member of the animal plankton over most of the Gulf, numerically at least, was the small copepod *Calanus finmarchicus*, which was taken at every Station (p. 115). This species plays much the same rôle in the vital economy of the Gulf as it does in Norwegian waters on the other side of the Atlantic, being the chief food for pelagic fishes, particularly the mackerel. It is well known to fishermen under the name of "red feed," from the reddish color of a mass of these little crustaceans. At times it occurs in almost unbelieveable numbers; for example our four-foot net hauls in Massachusetts Bay near Cape Ann in July often yielded two or three quarts of this Calanus. At this time the plankton of the Bay was almost exclusively composed of *C. finmarchicus*, with very few other copepods; *e. g.* Pseudocalanus, Eurytemora, and Metridia; an insignificant number of Sagittae (chiefly *S. elegans*); a few larval schizopods; an occasional full-grown schizopod (*Meganyctiphanes norvegica*), and a few medusae, *e. g.*, Aurelia, Cyanea, Melicertum, and the northern ctenophore, *Bolinopsis infundibulum.* We also obtained one specimen of the large pteropod *Clione limacina* in the Bay, and others off Cape Ann (p. 119). In the northeastern corner of the Bay, this general type of plankton was varied by the presence of great numbers of fish eggs (Station 1), and our several stations in the northeast corner of the Bay yielded many pelagic larvae of the cunner (Tautogolabrus), cod (*Gadus collarius*), witch flounder (*Glyptocephalus cynoglossus*), and sanddab (*Hippoglossoides platessoides*), with a few silver hake (Merluccius), redfish (*Sebastes marinus*), haddock (*Melanogrammus aeglifinus*), rockling (Enchelyopus) and other species (p. 107).

Twelve miles or so off Cape Ann (Station 2) there were very few fish eggs; and no fry; and over the western arm of the deep basin (Station 7) there were no eggs at all, but a considerable number of fish larvae, mostly cod, of which twenty-nine specimens were taken. The Calanus swarm, however, was nearly as dense as in the Bay; and we noted here, for the first time, the large boreal copepod *Euchaeta norvegica*, between seventy-five fathoms and the surface. There were no other copepod species in the haul. At this station we likewise captured two large *Meganyctiphanes norvegica*, and one specimen of the pelagic boreal amphipod, Euthemisto, which was taken frequently from this point on, while a swarm of *Sagitta elegans* gave a new aspect to the tow. Clione, too, was represented by several large specimens. There were neither Aurelia nor Cyanea so far off shore; but the four-foot net yielded several large *Beroe cucumis,* a cosmopolitan form already often recorded from the Gulf. Perhaps associated with the abundance of Calanus, were the numerous Wilson's petrels which surrounded the ship as soon as we hove her to at this station. From Station 7 we ran in shore again, and worked for two days in Ipswich Bay, a region where I had previously found an abundant plankton, and which is proverbial for whales, sharks, etc., and the seat of an important winter fishery. *Calanus finmarchicus* was still the prevalent organism, the nets bringing back a swarm of juveniles, besides several *Euchaeta norvegica,* great numbers of *Sagitta elegans* (Stations 8, 9, 10, 11, 12b), *Tomopteris helgolandica,* represented by a very large specimen in the quantitative haul at Station 11, and, among Medusae, Aurelia and Cyanea in large numbers, with a few *Melicertum campanula,* and *Phialidium languidum.* The latter species we found very widely distributed in the coastal waters of the Gulf.

But the most important feature of Ipswich Bay, to us, was the immense number of pelagic fish eggs, largely *Urophycis chus:* and a haul of the eight-foot beam trawl for thirty minutes at Station 8 yielded the following large haul of fishes; twelve skates (*Raja radiata*) two *Aspidophoroides monopterygias,* four *Zoarces anguillaris;* twenty silver hake (*Merluccius bilinearis,*) two hake (*Urophycis regius*), thirty-four squirrel hake, (*Urophycis chus*), two rocklings (*Enchelyopsis cimbrius*), forty-one sanddabs (*Hippoglossoides platessoides*), six rusty flounders, (*Limanda ferrugnea*), forty-eight witch flounders (*Glyptocephalus cynoglossus*), and seven large goosefish (*Lophius piscatorius*). The squirrel hake (*Urophycis chus*) were full of ripe eggs and milt; and comparison of their eggs, fertilized on board, with the pelagic eggs taken in the tow, established the identity of the most abundant of the latter as belonging to this species. This discovery is of great interest, because very little is known of the early stages of any members of this genus, and nothing of this particular species. It, and the other fishes will be described by Mr. W. W. Welsh. Meantime it may be noted here that the fish were spawning in twenty-two fathoms, temperature 42.4°, salinity 32.39‰. In spite of the great numbers of pelagic eggs, Ipswich Bay and the waters immediately to the north yielded but few fry, except for the sanddab (Hippoglossoides), of which twenty-four specimens of 10–22 mm. were taken at

Station 11. In Kittery Harbor, however, we obtained great numbers of Tautogolabrus and Merluccius.

Our enforced return to Gloucester for repairs on July 18 gave us an opportunity to compare the plankton off the Harbor mouth (Station 12) with what we had found a week or two previous, with the result that there had been no appreciable change, the waters still being filled with the Calanus swarm besides an occasional Euchaeta, and a few fish eggs, and many fry, as noted above.

Our run from Cape Ann to Casco Bay showed that the spawning area of the squirrel-hake, admitting our identification of the pelagic eggs to be correct, extended over the whole coast band, large hauls of fish eggs, including this species, being made at Stations 14 and 20. At the latter many cunner eggs (Tautogolabrus) were also taken; and a few eggs probably belonging to the mackerel, which were schooling in small numbers in this neighborhood at the time. Mackerel eggs were likewise taken in our surface tows at our anchorage at Orr's Island, on August 1. Only two species of fish fry were taken in numbers in the northwest corner of the Gulf and in Casco Bay. Most important of these, because of its purely boreal habitat, is the redfish (*Sebastes marinus*), no less than 320 larvæ of which were taken in the closing net and in the intermediate haul at Station 19 (p. 108). At Station 22, likewise, it was represented by fifty-three specimens, in the open net haul. In Casco Bay, larval cunners (Tautogolabrus) were numerous.

Along this stretch of coast we continued to find *Calanus finmarchicus* in large numbers, with a few *Euchaeta norvegica;* and at Station 13 we captured a few of the large blue copepod *Anomalocera patersoni* on the surface, a species frequently taken after this, occasionally in large numbers (p. 118); and several other copepods in lesser numbers, as shown in the table (p. 115). Off Cape Porpoise we first encountered the amphipod Euthemisto in large numbers. Here, too, our tows revealed many specimens of the pteropod *Limacina balea;* while Stations 19 and 22 added a fresh Chaetognath, *Sagitta serratodentata* in small numbers. Another addition to the plankton, in this region, was the large hydromedusa *Staurophora mertensii,* which we first met at Station 14, where three large specimens were taken in a haul of the four foot net from twenty fathoms. *Meganyctiphanes norvegica,* too, occasionally occurred in our hauls off Casco Bay, (Station 19). In the coast region Aurelia and Cyanea were taken in most of the hauls, but usually not on the surface; though several large specimens were seen floating at Station 22. Our most notable find in this region was four fragmentary specimens of the hydromedusa *Halopsis ocellata,* taken at Stations 15, 22, and 23. This species, first discovered in Massachusetts Bay (A. Agassiz, 1865, p. 102) has since been recorded only once, by Fewkes, (1888), who found it in considerable numbers "near the wharves at Grand Manan." The chief point of interest about this species is its otocysts, for though Agassiz figured them (1865) it has remained questionable whether they are open or closed, and consequently Browne, (1910) found it impossible to refer the genus definitely either to the Mitrocomidae or to the Eucopidae. Fortunately our specimens, though much battered, show these organs well, and it is easy to demonstrate that they are open pits. The opening is evident on surface views of the oral side of the velum, and large enough to admit a fine bristle. Consequently Halopsis is a mitrocomid. The specimens agree with Fewkes's statement as to the independent origin of the radial canals from the stomach (in the original account they are described as arising in four groups).

Our run out to Platt's Bank showed that very few fish were spawning except close to the shore, for the tows at Station 23, on the bank, contained no eggs at all, nor did we meet any over the deep trench a few miles further south (Station 24), while very few were found over Jeffrey's Bank (Station 25) except for a Lophius veil, with the eggs nearly ready to hatch, which we picked up from the surface at this station. And to complete the brief survey of fish eggs I may add that very few were taken at any of our stations further north or east; none at all at the off-shore stations over the Eastern Basin (Stations 27, 28) on German Bank (Stations 29, 30), off Lurcher Shoal (Station 31), off Mt. Desert Rock (Station 32) or in the Grand Manan Channel.

On the other hand we captured 190 larval red fish (Sebastes) on Platt's Bank (Station 23); 18 at Station 27, 61 at Station 28; and 27 at Station 32; but it was not taken on Jeffrey's Bank (Station 25); nor along the coast from Grand Manan to Penobscot Bay (Stations 33 to 39).

At our off-shore hauls the plankton repeated, in a general way, the conditions met nearer land, *Calanus* with a few other copepods, notably *Euchaeta norvegica* and *Anomalocera patersoni,* still forming the bulk of the hauls (Stations 23, 24, 27, 28). But the haul from twenty fathoms at Station 23 yielded an important addition to the list of copepods, in the Arctic Calanus, *C. hyperboreus,* represented by six specimens among the thousands of *C. finmarchicus.* We now met Meganyctiphanes more regularly, considerable numbers of this schizopod being taken at Station 27, 80–0 fathoms. And at Station

23 we found a single specimen of the medusa *Tiaropsis diademata*, which is abundant in Massachusetts Bay in June.

At Station 23 we first met *Pleurobrachia pileus*, and we frequently took it later, further north and east; we saw *Bèroe cucumis* on the surface, and captured sticklebacks, and a large isopod (Idotea) from floating Fucus. In these off-shore waters *Sagitta serratodentata* was more plentiful than we had found it before,— a case treated at length elsewhere (p. 121) and an occasional fragmentary agalmid was likewise taken (p. 121) besides considerable numbers of fish fry.

At Station 27 *Calanus finmarchicus* was taken in swarms at the surface, the only time we found it abundant at that level, in the day time, though it often was at night. Euthemisto was plentiful at the off-shore Stations 29 and 31, and at the former we took one *Tiara pileata*, and two Aglantha (40–0 fathoms), this being the first time the latter was encountered during the cruise. On the other hand, we found none of the typical shore forms, *e. g.*, Aurelia, Cyanea, Melicertum; and over the Eastern Basin not even Staurophora, Phialidium, Beroe, Bolinopsis, or Pleurobrachia, though the last three, of course, are not dependent upon shallow water at any stage in development.

German Bank proved interesting, for though the surface temperature was low (52°, Station 30) and the bulk of the tow consisted of *Calanus finmarchicus*, with a few Euchaeta, Anomalocera, a large number of the schizopod Euphausia, the amphipods *Hyperia galba* and Euthemisto, *Tomopteris helgolandica*, *Sagitta elegans*, and *S. serratodentata*, forming a typical boreal assemblage, the surface haul also yielded two large *Salpa fusiformis* and two specimens of the siphonophore *Physophora hydrostatica*. During the next day Salpae were occasionally seen on the surface; and at Station 31 several were taken in the tow, all *S. fusiformis* (p. 121). But here, as on German Bank, the plankton as a whole was the same as we had found over the Gulf as a whole, *Calanus finmarchicus* composing far the chief bulk of the haul. This proved to be an interesting station, because the open net from fifty-five fathoms brought back several specimens of the cold water Chaetognath *Eukrohnia hamata*, a species found on the surface in Arctic and Antarctic regions, but limited to the mesoplankton in temperate and tropical latitudes. This same haul also yielded two specimens of the large *Sagitta lyra;* and neither of these species was taken again during the voyage. The list of copepods also received an addition, *Euchirella rostrata*. After leaving this station we saw no more Salpae.

Twelve miles off Mt. Desert Rock, August 16, 3 A. M., we made a rich surface haul of *Calanus finmarchicus,* with a few other copepods, *e. g.* Centropages, Metridia, Anamalocera, and Euchaeta, besides *Meganyctiphanes norvegica,* Hyppolyte, Euthemisto, *Limacina balea, Sagitta elegans* and *S. serratodentata, Tomopteris helgolandica, Clione limacina,* Pleurobrachia, Phialidium, and agalmid fragments, *i. e.,* the plankton was of the same type as off shore and further west; and rich quantitatively. But when we approached shore, off Moose Peak, our hauls were extremely barren, by far the poorest yet made. The four-foot net, hauled for three quarters of an hour, at Station 33, with an electric light in its mouth, contained only a few Calanus, four medium sized Staurophora, and a few Sagittae, the whole, aside from the large Medusae, being less than 20 cc. in bulk. This was quite the contrary to what we expected, as the northeastern corner of the Gulf and the Bay of Fundy have always been credited with a rich pelagic life. But in the Grand Manan Channel (Station 34), the plankton was even poorer than at Station 33, the four foot net, hauled from 50–0 fathoms, containing almost nothing except a very few Calanus and other small copepods, while a few Staurophora were seen on the surface. And much the same condition was encountered in the mouth of the St. Croix River, where surface tows were made on August 18, very little being taken, or seen, except Staurophora. In Eastport Harbor, however, many Meganyctiphanes, probably attracted by refuse from the sardine factories, were taken on the surface.

When we returned through Grand Manan Channel, we made a haul off the north end of Campobello Island, where the four-foot net did not bring back even a single copepod; but it yielded large numbers of Balanus eggs in segmentation stages; and a few Staurophora were seen on the surface. Near the entrance of the Channel (Station 35) the water was hardly more productive, the whole catch of the four-foot net (35–0 fathoms), chiefly Calanus and Sagittae, being contained in an ordinary table spoon; while no Medusae or ctenophores were seen on the surface. That night, however, in Cutler Harbor, we found a fairly rich neritic plankton, chiefly copepods, gammarid amphipods, and the hydromedusid Sarsia. When we once more ran off shore to the edge of the deep basin, August 20 (Station 36), the water was occupied by the Calanus swarm, with a few Euthemisto, a few Euchaeta, many Sagitta, chiefly *S. elegans, Aglantha digitale, Beroe cucumis,* Meganyctiphanes, and Staurophora, *i. e.,* a typical Gulf of Maine plankton in considerable quantity. And the richness of this station and that of Station 32, showed that the edge of the dense Calanus swarm followed the 100 fathom curve, the barren zone being only a narrow coast belt.

At Station 38 and 39, the nets yielded comparatively little except diatoms (p. 133), though more than in Grand Manan Channel. In fact it was not until Penobscot Bay was passed that we once more ran into copepods in abundance near the coast. The poverty of the macroplankton in general was shared by the fish fry, for our nets did not yield a single young fish along this whole stretch of coast, *i. e.* Stations 33 to 39. At Station 40 we once more met a rich copepod plankton, chiefly *Calanus finmarchicus* on the surface as well as in the intermediate haul. *Calanus hyperboreus* was likewise represented by one specimen (20–0 fathoms). Considerable numbers of larval Sebastes were taken at this Station; and swarms of *Pleurobrachia pileus* and *Phialidium languidum* gave the tow a distinctive character different from any previously taken. Between Station 40 and Cape Ann (Station 41), the Calanus swarm was once more met, but at this Station there were about as many Centropages as Calanus on the surface; and a surface haul at night off the Cape (Station 42) yielded large masses of Calanus. The tow at this Station was notable for containing large numbers of the copepod *Anomalocera patersoni*, besides Euthemisto, *Tomopteris helgolandica, Sagitta elegans,* Cyanea, Staurophora, Phialidium, and many fish larvae. The plankton off Cape Cod at the end of August (Station 43) proved to be of the same type that we had found generally over the Gulf, the prevailing animal being *Calanus finmarchicus,* with *Eucheata norvegica* in less abundance; Euthemisto, Pleurobrachia, Beroe, Staurophora, and a few larval fishes were also taken. Our lines do not afford any information as to how far south the Calanus swarm extended; but some tows made by Capt. John McFarland of the fishing schooner VICTOR revealed this copepod in great numbers five miles east of Chatham, on September 20. However, twelve miles S. E. of Chatham, a day or two later, his tow shows that it was outnumbered by Pseudocalanus, five hundred to one. And, as pointed out (p. 121) he collected a pure Salpa plankton on the surface twenty-five miles off the same port on September 30, which is good evidence that Gulf Stream water was making its influence felt in that region.

Off Cape Ann (Station 42) fish fry of several species, notably cunner (Tautogolabrus), redfish (Sebastes), rockling (Enchelyopus) and witch flounder (Glyptocephalus) were taken; and in the southern half of Massachusetts Bay (Station 44) the hauls yielded many larval sanddabs (Hippoglossoides) and witch flounders (Glyptocephalus), with a few redfish (Sebastes), silver hake (Merluccius), and rockling (Enchelyopus). The hauls off Cape Cod (Station 43) contained only nine fish fry, five Sebastes, and four Enchelyopus.

Of the three components, Arctic, Boreal, and Temperate Atlantic, into which the northern pelagic communities can be divided according to Hjort (Murray and Hjort, 1912, p. 637), the plankton of the Gulf belongs distinctively to the Boreal, for only a single species distinctively characteristic of polar waters, *Calanus hyperboreus,* was detected in 1912. Thus the ctenophore *Mertensia ovum,* was conspicuously absent, though it is known from Massachusetts Bay (A. Agassiz, 1865) and is recorded from the Bay of Fundy by Fewkes, (1888). The polar pteropod *Limacina helicina* was likewise wanting, whereas its boreal relative *L. balea* was taken at several stations, in some abundance. Nor did we detect the Arctic prawn, *Hymenodora glacialis,* a species lacking in boreal as well as in tropical waters. On the other hand *Calanus finmarchicus,* the most characteristic animal of all in the Gulf, is the most important member of the Boreal, as opposed to the polar plankton, in the Norwegian Sea and in the North Sea; and it is the commonest copepod off San Diego, California (Esterly, 1905, p. 126). Euthemisto, *Meganyctiphanes norvegica,* and *Euchaeta norvegica* are all characteristic of the Norwegian Sea, and of the southern edge of the Newfoundland Banks (Murray and Hjort, 1912, p. 108). *Clione limacina,* too, is by no means a sure indication of polar water, for though it is abundant in the Labrador Current off the east coast of Newfoundland, and has been taken off the west coast of Greenland, near Spitzbergen, and at other Arctic stations, it is not associated with polar water in the Norwegian Sea, (Murray and Hjort, 1912, p. 107) but, on the contrary, is found in Atlantic water there, and south of Iceland. To judge, however, from its great abundance in high latitudes and comparative scarcity in our Gulf, it appears to reach its maximum development in a lower temperature than that of the Gulf of Maine in summer. And neither is *Eukrohnia hamata* purely Arctic, for it occurs in the mesoplankton at lower latitudes; as for example in the Bay of Biscay, where Fowler, (1905) found it in one haul from fifty fathoms, *i. e.*, at about the same depth as our one record, and in many hauls from greater depths. And there is no more reason to assume a polar origin for the Gulf of Maine specimens than there is for the Biscayan ones.

Most of the important Medusae and ctenophores, for example Aurelia, Cyanea, Melicertum, *Bolinopsis septentrionalis,* are regular inhabitants of the Norwegian Sea, and of the northern part of the North Sea. Staurophora is known from Helgoland; while *Pleurobrachia pileus* and *Beroe cucumis* are apparently cosmopolitan. *Tomopteris helgolandica* is known from the North Sea, the coast of

Norway, the English Channel, the northeast coast of Scotland, and from the Grand Banks of Newfoundland; and *Sagitta elegans* is a characteristic member of the North Sea plankton.

Most oceanic species so far detected in the collections, *e. g.*, *Salpa mucronata*, and *S. fusiformis*, *Sagitta serratodentata*, *Agalma elegans*, *Physophora hydrostatica*, are dwellers in warm or in temperate waters, the only far northern records of any of them being obviously the result of warm currents (for northern records of Salpa, see Apstein, 1909: of *Sagitta serratodentata*, see Ritter Zahony, 1911; Agalma and Physophora, see Bigelow, 1911. And the resemblance which the Gulf bears in a small way, to the Norwegian Sea in the more important constituents of its zoöplankton, is heightened by the fact that Salpa, Agalma, and Physophora are regular summer visitors to the latter with the northward movement of Atlantic water (Helland Hansen and Nansen, 1909, Murray and Hjort, 1912), while their presence in our Gulf is positive evidence of an influx of water from the northern edge of the Gulf Stream.

List of fishes.

(Identified by W. W. Welsh, U. S. Bureau of Fisheries).

1. *Larval and postlarval stages taken in the plankton hauls.*

Argentinidae.

Smelt. *Osmerus mordax* (Mitchill).

Portland Harbor	July 31	Surface	1 specimen	19.5 mm.

Herring Smelt. *Argentina silus* Ascanius.

Station 27	August 14	35 fathoms	1 specimen	49 mm.

Gasterosteidae.

Three-spined Stickleback. *Gasterosteus aculeatus* Linné.

Station 11	30–0 fathoms	1 specimen	2.3 cm.
Station 23	surface	4 specimens	3.9–3 cm.
Station 25	surface	8 specimens	3.9–2.8 cm.
August 13	surface	4 specimens	4.4–3.7 cm.
Station 29	surface	1 specimen	4.6 cm.
Station 30	surface	11 specimens	4.2–2.8 cm.
August 16	surface	1 specimen	4.2 cm.
Station 43	surface	2 specimens	3.3–2.8 cm.

Two-spined Stickleback. *Gasterosteus bispinosus* Walbaum.

Station 23	surface	9 specimens	3–2.6 cm.
August 13	surface	10 specimens	3.4–2.7 cm.
Station 29	surface	1 specimen	4.5 cm.

Syngnathidae.

Pipefish. *Siphostoma fuscum* (Storer).

Portland Harbor	July 31	surface	1 specimen	14.5 mm.

Labridae.

Cunner. *Tautogolabrus adspersus* (Walbaum) (?).

Station 5	July 12	surface	25 specimens	4.5–2.5 mm.
Gloucester Harbor	July 19	surface	7 specimens	6.5–5 mm.
Station 12	July 22	5–0 fathoms	6 specimens	6.5–5 mm.
Kittery Harbor	July 27	surface	102 specimens	6.5–3.5 mm.
Orr's Island, Me.	July 30	surface	35 specimens	6.5–3 mm.
Casco Bay	August 4	surface	80 specimens	5–2 mm.
Station 42	August 24	20–0 fathoms	3 specimens	9–6.75 mm.
Station 44	August 31	20–0 fathoms	1 specimen	8.5 mm.

Scorpaenidae.

Redfish. *Sebastes marinus* (Linné).

Station 12	July 22	5–0 fathoms	1 specimen	12 mm.
Station 14	July 24	20–0 fathoms	6 specimens	11–6.5 mm.
Station 19	July 29	20 fathoms	150 specimens	9–6.5 mm.
Station 19	July 29	25–0 fathoms	170 specimens	9.5–6.5 mm.
Station 22	August 7	30–0 fathoms	53 specimens	8.5–6.5 mm.
Station 23	August 7	20–0 fathoms	190 specimens	13.5–7 mm.
Station 27	August 14	35 fathoms	5 specimens	20.5–13 mm.
Station 27	August 14	80–0 fathoms	13 specimens	21–13 mm.
Station 28	August 14	30–0 fathoms	61 specimens	16–7.5 mm.
Station 31	August 15	55–0 fathoms	2 specimens	8–7 mm.
Station 31	August 15	25–0 fathoms	13 specimens	12.5–9 mm.
Station 32	August 16	surface	27 specimens	15–7 mm.
Station 40	August 22	20–0 fathoms	20 specimens	13–7.5 mm.
Station 42	August 24	20–0 fathoms	5 specimens	12–8.5 mm.
Station 43	August 29	35–0 fathoms	5 specimens	12.5–9 mm.
Station 44	August 31	25–0 fathoms	6 specimens	11.5–7 mm.

Cottidae.

Artediellus atlanticus Jordan and Evermann.

Station 19	40–0 fathoms	2 specimens	6.3–4.3 cm.
Station 21	60–0 fathoms	4 specimens	5.1–4.2 cm.

CYCLOPTERIDAE.

Lumpfish. *Cyclopterus lumpus* Linné.

Station 25	August 8	surface	16 specimens	91–13 mm.
Station 26b	August 13	surface	53 specimens	57–10.5 mm.
Station 27	August 14	surface	1 specimen	44 mm.
Station 30	August 14	surface	9 specimens	70–21 mm.
Between Petit Manan and Libbey Island	August 16	surface	39 specimens	34–14 mm.
Station 40	August 22	surface	1 specimen	10.5 mm.

LIPARIDIDAE.

Liparis liparis (Linné) (?).

Station 12	July 22	5–0 fathoms	9 specimens	9–5.5 mm.
Station 44	August 31	25–0 fathoms	2 specimens	7–5.5 mm.

BLENNIIDAE.

Pholis gunnellus (Linné).

Station 25	August 8	surface	1 specimen	39 mm.
	August 13	surface	1 specimen	29 mm.

Ulvaria subbifurcata (Storer) (?).

Station 5	July 12	surface	2 specimens	8 mm.
Station 12	July 22	5–0 fathoms	8 specimens	14–8 mm.
Station 14	July 24	20–0 fathoms	3 specimens	12–10 mm.
Station 20	July 31	7–0 fathoms	1 specimen	14 mm.
Station 42	August 24	20–0 fathoms	1 specimen	15.5 mm.

ZOARCIDAE.

Lycenchelys verrillii (Goode and Bean).

Station 21	60–0 fathoms	1 example	10 cm.

MERLUCCIIDAE.

Silver Hake. *Merluccius bilinearis* (Mitchill) (?).

Station 5	July 12	surface	8 specimens	4–2.5 mm.
Kittery Harbor, Me.	July 27	surface	22 specimens	4–2.5 mm.
Orr's Island, Me.	July 30	surface	2 specimens	3 mm.
Station 44	August 31	20–0 fathoms	9 specimens	10–6 mm.

Gadidae.

Cod. *Gadus callarias* Linné.

Station 7	July 16	18–0 fathoms	29 specimens	15–4.5 mm.
Station 11	July 17	25–0 fathoms	1 specimen	8.5 mm.
Station 12	July 22	5–0 fathoms	61 specimens	19.5–8 mm.

Haddock. *Melanogrammus aeglifinus* (Linné) (?).

Station 12	July 22	5–0 fathoms	6 specimens	21–10 mm.

Hake. *Urophycis sp.*

Station 16	July 26	surface	1 specimen	84 mm.
Station 25	August 8	surface	1 specimen	70 mm.
Station 27	August 14	surface	1 specimen	67 mm.
Station 30	August 14	surface	1 specimen	41 mm.
Station 31	August 15	surface	1 specimen	102 mm.

Rockling. *Enchelyopus cimbrius* (Linné).

Station 5	July 12	surface	5 specimens	5–3 mm.
Station 11	July 17	30–0 fathoms	6 specimens	38–12 mm.
Orr's Island	July 30	surface	1 specimen	2 mm.
Casco Bay	August 4	surface	1 specimen	5.5 mm.
Station 25	August 8	surface	1 specimen	42 mm.
Station 29	August 14	surface	1 specimen	20 mm.
Station 30	August 14	surface	1 specimen	31.5 mm.
Station 41	August 24	surface	1 specimen	23 mm.
Station 42	August 24	surface	2 specimens	16.5–13.5 mm.
Station 43	August 29	35–0 fathoms	4 specimens	44–39 mm.

Enchelyopus cimbrius (Linné). (?).

Station 11	July 17	25–0 fathoms	4 specimens	11–5 mm.
Station 12	July 22	5–0 fathoms	2 specimens	5.5 mm.
Station 20	July 31	7–0 fathoms	1 specimen	5 mm.
Station 42	August 24	surface	6 specimens	10–5 mm.
Station 44	August 31	25–0 fathoms	2 specimens	8.5–5 mm.

Cusk. *Brosme brosme* (Müller) (?).

Station 12	July 22	5–0 fathoms	1 specimen	13.8 mm.

Pleuronectidae.

Sanddab. *Hippoglossoides platessoides* (Fabricius).

Station 11	July 17	25–0 fathoms	24 specimens	22.5–10 mm.
Gloucester Harbor	July 18	surface	1 specimen	23.5 mm.
Station 21	August 2	60 fathoms	1 specimen	89 mm.

Hippoglossoides platessoides (Fabricius) (?).

Station 44	August 31	25–0 fathoms	24 specimens	9.5–6 mm.

Winter Flounder. *Pseudopleuronectes americanus* (Walbaum) (?).

Station 7	July 16	18 fathoms	1 specimen	10.5 mm.
Station 11	July 17	25–0 fathoms	1 specimen	13 mm.
Station 20	July 31	7–0 fathoms	1 specimen	6.5 mm.

Witch Flounder. *Glyptocephalus cynoglossus* (Linné).

No label			2 specimens	16.5–8.5 mm.
Station 12	July 22	5–0 fathoms	1 specimen	9.5 mm.
Station 14	July 24	20 fathoms	2 specimens	16.5–8 mm.
Station 21	August 2	60 fathoms	8 specimens	108 –65 mm.
Station 30	August 14	surface	1 specimen	18.5 mm.
Station 42	August 24	20–0 fathoms	6 specimens	18–10 mm.
Station 44	August 31	25–0 fathoms	20 specimens	16.5–9 mm.

Pleuronectids unplaced.

Station 7	July 16	18 fathoms	1 specimen	7 mm.
Station 12	July 22	5–0 fathoms	15 specimens	10–6 mm.

Lophiidae.

Goosefish. *Lophius piscatorius* Linné.

Station 5	July 12	Surface	1 specimen	6.5 mm.

Adult stages taken in the trawl.

Rajidae.

Little Skate. *Raja erinacea* Mitchill.

Station 16	25 fathoms	1 specimen

Prickly Skate. *Raja radiata* Donovan.

Station 6	27 fathoms	1 specimen
Station 8	22 fathoms	12 specimens

Scorpaenidae.

Redfish. *Sebastes marinus* (Linné).

Station 1	33 fathoms	1 specimen
Station 6	27 fathoms	14 specimens
Station 13	30 fathoms	1 specimen
Station 15	30 fathoms	2 specimens
Station 16	25 fathoms	6 specimens
Station 19	50 fathoms	1 specimen
Station 21	60 fathoms	7 specimens
Station 23	47 fathoms	5 specimens

Cottidae.

Triglops pingelii Reinhardt.

Station 1	33 fathoms	1 specimen
Station 6	27 fathoms	1 specimen

Sculpin. *Myoxocephalus octodecimspinosus* (Mitchill).

Station 1	33 fathoms	1 specimen
Station 6	27 fathoms	5 specimens
Station 17	16 fathoms	1 specimen
Station 19	50 fathoms	2 specimens

Sea Sculpin. *Hemitripterus americanus* (Gmelin).

Station 15	30 fathoms	1 specimen
Station 21	60 fathoms	1 specimen

Agonidae.

Alligator Fish. *Aspidophoroides monopterygius* (Bloch).

Station 1	33 fathoms	8 specimens
Station 6	27 fathoms	9 specimens
Station 8	22 fathoms	2 specimens
Station 15	30 fathoms	1 specimen

Blenniidae.

Ulvaria subbifurcata (Storer).

Station 6	27 fathoms	1 specimen
Station 16	25 fathoms	1 specimen

Zoarcidae.

Eelpout. *Zoarces anguillaris* (Peck).

Station 6	27 fathoms	3 specimens
Station 8	22 fathoms	4 specimens
Station 15	30 fathoms	7 specimens

Merlucciidae.

Silver Hake. *Merluccius bilinearis* (Mitchill).

Station 1	33 fathoms	1 specimen
Station 8	22 fathoms	20 specimens
Station 15	30 fathoms	2 specimens
Station 16	25 fathoms	1 specimen
Station 21	60 fathoms	9 specimens

Gadidae.

Cod. *Gadus callarius* Linné.

Station 1	33 fathoms	1 specimen
Station 6	27 fathoms	2 specimens

Haddock. *Melanogrammus aeglifinus* (Linné).

Station 15	30 fathoms	1 specimen
Station 16	25 fathoms	1 specimen

Spotted Hake. *Urophycis regius* (Walbaum).

Station 8	22 fathoms	2 specimens
Station 17	11 fathoms	3 specimens
Station 21	60 fathoms	1 specimen

Squirrel Hake. *Urophycis chus* (Walbaum).

Station 8	22 fathoms	34 specimens
Station 13	30 fathoms	2 specimens
Station 15	30 fathoms	4 specimens
Station 16	25 fathoms	1 specimen
Station 21	60 fathoms	2 specimens

Rockling. *Enchelyopus cimbrius* (Linné).

Station 1	33 fathoms	1 specimen
Station 8	22 fathoms	2 specimens
Station 15	30 fathoms	1 specimen
Station 16	25 fathoms	2 specimens

PLEURONECTIDAE.

Sanddab. *Hippoglossoides platessoides* (Fabricius).

Station 6	27 fathoms	7 specimens
Station 8	22 fathoms	41 specimens
Station 13	30 fathoms	2 specimens
Station 15	30 fathoms	3 specimens
Station 16	25 fathoms	2 specimens
Station 21	60 fathoms	3 specimens

Rusty Flounder. *Limanda ferruginea* (Storer).

Station 6	27 fathoms	3 specimens
Station 8	22 fathoms	6 specimens
Station 15	30 fathoms	1 specimen

Winter Flounder. *Pseudopleuronectes americanus* (Walbaum)

Station 17	11 fathoms	6 specimens

Witch Flounder. *Glyptocephalus cynoglossus* (Linné).

Station 1	33 fathoms	1 specimen
Station 6	27 fathoms	1 specimen
Station 8	22 fathoms	48 specimens
Station 16	25 fathoms	1 specimen
Station 21	60 fathoms	1 specimen

LOPHIIDAE.

Goosefish. *Lophius piscatorius* Linné.

Station 8	22 fathoms	7 specimens
Station 15	30 fathoms	2 specimens
Station 21	60 fathoms	3 specimens

List of copepods.

(Identified by C. O. Esterly).

Stations →	2	4	5	6	7	11	12	14	15	16	19	19	20
Depths →	60-0	15-0	0	27-0	75-0	25-0	40-0	20-0	15-0	15-0	25	25-0	7-0
Calanus finmarchicus	×	×	×	×	1000	1000	×	×	×	50	100	50	40
Calanus hyperboreus	....	....	....	....	....	....	....	....	....	....	....	....	....
Pseudocalanus elongatus	....	....	....	×	....	1	....	....	....	1	3	3	3
Paracalanus parvus	....	....	....	....	....	....	....	....	....	....	....	....	....
Euchirella rostrata	....	....	....	....	....	....	....	....	....	....	....	....	....
Euchaeta norvegica	....	....	....	....	1	....	×	....	....	....	....	....	....
Centropages hamatus	....	....	....	....	....	....	....	....	....	1	....	....	....
Centropages typicus	....	....	....	....	....	....	....	....	....	....	1	....	1
Temora longicornis	....	....	....	....	....	....	....	....	....	1	....	....	1
Eurytemora herdmani	....	....	....	×	....	....	....	....	....	1	....	....	....
Metridia lucens	....	....	....	×	....	100	....	....	....	....	....	....	....
Anomalocera patersoni	....	....	....	....	....	....	×	....	....	....	....	....	....
Acartia clausi	....	....	....	....	....	....	....	....	....	....	....	....	....
Acartia longiremis	....	....	....	....	....	....	....	....	....	....	....	....	2
Tortanus discaudatus	....	....	....	....	....	....	....	....	....	....	....	....	....
Corynura discaudatus	....	....	....	....	....	....	....	....	....	....	....	....	1

Stations →	21	22	23	24	25	25	26	26b	27	27	27	28	29
Depths →	10-0	30-0	20-0	0	30-0	20-0	0	0	0	80-0	35-0	25-0	20-0
Calanus finmarchicus	×	×	1000	×	100	20	×	×	×	500	500	×	×
Calanus hyperboreus	....	....	6	....	....	....	....	....	....	....	....	....	....
Pseudocalanus elongatus	....	....	....	....	....	1	....	....	....	....	....	....	....
Paracalanus parvus	....	....	....	....	....	....	....	....	....	....	....	....	....
Euchirella rostrata	....	....	....	....	....	....	....	....	....	....	....	....	....
Euchaeta norvegica	....	....	4	....	....	....	....	....	....	2	10	....	....
Centropages hamatus	....	....	....	....	....	....	....	....	....	....	....	....	....
Centropages typicus	....	....	....	....	....	....	....	×	....	....	....	....	....
Temora longicornis	....	....	....	....	....	....	....	×	....	....	....	....	....
Eurytemora herdmani	....	....	....	....	....	....	....	....	....	....	....	....	....
Metridia lucens	....	....	....	....	5	1	....	....	....	2	....	....	....
Anomalocera patersoni	....	....	....	×	....	....	....	×	....	....	1	....	....
Acartia clausi	....	....	....	....	....	....	....	....	....	....	....	....	....
Acartia longiremis	....	....	....	....	....	....	....	....	....	....	....	....	....
Tortanus discaudatus	....	....	....	....	....	....	....	....	....	....	....	....	....
Corynura discaudatus	....	....	....	....	....	....	....	....	....	....	....	....	....

Stations →	30	31	32	35	36	37	38	39	40	40	41	41	42
Depths →	0	55-0	0	40-0	75-0	15-0	40-0	75-0	0	25-0	0	20-0	0
Calanus finmarchicus	×	50	×	×	×	×	100	×	×	50	40	50	100
Calanus hyperboreus	....	....	....	....	....	....	....	....	....	1	....	....	....
Pseudocalanus elongatus	....	....	....	....	....	....	1	....	....	1	....	....	....
Paracalanus parvus	....	....	....	....	....	....	....	....	....	....	....	....	....
Euchirella rostrata	....	1	....	....	....	....	....	....	....	2	....	....	....
Euchaeta norvegica	....	×	×	....	×	....	....	....	....	....	....	....	....
Centropages hamatus	....	....	....	....	....	....	....	....	....	....	....	....	....
Centropages typicus	....	....	×	....	....	....	....	....	....	1	30	1	60
Temora longicornis	....	....	....	....	....	....	....	....	....	....	....	....	....
Eurytemora herdmani	....	....	....	....	....	....	....	....	....	....	....	....	....
Metridia lucens	×	4	×	....	....	....	1	....	....	....	....	....	....
Anomalocera patersoni	×	....	×	....	....	×	....	....	×	....	×	....	12
Acartia clausi	....	....	....	....	....	....	....	....	....	....	....	....	....
Acartia longiremis	....	....	....	....	....	....	....	....	....	....	....	....	....
Tortanus discaudatus	....	....	....	....	....	....	....	....	....	....	....	....	....
Corynura discaudatus	....	....	....	....	....	....	....	....	....	....	....	....	....

Stations →	42	43	43	44	44	Gloucester	Rockport	Kittery	Portland	A.	B.	C.
Depths →	15-0	35-0	85-60	0	20-0					8	0	10
Calanus finmarchicus	×	2000	1	1	50	×	20	×	×	50	300	5
Calanus hyperboreus	....	....	....	....	....	....	....	....	....	....	....	....
Pseudocalanus elongatus	....	....	....	....	....	×	20	×	....	1	10	500
Paracalanus parvus	....	....	....	....	....	×	....	....	....	..	....	....
Euchirella rostrata	....	....	....	....	....	....	....	....	....	....	....	....
Euchaeta norvegica	....	1	1	....	....	....	....	....	....	....	....	....
Centropages hamatus	....	....	....	....	....	....	....	....	....	1	....	....
Centropages typicus	....	....	....	1	....	....	....	....	....	3	1	10
Temora longicornis	....	....	....	....	....	....	....	....	×	1	....	1
Eurytemora herdmani	....	....	....	....	....	×	1	×	....	....	....	....
Metridia lucens	....	....	....	....	1	....	....	....	....	....	....	1
Anomalocera patersoni	....	....	....	....	....	....	....	....	....	....	....	....
Acartia clausi	....	....	....	....	....	×	....	....	....	....	....	....
Acartia longiremis	....	....	....	....	....	×	....	....	....	1	....	....
Tortanus discaudatus	....	....	....	....	....	....	....	....	×	....	....	....
Corynura discaudatus	....	....	....	....	....	....	....	....	×	....	....	....

The numbers indicate the proportional abundance of species in a haul, not numerical occurrence. × indicates that the species occurred: —

Station A	6 miles off Cape Porpoise	August 18	8 fathoms.
Capt. John McFarland.			
Station B	8 miles E. of Chatham	September	surface.
Capt. John McFarland.			
Station C	12 miles S. E. of Chatham	September	10 fathoms.
Capt. John McFarland.			

Distribution of the more important plankton species.

Among the objects of the exploration of the Gulf is the correlation of the distribution, seasonal and geographic, of the more important members of the plankton with the physical characters of the waters in which they live; and the determination of the factors which govern their times of reproduction, movement, and abundance. Obviously the summer work in 1912 is only the first attack on the problem; but the data acquired is valuable because salinity and temperature are known for the various captures, and can be used as the basin of future work. In the following notes, the occurrence of some of the more important animals is summarized, without any reference to earlier records for the region.

Calanus finmarchicus.— As pointed out, (p. 99) this copepod was taken at every station, including the harbors of Gloucester, Kittery, and Portland; and it greatly predominated over all others at most of the off-shore stations. The exceptions, as noted above (p. 105), and in the table (p. 115), were the surface hauls at Stations 41 and 44, which yielded nearly equal numbers of Calanus and of Centropages; the closing net haul at Station 43, in which there were about as many Euchaeta as Calanus, and Capt. McFarland's haul twelve miles S. E. of Chatham, late in September, in which Pseudocalanus outnumbered Calanus one hundred to one.

In twelve hauls the copepod constituent of the plankton was exclusively Calanus, *e. g.* in the northeastern part of Massachusetts Bay and off Cape Ann in July; and at the off-shore stations as a whole very few other copepods were found. Thus at Station 7, there were about 1,000 Calanus to one Euchaeta; at Station 23, about 1,000 *Calanus finmarchicus* to six *C. hyperboreus* to four Euchaeta; at Station 27, 500 Calanus to two Euchaeta to two Metridia; at Station 28, pure Calanus; and at Station 43, in the open net, 2,000 Calanus to one Euchaeta; *cf.* table (p. 116).

Calanus hyperboreus. This Arctic species was taken twice, at Station 23, 20–0 fathoms, six specimens, and Station 40, 20–0 fathoms, one specimen. The importance of these captures has been noted (p. 106).

Euchaeta norvegica.— This species has been detected at Stations 7, 8, 12, 23, 27, 31, 32, 36, 43, and from two miles off the Isles of Shoals, *i. e.*, Massachusetts Bay, Ipswich Bay, both arms of the deep basin, off Cape Cod, on Platts' Bank, off the Nova Scotian Coast and the coast of Maine. Thus *Euchaeta norvegica* was generally distributed over the Gulf, though of irregular occurrence. The only localities where it was abundant were at Station 36, in a haul with the open net at seventy-five fathoms, and at Station 43, where many were taken in the closing net at eighty-five to sixty fathoms, forming the bulk of the haul. As most of the hauls were taken from intermediate depths, neither the horizon from which the specimens came, nor, consequently, the precise salinity and temperature can be determined. The known salinities and temperatures are:—

Station 32	surface	temperature 57°	salinity 32.51‰.
Station 43	85–60 fathoms	temperature 42°	salinity about 33.5‰.

Euchaeta was only once taken in a surface haul (Station 32), and the fact that it was most abundant in deep hauls agrees with its occurrence in the Norwegian Sea.

Anomalocera patersoni. — This copepod was taken at Stations 13, 24, 26b, 27, 30, 37, 40, 41, 42, being thus generally distributed over the western side of the Gulf, in Frenchman's Bay, and on German Bank. But it was not taken in Massachusetts Bay, nor over the off-shore portion of the Gulf as a whole, its only occurrence far from land being at Station 24. It was taken in surface hauls, never in the closing net, only once (Station 37) in the open net from intermediate depths. The temperatures at which it occurred ranged from 52°–61°, the salinity from 31‰ to 32.7‰. The fact that it was a purely surface form makes it probable that it was more widely distributed than our records show, for comparatively few hauls were made at the surface with the large net. But it was conspicuously absent from the surface hauls made at Stations 27, 28, 29, 31, 32, a fact showing that it is not brought to the Gulf by the indraught of oceanic water which is noticeable over the region covered by these stations.

Meganyctiphanes norvegica.— The following notes are based only on the occurrence of large adults of unmistakable identity; probably the list of localities will be largely augmented by identification of the large series of young schizopods. Thus restricted, Meganyctiphanes was taken at Stations 3, 7, 19, 25, 26a, 27, 32, in Eastport Harbor, and two miles southeast of Duck Island, Mt. Desert: *i. e.*, Massachusetts Bay, the coast of Maine, Jeffrey's Bank, the region off Casco Bay, and both sides of the deep basin. The oceanographic data of the captures is as follows:—

Station 25	surface	temperature 56°	salinity 32.34‰
Eastport Harbor			
	surface	temperature 50°	salinity about 32.5‰
Station 27	closing net		
	40 fathoms	temperature 45°	salinity about 33.6‰
Station 32	surface	temperature 57°	salinity 32.51‰
Station 26a	surface	temperature 57°	salinity about 31.4‰
Off Duck Island	surface	temperature 56°	salinity about 32.3‰

Euthemisto compressa (Plate 5).— This common boreal amphipod occurred at twelve stations, so distributed as to show that it occurs generally over the Gulf. In Massachusetts Bay it was taken once (Station 44), and the records cover Platt's Bank (Station 23), Jeffrey's Bank (Station 25), off Cape Cod (Station 43), off Cape Elizabeth (Stations 19, 22, 26b), off Seguin Island (Station 40), off Mt. Desert Rock (Station 32), the Eastern Deep Basin, both off shore and near shore (Stations 27, 36), and the neighborhood of Lurcher Shoal (Station 31). It was not taken in the closing net, and the only two captures for which the horizon is known give the following data:—

Station 27	surface	temperature 59°	salinity 32.6‰
Station 32	surface	temperature 57°	salinity 32.5‰

The other captures are from open hauls from intermediate depths. The largest number were taken at Station 32, surface; Station 31, at 55–0 fathoms; and Station 43, 35–0 fathoms. It was not found on German Bank (Stations 29, 30).

Clione limacina (Plate 5).— Apparently this large and striking species is not abundant anywhere in the Gulf, at least in summer, though it occurs in dense swarms in the Labrador Current and between Norway and Spitzbergen. Although it was taken at nine stations, Nos. 2, 6, 7, 11, 14, 19, 22, 25, 32, *i. e.*, in Massachusetts Bay, off Cape Ann, between Jeffrey's Ledge and the coast, off Casco Bay, over Jeffrey's Bank and off Mt. Desert Rock, the total number of specimens was only sixteen, the most at any station, three; and it is such a conspicuous object in the tow, that it is not likely that any were overlooked. These stations are all near shore, the furthest out being only some twenty miles from land; and so many off-shore hauls were made (*e. g.*, Stations 23, 24, 27, 28, 29, 30, 31) that its absence from the more nearly oceanic part of the Gulf can hardly be laid to an accidental failure to capture specimens. It was not found in the northeastern part of the Gulf, nor in the Grand Manan Channel (Stations 33, 34, 35, 36, 37); but its absence from the latter is probably associated with the general poverty of the zoöplankton in that region. It was taken three times in the closing net, at 30 fathoms (Stations 22, 25), and 20 fathoms (Station 19), and once on the surface (Station 32). Probably it would have been found oftener at the latter horizon had we made more surface hauls near shore, especially at night. But as it happened, most of the night hauls were made far off shore, where Clione was not found. The hauls afford the following data on temperature and salinity:—

Station 2	30 fathoms	temperature 41.5°	salinity 32.6‰.
Station 19	20 fathoms	temperature about 47°	salinity about 32.5‰.
Station 22	30 fathoms	temperature about 46.5°	salinity about 32.6‰.
Station 25	30 fathoms	temperature about 48.5°	salinity about 32.9‰.
Station 32	surface	temperature 57°	salinity 32.5‰.

The salinity ranges from 32.5–32.9‰, the temperature from 41.5° to 57°; and at all other stations where Clione was taken, the nets, in their course, passed through waters with physical characters lying within these limits. In the Gulf, adult Clione occurs over a wide range of salinity and temperature, in water fully 10° warmer than the Labrador Current. But our collections throw no light on the conditions under which it reproduces.

Limacina balea (Plate 5).— The occurrence of this pteropod was even more circumscribed than that of *Clione limacina.* It was taken at Stations 19, 22, 23, 24, 25, 30, 40, *i. e.*, in two general regions, first in the northwest corner of the Gulf, off Casco Bay and over the deep trench beyond Platt's Bank and Jeffrey's Bank, and second, on German Bank. The known salinities and temperatures of the captures are:—

Station 19	25 fathoms	closing-net	temperature 47°	salinity 32.5‰
Station 25	30 fathoms	closing net	temperature about 48°	salinity 32.9‰
Station 30	surface		temperature about 52°	salinity 32.7‰

Thus it was inhabiting rather warmer water than Clione (47°–52° as against 41°–57°), but of about the same salinity; and the capture at Station 30, on the surface, is particularly interesting, because *Salpa fusiformis* was likewise taken at that Station. The other captures of Limacina were in open nets from 20–30 fathoms. Unlike Clione, the specimens were of various ages; a swarm of small ones being taken at Station 19, the largest at the last Station at which it occurred, *i. e.*, 40. This suggests that its chief period of growth is July and August in the Gulf.

Salpae (Plate 5).— Salpae were observed over only a small area, from Station 30 to Station 31; several *S. fusiformis* being taken at each Station, and others seen floating on the surface. But a large haul of *S. mucronata* was made twenty-five miles off Chatham, on the surface, September 30, by Capt. John McFarland of the fishing schooner VICTOR. The geographic importance of these hauls has been noted (p. 107).

Tomopteris helgolandica. This is the only species of the genus encountered, and was taken at Stations 11, 14, 30, 32, 40, 42, and 44, *i. e.*, in Massachusetts Bay, north of Cape Ann, off Cape Porpoise, off Mt. Desert, on German Bank, off Seguin, and once in the Kennebec River. It was not taken in any of the off-shore hauls. The known salinities and temperatures are:—

Station 30	surface	temperature 52°	salinity 32.7‰
Station 32	surface	temperature 57°	salinity 32.5‰

The other captures were in open nets from considerable depths (20–60 fathoms).

Chaetognaths.— Sagittae were taken in greater or less numbers at almost every station. But the determination of most of the species of this genus is so difficult that only four, *Sagitta serratodentata*, *S. elegans*, *S. lyra*, and *Eukrohnia hamata* have been selected, as being so easily recognized that the records can be depended upon. And the identifications of these have been verified by Mr. E. L. Michael. *Sagitta serratodentata*, especially, is a useful index-species, because the serrate margins of its jaws separate it from all its allies. Among the Sagittae in the GRAMPUS collection it is likewise readily identified by its stiff, slender body, and very large spermaries.

Sagitta serratodentata (Plate 5) was taken at Stations 19, 21, 22, 23, 25, 27, 28, 30, 31, 32, 33, 36, 38, 40, 41, 44, but not in any of the bays or harbors, or in the Grand Manan Channel. The list of stations shows that it occurred very generally over the Gulf, *i. e.*, in Massachusetts Bay, off Portland, on Platt's and Jeffrey's Banks, over the Eastern Basin, on German Bank, and off the coast of Maine. But the table of specimens taken at each station shows that the only ones at which more than five were taken were no. 25, 28, 30, 31, 32, and 36. Only one specimen was taken in Massachusetts Bay, one off Boon Island (Station 41), one off Monhegan (Station 21), and two each at Stations 19, 22, and 40. Evidently, then, its centre of abundance was off shore. It was not common anywhere near shore. The known salinities and temperatures of the captures are:—

Station 25	30 fathoms	closing net	temperature about 48°	salinity 32.9‰
Station 27	30 fathoms	closing net	temperature 46°	salinity 33.3‰
Station 30	surface		temperature 52°	salinity 32.7‰
Station 32	surface		temperature 57°	salinity 32.5‰

The other captures were in open nets. The largest hauls were at Stations 31 and 32, where swarms were taken.

Comparison between the occurrence of *S. serratodentata* and *S. elegans* shows an interesting difference in quantitative distribution. The latter was taken at even more stations than the former, very generally over the whole area, including bays and harbors. It occurred in great numbers at Stations 2 and 7, where no *serratodentata* were taken, and also at Station 44, where we captured only one *serratodentata*. Swarms of *S. elegans* were also encountered at Stations 12 and 14, where *serratodentata* was absent. At Stations 19, 20, 25, 27, 33, 38, 40, 44, it was numerous, from 10 to 30 or more specimens being taken at each, where *serratodentata* was represented by only a few specimens; and at Station 30 we encountered a swarm. On the other hand, at Stations 28, 31, 32, where we met swarms of *serratodentata*, they far outnumbered the *elegans*, as shown in the accompanying table.

	Number of specimens	
Station	*S. elegans*	*S. serratodentata*
2	25	0
6	2	0
7	swarm	0
11	4	0
12	swarm	0
14	20	0
19	15	2
20	30	0

Station	Number of specimens *S. elegans*	*S. serratodentata*
21	0	1
22	2	2
23	1	2
25	23	8
27	15	5
28	6	25
30	swarm	12
31	2	64
32	20	swarm
33	50	4
35	3	0
36	30	15
38	swarm	2
40	10	2
41	0	1
43	3	0
44	25	1

The stations at which *S. elegans* was most abundant (Plate **5**) were 2, 7, 12, 14, 19, 20, 25, 27, 30, 32, 33, 36, 38, 44. Most of these stations are near shore; the only one which is not, Station 7, is within the influence of coast water, as described above (p. 91), and the same is true of Station 25. At Station 43, however, but few were taken, and salinity shows that this is not coast water. So far as last summer's work shows, *elegans* is neritic in the Gulf; *serratodentata* oceanic. But there is, of course, no sharp line between the two.

Two other chaetognaths may be mentioned here, because of their geographic importance: — *Sagitta lyra*, taken once, two specimens, Station 31, 55–0 fathoms, and *Eukrohnia hamata*, likewise taken only once, in the same haul, about twenty specimens. This species is discussed (p. 106).

Medusae.— There are several Medusae of importance in the present connection. Chief among them, because so often called an Arctic form, is *Staurophora mertensii;* but as pointed out (p. 106) this species is not an index of polar water, for it is known from Helgoland. Large Staurophora (Plate **6**) were seen, and taken, at Stations 14, 15, 19, 22, 23, 25, 26, 26b, 31, 33, 34, 36, 40, 41, 42, 43, in the Grand Manan Channel, and at Eastport; showing that it was very generally distributed over the Gulf, with the notable exceptions that it was not met with in Massachusetts Bay, at the off-shore Stations (27, 28), in the Eastern Basin nor on German Bank (Stations 29, 30). Its absence off shore is not surprising, because it is undoubtedly neritic; but its absence from Massachusetts Bay is less easily explained, because it is often very abundant there in May and June. The known salinity at which it was taken ranges from 32.5‰ to 32.7‰, the known temperature from 50°–64°, all being surface records. But most of the actual specimens taken came from intermediate hauls with open nets; and this was notably so at Stations 14, 15, 19, 25, 36, 41, and 43, where none were taken or seen on the surface. And the Staurophorae seen floating were usually from ½ to 2 fathoms down, seldom on the actual surface as Aurelia so often is. None were taken in closing nets. Our records do not suggest that Staurophora is restricted to cold waters; but probably the young stages are more sensitive to temperature.

Aurelia and Cyanea (Plate 6) can be considered together, as the Gulf of Maine, unlike the Norwegian Sea, has only one species, or variety, of Cyanea, which is not a migrant from elsewhere, but a permanent inhabitant, breeding and going through its young stages here. As might have been expected, both these Medusae were most numerous near shore, Aurelia particularly so in the bays and harbors; and they are so large and conspicuous that they are easily seen on the surface, even if not taken in the net.

In Massachusetts Bay, early in July, we saw many Aurelia, though, as it chanced, no Cyanea; but on our return thither at the end of August, both genera were seen floating on the surface at various spots between Gloucester and Provincetown. During our work along the coast between Cape Ann and Portland, the two genera were frequently recorded, both in the nets and on the surface, both of them being generally distributed in the coast waters in this region. But on the run to Platt's Bank we left them behind at about Lat. 43° 15′, long. 69° 50′, and saw and took neither of them on the course thence to Jeffrey's Bank (Station 25) or until approaching the mouth of Penobscot Bay, where (Station 26) both species once more appeared on the surface. Similarly on the run from Cape Elizabeth toward Nova Scotia the last Aurelia was seen at about 69° long. 43° 30′ lat., and neither genus was found until we approached the coast again between Mt. Desert and Grand Manan. In the Grand Manan Channel, at Eastport, and during the run westward along the coast, both were seen frequently, except at Stations 38 and 39. But neither species was encountered anywhere in as great abundance as they are often seen, except off Cape Cod, on August 29, when Aurelias were passed in swarms. The greatest number of Cyaneas were at Station 14 and in Penobscot Bay (Station 21a).

As Damas has pointed out (Helland Hansen and Nansen; 1909, pt. 1, p. 101) Cyanea is one of the most important index-species of the larger plankton, because its attached stage lives in shallow water; consequently wherever Cyaneas are found off shore, it shows that there is a considerable admixture of coast water, and the same is true of Aurelia. Our data is important as showing that neither of them is general over the Gulf; both seem, if not absolutely, at least chiefly limited to a rather narrow coast-band all around the Gulf, even more so than Staurophora. And this fact suggests that there is comparatively little mixing of offshore and coast water in August. In early July as pointed out (p. 62), there is a pronounced fresh tongue off Cape Ann; but this flow of coast water probably reaches its maximum in June, when the Aurelias and Cyaneas are still very small, or perhaps even before they are set free.

Phialidium languidum affords another example of the distribution of a neritic species. It was taken at Stations 22, 24, 25, 31, 32, 38, 40, 41, 42, 43, and in all the harbors and bays, especially Kittery, Winter Harbor and the Kennebec River; and also near Gloucester. These records show that it was found further off shore than either Aurelia or Cyanea, *i. e.*, near Platt's Bank (Station 24) and on Jeffrey's Bank (Station 25). But we did not find it on our run across the Eastern Basin toward Nova Scotia, nor on German Bank; meeting it again at Station 31 and 32, but not at Station 36. It swarmed at Station 32 and Station 40, on the surface, the salinity and temperature being: —

Station 32	surface	temperature 57°	salinity 32.5‰
Station 40	surface	temperature 58°	salinity about 32‰

It was abundant in the harbors with lower salinity.

Much more strictly confined to the coast water is the medusa *Melicertum campanula*, which attains sexual maturity at just the time of our cruise. Great swarms were met with in Kittery Harbor, July 12 and 23, many in Gloucester and in Rockport Harbor, July 9–12; but the only outside stations at which it was taken were Nos. 4, 8, 12, 14, 22, none of them over ten miles from land. In past years, likewise, I found it very common in Penobscot Bay and at Grand Manan: but all its records in the Gulf are close to shore.

Siphonophores.— Only two species of siphonophores, *Agalma elegans* and *Physophora hydrostatica*, were taken on the cruise; but their few occurrences are worth special notice because they are typical oceanic organisms, and both belong to the warm waters of the North Atlantic, though both are carried to Norwegian waters by the Gulf Stream.

Physophora was taken at Station 30, on the surface, two specimens. Agalma was more generally distributed, being captured at Stations 7, 27, 28, 32, 39, a total of eight very fragmentary specimens. Unfortunately, most of them have all the organs stripped off the stem, not a tentillum being intact; and as the latter organs are the chief generic character, identification is not beyond dispute. But the general form of the few bracts which remain attached, and of the bells taken in the same hauls, suggests identity with *Agalma elegans* rather than with its close ally, Stephanomia. The records are all from the off-shore part of the Gulf.

Ctenophores.— Two ctenophores were taken and seen frequently, *Pleurobrachia pileus* and *Bolinopsis septentrionalis,* neither of which was generally distributed over the Gulf, though both were taken at many localities.

Pleurobrachia (Plate 6) was found at Stations 23, 27, 29, 30, 31, 32, 40, 43: in the Kennebec River and off the Grand Manan Bank: several times, notably at Station 40, in great abundance. That is to say, during July and August it was wholly absent from Massachusetts Bay, and from the coast waters between Cape Ann and Casco Bay; but was of general occurrence in the northeastern part of the Gulf, over German Bank, and the Eastern Basin, as well as off Cape Cod (Station 43). Swarms were encountered at Stations 30, 31, and 40; the salinities and temperatures being:—

Station 30	surface	temperature 52°	salinity about 32.7‰
Station 31	surface	temperature 56°	salinity about 32.8‰
Station 40	surface	temperature 58°	salinity about 32‰

The salinity was not taken at Station 40, but is estimated from the records of neighboring stations. At Station 40, the swarm consisted of small individuals; at Stations 30 and 31, of large and small; and it is interesting to observe that the swarm at Station 40 was in water with very little microplankton (p. 133) while a few miles to the east, where there was an abundant microplankton, we found no Pleurobrachia.

Bolinopsis infundibulum (Plate 6) was taken (or seen floating on the surface) at Stations 4, 6, 9, 11, 22, 25, 34, and 43, *i. e.*, in Massachusetts Bay, the coastal waters north of Cape Ann, Jeffrey's Bank, the Grand Manan Channel, and off Cape Cod; but it was apparently absent at all the off-shore stations, at Platt's Bank and on German Bank: nor was it abundant anywhere. A third genus, Beroe, was likewise seen often; and all the specimens taken belong to the cosmopolitan species *B. cucumis,* often recorded before from the Gulf.

Results of the quantitative hauls.

(Plate 7).

In using the Hensen net for quantitative hauls we were most seriously handicapped by working from a sailing vessel, because hauls of this sort are significant only if the vessel is practically motionless when they are taken; and it was impossible to hold the vessel motionless with the auxiliary engine in a breeze. Consequently we could carry on this line of work only at the stations which were occupied in calm weather. Small nets might have been hauled by hand from the dory at anchor; but this was not practicable with the large apparatus with which we were provided. The qualitative composition of the catches made with the Hensen net shows that they did not afford a fair estimate of the plankton even under favorable circumstances, because they seldom yielded any Sagittae; organisms which are plentifully represented in the four-foot net hauls. The trouble was, probably, that the nets were hauled too slowly, our hoisting engine reeling in at a rate of only about ten fathoms (about eighteen meters) per minute, which allowed the more active animals to escape. But the copepods, which usually form the bulk of the plankton of the Gulf, are more fairly represented. These shortcomings make it out of the question to draw any exact conclusion from the hauls. But they serve to show, in a general way, the relative richness of the plankton over different parts of the region. The four-foot net hauls, too, help very materially, by supplementing the few quantitative hauls; and although I recognize that the various four-foot net hauls are not directly comparable with one another, because rate of towing, etc. is never exactly the same at any two stations, and because the level at which the major part of the haul was made, with the open nets, might, or might not coincide with the zone richest in plankton, yet they do show, in a general way, whether the water was very rich, barren, or intermediate. And the fact that the results agree fairly well with those of the Hensen nets gives them a greater value than they could be credited with if unsupported by this more exact, though less extensive evidence. The four-foot hauls were made as nearly comparable as possible, by being of the same duration (with few exceptions $\frac{1}{2}$ hour); and by being made with the vessel travelling at such a speed that the wire rope made an angle of about 60°, the same weight (seventy pounds) being invariably used. The catch was placed in jars, killed with formalin, and allowed to settle, usually over night, and then measured for bulk. The Hensen net hauls were preserved entire in formalin, and measured for bulk at Cambridge, being allowed to settle before measurement, until no further visible shrinkage took place. The data of the quantitative hauls are:—

Station	Vol. c. c.	Relative no. of copepods
2	25	239
4	5	104
7	6.5	471
8	5±	
11	2	30
15	1	11
21	1	
22	3	97
25	8	125
28	3	25
31	3	20
35	only a trace	trace
36	3	50
38	2	24
43	1.5	15

To obtain the number of copepods, the mass was diluted to 150 cc., well mixed, and while the plankton was in suspension, three cc. taken, by a pipette and counted: most of them were tried twice and the results averaged. The total number of copepods in each haul is not given, but can be easily obtained by a simple calculation. Most of them are *Calanus finmarchicus.*

The volumes of the four-foot qualitative hauls (omitting the surface hauls made with this net), in hundreds of cubic centimetres, are: —

Station	Volume	Station	Volume
4	19	25	3
6	19	27	4.7
7	9.5	28	8
8	9.5	29	2.5
11	4.7	31	3
12	9.5	33	less than 1

Station	Volume	Station	Volume
14	20	34	trace
15	very small	35	trace
16	" "	36	7
19	4.7	38	2
20	4.7	40	3.5
21	(less than 2)	42	13
22	9.5	43	4.5
23	19	44	4.5

When analyzed, the foregoing tables, which in general bear each other out, show that we may separate the catches into three classes, rich, fair, and poor. The first, which I limit arbitrarily to stations where the volume of the quantitative catch was three or more cubic centimetres, and the number of copepods ninety or more in every three cc. when diluted to 150 cc. with water, includes Stations 2, 4, 7, 8, 22, and 25; the second, with quantitative hauls of one to three cc., and ten to ninety copepods, Stations 11, 15, 25, 28, 31, 36, 38, 43; the third, with quantitative haul less than one cc. in bulk, and less than fifteen copepods, Station 35. These classes agree fairly well with the volumes of the qualitative (four-foot net) hauls, as is shown by the following table, the stations in italics being the ones at which quantitative hauls were made.

1	2	3
Qualitative 800 cc. or more Quantitative 3 cc. or more with 90 or more copepods	Qualitative 200–800 Quantitative 1–3 copepods 10–90	Qualitative below 200 Quantitative less than 1 copepods, fewer than 10
2	*11*	16
4	*15*	*21* [1]
6	19	33
7	20	34
8	27	*35*
12	*28* [1]	
14	29	
22	*31*	
23	*36*	
25	*38*	
28	40	
32	*43*	
42		

[1] Station 28 is on the line between 1 and 2, 21 on the line between 2 and 3.

The richest zoöplankton (p. 99, 100) both in volume and in the number of copepods, was found in the northern part of Massachusetts Bay, off Cape Ann, in Ipswich Bay, over the western arm of the 100-fathom basin, off Cape Porpoise, and on Platt's Bank; the poorest, in the Grand Manan Channel, and along the northeast coast of Maine, where the water was almost barren (p. 104). In the cold fresh water along the southern coast of Maine, and in general over the northeastern part of the Gulf along the west coast of Nova Scotia the richness of the plankton was intermediate, column 2 in preceding table. Along shore from Casco Bay to Penobscot Bay it was poor on our first visit early in August, but with a rich diatom plankton; and on our return, this type of plankton was found from Petit Manan to Penobscot Bay; but off the Penobscot and the Kennebec Rivers there were more copepods, enough to bring the hauls into column 2.

Microplankton.

The microplankton will be the subject of a special report, consequently no attempt is made here to identify all the species. But its character varies so much at the different stations, and proves so characteristic of different regions, that the following notes are pertinent.

An examination of the hauls with the no. 20 net, made at Stations 1, 6, 7, 8, 9, 12, 12a, 13, 16, 17, 19, 21, 21a, 22, 23, 24, 25, 26, 26a, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, as well as at various localities in Casco Bay, shows that the microplankton was of two principal types, one consisting chiefly of the peridinian, *Ceratium tripos,* the other of various diatoms, mainly species of Chaetoceras and Rhizosolenia. The diatom plankton usually contains a few Ceratium; and at several localities the two types are mixed together. Quantitatively, too, as well as qualitatively, there is much variation between the hauls made in different parts of the Gulf (Plate 8) though our brief period of work throws no light on seasonal fluctuations.

At our first few stations, in the northern half of Massachusetts Bay and in the neighborhood of Cape Ann, the microplankton proved to be very scanty in amount, consisting of a few Ceratium, an occasional Peridinium, hardly any diatoms in spite of proximity to land; but a considerable number of eggs and larvae of various Metazoa, chiefly copepods. And when we returned to Massachusetts Bay in the latter half of August, no apparent change had taken place, the hauls at

Station 44 and off Marshfield consisting of a few *Ceratium tripos*, with no diatoms at all, but a large amount of dirt and débris, and copepod eggs. It appears, then, that the water of the northern half of Massachusetts Bay, throughout July and August, was occupied by a very scanty Ceratium plankton, with very few diatoms.

North of Cape Ann the same scanty Ceratium plankton was found occupying a belt some fifteen miles broad, as far north as Cape Porpoise, both in July (Stations 9, 11, 12b, 13) and on the return, late in August (Station 41). But in Ipswich Bay, just north of Cape Ann, close to land (Station 8), the plankton, though equally scanty, was mixed, containing a considerable number of diatoms, especially various species of Chaetoceras, and *Asterionella japonica*, which gives it a character quite distinct from that of Massachusetts Bay, or from the neighboring stations further off shore.

No station was occupied immediately abreast of Cape Ann on the voyage north; but on the return, August 24, we made a haul some four miles off the Cape (Station 42), finding an almost pure Ceratium plankton, with very few diatoms. But though qualitatively this agreed with Massachusetts Bay, it was considerably richer quantitatively, than at any of the stations immediately north or south of the Cape. This was likewise true of our hauls over the western arm of the deep basin in early July (Station 7), and off Cape Cod at the end of August (Station 43). At both of these, *Ceratium tripos* was the prevailing organism; and with it were large numbers of Peridinium, but no Chaetoceras or Asterionella. Inasmuch as the samples taken at the two stations are hardly distinguishable from each other, either qualitatively or quantitatively, it is fair to assume that they represent the characteristic facies of the summer microplankton for the general region which they cover; one distinctly richer in mass, as well as in species, than that found in Massachusetts Bay; but with the same organism, *Ceratium tripos*, occupying the leading position, and with equally few diatoms.

The Ceratium plankton reached its maximum density over a roughly oval area southwest of Cape Elizabeth (Plate **8**), which we traversed twice, (Stations 19, 22, 23, 26b) with an interval of seven days between our two visits. On our second visit, when running our line to Nova Scotia we were struck by the "slick" oily appearance of the water, some thirty-five miles off Cape Elizabeth; and consequently stopped the vessel for a surface tow (Station 26b). The net, when brought aboard, was distinctly reddish, and its meshes clogged with what proved to be a mass of Ceratium, with a very few Peridinium, and an occasional diatom; and this phenomenon continued for several miles.

At Stations 19, 22, 23, Ceratium was not so phenomenally plentiful; but still far more abundant than at any station further to the south; and the microplankton was almost pure *Ceratium tripos*, with an occasional Peridinium, but few, if any, diatoms; though it contained a considerable amount of copepod eggs, fish eggs, nauplii, etc., corresponding to the rich macroplankton encountered there (p. 101). Further east, on Jeffrey's Bank, the microplankton was much less abundant, but still mostly *Ceratium tripos*, with a very few diatoms, among which I noted the genus Chaetoceras, and the characteristic needle-like chains of *Nitzschia seriata*.

Along the coast from Casco Bay to the mouth of Penobscot Bay (Stations 16, 21) there were, on the other hand, very few Ceratium, but the microplankton, which was fairly rich, in contrast with a very scanty macroplankton, consisted almost wholly of diatoms, the principal forms being various species of Chaetoceras, *Thalassiosira gravida*, *Nitzschia seriata*, and *Asterionella japonica*. Over the eastern arm of the deep basin (Stations 27, 28), the pure Ceratium plankton characteristic of the waters further west gave way to a mixed plankton, rather poor quantitatively, in which Ceratium was associated with a few Peridinium and various diatoms, among them several species of Chaetoceras, and *Thalassiosira gravida*. And a similar type, but quantitatively richer, was revealed by our hauls on German Bank (Stations 29, 30), where several species of Chaetoceras, *Rhizosolenia setigera* and other species of the genus, and Thalassiothrix were especially prominent in the hauls. These two stations were within a few miles of each other, and it is therefore interesting to note that at Station 29 the plankton was far richer, both quantitatively and in species, than at Station 30; and that Ceratium played, proportionately, a greater rôle. However, the microplankton at both these stations, and over the eastern basin (Stations 27, 28) can be classed as Ceratium with a large admixture of diatoms, the latter probably of neritic origin for the most part.

At Station 31, off Lurcher Shoal, the microplankton was very scanty, consisting chiefly of minute copepods and their eggs, and nauplii; but there were a few Ceratium and diatoms, especially Chaetoceras and Asterionella, *i. e.*, it was of the mixed type. And much the same thing was encountered off Mt. Desert Rock (Station 32), but quantitatively rather richer, the two most prominent organisms being *Ceratium tripos*, and the diatom Asterionella, with a few Chaetoceras and Peridinium. As we approached the mouth of the Grand Manan Channel (Station 33), Ceratium was no longer found and the microplankton became very scanty, just as the macroplankton did (p. 104), consisting of various diatoms, chiefly Chaetoceras and Asterionella: and it grew poorer and poorer as we sailed eastward. In the Channel the microplankton was very scanty indeed, purely diatom, several species of Chaetoceras, and Asterionella being the most important forms, with a few Thalassiothrix, etc.

The poverty of the microplankton in the Channel was paralleled, to an even more extreme degree, by the macroplankton, and is one of the most interesting observations made on the trip, as the fact that herring occasionally swarm here shows that at times the plankton must be much more abundant than we found it.

On the voyage homeward Ceratium was once more met in considerable numbers at Station 36, where the haul revealed a mixed plankton of the type general over the Eastern basin. (Plate **8**).

On August 21, when passing Great Duck Island, one of the small islands off Mt. Desert, the appearance of the water was noticeably "soupy" and immediately the vessel was hove to, and a surface haul made with the no. 20 net. When brought on board, the net was filled with a brown slimy mass which, on examination, proved to consist almost wholly of countless numbers of chains of *Asterionella japonica*, with a few other diatoms, particularly Chaetoceras. This phenomenon was so striking that we took frequent samples as we sailed westward, finding that the Asterionella swarm continued for some miles, though nowhere else was the mass of diatoms so dense as it was off Duck Island. At Station 38 a surface haul revealed much the same type of microplankton, but less dense, with more Chaetoceras, and a few Peridinium, but no Ceratium. During the following night, while running from Station 38 to Station 39, a surface tow, abreast of the mouth of Penobscot Bay, was made to ascertain the extent of the Asterionella swarm; this tow revealed a diatom plankton, chiefly Asterionella, very much like Station 38, but rather less in amount. But at Station 39, we had evidently passed out of this belt, for though our hauls yielded many diatoms, there were also many *Ceratium tripos; i. e.* we were once more in the region of mixed microplankton; though the water was yet visibly cloudy. This phenomenon continued as we crossed the mouth of Penobscot Bay, until suddenly, when some six miles off Seguin Island, there was a visible change and the surface water grew perfectly clear. The vessel was at once hove to, and Station 40 occupied, making a series of tows. The no.

20 net brought in very little indeed; but the coarser nets yielded great numbers of the common cosmopolitan ctenophore *Pleurobrachia pileus,* which had been previously represented only by occasional individuals; thus showing that we had run out of the diatom swarm. And a pure diatom plankton was not met again on the run from the Kennebec to Cape Ann. A haul sixteen miles S. S. W. from Seguin yielded a rather barren plankton, chiefly Ceratium, with a very few Asterionella but no Chaetoceras; and, as noted above, the same type was found at Stations 41, and 42, which, with the data of stations made in July shows that a rather sparse Ceratium plankton is the normal summer type for a belt reaching from Cape Elizabeth to Cape Ann, just as it is for Massachusetts Bay.

There was a striking difference between the plankton in Casco Bay and in Penobscot Bay. In the latter, at our only Station (21a) the water was extremely barren, there being almost no microplankton, except a few Chaetoceras. In Casco Bay (Station 16, 17, 20) on the other hand, there was an extremely rich diatom plankton, consisting almost altogether of various species of Chaetoceras and Rhizosolenia with various metazoan larvae.

At Orr's Island, on July 28, the surface water was full of Chaetoceras and a large number of the diatom Navicula; but two days later, this type of plankton had entirely disappeared, its place being taken by hosts of ophiuran plutei, copepods, and small Medusae, *e. g.* Phialidium and Sarsia, without any apparent change in the physical nature of the water.

BLE OF STATIONS.

H = Hensen quantitative net. Dr = Dredge.
T = 8 ft. Beam trawl. S = Silk net, mesh 38 per inch.

ureau of Fisheries 10,000 should be added to each Station number, e. g., 10,001.

Depths of hauls	Depth of temperatures	Depth Current	Depth H_2O sample
33, 0	0, 33	0, 33	0, 33
0, 30, 65–0	0, 10, 35, 60	0, 60	0, 40, 65
31	0		
15–0, 31–0	0	0, 27	
0	0, 27	0, 27	0, 27
27, 0, 27–0, 15–0	0, 10, 27	0, 27	0, 27
0, 75–0, 145–0	0, 25, 50, 75, 125	0, 145	0, 75, 125
22–0, 20–0, 0, 22	0, 22	0, 22	0, 22
0	0, 50	0, 65	0, 50
25, 0	0		
0, 30–0, 60–0	0, 15, 30, 45, 60	0, 60	0, 25, 60, 80
47–0; 47–0	0		
	0, 80	0, 80	0
0, 30	0		
0, 20–0	0, 5, 15, 25	0, 25	0, 25
30, 17, 0, 15–0, 20–0	0, 5, 10, 20, 30		0, 30
19, 25, 0, 15–0	0, 5, 10, 15, 20		0, 20
15, 0	0		
20	0		
50, 0, 0, 20–0, 25	0, 20, 30, 40, 50	0	0, 50
0, 7–0	0		0
60, 10–0, 0, 20, 60–0	0, 15, 30, 45, 60	0, 60	0, 60
8–0, 0	0		0
30–0, 0, 45–0, 30.	0, 45		45
47, 20–0, 0	0 15, 25, 35, 45	0	0, 45
0	0, 105		
0, 30–0, 30, 50–0	0, 10, 20, 30, 40, 55	0, 55	0, 55
0	0 64	0, 64	0, 64
0	0		
0, 0	0		0
0, 0, 80–0, 30, 90–0	0, 25, 50, 75, 100	0, 100	0, 50, 100
25–0, 0, 0, 0	0, 10, 20, 30, 60, 80, 100, 120	0	0, 30, 120
20–0, 0, 0	0, 10, 20, 30, 35		0, 35
0, 0, 0	0		
60–0, 25–0, 0, 0, 70–0	0, 20, 40, 60, 75		0, 75
0, 0	0, 88		0, 88
15–0, 0	0, 5, 15, 25, 35		0, 35
50–0, 0	0, 10, 25, 40, 55		0, 55
40–0, 0, 0, 40–0	0, 10, 20, 30, 40, 45		0, 45
75–0, 0 0 0	0, 20, 60, 80, 100		0, 100
22, 15–0, 0	0, 10, 20		
40–0, 10–0, 40–0, 0, 0, 0	0, 20, 30, 40, 48	0, 48	0, 48
75–0, 0	0, 20, 40, 60, 80		0, 80
25–0, 0, 0	0		
20–0, 0, 0	0, 80		0, 80
15–0, 0, 0	0		
35–0, 90–0, 85–60, 0, 0	0, 20, 40, 60, 80, 95	0, 95	0, 40, 95
20–0, 0, 0	0, 10, 20, 30	0	0, 30
	0, 20, 30, 40		0, 40
	0, 30		0, 30

TABLE OF STATIONS.

The depths are by soundings, in fathoms.

A = 4 ft. open net. D = No. 20 silk net. H = Hensen quantitative net. Dr = Dredge.
C = horizontal closing net. E = Scrim net. T = 8 ft. Beam trawl. S = Silk net, mesh 38 per inch.

Note. To agree with the Station numbers of the U. S. Bureau of Fisheries 10,000 should be added to each Station number, e. g., 10,001.

Station	Date	Time	Lat. N.	Long. W.	Depth	Nets	Depths of hauls	Depth of temperatures	Depth Current	Depth H_2O sample
1	July 9	4 P. M.	42°30′	70°34′	33	T E	33, 0	0, 33	0, 33	0, 33
2	" 10	10 A. M.	42°32′	70°23′	65	A C H	0, 30, 65–0	0, 10, 35, 60	0, 60	0, 40, 65
3	" "	P. M.	42°37′	70°22′	31	T	31	0		
4	" 11	8 A. M.	42°33′	70°33′	27	A H	15–0, 31–0	0	0, 27	
5	" 12	3 P. M.	42°32′	70°36′	27	C.	0	0, 27	0, 27	0, 27
6	" 13	11 A. M.	42°22′	70°43′	27	T A H. C	27, 0, 27–0, 15–0	0, 10, 27	0, 27	0, 27
7	" 15	4 P. M.	42°44′	69°50′	145	D A H	0, 75–0, 145–0	0, 25, 50, 75, 125	0, 145	0, 75, 125
8	" 16	8 A. M.	42°45′	70°39′	22	H A D T	22–0, 20–0, 0, 22	0, 22	0, 22	0, 22
9	" 16	12 M.	42°49′	70°28′	65	D	0	0, 50	0, 65	0, 50
10	" 16	4 P. M.	42°53′	70°41′	25	T A	25, 0	0		
11	" 17	11 A. M.	43°4′	70°20′	60	D A H	0, 30–0, 60–0	0, 15, 30, 45, 60	0, 60	0, 25, 60, 80
12	" 22	2 P. M.	42°32′	70°33′	47	D A	47–0; 47–0	0		
12b	" 23	12 M.	42°53′	70°20′	80			0, 80	0, 80	0
13	" 24	12 M.	43°16′	70°20′	30	D T	0, 30	0		
14	" 24	1 P. M.	43°19′	70°13′	25	E A	0, 20–0	0, 5, 15, 25	0, 25	0, 25
15	" 25	10 A. M.	43°37′	70°	30	T Dr. E A H.	30, 17, 0, 15–0, 20–0	0, 5, 10, 20, 30		0, 30
16	" 26	11 A. M.	43°42′	69°42′	19	Dr T E A	19, 25, 0, 15–0	0, 5, 10, 15, 20		0, 20
17	" 27	10 A. M.	43°41′	70°8′	15	T E	15, 0	0		
18	" 27	12 M.	43°41′	70°3′	20	Dr	20	0		
19	" 29	11 A. M.	43°30′	69°48′	50	T E D A C.	50, 0, 0, 20–0, 25	0, 20, 30, 40, 50	0	0, 50
20	" 31	10 A. M.	43°39′	70°7′	10	D A	0, 7–0	0		0
21	Aug. 2	3 P. M.	43°38′	69°13′	60	T A D C H	60, 10–0, 0, 20, 60–0	0, 15, 30, 45, 60	0, 60	0, 60
21a	" 3	3 P. M.	44°5′	69°1′	8	A D	8–0, 0	0		0
22	" 7	10 A. M.	43°26′	70°4′	47	A D H C.	30–0, 0, 45–0, 30.	0, 45		45
23	" 7	4 P. M.	43°10′	69°40′	47	T A D	47, 20–0, 0	0 15, 25, 35, 45	0	0, 45
24	" 7	10 P. M.	43°2′	69°19′	106	E	0	0, 105		
25	" 8	9 A. M.	43°26′	68°49′	55	D A C H	0, 30–0, 30, 50–0	0, 10, 20, 30, 40, 55	0, 55	0, 55
26	" 8	3 P. M.	43°40′	69°2′	64	D	0	0 64	0, 64	0, 64
26a	" 8	9 P. M.	43°41′	69°38′		A	0	0		
26b	" 13	4 P. M.	43°28′	69°25′		D S	0, 0	0		0
27	" 14	1 A. M.	43°26′	68°06′	100	D E A C. H.	0, 0, 80–0, 30, 90–0	0, 25, 50, 75, 100	0, 100	0, 50, 100
28	" 14	9 A. M.	43°26′	67°20′	120	A D E S	25–0, 0, 0, 0	0, 10, 20, 30, 60, 80, 100, 120	0	0, 30, 120
29	" 14	6 P. M.	43°26′	66°25′	35	A E D	20–0, 0, 0	0, 10, 20, 30, 35		0, 35
30	" 14	9 P. M.	43°18′	66°28′		A E D	0, 0, 0	0		
31	" 15	8 A. M.	43°45′	66°55′	75	A C D E H	60–0, 25–0, 0, 0, 70–0	0, 20, 40, 60, 75		0, 75
32	" 16	3 A. M.	43°56′	67°58′	88	A D	0, 0	0, 88		0, 88
33	" 16	6 P. M.	44°25′	67°30′	35	A D	15–0, 0	0, 5, 15, 25, 35		0, 35
34	" 17	4 A. M.	44°50′	66°53′	55	A D	50–0, 0	0, 10, 25, 40, 55		0, 55
35	" 19	6 P. M.	44°36′	67°11′	45	A D S H	40–0, 0, 0, 40–0	0, 10, 20, 30, 40, 45		0, 45
36	" 20	11 A. M.	44°16′	67°23′	101	A D S E	75–0, 0 0 0	0, 20, 60, 80, 100		0, 100
37	" 21	7 A. M.	44°17′	68°5′	22	A A C	22, 15–0, 0	0, 10, 20		
38	" 21	6 P. M.	43°51′	68°33′	48	A. C. H. D E S	40–0, 10–0, 40–0, 0, 0, 0	0, 20, 30, 40, 48	0, 48	0, 48
39	" 22	9 A. M.	43°37′	69°1′	80	A D	75–0, 0	0, 20, 40, 60, 80		0, 80
40	" 22	3 P. M.	43°37′	69°36′		A D S	25–0, 0, 0	0		
41	" 24	11 A. M.	43°6′	70°12′		A D S	20–0, 0, 0	0, 80		0, 80
42	" 24	9 P. M.	42°51′	70°29′		A D S	15–0, 0, 0	0		
43	" 29	12 M.	42°11′	69°53′	95	A H C D S	35–0, 90–0, 85–60, 0, 0	0, 20, 40, 60, 80, 95	0, 95	0, 40, 95
44	" 31	9 A. M.	42°9′	70°22′	30	A D S	20–0, 0, 0	0, 10, 20, 30	0	0, 30
45	" 31	1 P. M.	42°20′	70°36′				0, 20, 30, 40		0, 40
46	" 31	3 P. M.	42°30′	70°39′	30			0, 30		0, 30

	36	37	38	39	40	41	42	43	44	45	46
	52.5	55	55.5	56	58	61	61	60	58	61	61
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.6	.....	50.9	.....	.....	....	.....	....	.....	52.7	.....	.....
	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
.6	49.2	49.8	49.9	49.	....	.....	....	50.9	45.9	47.7	.....
	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
.6	.....	.....	48.7	.....	....	.....	....	.....	44.3	44.9	44.3
	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
	.....	.....	48.3	48.	....	.....	....	46.5	.....	43.1	.....
.5	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
	.....	.....	48.3	.....	....	.....	....	.....	.....	.....	.....
	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
	46.8	.....	.....	47.	....	.....	....	42.	.....	.....	.....
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	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
	45.7	.....	.....	44.8	....	40.3	....	41.3	.....	.....	.....
	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
	.....	.....	.....	.....	....	.....	....	41.3	.....	.....	.....
	45.4	.....	.....	.....	....	.....	....	.....	.....	.....	.....
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TABLE OF TEMPERATURES (degrees are Fahrenheit).

Stations / Depths	1	2	3	4	5	6	7	8	9	10	11	12	12b	13	14	15	16	17
0	64	65	66	56	61.3	61	64	61	67.5	61	59	60	57	57	57	58	57	57
5															55.2	54.5	53.6	
10		49.2				43.3										51.4	51.4	
15											44.9				44.4		47.7	
20								42.4								45.5	45.4	
25			41.1		41.3	41.3	45.3								43.3			
30											41.3					44.4		
35	41	40.3																
40																		
45											40.3							
50							40.3		40.									
55																		
60		40.3									40.3							
65																		
70																		
75							40.3											
80													39.4					
85																		
90																		
95																		
100																		
105																		
110																		
115																		
120																		
125							40.3											

Stations / Depths	18	19	20	21	21a	22	23	24	25	26	26a	26b	27	28	29	30	31	32
0	57	57	55	55.5	56.3	62	64	61	56	57	57	61	59	59	50.6	52	56	57
5																		
10									49.2					50.7	49.7			
15				48.6			47.5											
20		47.3							49.2					47.7	49.4		52.7	
25							45.2						46					
30		45.6		46.7					48.4					45.6	49.4			
35							42.1								49.3			
40		42.6							46.8								50.4	
45				45.5		40.3	40.8											
50		42.2											45					
55									46.2					45.3				
60				45													46.7	
65										45.8								
70																		
75													43.3				45.8	
80														45.3				
85																		
90																		
95																		
100													42.8	45.3				
105								40.3										
110																		
115																		
120														45.3				
125																		

Stations / Depths	33	34	35	36	37	38	39	40	41	42	43	44	45	46
0	51.1	50	51	52.5	55	55.5	56	58	61	61	60	58	61	61
5	50.7													
10		49.7	49.6		50.9							52.7		
15	49.7													
20			49.6	49.2	49.8	49.9	49				50.9	45.9	47.7	
25	49.4	49.7												
30			49.6			48.7						44.3	44.9	44.3
35	49.3													
40		49.3				48.3	48				46.5		43.1	
45			49.5											
50						48.3								
55		49.2												
60				46.8			47				42.			
65														
70														
75														
80				45.7			44.8		40.3		41.3			
85														
90														
95											41.3			
100				45.4										
105														
110														
115														
120														
125														

6	38	39	41	43	44	45	46
75	32.32	......	32.07	32.39	32.03	31.92	31.67
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	32.52	......	32.56
...	......	......	......	......	......	......	......
...	......	......	......	33.15	......	32.89	......
...	......	......	......	......	......	......	......
...	32.95	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	33.37	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	33.69	......	......	......
31	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......

Gloucester, surface, July 22, 31.7.

TABLE OF SALINITIES.

Stations	1	2	5	6	7	8	9	11	12b	14	15	16	19	20	21	21a
0	32.07	31.74	31.67	31.00	31.62		31.44	31.92	31.02	31.08	31.26	31.20	31.92	[1]	32.43	30.61
5																
10																
15																
20						32.39						32.14				
25				32.52				32.61								
30			32.57								32.38					
35	32.65															
40		32.77														
45																
50							32.84						32.97			
55																
60								32.85							32.94	
65		32.92														
70																
75					33.40											
80								33.04								
85																
90																
95																
100																
105																
110																
115																
120																
125					33.78											
Depths																

Stations	22	23	24	25	26	27	28	29	31	32	33	34	35	36	38	39	41	43	44	45	46
0		32.52	32.50	32.34	......	32.66	32.75	32.70	32.84	32.51	32.68	......	32.57	32.75	32.32	......	32.07	32.39	32.03	31.92	31.67
5																					
10																					
15																					
20																					
25																					
30																			32.52		32.56
35								32.92			32.68										
40																		33.15		32.89	
45	32.74	33.30											32.65								
50						33.64									32.95						
55				33.22								32.56									
60																					
65					33.13																
70																					
75									33.82												
80																33.37					
85																					
90										34.13											
95																		33.69			
100						33.80								34.31							
105			33.57																		
110																					
115																					
120							34.54														
125																					
Depths																					

[1] Surface sample taken at this Station was lost.

Boothbay Harbor, 7 fathoms, August 4, 31.71. Gloucester, surface, July 12, 31.8. Orr's Island, July 28, 5 fathoms, 31.7. Orr's Island, surface, 31.5. Six miles S. E. Bakers Island, surface, July 15, 32.14. Gloucester, surface, July 22, 31.7.

6	38	39	41	43	44	45	46
..98	24.35	......	23.54	23.89	23.84	23.42	23.22
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
...	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	25.72	......	25.81
....	......	......	......	......	......	......	......
....	......	......	......	26.21	......	26.23	......
....	......	......	......	......	......	......	......
....	25.95	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	26.81	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	27.45	......	......	......
.69	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......
....	......	......	......	......	......	......	......

TABLE OF DENSITIES

Stations / Depth	1	2	5	6	7	8	9	11	12b	14	15	16	19	20	21	21a	22	23	24	25	26	27	28	29	31	32	33	34	35	36	38	39	41	43	44	45	46
0	23.05	22.08	23.23	23.45	22.71		22.22	23.64	23.85	23.19	23.23	23.29	23.89	[1]	23.21	22.93	...	23.41	23.80	24.26	24.30	24.21	24.28	25.19	24.05	24.30	25.09		25.00	24.98	24.35		23.54	23.89	23.84	23.42	23.22
5																																					
10																																					
15																																					
20						25.70						25.19																									
25				25.93	25.89			25.97																													
30			26.02								25.64																								25.72		25.81
35	26.18																							25.74			25.57										
40		26.28																																26.21		26.23	
45																	25.90	26.72											25.60								
50							26.48						26.44									26.77									25.95						
55																				25.58								25.59									
60								26.43							26.40																						
65		26.52																			26.43																
70																																					
75					27.00																				27.06												
80								26.89																								26.81					
85																																					
90																										27.48											
95																																		27.45			
100																						27.55								27.09							
105																			27.19																		
110																																					
115																																					
120																							28.03														
125					27.84																																

[1] Surface sample taken at this Station was lost.

	1			37	38	41	43	44
.	E by S 10.2 .25	S S 12	W 5	0 0 0	S W 8.4 .2	W	S E 39.4 1	N E .75

TABLE OF CURRENT MEASUREMENTS

All bearings are magnetic.

Surface.

Stations	1	2	4	5	6	7	8	9	11a	11b	11c	14	19	21	23
Flow toward	E by S	S S E	E by N	NW	N N E	W	W by S	NE by E	W	N by W	N W	S W	S	N E	0
Vel; cm per sec.	10.2	12 7	20.7	11.7	21 0	20 7	14 8	1 8	13 2	3 3	17 7	24.	22 1	10 4	0
Knot per hour	.25	.30	.5	.25	5	5	.37	.05	3	12	45	62	.5	.25	0

Stations	25	26	27	28	29	31–32	35 Flood	35 Ebb	36	37	38	41	43	44
Flow toward	N by E	N N W	S S E	E S E	S	W by S	E	S W	NW by W	0	S W	W	S E	N E
Vel; cm per sec.	13 2	Trace	17.4	12.7					33	0	8.4		39.4	
Knot per hour	3	Trace	45	3	.5–1.	2 –3.	1 ±	1 ±	.85	0	.2		1	.75

Bottom.

Stations	1	2	4	5	6	7	8	9	11a	11b	14	21	25	27	38	43
Depth fath.	33	60	27	27	27	145	22	50	60	60	25	60	55	100.	48	95
Flow toward	E by N	0	S E	S E	E	E	S E	S S E	N N W	E by N	E by S	S E	E S E	S by W	N W	N by W
Vel. cm. per sec.	10.8	0	8.7	9.7	11.	7.2	7.3	7.1	3	1.5	11.8	4.8	10.3	11.6	6.4	14.
Knots per hour	.25	0	.2	.25	.25	.18	.18	.18	Trace	Trace	.28	Trace	.25	.28	.13	.37

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EXPLANATION OF PLATES.

PLATE 1.

Temperatures at 25 fathoms, - - - - -, and at the bottom ———, July and August, 1912.

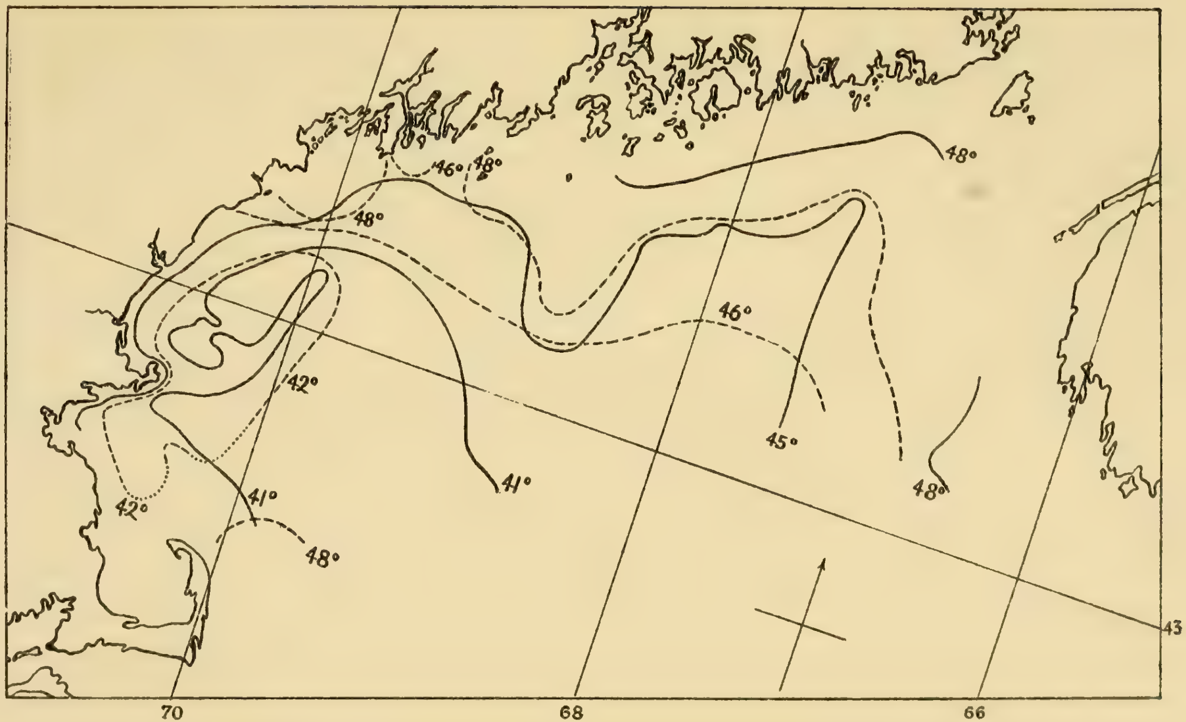
48°
46°
48°
48°
46°
45°
48°
42°
41°
42°
41°
48°
43
70
68
66

PLATE 2.

Salinities at the surface, ———, and at 25 fathoms - - - - -, July and August 1912.

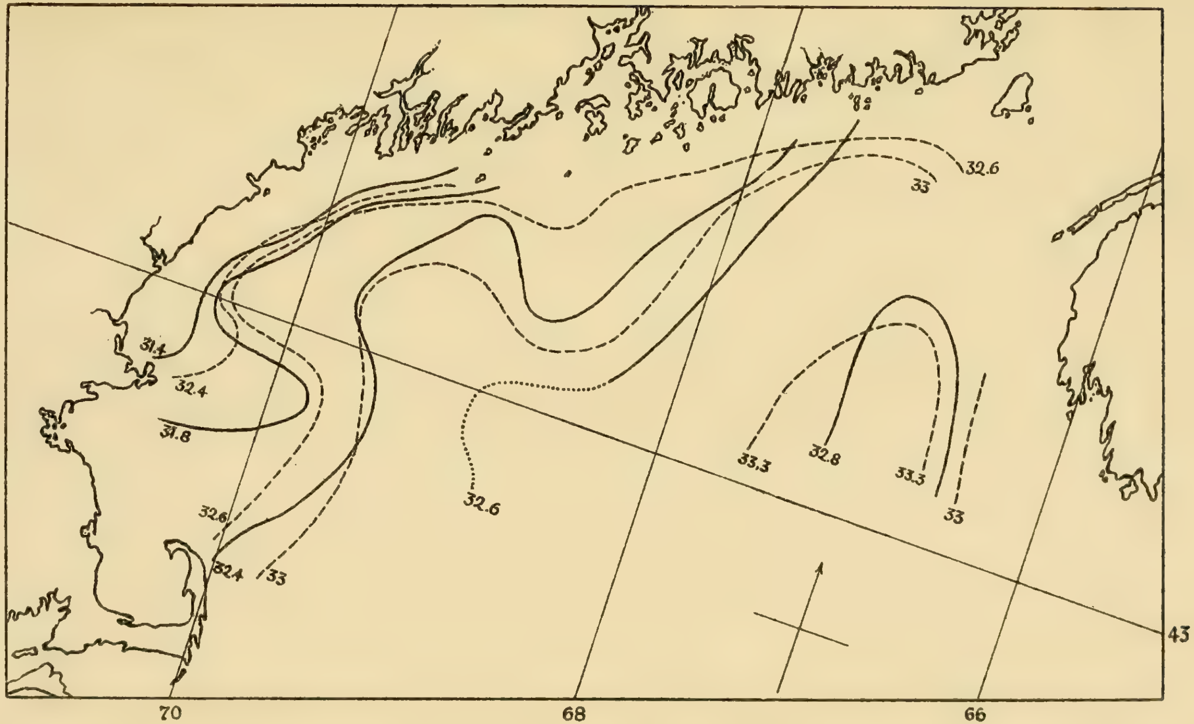
31.4
32.4
31.8
32.6
32.4
33
32.6
32.6
33
33.3
32.8
33.3
33
43
70
68
66

PLATE **3**.

Salinities at 50 fathoms ———, and at the bottom - - - - -, July and August, 1912.

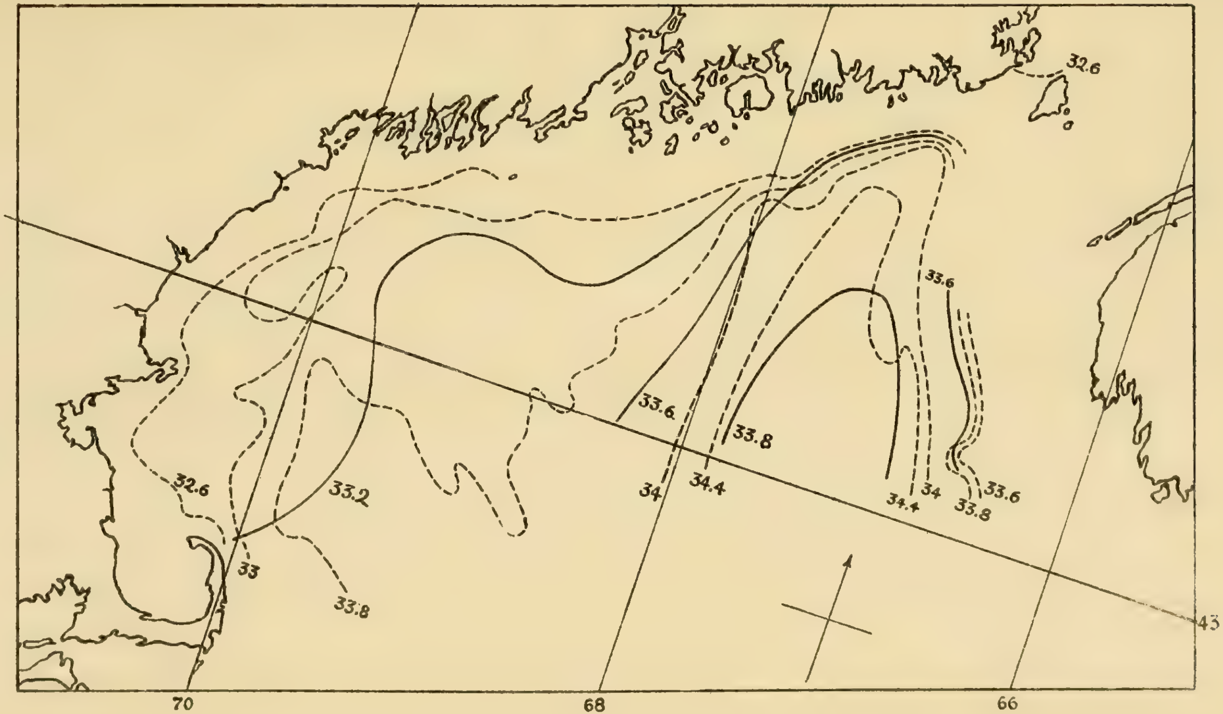
32.6
33.6
33.6
33.8
33.8
34
34
34.4
34.4
33.6
33.8
32.6
33.2
33
33.8
43
70
68
66

PLATE 4.

Circulation of water in the Gulf, July and August, 1912, as shown by salinities and temperatures.


43
70
68
66

PLATE 5.

Occurrences of pelagic animals.

C. Clione limacina.

L. Limacina balea.

S. Sagitta serratodentata, abundant.

s. " " scarce.

H. Eukrohnia hamata.

F. Salpa fusiformis.

M. " mucronata.

E. Euthemisto compressa.

The curve ——— marks the off-shore limit to abundance of Sagitta elegans, the curve - - - - - the in-shore limit to abundant S. serratodentata.

Plate 5

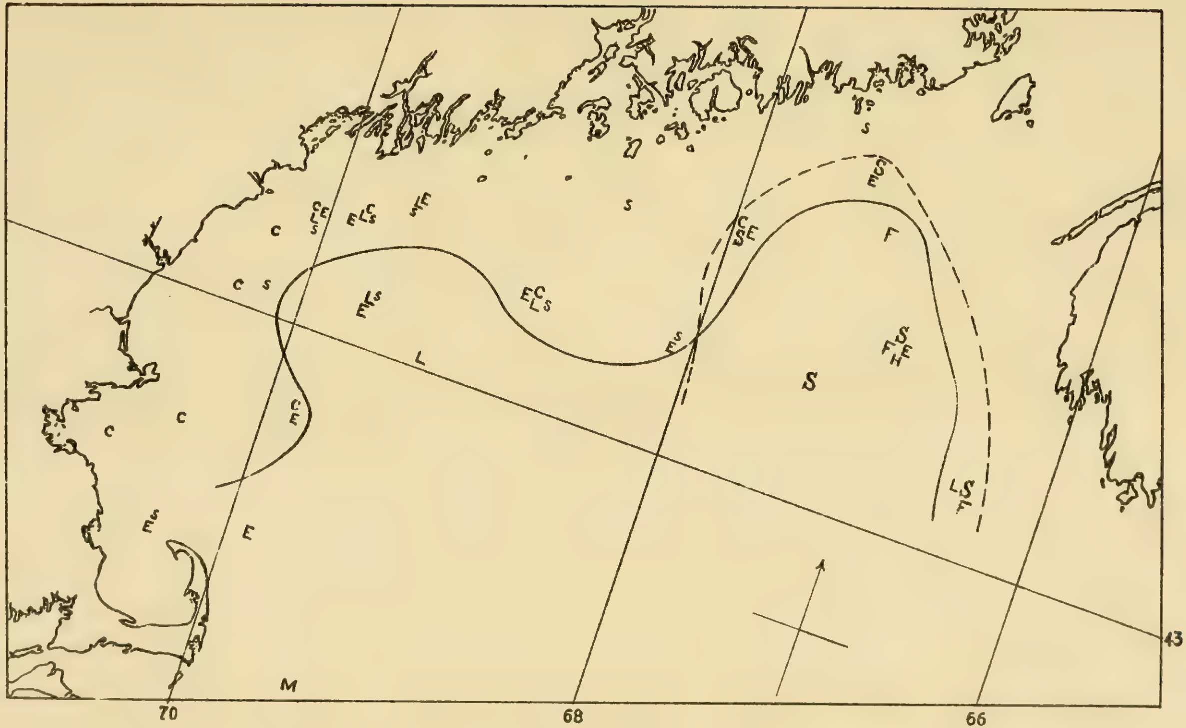

PLATE 6.

Occurrences of Medusae, Ctenophores and Siphonophores.

S. Staurophora mertensii.
A. Aglantha digitale.
P. Pleurobrachia pileus.
B. Bolinopsis infundibulum.
H. Physophora hydrostatica.
The curves mark the off-shore limit of abundant Aurelia and Cyanea.

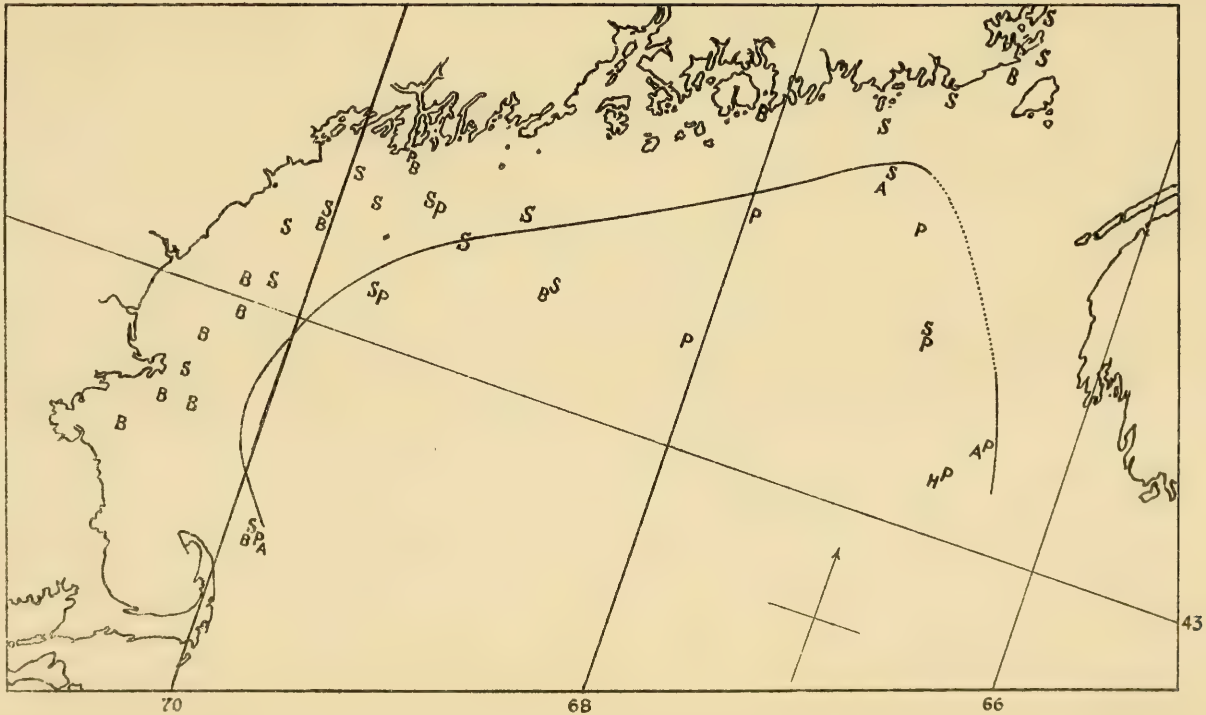
70
68
66
43

PLATE 7.

Quantitative distribution of copepods in July and August, 1912, showing regions in which they were very abundant (1); intermediate (2); scarce (3); (see page 129).

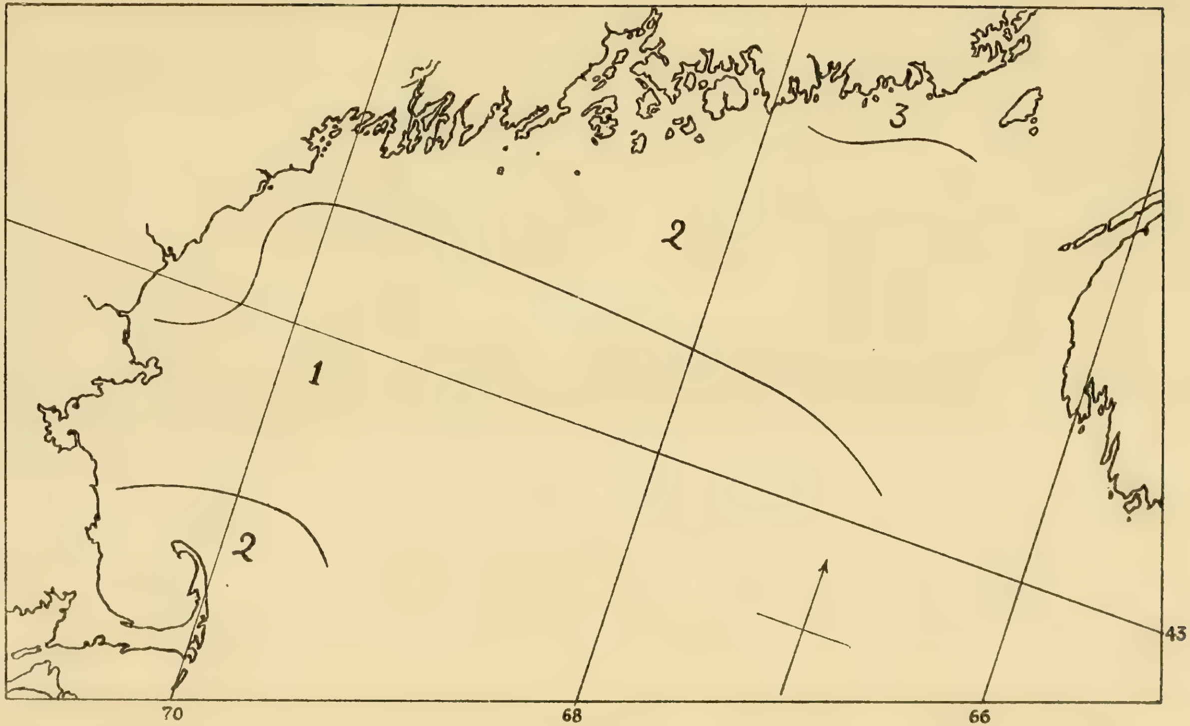
2
3
1
2
43
70
68
66

PLATE 8.

Distribution of microplankton, July and August, 1912.

Abundant Ceratium plankton.

Intermediate Ceratium plankton.

Scanty Ceratium plankton.

Mixed plankton.

Scanty mixed plankton.

Abundant diatom plankton.

Intermediate diatom plankton.

Scanty diatom plankton.

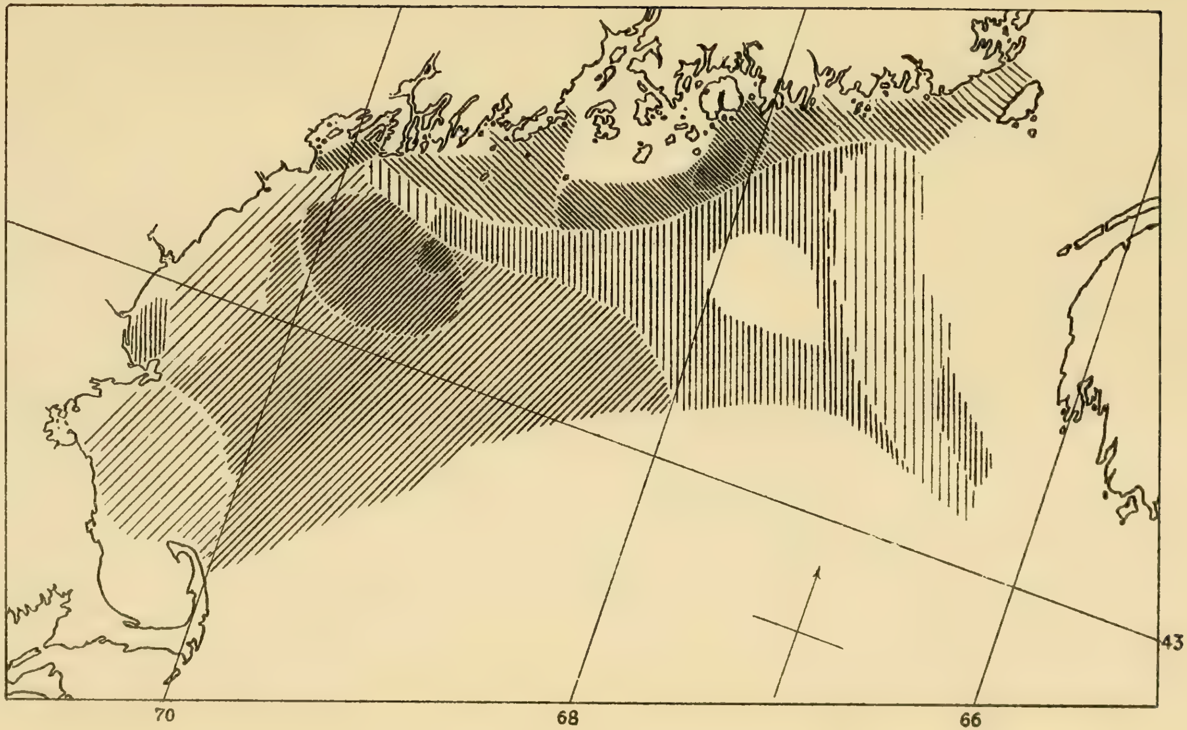
70
68
66
43

PLATE 9.

Chart of the Gulf of Maine, with stations occupied by the GRAMPUS, July and August, 1912, and surface temperatures.

Plate 9

FOLDOUT

The following Publications of the Museum of Comparative Zoölogy are in preparation: —

LOUIS CABOT. Immature State of the Odonata, Part IV.
E. L. MARK. Studies on Lepidosteus, continued.
" On Arachnactis.
A. AGASSIZ and C. O. WHITMAN. Pelagic Fishes. Part II., with 14 Plates.
H. L. CLARK. The "Albatross" Hawaiian Echini.

Reports on the Results of Dredging Operations in 1877, 1878, 1879, and 1880, in charge of Alexander Agassiz, by the U. S. Coast Survey Steamer "Blake," as follows:—

A. MILNE EDWARDS and E. L. BOUVIER. The Crustacea of the "Blake."
A. E. VERRILL. The Alcyonaria of the "Blake."

Reports on the Results of the Expedition of 1891 of the U. S. Fish Commission Steamer "Albatross," Lieutenant Commander Z. L. Tanner, U. S. N., Commanding, in charge of Alexander Agassiz, as follows:—

K. BRANDT. The Sagittae.
" The Thalassicolae.
O CARLGREN. The Actinarians.
R. V. CHAMBERLIN. The Annelids.
W. R. COE. The Nemerteans.
REINHARD DOHRN. The Eyes of Deep-Sea Crustacea.
H. J. HANSEN. The Cirripeds.
" The Schizopods.
HAROLD HEATH. Solenogaster.
W. A. HERDMAN. The Ascidians.
S. J. HICKSON. The Antipathids.
E. L. MARK. Branchiocerianthus.
JOHN MURRAY. The Bottom Specimens.
P. SCHIEMENZ. The Pteropods and Heteropods.
THEO. STUDER. The Alcyonarians.
—— The Salpidae and Doliolidae.
H. B. WARD. The Sipunculids.

Reports on the Scientific Results of the Expedition to the Tropical Pacific, in charge of Alexander Agassiz, on the U. S. Fish Commission Steamer "Albatross," from August, 1899, to March, 1900, Commander Jefferson F. Moser, U. S. N., Commanding, as follows:—

R. V. CHAMBERLIN. The Annelids.
H. L. CLARK. The Holothurians.
—— The Volcanic Rocks.
—— The Coralliferous Limestones.
S. HENSHAW. The Insects.
R. VON LENDENFELD. The Siliceous Sponges.
—— The Ophiurans.
G. W. MÜLLER. The Ostracods.
MARY J. RATHBUN. The Crustacea Decapoda.
G. O. SARS. The Copepods.
L. STEJNEGER. The Reptiles.
C. H. TOWNSEND. The Mammals, Birds, and Fishes.
T. W. VAUGHAN. The Corals, Recent and Fossil.

PUBLICATIONS

OF THE

MUSEUM OF COMPARATIVE ZOÖLOGY

AT HARVARD COLLEGE.

There have been published of the BULLETIN Vols. I. to LIV.; of the MEMOIRS, Vols. I. to XXIV., and also Vols. XXVI. to XXIX., XXXI. to XXXIV., XXXVI. to XXXVIII., and XLI.

Vols. LV. to LVIII. of the BULLETIN, and Vols. XXV., XXX., XXXV., XXXIX., XL., XLII. to XLVIII. of the MEMOIRS, are now in course of publication.

The BULLETIN and MEMOIRS are devoted to the publication of original work by the Officers of the Museum, of investigations carried on by students and others in the different Laboratories of Natural History, and of work by specialists based upon the Museum Collections and Explorations.

The following publications are in preparation:—

Reports on the Results of Dredging Operations from 1877 to 1880, in charge of Alexander Agassiz, by the U. S. Coast Survey Steamer "Blake," Lieut. Commander C. D. Sigsbee, U. S. N., and Commander J. R. Bartlett, U. S. N., Commanding.

Reports on the Results of the Expedition of 1891 of the U. S. Fish Commission Steamer "Albatross," Lieut. Commander Z. L. Tanner, U. S. N., Commanding, in charge of Alexander Agassiz.

Reports on the Scientific Results of the Expedition to the Tropical Pacific, in charge of Alexander Agassiz, on the U. S. Fish Commission Steamer "Albatross," from August, 1899, to March, 1900, Commander Jefferson F. Moser, U. S. N., Commanding.

Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in charge of Alexander Agassiz, on the U. S. Fish Commission Steamer "Albatross," from October, 1904, to April, 1905, Lieut. Commander L. M. Garrett, U. S. N., Commanding.

Contributions from the Zoölogical Laboratory, Professor E. L. Mark, Director.

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