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EXPLORATIONS OF THE COAST WATER BETWEEN CAPE COD AND HALIFAX IN 1914 AND 1915, BY THE U. S. FISHERIES SCHOONER GRAMPUS. OCEANOGRAPHY AND PLANKTON.

By Henry B. Bigelow.

With Two Plates.

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No. 8.— *Explorations of the Coast Water between Cape Cod and Halifax, in 1914 and 1915, by the U. S. Fisheries Schooner Grampus. Oceanography and Plankton.*

By Henry B. Bigelow.

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Introduction.

In 1914 the summer cruise of the Grampus was planned to afford a general survey of the coast water, out to the 1000 fathom curve, from Cape Cod to Halifax.[1]

Sailing from Gloucester on July 18, the first section was made across the western end of Georges Bank, to the continental slope; we then ran eastward, along the southern and southeastern edge of the Bank, to longitude 66° 10′ w.; whence a second section was made across its eastern part, to the basin of the Gulf of Maine. The third section was from the eastern edge of the Bank across the deep Eastern Channel, the Northern Channel, and the coastal bank, to Shelburne, Nova Scotia.

On July 27th the Grampus anchored some thirty miles off Shelburne, in thirty fathoms of water, and measurements of the surface current were taken hourly for twelve hours, covering an entire tide, ebb and flood (p. 203); with occasional readings on the bottom. We then ran offshore once more, via Roseway Bank and the basin southeast of it, to the continental slope in longitude 63° 58′; thence to Halifax. With orders to return to United States waters, owing to the European war, the Grampus, on August 6th, sailed southward as far as the southwestern edge of Emerald Bank, then westward, toward the Gulf of Maine, via Shelburne.

Locating the Gulf of Maine stations at the same positions as those of 1912 and 1913 (Plate 1), the Grampus proceeded from Woods Hole,

[1] For a summary of the Cruise of 1914, see Bigelow, (1914c).

across the continental shelf to the edge of the Gulf Stream; making two successful sets of the long trawl for Tile fish, in 80 and 105 fathoms. The catch at the latter was nineteen fish, with an aggregate weight of about 350 pounds. On August 28th the GRAMPUS returned to Gloucester.

From May to October, 1915, the GRAMPUS was employed in an investigation of the Herring in the Gulf of Maine, and with oceanographic cruises (Plate 2). Between May 4th and 14th lines were run from Gloucester across the Gulf to German Bank and Yarmouth, Nova Scotia; thence to Mount Desert Island; and along shore back to Gloucester. During the last half of June we made sections from Boothbay, Maine to Cape Sable; Shelburne, Nova Scotia, to the continental slope; thence via Brown's Bank, the Eastern Channel, and the southern half of the Gulf of Maine, to Gloucester.

On August 31st the GRAMPUS once more sailed from Gloucester to Cape Sable and Shelburne; thence, after making two stations off Shelburne, to Eastport, Maine. In October two sections were run across the mouth of Massachusetts Bay; and a partial one from Woods Hole, south across the continental shelf. Besides these oceanographic cruises, other stations were occupied, along shore, during the fisheries investigations (Plate 2), notably one in the Bay of Fundy Deep, a locality not visited previously. Details of the stations are tabulated below (p. 330).

During 1914 and 1915 complete oceanographic records were taken at 126 stations; 311 tows made with the horizontal, 76 with the quantitative nets.

The equipment of the GRAMPUS (Bigelow, 1915, p. 154) has been much improved since 1913, the old deep-sea thermometers having been replaced by a set of thermometers of the latest type, our stock of stop-cock water-bottles increased to six, and the thermometer frames attached to the water-bottles, allowing the two sets of instruments to be operated simultaneously. We also used an Ekman reversing water-bottle, the instrument generally employed by European geographers. But it proved far less reliable than the stop-cock bottles, often failing to close when there was any stray to the wire. The ship carried three Ekman current-meters, and a Lucas sounding machine. The set of plankton-nets comprised large and small horizontal tow-nets of fine and coarse silk; meter-nets for horizontal work of stramin, Helgoland nets of fine and coarse silk and of stramin; meter-nets of netting and silk of the MICHAEL SARS pattern (Murray and Hjort 1912, p. 46), a Peterson young fish-trawl; and quantitative nets. The usual fishing gear and harpoons were also carried; in short, a thoroughly modern oceanographic outfit.

The general program for each station consisted of a set of serial temperatures and water-samples, at 3–7 levels according to the depth, and repeated in case of any apparent discrepancy; a vertical haul with the quantitative net,[1] especially for copepods; surface hauls with the fine (no. 20 silk) and coarse (no. 5 silk) nets for microplankton, copepods, etc., and fish eggs; and hauls at intermediate depths with the Helgoland, and other horizontal nets. The number of the latter depended on the depth, the nets being usually attached simultaneously to the wire at the desired levels. The surface temperature was recorded hourly throughout the cruise. On the only occasion when current measurements were taken (p. 203) the ship was anchored for the purpose.

For the identification of specimens thanks are due to Dr. W. M. Tattersall (euphausiids); Dr. C. O. Esterly (copepods); Mr. W. F. Clapp, (pteropods and heteropods); Mr. W. W. Welsh (young fishes); Mr. L. Radcliffe (fish eggs); and to Dr. Johan Hjort for assistance in preparing some of the profiles.

Oceanography.

Temperatures and Salinities in 1914.

The records for 1914, covering as they do the whole breadth of the continental shelf, and all being taken in a month's period, justify the description of the hydrography of that summer in some detail.

Surface Temperature.— The surface temperature (Fig. 1) of the southern and western parts of the Gulf of Maine was about the same in 1914 as in previous years, (15°–18°), with a band of distinctly colder water, (11°–15°), along its northern and eastern shores, including Brown's Bank, the minimum being 6°, some thirty miles off Cape Sable. The warm surface, (18°–20°), noted off Cape Cod in 1912 and 1913 obtained there in 1914 also: apparently, then, this phenomenon is normal; and this year we were able to demonstrate, what previously was supposition only, that this warm area was separated from the still warmer Gulf Stream by lower temperatures, (11°–15°), on Georges Bank. Along the southern edge of the latter the influence of the Gulf Stream is evidenced by the warmer surface (18°–20°). Judging from

[1] In 1914 the quantitative nets were of the Hensen pattern (Johnstone 1908): in 1915 these were replaced with nets of the Michael Sars pattern, one half meter in diameter of mouth.

the previous year the 20° curve probably followed the 200 meter contour as far west as Longitude 70°, in July. But by the end of August a surface temperature of 20° was found within fifteen miles of Marthas Vineyard. The very cold water off Cape Sable, noted above, was only a local phenomenon, associated no doubt with vertical currents, for the temperature was higher (10°–12°) along the southeast coast of Nova Scotia.

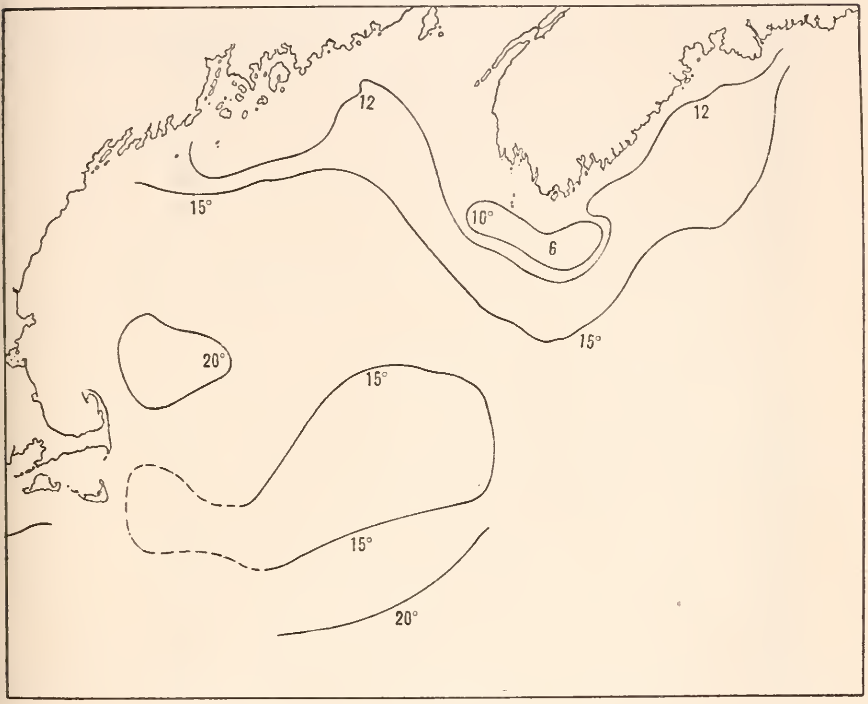

FIG. 1.—Surface temperature, July–August 1914.

Temperature Sections.— Temperature and salinity sections are chiefly interesting as the basis for the profiles, and charts for different levels. The temperature curves for the Gulf of Maine are of the same general types as in 1913 (1915). Thus both in the eastern and in the western basins the water was coldest in the mid-depths (about 100 meters); down to which level vertical cooling was very rapid at all the deep Gulf stations, most so in the western part (Fig. 2).

In the sink east of Cape Ann (Station 10253), however, and the trough west of Jeffrey's Ledge, the temperature was practically uniform, below the level of the enclosing rim. In the southeast and northeast parts of the Gulf, too, and in the Eastern Channel (Station 10227, Fig. 2), the water was coldest on the bottom, instead of in the mid-depths. In 1914 there was no exception to the rule that in summer the

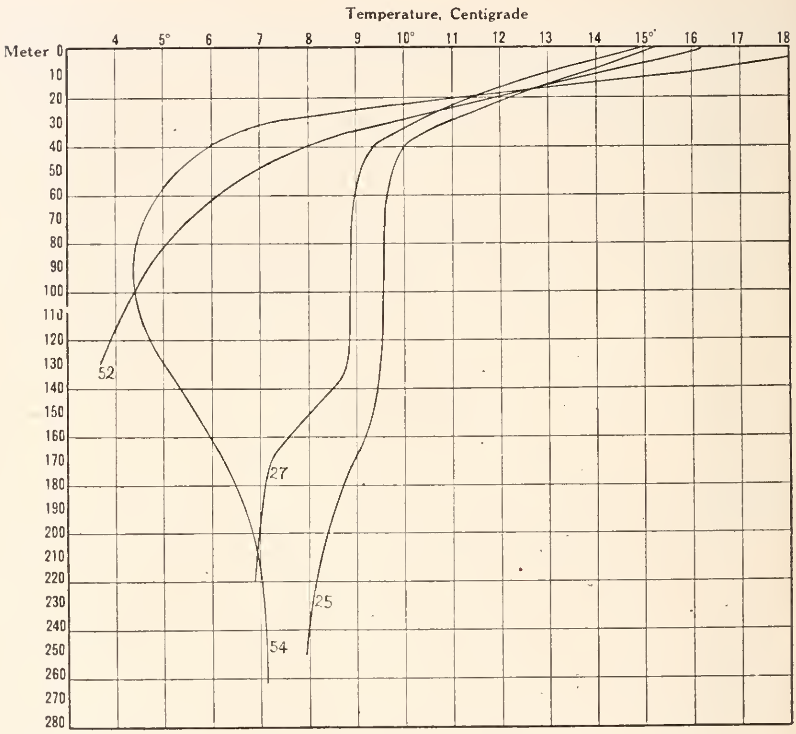

Fig. 2.— Temperature sections in the western (Stations 10252, 10254) and southeastern parts of the Gulf of Maine (Station 10225), and in the Eastern Channel (Station 10227), July 1914.

surface is progressively cooler and cooler, the bottom, depth for depth, progressively warmer and warmer, following the northern coast of the Gulf from Massachusetts Bay around to the Bay of Fundy, the vertical range of temperature decreasing from about 12° off Cape Ann, to practically *nil* in the Grand Manan Channel (1914a).

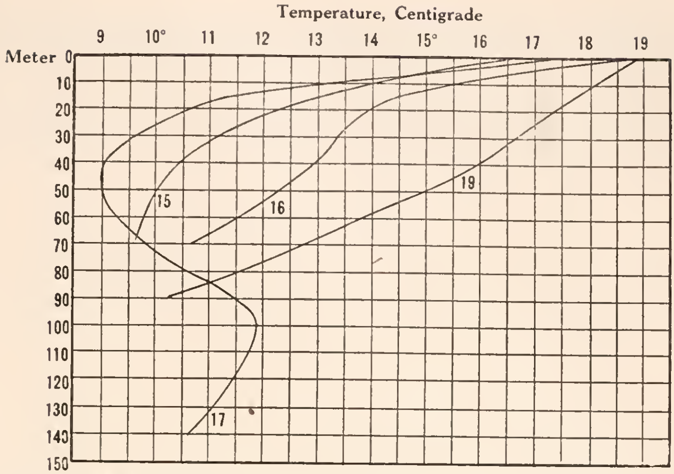

Fig. 3.— Temperature sections on the western part of Georges Bank, Stations 10215, 10216, 10217, 10219, July 1914.

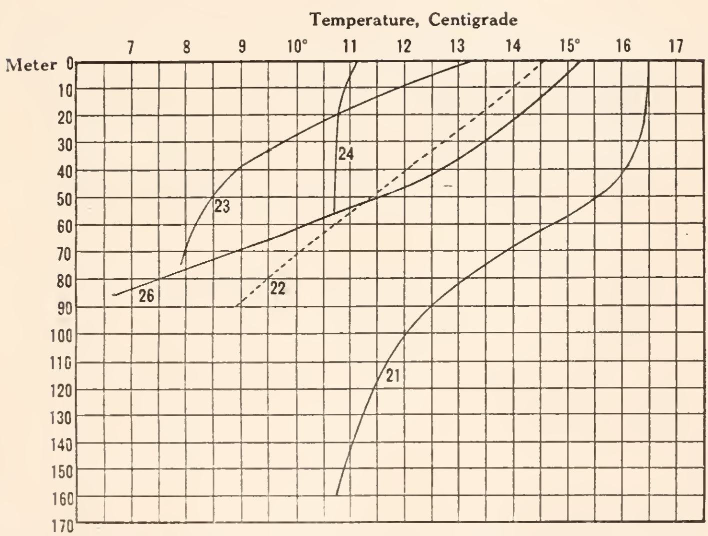

Fig. 4.— Temperature sections on the eastern part of Georges Bank, Stations 10221, 10222, 10223, 10224, 10226, July 1914. The curve for Station 10222 is approximate only.

On German Bank (Station 10244), likewise, the temperature was almost uniform (9.5°–10°) from surface to bottom, as in previous years (1914a, 1915).

On Georges Bank as a whole (Fig. 3, 4) the vertical range of temperature was considerable, with the water coldest on the bottom, and the rate of vertical cooling more uniform than in most parts of the Gulf

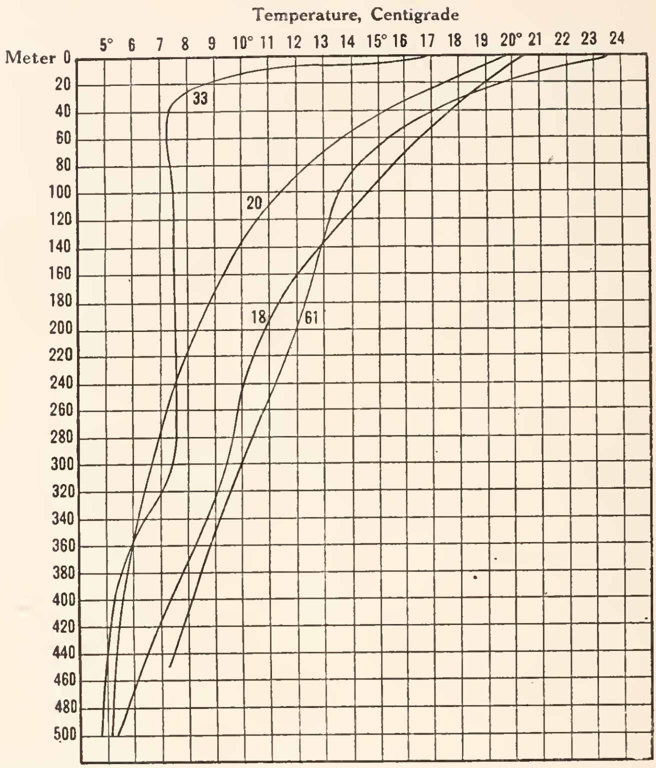

Fig. 5.— Temperature sections over the continental slope, Stations 10218, 10220, 10233, 10261, July–August 1914.

(Fig. 2). But Station 10217, over the 150 meter contour on the southwest slope of the Bank is an exception to this rule, its minimum lying at 40–50 meters instead of on the bottom. Locally, on the northeast part of the Bank (Station 10224), the water was so thoroughly mixed by vertical circulation that the temperature was practically uniform

(10.5°–11°) from top to bottom; and this was probably the case elsewhere on its shallower and more broken parts, *e. g.*, near Cultivator Shoal, where the tidal currents are proverbially violent.

The two deep Stations (10218 and 10220, Fig. 5) off the southern face of the Bank are of the usual oceanic type, cooling at a decreasing rate, from the surface down to 500 meters. But while the two were about alike on the surface (20°), the water at 300 meters was 3°–4° cooler off the southeastern part of the Bank (Station 10220) than it was 100 miles further west.

On Brown's Bank (Station 10228, Fig. 6) the water cooled rapidly from the surface (14°) down to 40 meters (8.5°), below which level, the temperature was practically uniform down to the bottom. And this

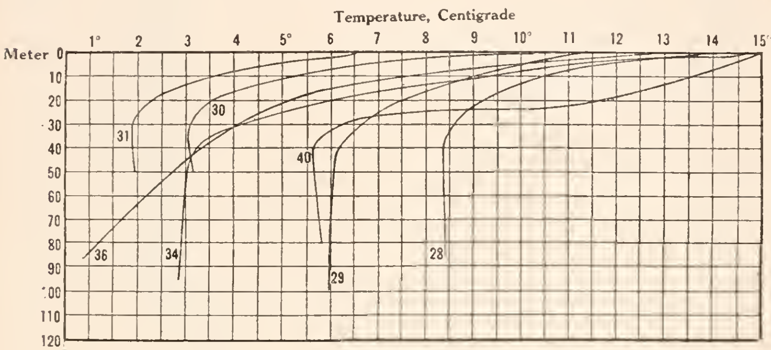

FIG. 6. Temperature sections on Brown's Bank (Station 10228), in the Northern Channel (Station 10229) and at the shallow Stations and Banks off southern Nova Scotia (Stations 10230, 10231, 10234, 10236, 10240), July–August 1914.

same type of curve is characteristic of the shoals south of Nova Scotia, *e. g.*, Le Have and Emerald Banks, and of a narrow zone near its southeastern coast, though the water there was much colder, the temperature being only 1.7° at 20–50 meters off Shelburne (Station 10231) and the bottom water, in 75–85 meters off Halifax (Stations 10236, 10237, Fig. 6) even colder (.76°–1.1°). The Nova Scotian Banks (Stations 10234, 10240, Fig. 6) were likewise colder than Brown's Bank.

The temperatures in the basins south of Nova Scotia are especially instructive. At every station on this part of the shelf where the water was more than 100 meters deep, the temperature was lowest in the mid-depths, with warmer water below (Fig. 7). In the deep off Halifax, and on the edge of Emerald Bank, this warming was followed by a slight cooling close to the bottom. But in the basin north of Le Have Bank (Station 10235) the temperature rose continuously, from the minimum layer down to the bottom, a type of curve similar to the deep stations in the western and northern parts of the Gulf of Maine.

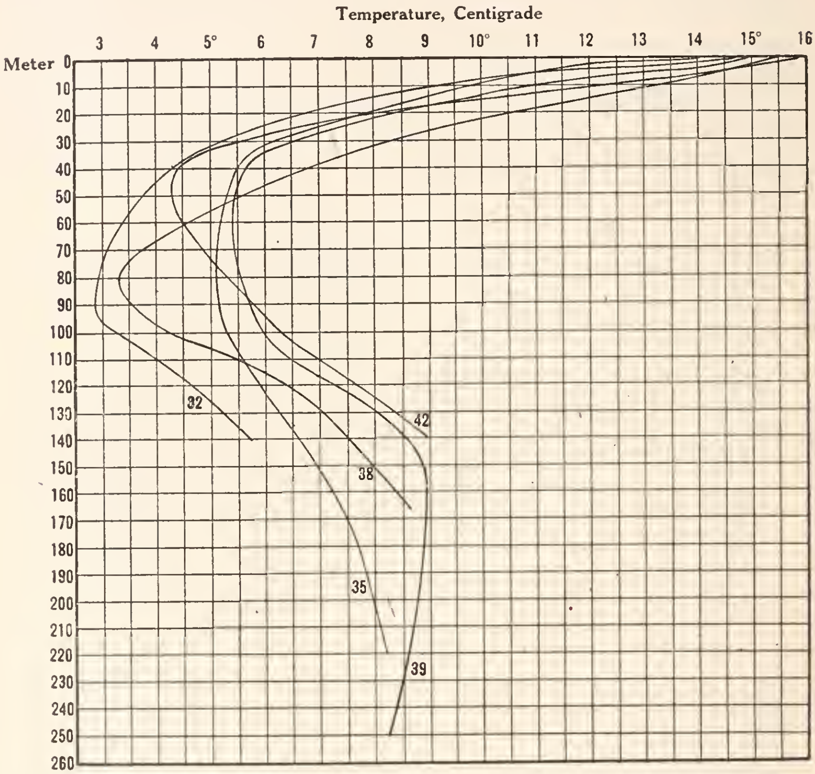

Fig. 7.— Temperature sections in the basins off southern Nova Scotia, Stations 10232, 10235, 10238, 10239, 10242, July–August, 1914.

The minimum temperature at these deep stations was lowest between Le Have and Roseway Banks (Station 10232, 2.8°); rising to about 5° in the basin off Halifax (Station 10239).

Station 10233 (Fig. 5) on the continental slope south of Nova Scotia is interesting because instead of showing the steady vertical cooling which characterized the stations at the same relative position further

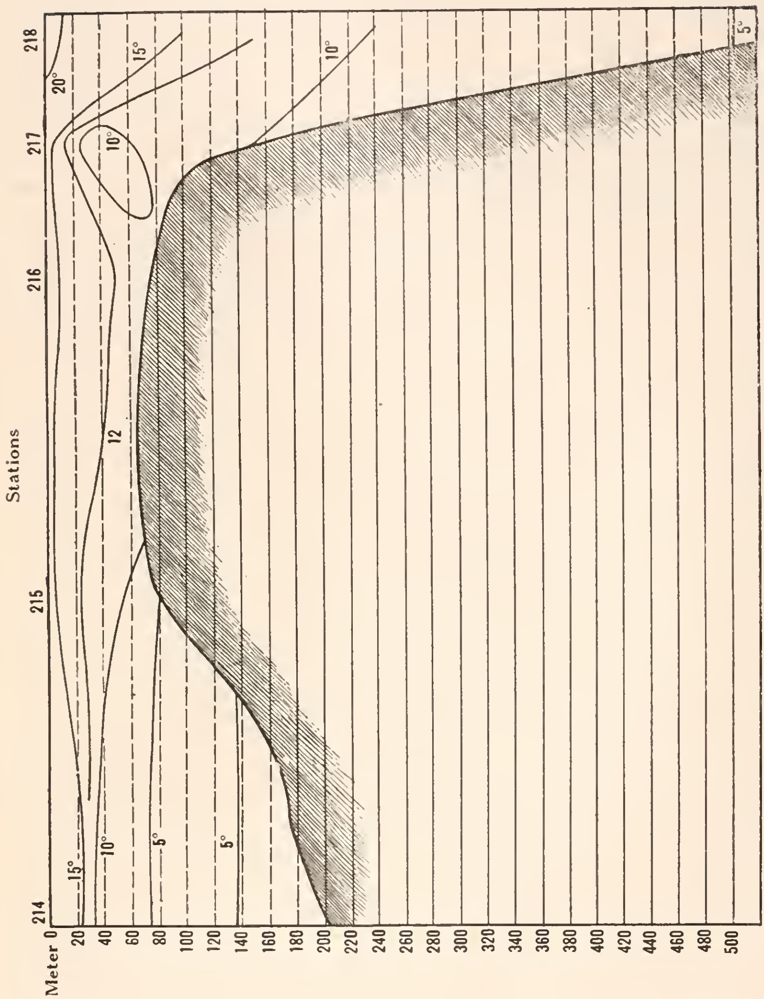

Fig. 8.— Temperature profile from basin of the Gulf of Maine (Station 10214) across the western part of Georges Bank, to the continental slope (Station 10218), July 1914.

west (Stations 10218, 10220, Fig. 5), the temperature was practically uniform from forty meters down to 300 meters.

The water was considerably warmer on the continental shelf south of Marthas Vineyard than anywhere in the Gulf of Maine, or off Nova Scotia.

Temperature Profiles.— The relationship of the water of the Gulf of Maine to the Atlantic water is illustrated by profiles across the west and east ends of Georges Bank. Thus the Western Basin of the Gulf, (Fig. 8), with its minimum of 4°–5° at 100 meters, was much colder at all depths than the water south of the Bank; for example to find water on the continental slope, as cold as the 100 meter-level in the Gulf, we must go below 500 meters; while 10° water lay at 40 meters in the Gulf; but only below 150 meters on the slope. And the surface water at Station 10218 was warmer than any water anywhere in the Gulf. But there is much less difference between the two ends of the profile across the eastern part of the bank, Gulf water being warmer here than further west (Fig. 9), ocean water colder (p. 171).

The two profiles, combined, reveal the existence of a clearly defined cool band (8°–10°), lying on the middle of the bank at its eastern, over the southern edge at its western end. And they are further interesting for their demonstration that the cold water of the Atlantic abyss (4°–5°), was separated from the bottom water of the Gulf of Maine by a much warmer zone (8°–10°) of bottom water; a phenomenon with which we are already familiar further south (1915), and one of great importance for its bearing on the origin of the Gulf water (p. 240). The profile running from Georges Bank to Cape Sable, via the Eastern Channel (Fig. 10) shows that the eastern side of the Channel was appreciably warmer than the western, below the level of its confining banks, though the waters over the latter were of about the same mean temperature on the two sides. But it is chiefly interesting for its illustration of the sudden change which takes place, east of Brown's Bank, from the moderate temperatures of the banks, and of the upper layers of the Gulf of Maine as a whole, to very much colder water next southern Nova Scotia.

This cold water, characterized by the almost polar temperatures of 1°–2°, extended in a continuous band along the coast from Cape Sable to Halifax (Fig. 11–13). And I may forestall the following discussion (p. 234) so far as to say that it is undoubtedly the product of the Cabot Current. In summer it is limited here to a narrow coastal zone; projecting thence outward like a shelf, along the 50 meter-level, into warmer water offshore. Thus on the Halifax line (Fig. 13) water

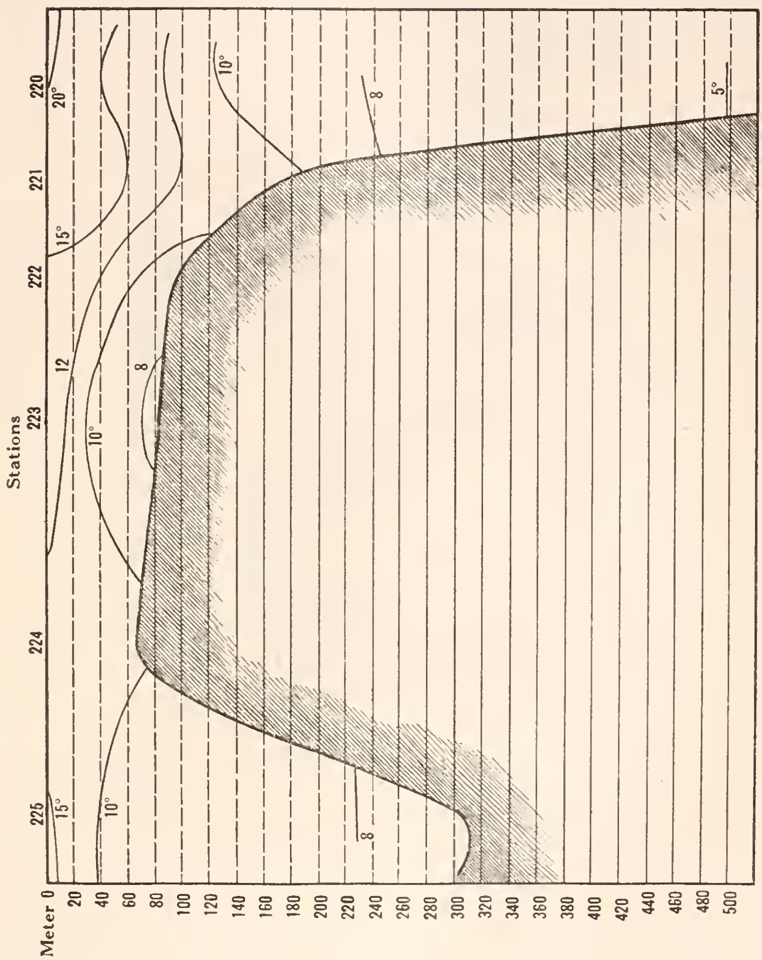

Fig. 9.— Temperature profile from the southeast corner of the Gulf of Maine (Station 10225) across the eastern part of Georges Bank, to the continental slope (Station 10220). July 22–23, 1914.

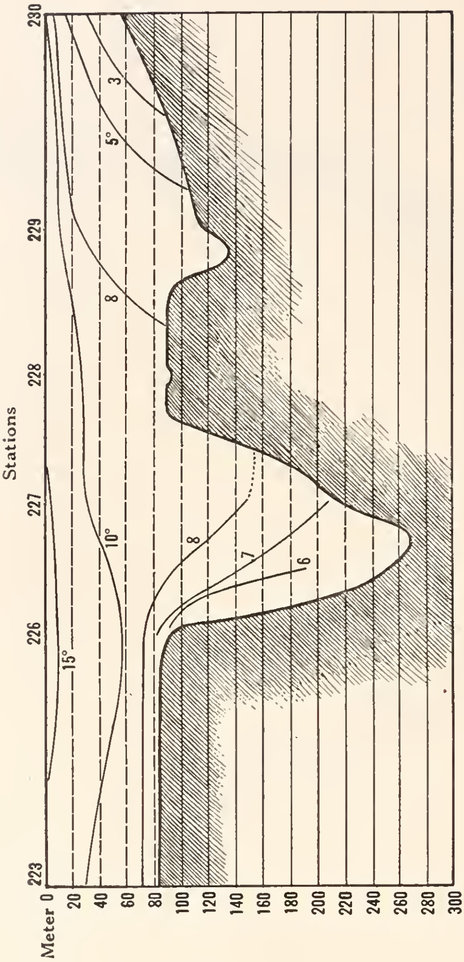

Fig. 10.— Temperature profile from the eastern part of Georges Bank (Station 10223) across the Eastern Channel, (Stations 10227), Brown's Bank (Station 10228) and the Northern Channel (Station 10229) to the neighborhood of Cape Sable (Station 10230). July 23–25, 1914.

colder than 2° hugged the shore closely; and off Shelburne it extended seaward only to Roseway Bank (Fig. 11). But on this line its effect was unmistakable much further offshore, reaching to Le Have Bank by an eddy-like movement (Fig. 12, 15); and the fact that the upper layers over the slope were much colder here (Station 10233) than off

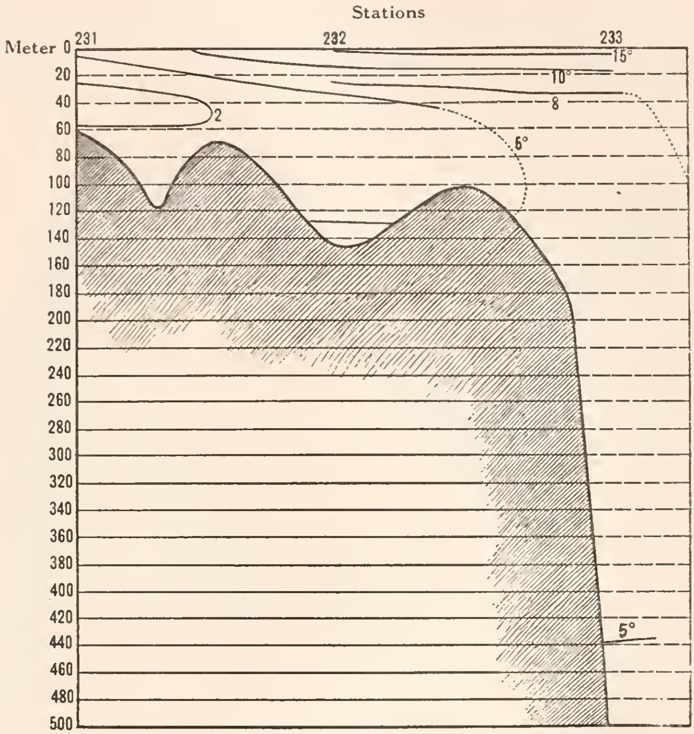

Fig. 11.— Temperature profile across the continental shelf off Shelburne, Nova Scotia (Stations 10231, 10232, 10233). July 27–28, 1914.

Georges Bank (p. 170), is probably also due to the influence of this frigid coast water.

The profiles off Halifax (Fig. 12, 13) illustrate more graphically than do the temperature sections (p. 171) the contrast between the warm (8°) water in the bottoms of the deeps on this part of the shelf, and the colder water in the mid-depths.

The profile off Marthas Vineyard is sufficiently illustrated by Fig. 14; the only feature deserving emphasis being the cool water (9–10°) on the bottom between the 40 and 90 meter contours, and the fact that this is separated from the cold water of the abyss by a warmer zone.

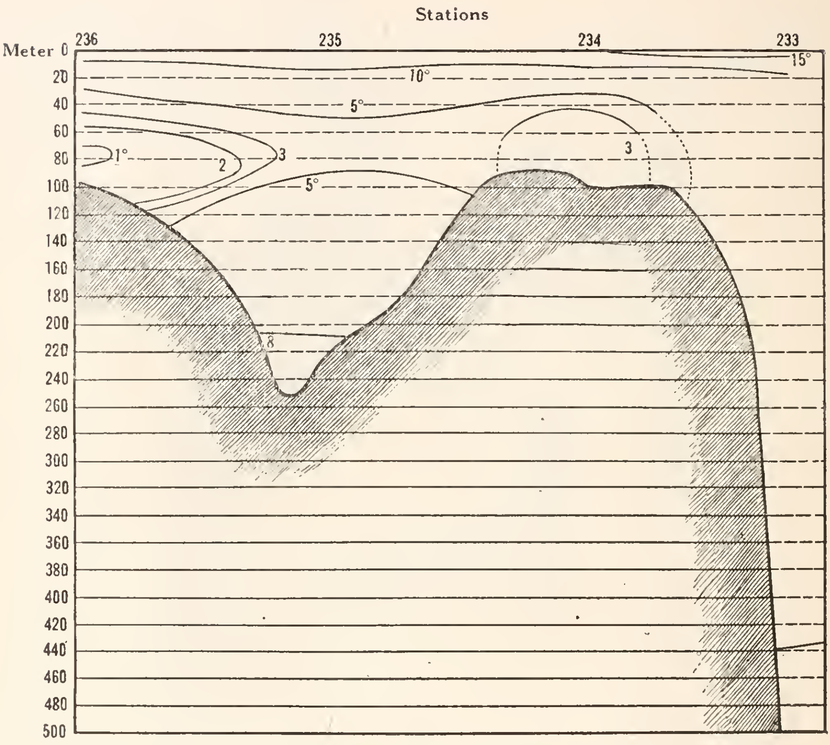

Fig. 12.— Temperature profile crossing the continental shelf obliquely off Halifax (Station 10236 – Station 10233) July 29–August 2, 1914.

Temperature at the 40, 100, and 200 Meter-levels.— The surface temperatures of our waters in summer are chiefly the product of solar warming, and local vertical circulation. But the penetration of solar heat being very slow, except close to the surface, temperatures at, and below 40 meters may be expected to throw more light on the origin and movements of the waters concerned.

The temperature charts for the 40 meter and 100 meter-levels show graphically how the frigid water off southern Nova Scotia is separated from the cool waters of the western part of the Gulf of Maine, by higher temperatures in its eastern half, the latter continuous via the Eastern Channel, with the warm waters outside the continental slope. And the curve for 8° at 40 meters, 5° at 100 meters shows that this comparatively warm water follows the northern coast of the Gulf westward, beyond Penobscot Bay. The coastal character of the cold water off southern Nova Scotia, and its seaward extension to and including Le Have Bank, appears even more clearly on the charts than in the profiles (p. 177). And they amplify the latter by

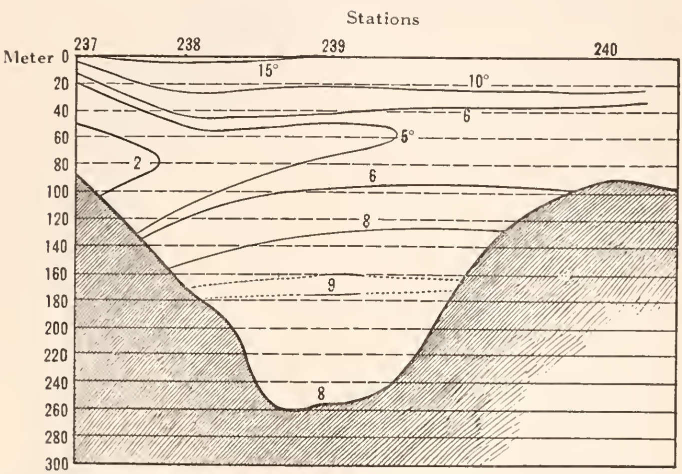

Fig. 13.— Temperature profile from Halifax (Station 10237) to Emerald Bank (Station 10240), August 6 – 7, 1914.

revealing the presence of a tongue of much higher temperature approaching the land off Halifax, apparently an offshoot from the still warmer water outside the continental slope (Fig. 15, 16).

I need only call further attention, on the 40 meter chart (Fig. 15), to the cool (8°–10°) band already mentioned (p. 174) as dividing the warmer (10–12°) water of Georges Bank obliquely, from northeast to southwest.

The ocean area deeper than 200 meters, on the part of the continental shelf under consideration, is confined to the deep basins of the Gulf of Maine, to the Eastern Channel; and to two isolated basins south of Nova Scotia. The temperature was 6°–7° in the western basin of the Gulf, 8°–9° in its southeastern corner, 6°–7° in the Eastern Channel (Fig. 17), 6°–7° in the southern half of the Eastern Basin, in its northern half 8°. The two basins off Nova Scotia were likewise

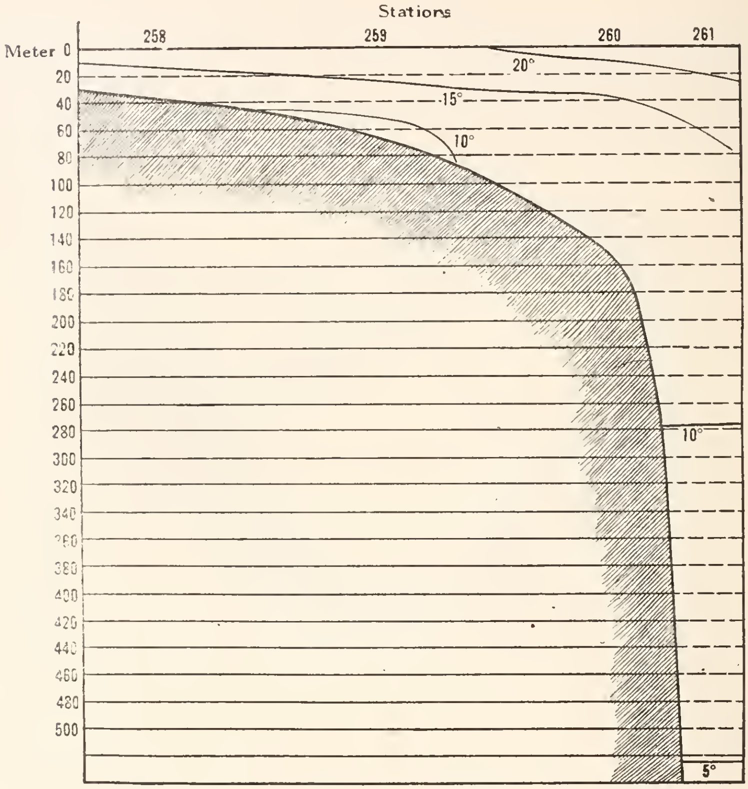

FIG. 14.— Temperature profile across the continental shelf south of Marthas Vineyard (Stations 10258–10261), August 25–26, 1914.

8° at this level. Off the southern face of Georges Bank the 200 meter temperature was about 10°.

In the foregoing charts the temperatures off Marthas Vineyard have been omitted because taken so late in the season that they are not directly comparable with the others.

Surface Salinity. — Surface salinity being unaffected by solar warming, might be expected to reproduce in its main features, the temperatures at some little depth rather than the surface. And such is very clearly the case in the region under discussion, its distribution

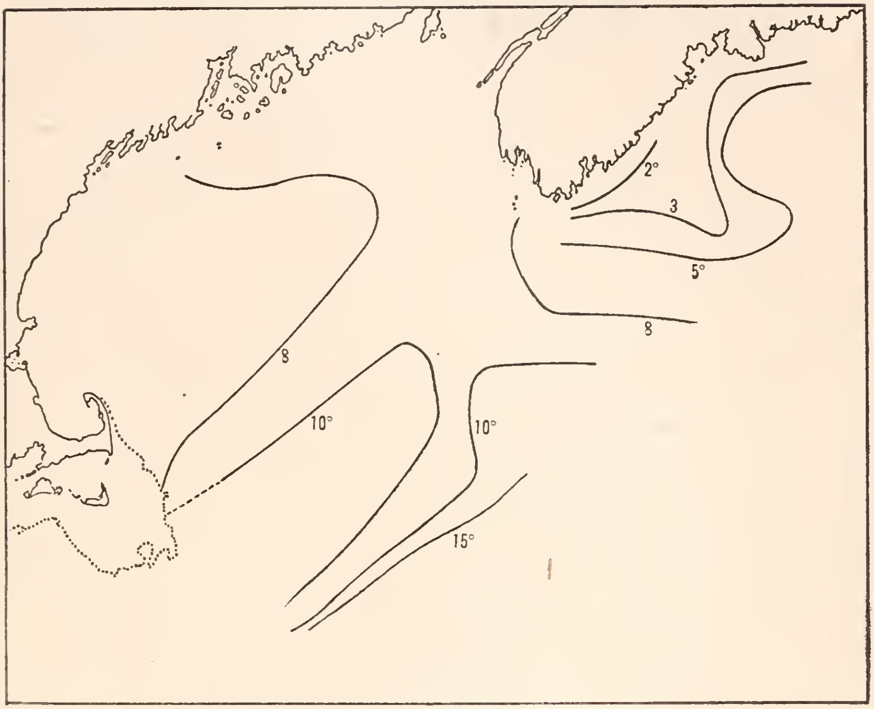

FIG. 15.— Temperature at 40 meters, July–August 1914.

(Fig. 18), suggesting, though it does not exactly reproduce that of temperature at 40 meters (Fig. 15). Thus there are two distinct areas of low salinity, one in the western side of the Gulf of Maine, the other off southern Nova Scotia, separated by salter water (32.‰+) in the eastern half of the Gulf. And the curve for 32‰ recalls that for 8° temperature in the extension of salter water (32.5‰+) from the east westward along the northern shore of the Gulf, as far as Penobscot Bay. But this salt water was not directly continuous with the even higher ocean salinities, being enclosed by slightly fresher water in the southeastern corner of the Gulf.

The lowest salinities of all (31‰ —) like the lowest temperatures lay close to the southern coast of Nova Scotia, water fresher than 32‰ spreading seaward, fanlike off Shelburne, with an apparent tendency to swing around Cape Sable, contrasting with a salter tongue approaching the land off Halifax. Attention should also be drawn to the fact that surface salinities disclose an unmistakable fresh band, running diagonally across Georges Bank, corresponding to the low tempera-

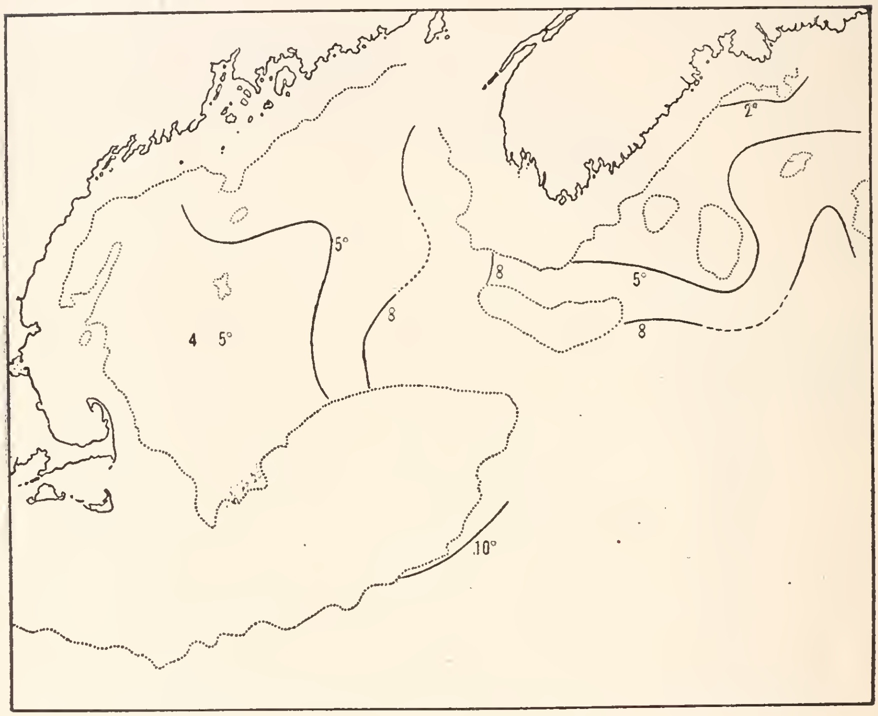

Fig. 16.— Temperature at 100 meters, July–August 1914.

ture there. And the sharp contrast in salinity between coastal and ocean water, illustrated by the sudden north-south rise in salinity along the southern edge of Georges Bank, also deserves mention.

Salinity Sections.— The water of the Gulf of Maine was freshest on the surface, saltest on the bottom (Fig. 19), the only exception to this rule being a slight decrease of salinity below 150 meters at one

Station (10249). Throughout the deeper parts of the Gulf the vertical range of salinity was considerable, the general type of vertical distribution, for its northern half, agreeing so closely with that of past years, that it is not necessary to reproduce the curves. And we again found the decrease in vertical range, passing northeast from Cape Ann, with which we are familiar (1914a, 1915).

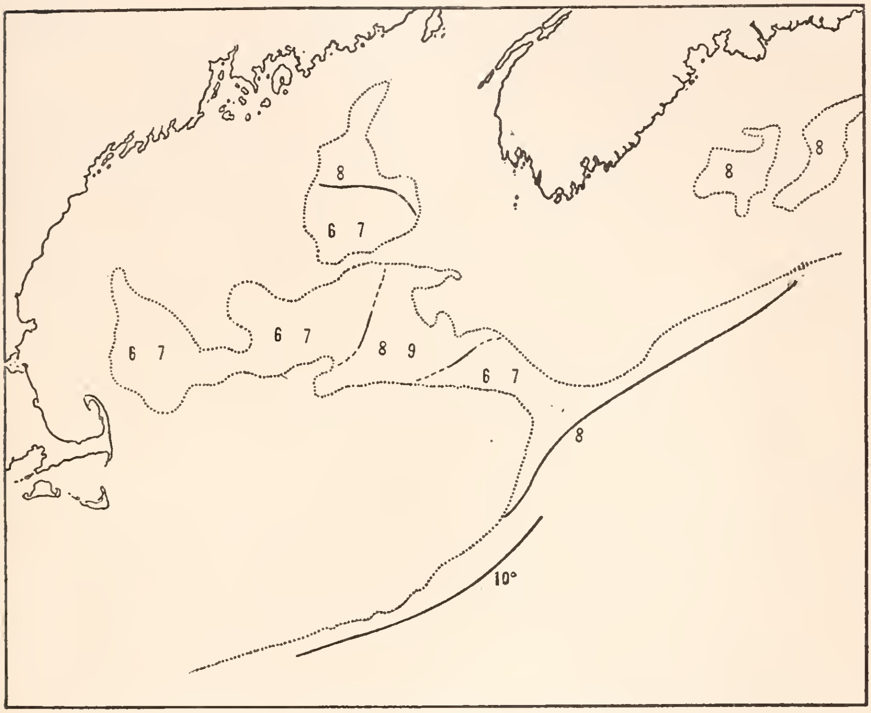

Fig. 17.— Temperature at 200 meters, July–August 1914.

In the southeastern corner of the Gulf (Station 10225), new ground for us, salinity increased very rapidly with increase of depth, to about 35‰ at 140 meters (Fig. 19), a higher reading than has ever been recorded before for any part of the Gulf; below that depth it was practically uniform down to the bottom, in 250 meters. And the salinity curve for the Eastern Channel (Station 10227) is of the same type.

On the Nova Scotia Banks, too, there was a very rapid vertical rise in salinity, from the surface downward (Fig. 22). And the stations in the basins on this part of the shelf (Fig. 23) differ from the shallower ones chiefly in continued vertical rise of salinity corresponding to the increased depth. But in the sink off Halifax, salinity was vertically uniform below 150 meters, which is the level to which the

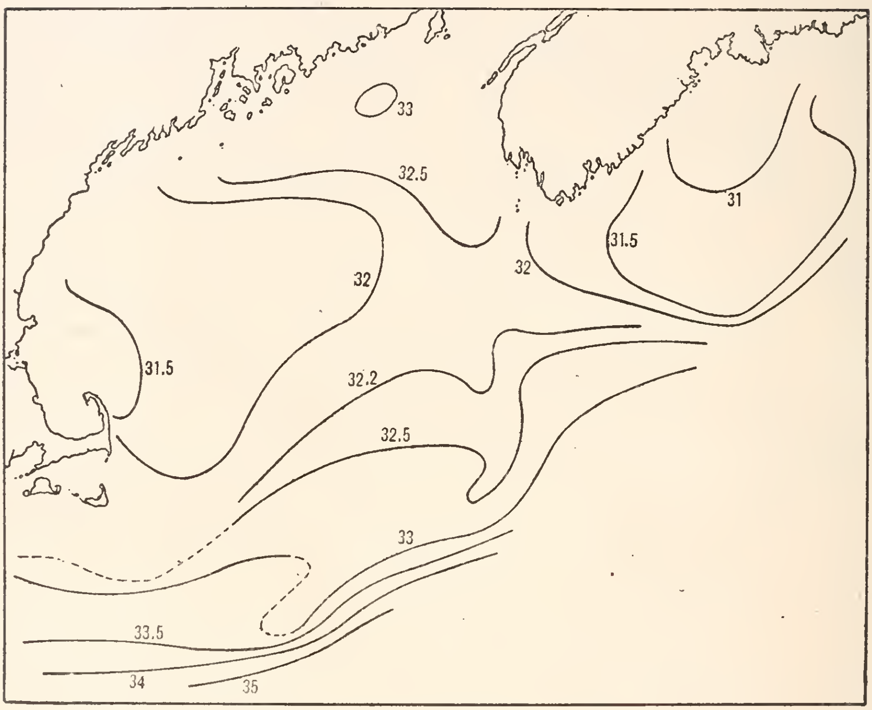

Fig. 18.— Surface salinity, July–August, 1914.

enclosing rim rises on the south. And this was probably also the case in the basin west of Sambro Bank (Station 10235).

The salinity curves for the deep Stations (10218 and 10220) off Georges Bank and abreast of Marthas Vineyard (Station 10261, Fig. 24) are all of one type, freshest on the surface, with the maximum at 40–100 meters, below which the salinity decreases slowly, to about 34.9–35‰ at the lowest level (450–500 meters). Station 10218 was much

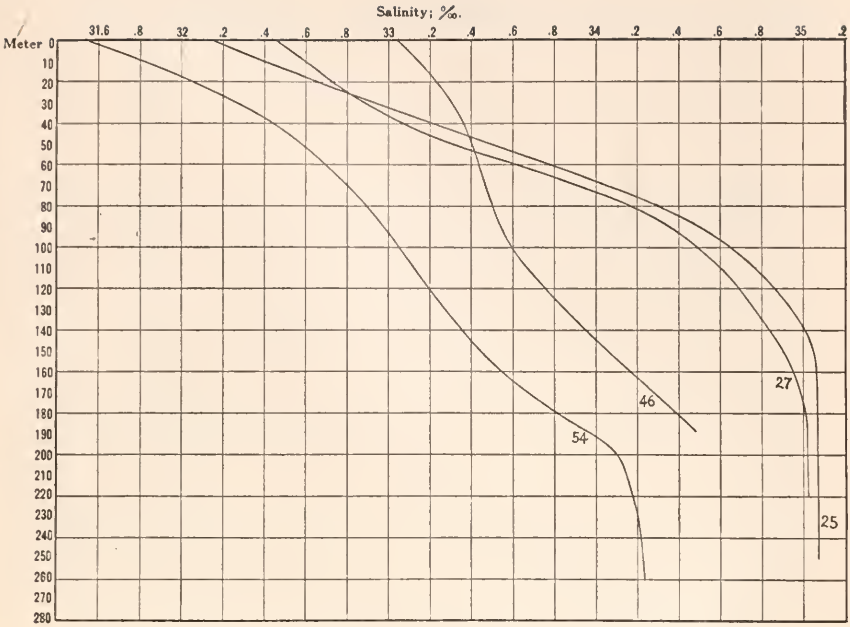

Fig. 19.— Salinity sections in the Western (Station 10254), and Eastern Basins of the Gulf of Maine (Station 10246): in its southeast corner (Station 10225) and in the Eastern Channel (Station 10227), July–August, 1914.

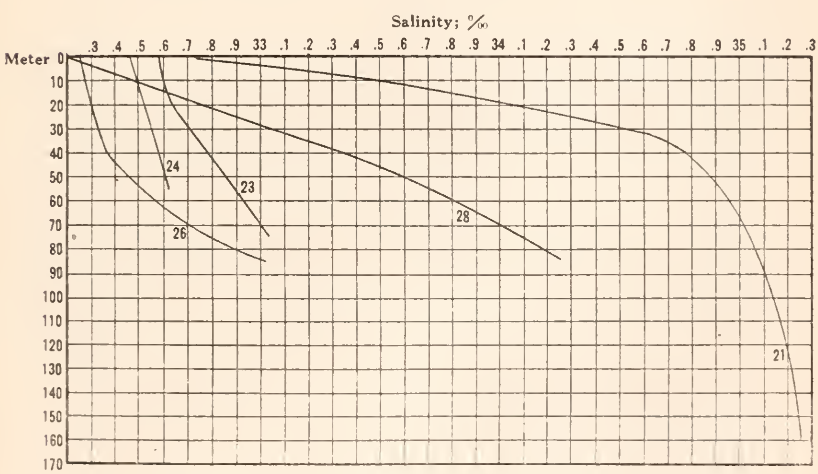

Fig. 20.— Salinity sections on the eastern part of Georges Bank (Stations 10221, 10223, 10224, 10226) and on Brown's Bank (Station 10228). July, 1914.

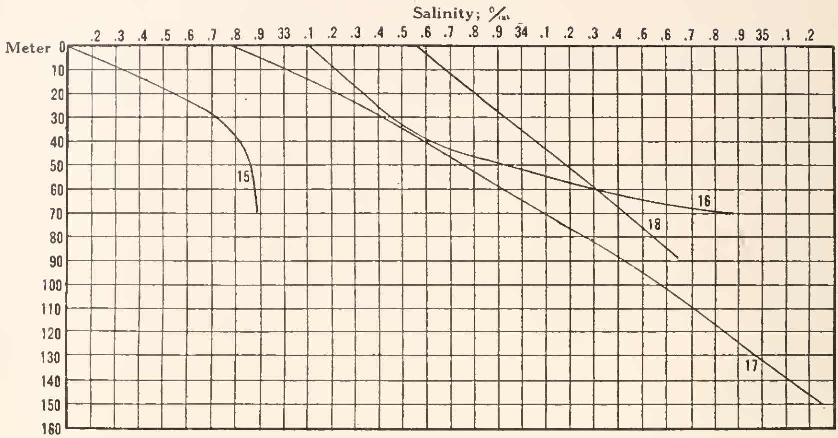

Fig. 21.— Salinity sections on the western part of Georges Bank (Stations 10215, 10216, 10217, 10219). July 1914.

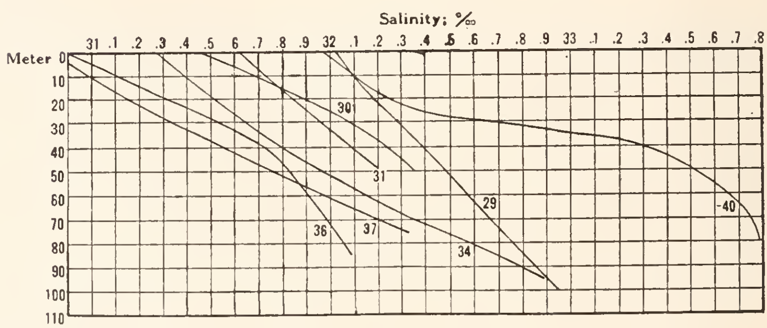

Fig. 22.— Salinity sections in the Northern Channel (Station 10229), and at the shallow stations off southern Nova Scotia (Stations 10230, 10231, 10234, 10236, 10237, 10240). July–August 1914.

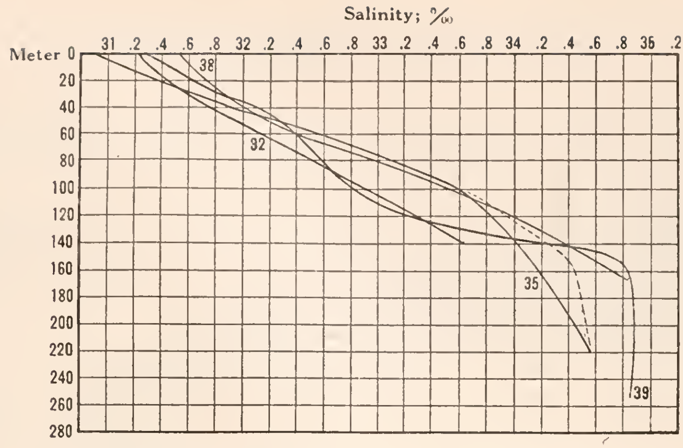

Fig. 23.— Salinity sections in the basins off southern Nova Scotia, (Stations 10232, 10235, 10238, 10239), July–August 1914.

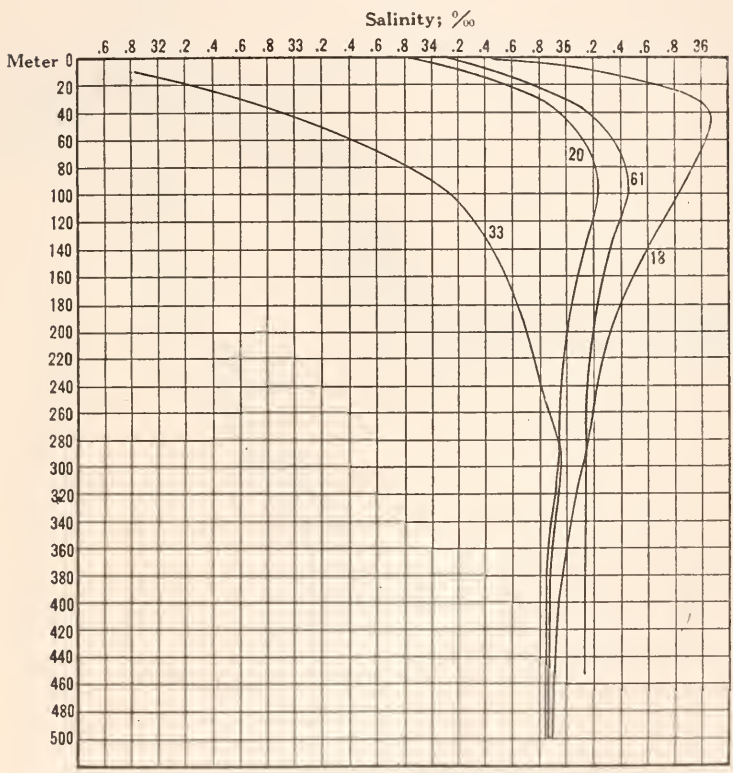

Fig. 24.— Salinity sections over the continental slope (Stations 10218, 10220, 10233, 10261), July and August 1914.

the saltest of the three, its salinity rising above 36‰ at 40–50 meters, Station 10220 the freshest. But while the maximum for Station 10261 was only about 35.4‰, it was slightly the saltest of the three below 300 meters.

The deep Station off Nova Scotia (10233, fig. 24) was much fresher on the surface, as fresh, indeed, as the water on the continental shelf; the salinity rising to the maximum of 34.96‰ at 300 meters: below which it decreased to 34.83‰ at 500 meters, *i. e.*, about the same as the water off Georges Bank at the same level.

The stations on the continental shelf south of Marthas Vineyard are still to be mentioned. Close to the land (Stations 10258 and 10263) the vertical salinity range was considerable, but very small (only

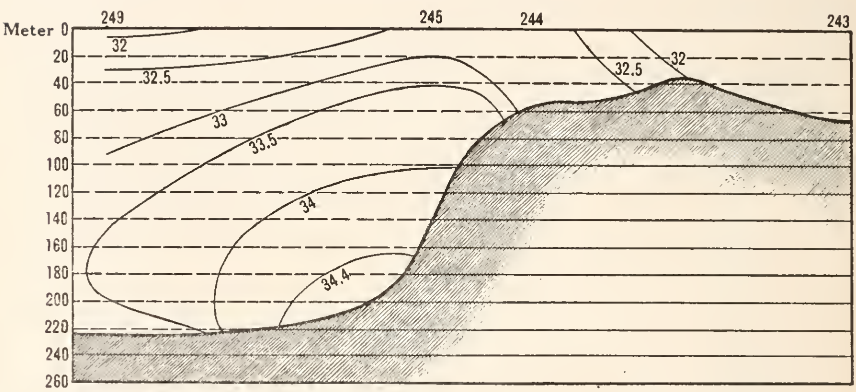

Fig. 25.— Salinity profile from the Eastern Basin of the Gulf of Maine (Station 10249) across German Bank (Station 10244) to the neighborhood of Cape Sable (Station 10243) August 11–13, 1914.

about .1‰) over the 60 meter contour (Station 10259), and the curve for the latter was of an unusual type, saltest on the surface, freshest in mid-depths.

Salinity Profiles.— The high salinity of the eastern as compared with the western side of the Gulf, now known to be a characteristic feature in summer (1914a, 1915), is sufficiently illustrated by a profile running from the center of the Eastern Basin toward Cape Sable (Fig. 25). But though the influence of the still salter water of the Eastern Channel was evident in the high salinity at Station 10245, German Bank (Station 10244) was its eastern limit; east of which there was a sudden transition to much lower salinity in the Northern Channel and off Cape Sable (Stations 10229, 10230, p. 336).

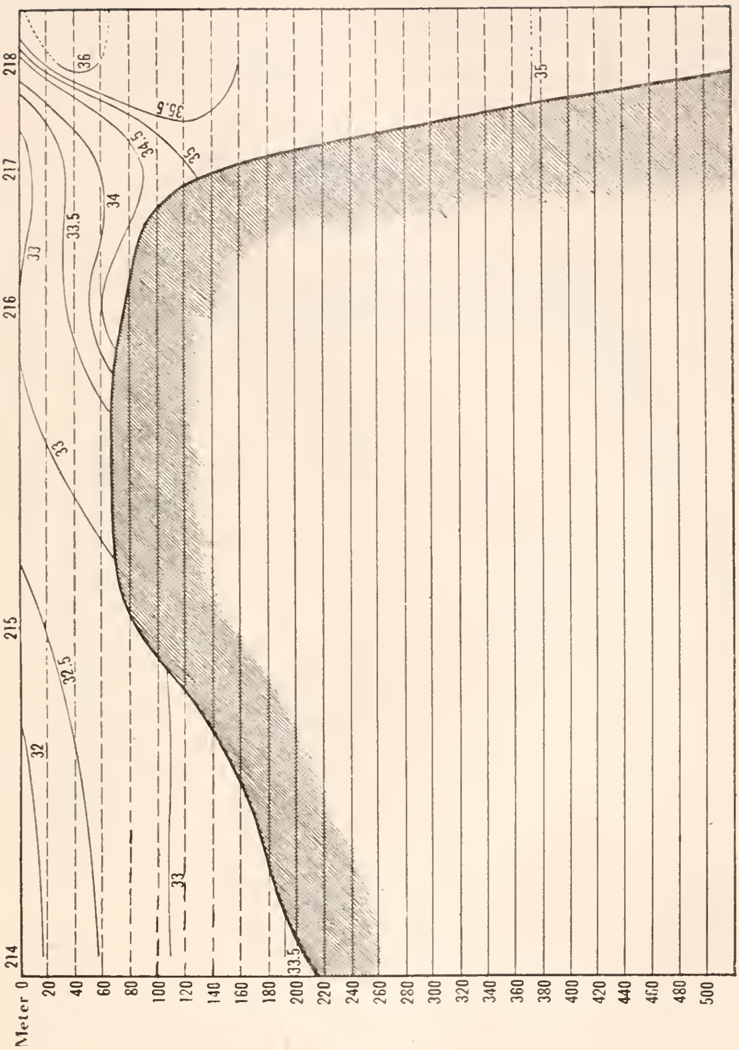

FIG. 26. Salinity profile crossing the western end of Georges Bank, from the basin of the Gulf of Maine on the north (Station 10214) to the continental slope on the south, July 19–21, 1914.

Salinities were much lower in the Western Basin of the Gulf of Maine than over the continental slope (Fig. 26); and the general increase of salinity, from north to south across the profile, above the level of Georges Bank, contrasted with the horizontal uniformity of salinity in this part of the Gulf below that depth, shows how effective a barrier the Bank is to any mixture of the two waters below it. At the eastern

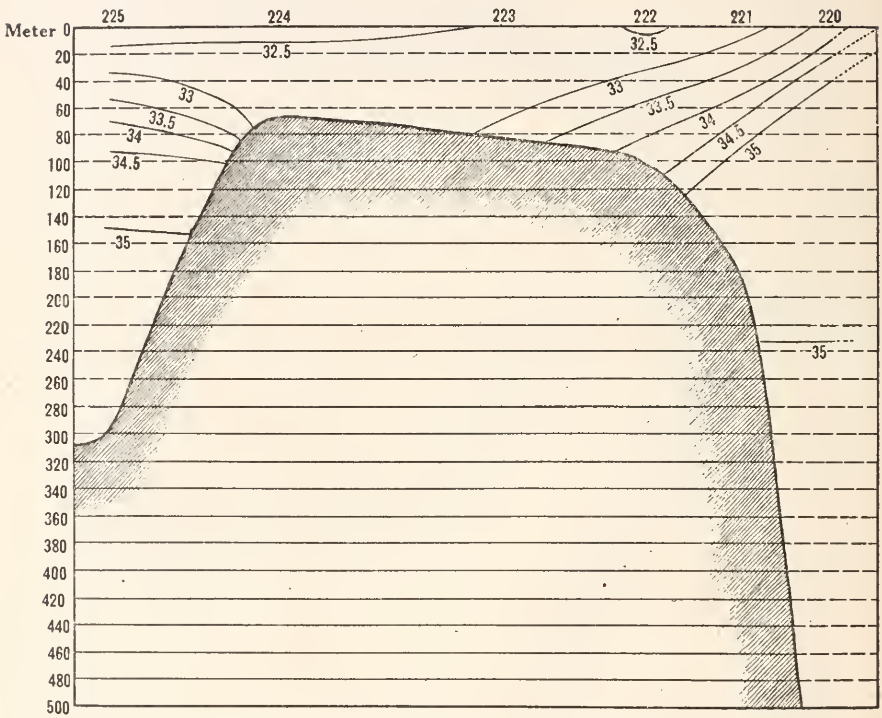

Fig. 27.— Salinity profile crossing the eastern end of Georges Bank from the Gulf of Maine (Station 10225) to the continental slope, July 22–23, 1914.

end of the Bank there is less contrast in salinity (Fig. 27), just as there is in temperature between Gulf water, and the water over the continental slope, and for a similar reason, Gulf water being considerably salter, especially near the bottom, water south of the Bank fresher, than further west. At the western end of the Bank the profile (Fig. 26) reaches practically undiluted Gulf Stream water, with salinities

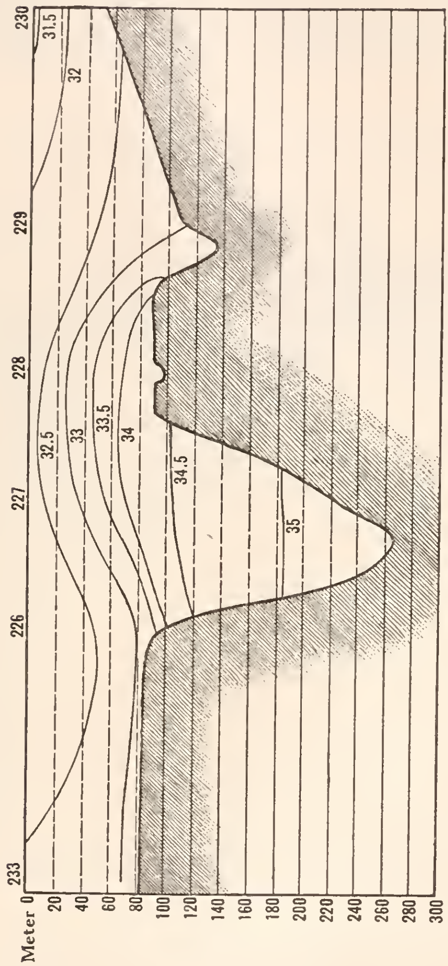

FIG. 28.— Salinity profile running from Georges Bank (Station 10223) across the Eastern Channel (Station 10227), Brown's Bank (Station 10228) and the Northern Channel (Station 10229) to the neighborhood of Cape Sable (Station 10230). July 23–25, 1914.

of upwards of 36‰; a fact worth noting, since this is the only time the GRAMPUS has encountered it on her recent cruises (1914a, 1915).

The salinity profile running from Georges Bank, across the Eastern Channel, toward Nova Scotia, shows that though the water was of about the same temperature over Brown's, as on Georges Bank, it was decidedly salter there (34‰). But its most interesting feature,

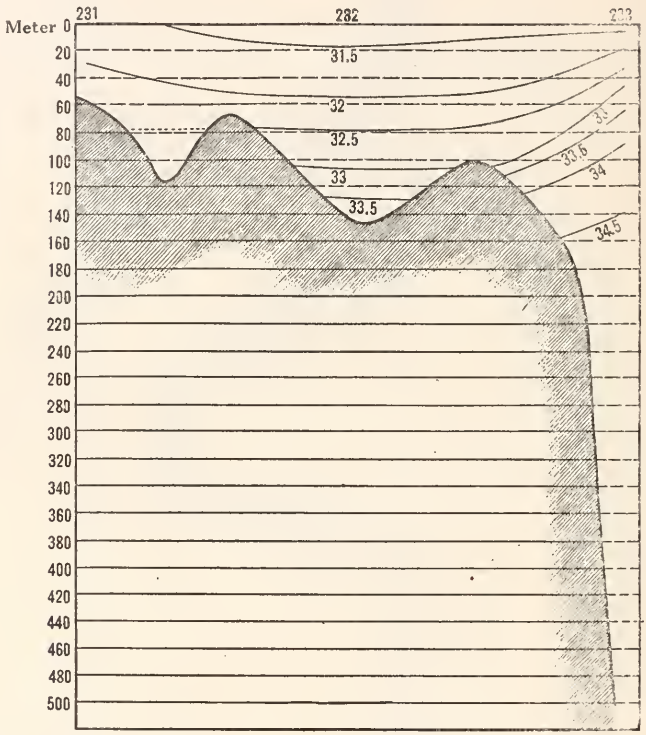

FIG. 29.— Salinity profile crossing the continental shelf off Shelburne, Nova Scotia (Stations 10231–10233), July 27–28, 1914.

and that of the succeeding profiles (Fig. 29–31), is that the low temperature of the Nova Scotian coast water (p. 174) is accompanied, in the upper layers, by correspondingly low salinity. Off Halifax (Fig. 31) the freshest water, like the lowest temperature, was localized close to the land, with a considerable increase in salinity, passing offshore.

But off Shelburne (Fig. 29) the upper layers, down to 40 meters or so, were uniformly fresher than 32‰ across the whole breadth of the shelf. And salinity, like temperature was lower over Le Have Bank (Fig. 30) than immediately north of it, a fact connected with the eddy-like circulation in this region (p. 182). Contrasting with the low salinity of the upper layers, that of the bottom waters of the basins off Shel-

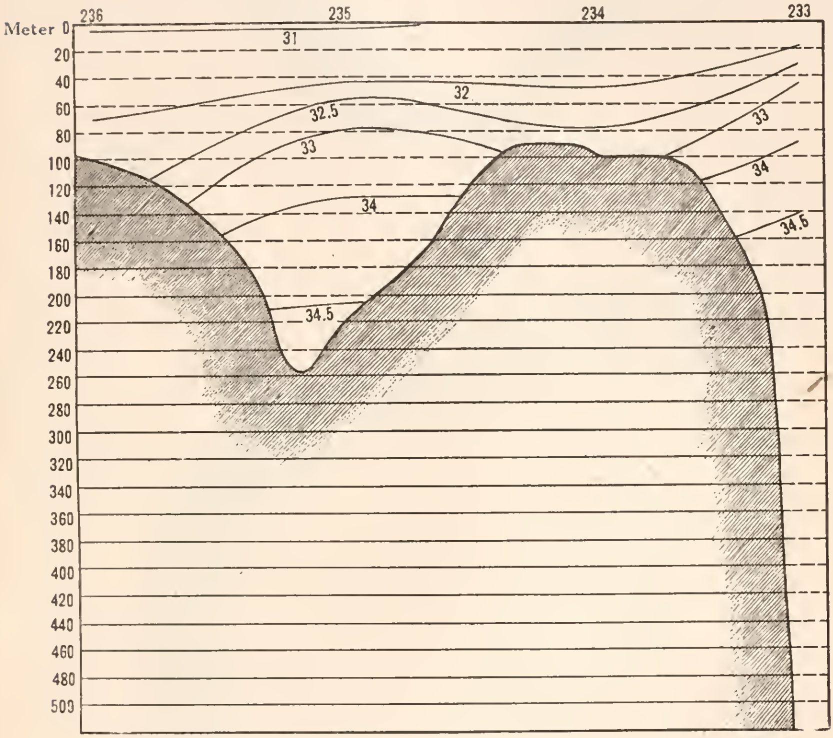

FIG. 30.— Salinity profile crossing the continental shelf obliquely off Halifax (Stations 10236–10233. July 27–August 2, 1914.

burne and Halifax and on Emerald Bank (Fig. 30, 31) was very high, the latter being as salt as the water over the continental shelf off Shelburne (Fig. 29, 30). But, as pointed out, the latter was itself considerably fresher than the water at corresponding locations on the slope further west, its maximum salinity being only about 34.9‰,

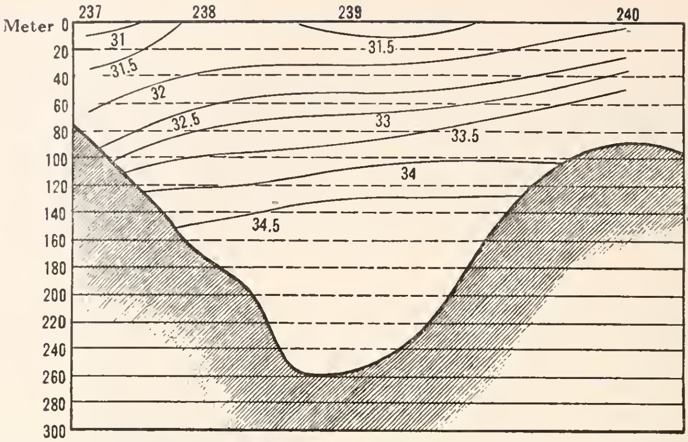

FIG. 31.— Salinity profile from Halifax (Station 10237) to Emerald Bank (Station 10240). August 6–7, 1914.

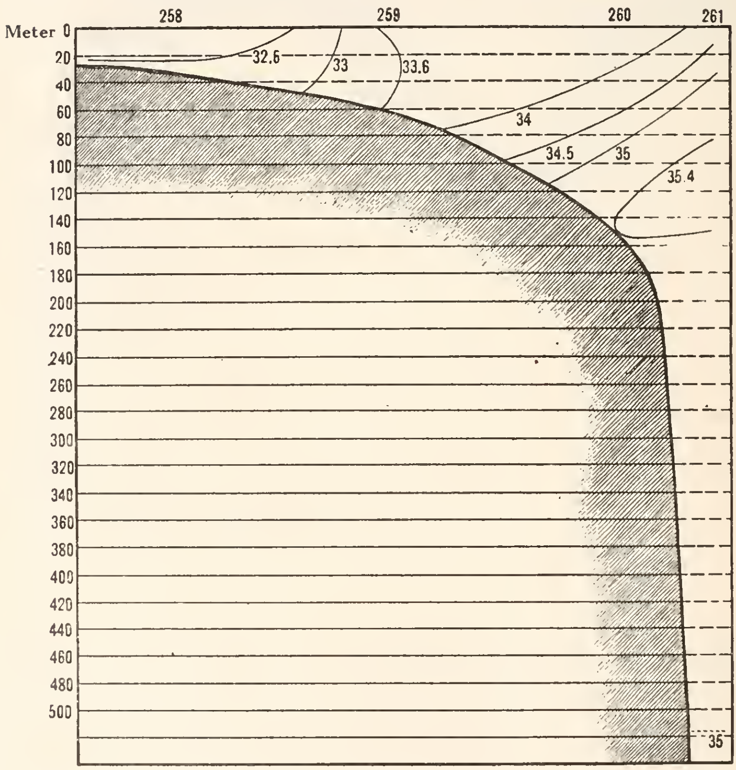

FIG. 32.— Salinity profile crossing the continental shelf off Marthas Vineyard, August 25–26, 1914.

a value actually below that of the bottom water of the southeastern part of the Gulf of Maine (p. 183).

Finally, the salinity profile from Marthas Vineyard to the continental shelf (Fig. 32) deserves brief mention. Along this line the general and characteristic increase in salinity from the land out across the shelf, reappears. And the peculiar conditions over the 60 meter contour (Station 10259), where the mid-depth was fresher than either

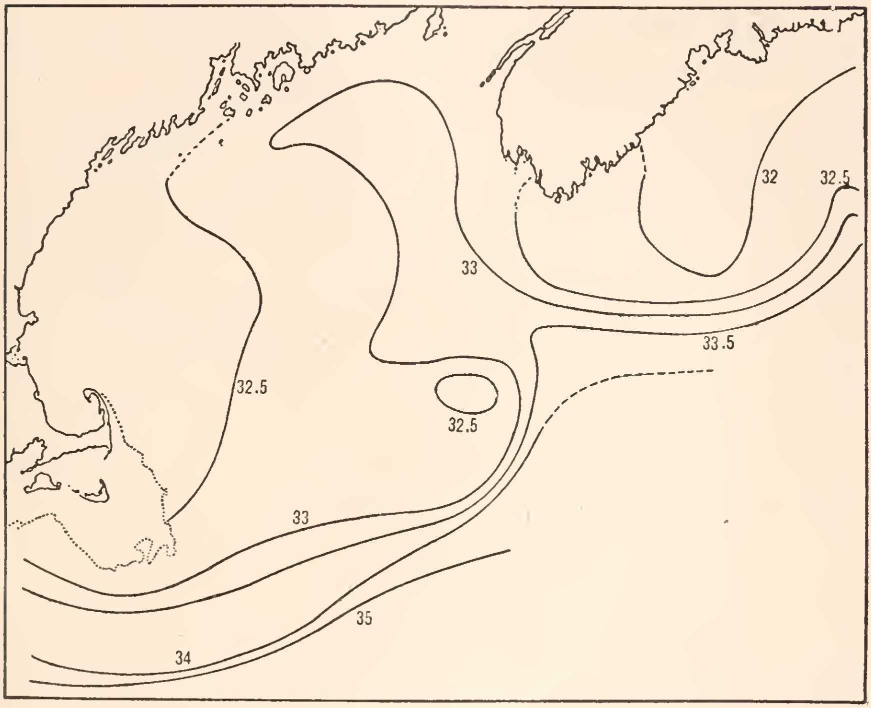

Fig. 33.— Salinity at 40 meters, July–August, 1914.

surface or bottom, suggest that the fresh, cool land water was moving seaward at about the 40 meter-level, while the fact that there was little further rise in salinity in the upper 40 meters for a distance of 30 miles south of this point, is evidence of the mixing of land and ocean waters.

Salinity at the 40, 100, and 200 Meter-levels.— At 40 meters (Fig. 33), the fresh areas, in the western half of the Gulf of Maine and again off the southern part of Nova Scotia, are as evident as on the surface (p. 181, Fig. 18); as is the fact that the water is much salter (35‰+) over the continental slope than anywhere on the shelf. The ocean water in the eastern side of the Gulf appears as a tongue of 33‰+ extending northwestward from the Eastern Channel and Brown's Bank nearly to the coast of Maine, turning westward along the coast to Penobscot Bay, with a secondary intrusion into the southeastern corner of the

Fig. 34.— Salinity at 100 meters, July–August, 1914.

Gulf, and even salter water (33.5‰) in the Eastern Channel. But the fresh tongue, so evident on the surface over nearly the whole length of Georges Bank (p. 182, Fig. 18), reappears only at the northeastern end of the Bank (Station 10226) at this level. And water salter than 33‰, which hardly encroaches at all on Georges Bank at its eastern end, covers almost half its breadth, at its western.

The salinity curves off southern Nova Scotia show the southward and westward expansion of comparatively fresh water off Shelburne, and the salter tongue approaching the land off Halifax as clearly at 40 meters as on the surface (Fig. 18).

There was no essential variation from this general distribution of salinity, *i. e.*, freshest in the western part of the Gulf of Maine and off southern Nova Scotia, saltest over the continental slope, down to

FIG. 35. Salinity at 200 meters, July–August, 1914.

100 meters, except such as results from the enclosure of the basin of the Gulf by its southern rim (Fig. 34). And the influence of ocean water in the southeastern part of the Gulf, (34.‰), with its chief line of dispersal toward the northeastern corner, and thence westward along the coast of Maine, is as unmistakable on the 100 meter as on the 40 meter chart. The tongue of high salinity (33.5–34‰) off Halifax

is even more pronounced at 100 meters than at the shallower levels, besides approaching much nearer the land, to swing, eddy like, westward along the coast.

The sudden east-west rise in salinity in the Northern Channel between Brown's Bank and Cape Sable, the only direct connection between the coast water off southern Nova Scotia, and the Gulf of Maine at this level, is discussed below (p. 238).

At 200 meters (Fig. 35) the salinity was about 33‰–34‰ in the basin as a whole, rising to 35‰ in its southeastern corner and in the Eastern Channel; and to 35.3‰ off the southern face of Georges Bank. And the salinity was slightly higher (34.4–34.9‰) in the basins off southern Nova Scotia than in the inner parts of the Gulf.

Temperature and Salinity on the Bottom.— The Cruise of 1914 allows the salinity and temperature of the bottom water to be charted for the entire breadth of the continental shelf east of Cape Cod, for the first time. But even these charts (Fig. 36, 37) are, of course, for midsummer only: in the cold months hydrography would be different. However, they are of interest as showing the physical environment of the bottom fauna in that year and season.

The most interesting feature of the temperature chart (Fig. 36) is that the bottom waters, independent of depth, are coldest in the western part of the Gulf of Maine (3.6° in the trough west of Jeffrey's Ledge), and off southern Nova Scotia, these two cold areas being separated by considerably warmer water (7°–8°) in the eastern part of the Gulf of Maine, just as is the case in the mid-depths (p. 179). In the western part of the Gulf the coldest bottom water formed a band between the 75 and 100 meter contours; off Nova Scotia, the minimum, 1°–2°, lay between 20 and 50 meters, with much higher bottom temperatures (8°–9°) in the deeps off Halifax.

The bottom temperature was much higher (10°–12°) on Georges Bank as a whole, and on the outer part of the continental shelf off Marthas Vineyard than anywhere in the Gulf, at an equal depth, or on either German Bank (9°–10°), Brown's Bank (8°–9°) or Le Have Bank (2°–3°). And, judging from past years (1914a, 1915) Nantucket Shoals were probably likewise colder than Georges Bank on the bottom, while the curves show an indentation of 7°–8° water from the northeast on the eastern end of the latter (p. 179).

In the Gulf, bottom salinity (Fig. 37) corresponds much more closely with depth than does bottom temperature, the shoal coastal zone being, as a whole, the freshest, as exemplified by the zone of 32–33‰, which follows the coast all the way from Marthas Vineyard to Halifax, probably including Nantucket Shoals, as well as the northern half of Georges Bank. And Le Have Bank was also fresher than 33‰ on the bottom. On the other hand bottom water salter than 34‰ corresponds, though not precisely, to the deep basin of the Gulf, and includes the deep basins off Halifax (34.–34.9‰). But the bottom of the shallow Brown's Bank was almost equally salt (34.2‰), a phenomenon connected with the intrusion of water of high salinity

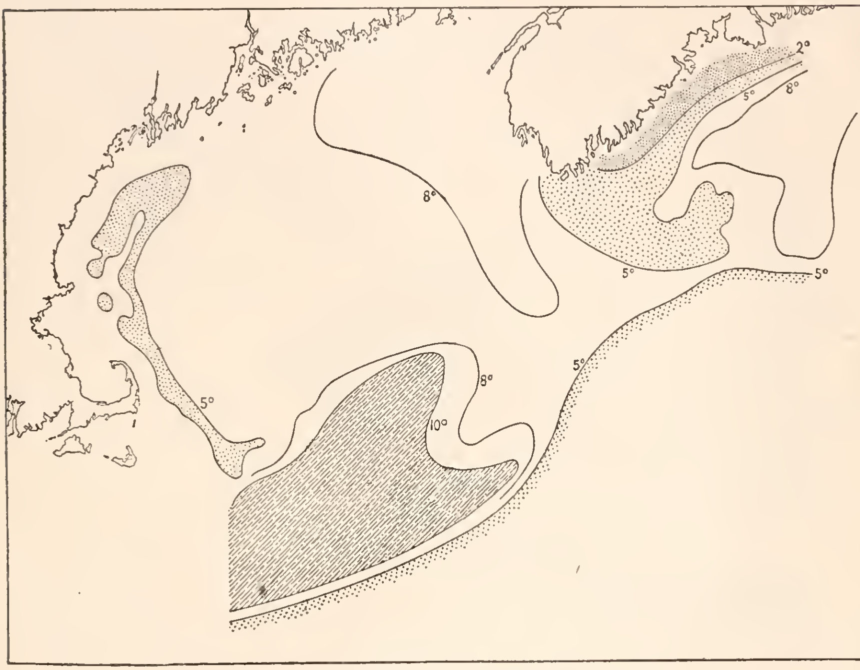

FIG. 36.— Temperature on the bottom, July–August, 1914.
⁞⁞⁞ = 2° –; ⁝⁝⁝ = 2° – 5°; ▨ = 10° +

via the Eastern Channel (p. 196), which also raises the bottom salinity of the southeastern corner of the Gulf above 35‰. The bottom water along a narrow belt following the continental slope between the 100 and 250 meter contours, was likewise salter than 35‰. Farther down the slope, however, the bottom salinity was lower, corresponding to the depth, and we found no bottom water as salt as 35‰ east of the Eastern Channel.

Density, at the Temperature in Situ.— In a region where waters of different temperatures and salinities meet, where local vertical circulation is active, and where winter cooling and summer warming are pronounced, the distribution of density in the upper layers must not only be complex, but constantly changing at any given locality. And Gulf waters are no exception to this rule, if small differences be considered. But in its main outlines the density of the Gulf is compara-

Fig. 37.— Salinity on the bottom, July–August, 1914.

⁝⁝⁝ = 33 ‰ −; ▨ = 35 ‰ +.

tively uniform in summer. In 1914 and 1915, as in previous years (1914a, 1915), density, both on the surface and in the depths, was higher in the eastern than in the western part of the Gulf. But local differences were more pronounced in 1914, owing to the distribution of salinity (p. 231). And the area of low surface density (below 1.023), noted over the Western Basin in 1912 and 1913 (1914a, 1915) was much more extensive in 1914. In August, 1915, the surface density of the Western Basin (Station 10307; 1.0233) was lower than that of the waters east and north of it (Station 10318, surface density 1.0242); but the surface density off Cape Ann was even lower (Station 10306; density 1.0228).

It is now possible, for the first time to compare the density of the Gulf of Maine, and of the waters off southern Nova Scotia, with that

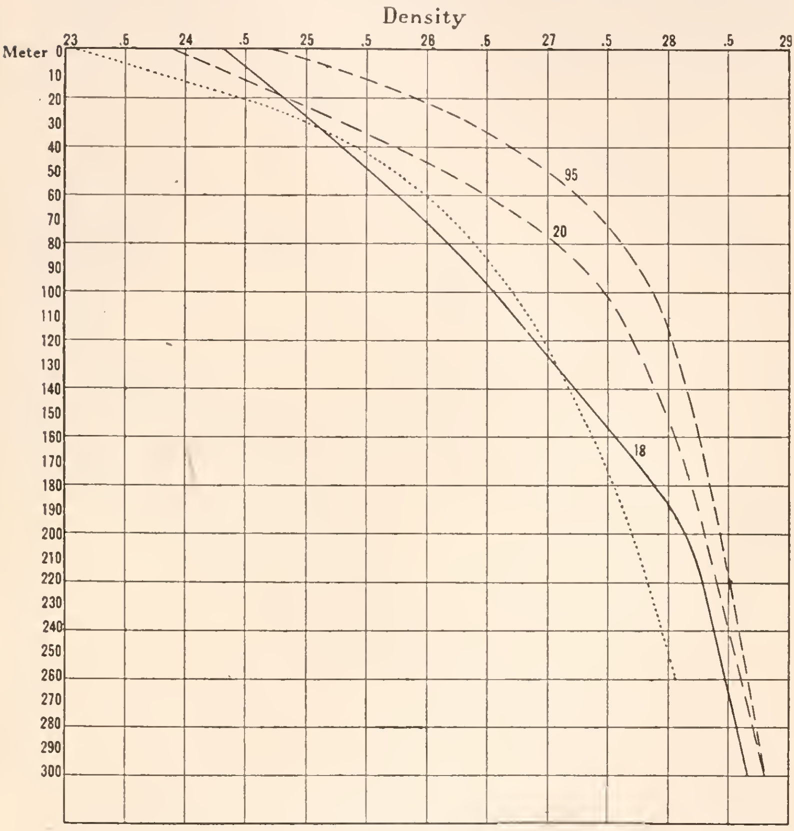

Fig. 38.— Summer density in the Western Basin of the Gulf of Maine. . . . , (average of 1914 and 1915); in the inner edge of the Gulf Stream ——— (Station 10218); and in the mixed water over the continental slope - - - - - - (Stations 10220, 10295).

over Georges Bank, in the inner edge of the Gulf Stream (Fig. 38), and in the mixed water along the continental slope. Down to 150 meters or so density was about the same in the western part of the Gulf as in the Gulf Stream water, except for the immediate surface of the former, which was decidedly lighter, owing to solar warming, with no corresponding increase in salinity. And even this slight difference does not extend to the eastern part of the Gulf, surface density being nearly the same there as on Georges Bank, or at Station 10218. Thus, on the profile across the western end of Georges Bank, there was no great general difference in density, down to the level of the Bank, between the waters over it, and north and south of it, though below that level the latter were considerably the densest. But, and this

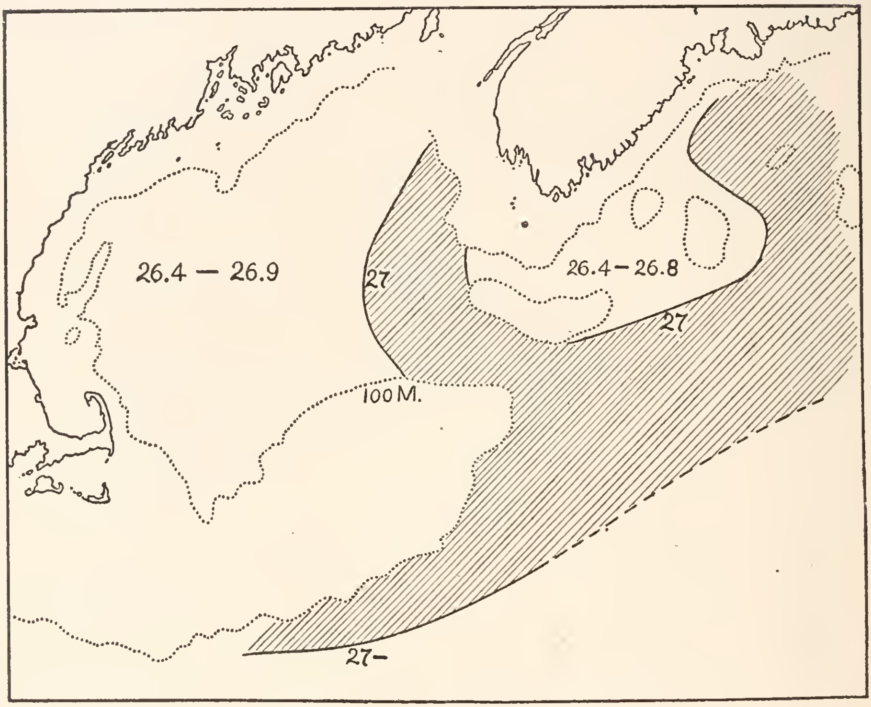

Fig. 39.— Density at 100 meters, July–August, 1915. Density above 1.027 is shaded.

is one of the most significant hydrographic discoveries made by the Grampus, the mixed water along the slope further east (Stations 10220, 10233, 10295), was considerably denser, from 50 down to about 180 meters, than the Gulf of Maine on the one hand, or Gulf Stream water on the other (Fig. 38), *i. e.*, at just the level where, owing to the topography of the bottom, ocean water can enter the Gulf only via the Eastern Channel. Below the latter the difference in density between Gulf Stream and mixed water diminishes, until at and below 200 meters, it is of doubtful validity.

The density at 100 meters, at which level the Gulf is practically an enclosed estuary (Fig. 39), is particularly instructive for its bearing on circulation (p. 239); for it not only shows this dense water (1.027+) separating the lighter Gulf Stream water from the slope in a triangle constantly widening from Station 10218 eastward, but reveals an equally dense tongue filling the Eastern Channel, and extending thence (Station 10225) northward into the Eastern Basin, while a second

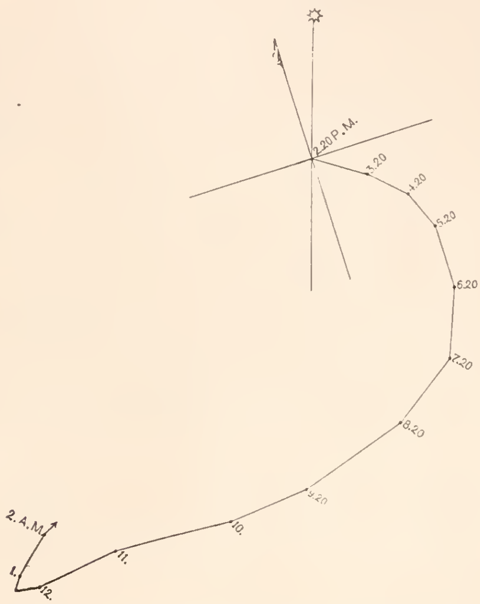

Fig. 40.— Diagram showing the surface current, at Station 10231, from 2.30 A. M. to 2 P. M. The distances between the dots give the drift. 1.5 cm. = 1 sea mile. The compass arrows are true and magnetic: variation about 19° W.

dense tongue (27+) approaches the land off Halifax, corresponding to the high salinity there (197). The intrusion of dense water into the Gulf via the Eastern Channel is equally evident down to about 200 meters; but below this level it is barred from the Eastern Basin by the ridge which encloses the latter on the south (Plate **2**).

Current Measurements.— The Ekman current-meter was used at one Station (10231) in 1914, off Shelburne, where measurements were taken at a depth of 3 fathoms, hourly for twelve hours, to cover an entire tide, ebb and flood. Bottom (30 fathom) readings were taken hourly, for four hours, and then again after two hours, covering the ebb, and the first of the flood. The results of these two sets are given in full in the table, and the surface drift shown graphically in Figure 40. The movements of the surface water off Nova Scotia are greatly influenced by the wind (British Admiralty, 1903); hence the value of current measurements depends largely upon the weather. In the present instance, we were favored by a dead calm, preceded by two days of light variable winds; hence the current may probably be taken as normal for the time and place.

The current at three fathoms was southeasterly at first; then veered through south to southwest, which was its general course for the major part of the flood; then shifted suddenly to the northeast at the commencement of the ebb. During most of the set the velocity was considerable, rising to nearly one knot per hour during the last half of the flood. The general movement of water for the whole tide (Fig. 40) was about four miles toward the southwest.

The bottom current flowed toward the E N E during the ebb, veering to the southwest at the beginning of the flood. Its flow was much less rapid than the surface current, its maximum, at the strength of the ebb, only .34 knot. The records are not sufficiently complete to establish whether or not there was any dominant flow on the bottom. But the fact that the direction of flow was practically uniform during the ebb, and that it was exactly reversed at the commencement of the flood, suggests that the dominant movement, if any, was small.

Current at 3 fathoms. Station 10231–July 27–28. High tide, Halifax, 11.40 A. M. High tide, Shelburne, 12.26 P. M.

(Directions are compass bearings (magnetic) from which current flows).

July 27, P.M.

Time	2.30	3.20	4.20	5.20	6.20	7.15	8.10	9.20	10.00	11
Duration, seconds	300	300	300	300	300	300	300	300	300	300
Direction	WNW	NW	NW	N	N	NE	ENE	E by N	E	E by S
Vel. cm. per sec.	22.3	25.2	12.4	21.9	29.5	29.07	44.2	51.4	49.9	48.5
Vel. knot per hour	.43	.48	.24	.43	.57	.57	.85	.99	.97	.94

July 28, A.M.

Time	12.10	1	2
Duration, seconds	300	300	300
Direction	ENE	SW by S	WSW
Vel. cm. per sec.	30.9	6.2	28.6
Vel. knot per hour	.59	.12	.55

Current at 30 fathoms. Station 10231.

July 27, P.M.

Time	2.15	3.10	4	5	7	8
Duration, seconds	600	300	300	390	600	300
Direction	W by S	WSW	WSW	WSW	?	NE
Vel. cm. per sec.	12.8	17.6	11.2	5.8	8.1	10.9
Vel. knot per hour	.24	.34	.21	.11	.15	.21

A strong southwesterly surface drift was also noticed on July 29, when the current set the ship about 15 miles to the southwest, during the occupation of Station 10235 and the run thence to the coast, with a brisk east wind and rough sea.

No current measurements were taken in 1915. But both in May and in June of that year we encountered a very strong surface current on German Bank, in the former instance toward the west, in the latter toward the north and northwest, which cannot be explained by the tides; and though these could not be measured accurately, the May current had a velocity of at least one knot.

Seasonal Changes in Temperature and Salinity.

We already have a fairly complete knowledge of the regular seasonal changes which take place in the shallow waters off the western shore of the Gulf (1914a, 1914b, 1915). And the records for 1915 add a general view of the summer cycle for the Gulf as a whole, with much needed light on the seasonal fluctuations of the Cabot Current.

The seasonal variations may first be outlined for the more instructive and better known localities individually, a composite picture of the annual cycle of the Gulf as a whole being attempted below (p. 213).

The water off Cape Ann, (Fig. 41 [1]), as a whole, is coldest in February (1914b); solar warming is first evident in March, when the temperature of the surface rises to that of the deeps; and after that the surface water warms very rapidly, from about 3.5° to its maximum of 17°–18°, which is reached at the end of July or early in August. The surface then cools almost as rapidly as it warmed, its temperature

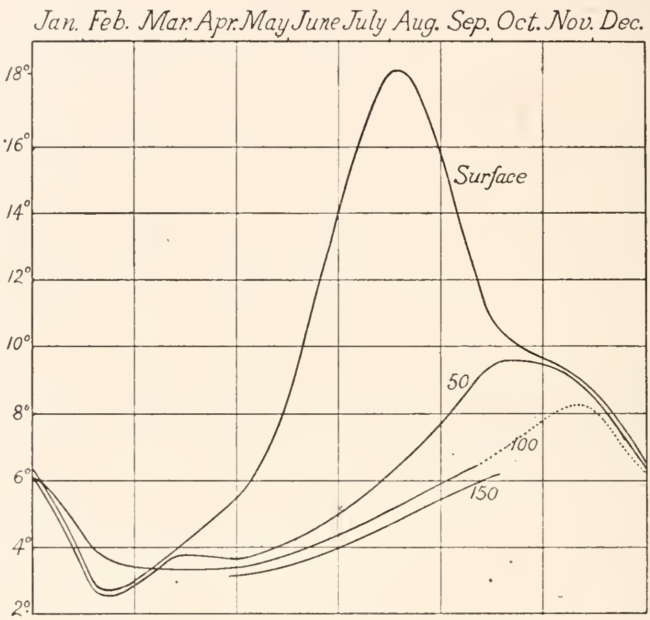

Fig. 41.— Annual range of temperature in the sink off Cape Ann at the surface, 50 meters, 100 meters, and 150 meters. (1912–1915). This is at the location of Station 10253 in 1914.

falling to about 10° by the first of October, after which there is a slower, but constant cooling, to the February minimum. Summer warming is less evident and the maximum reached later and later, as the depth increases; at 50 meters the maximum is about 9°–10°, early in October; at 100 meters about 8° in November.

The salinity is highest at this locality in March (above 33‰ for

[1] The diagrams for temperature and salinity off Cape Ann (Fig. 41, 42), are combined from the records of 1912–1915, but the annual variations are small.

the whole column), when spring freshening (1914b, p. 401) commences, the surface salinity diminishing until midsummer (July–August), with a change, in that period of about 2‰. The process is then reversed, the rise being equally rapid at first (August–October), then slower, but uninterrupted, until the maximum is once more attained. In the deep layers the maximum salinity is attained later (August–

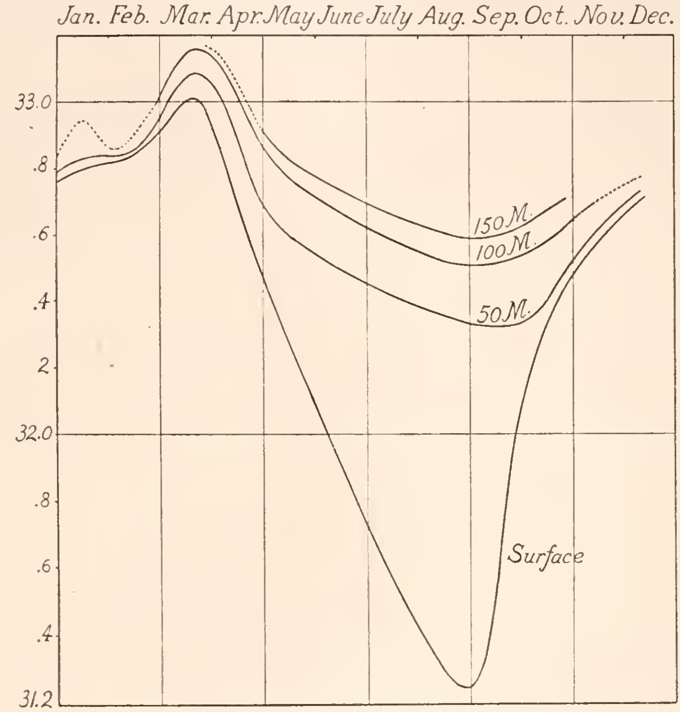

Fig. 42.— Annual range of salinity in the sink off Cape Ann, at location of Station 10253, at the surface, 50 meters, 100 meters and 150 meters, (1912–1915).

September); and the freshening is less and less pronounced as the depth increases, the annual range at 100 meters being only about .7‰. But the water is at its maximum salinity at about the same season, in all depths.

This region, the only one for which the records cover the entire year, typifies the temperature cycle of the upper layers of the western part of the Gulf as a whole. Thus both in the trough north of Cape Ann (Fig. 43), and over the Western Basin (Fig. 45, 46), the same rapid warming of the surface takes place during the spring and early summer, culminating in August; after which the water cools once more. And in the trough seasonal warming is appreciable down to 150 meters, just as it is off Cape Ann (Fig. 41). But in the deep Western Basin very little seasonal change took place with the advance of the season, in 1915, below 100 meters, which was the level of minimum temperature (p. 215). The temperature of the eastern half of the

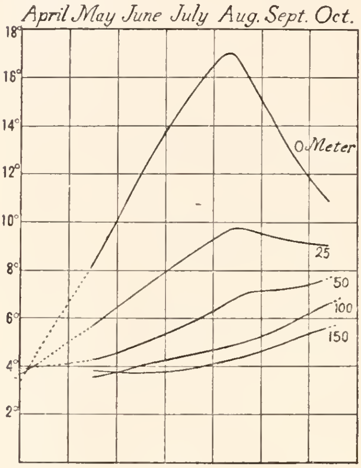

Fig. 43.

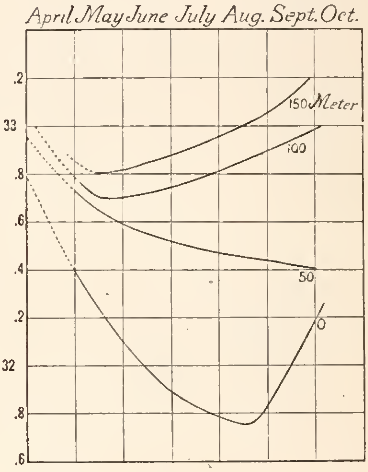

Fig. 44.

Fig. 43.— April to October temperatures at the surface, 25, 50, 100 and 150 meters, in the trough north of Cape Ann, for 1913–1915 (Stations 10278, 10325).
The dotted curves are for 1913 (1914b, p. 393).

Fig. 44.— April to October salinity at the surface, 50, 100 and 150 meters, in the trough north of Cape Ann for 1913–1915 (Stations 10278, 10325).
The dotted curves are for 1913 (1914b).

Gulf likewise rose, from May onward, as might have been expected. But the seasonal range of surface temperature is smaller there than in the west, (4°–20° in the western, 3°–13° in the Eastern Basin); and its maximum reached later in the season (Fig. 49, 51, 52). Thus summer warming results in a great increase in the vertical range of temperature, from spring to mid-summer, over the whole Gulf, except at localities, such as German Bank and the Grand Manan Channel, where the water is kept thoroughly mixed by strong tidal currents.

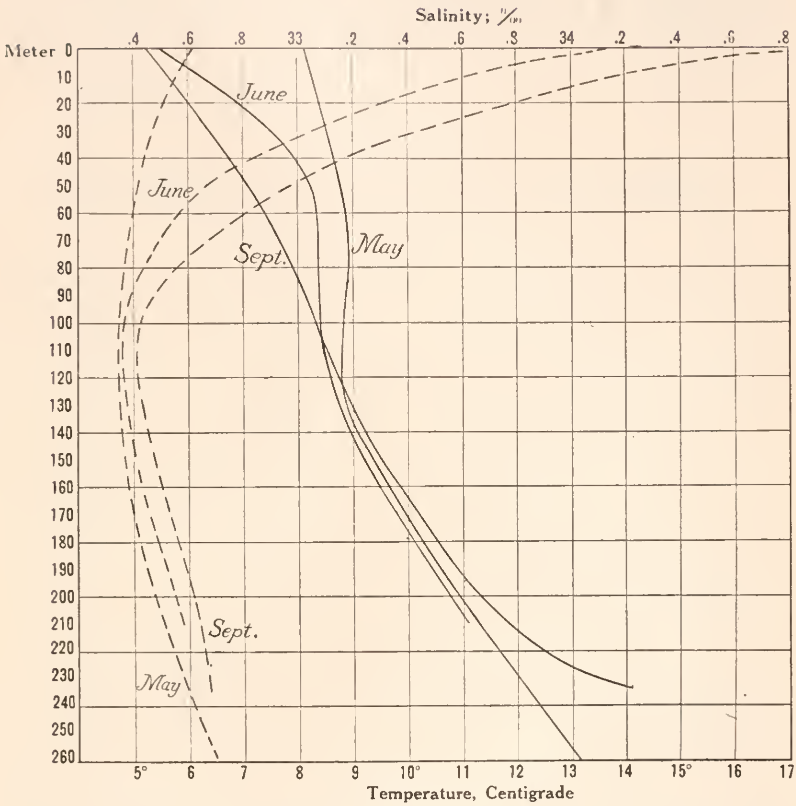

FIG. 45.— Temperature sections . . . . . ., and salinity sections ———, in the Western Basin of the Gulf of Maine, in May (Station 10267), June (Station 10299) and September (Station 10307, August 31) 1915.

But this vertical inequality is again obliterated during the autumn in the eastern, just as it is in the western part of the Gulf (1914b).

Even apart from such disturbing elements as vertical circulation caused by local currents, the seasonal range of salinity is less uniform over the Gulf than is that of temperature. To begin with, the seasonal variation is much smaller in the deep basin than near land, as

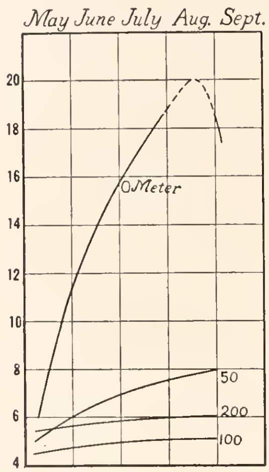

Fig. 46.

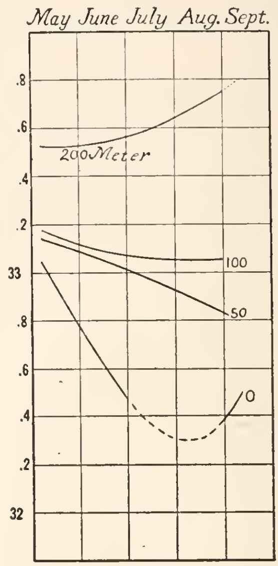

Fig. 47.

FIG. 46.— Temperature at the surface, 50, 100 and 200 meters, in the Western Basin, May–September, 1915.

FIG. 47.— Salinity at the surface, 50, 100 and 200 meters, in the Western Basin, May–September, 1915.

might be expected in view of the influence of river water (p. 239; 1914a, 1915). Thus over the Western Basin the surface salinity changed only by about .7‰ (Fig. 45, 47) from May to September, as against a range of nearly 2.‰ off Cape Ann (Fig. 42); though the surface was at its minimum at about the same season. And there was practically no seasonal change in the mid-depths of the Western Basin; a statement likewise true of the bottom water from May to June. The latter, however, showed a decided rise in salinity from June to September. Similarly, the range of salinity in the Eastern Basin, in the

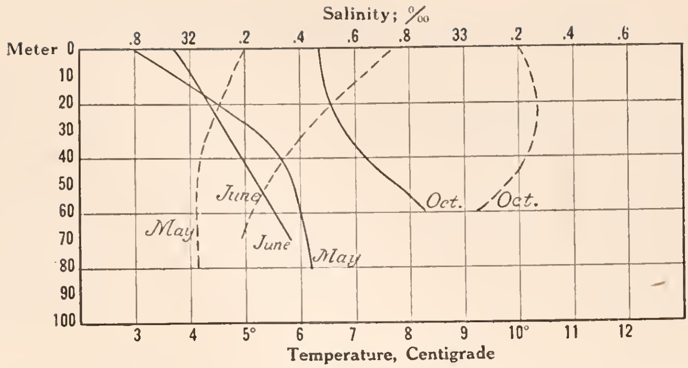

FIG. 48.— Temperature sections ...... and salinity sections ———, off Matinicus, in May (Station 10276), June (Station 10287 and October (Station 10329), 1915.

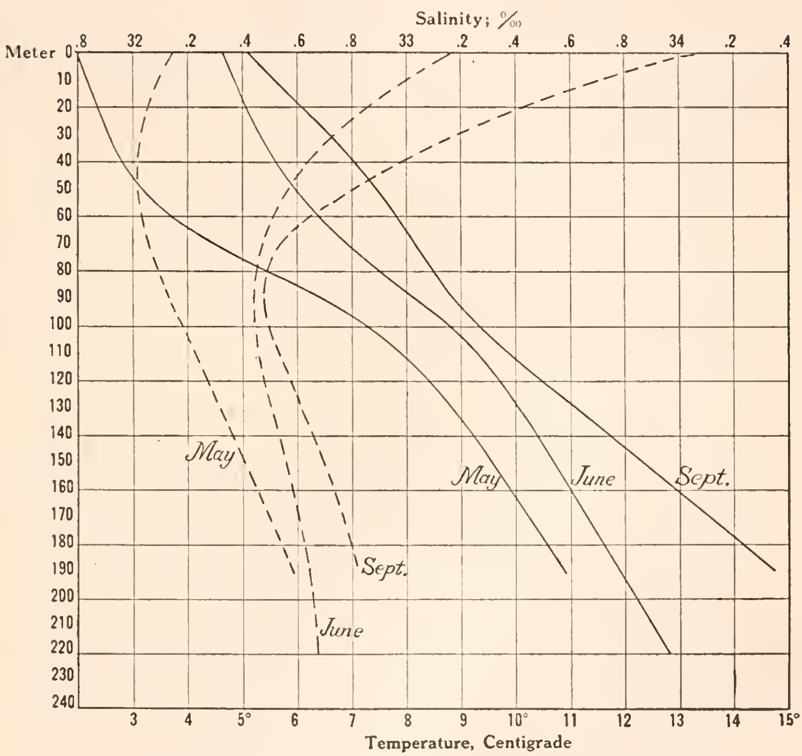

FIG. 49.— Temperature sections ,......, and salinity sections, ———, in the eastern part of the Eastern Basin of the Gulf of Maine, May (Station 10270), June (Stations 10288 and 10289), and September (Station 10310), 1915.

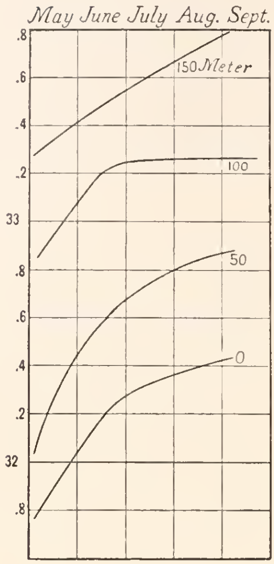

Fig. 50.

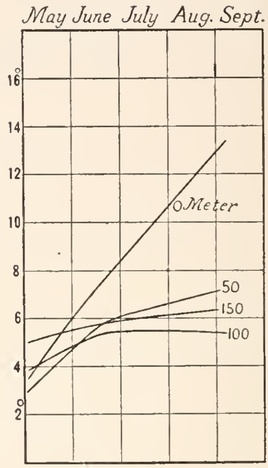

Fig. 51.

Fig. 50.— Salinity at the surface, 50, 100, and 150 meters in the eastern part of the Eastern Basin, May–September, 1915.

Fig. 51.— Temperature at the surface, 50, 100, and 150 meters in the eastern part of the Eastern Basin, May–September, 1915.

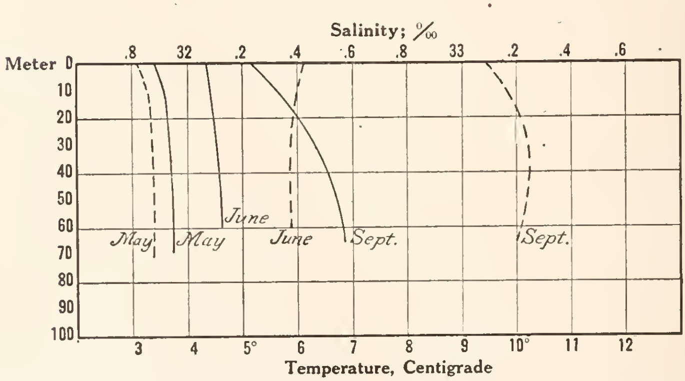

Fig. 52.— Temperature sections, ... , and salinity sections ———, on German Bank, May (Station 10271) June (Station 10290) and September (Station 10311), 1915.

seasons covered by our work, was only about .6‰ on the surface (Fig. 49, 50), though here the change was practically as great at all depths as on the surface.

Another local difference, which deserves special note, for its bearing on the cause of the annual spring and summer freshening, is that salinity reaches its minimum much earlier in the year in the eastern than in the western part of the Gulf. For example, while salinity is at its maximum, and the upper layers at their minimum, at about the same season (Fig. 44) in the trough north of Cape Ann

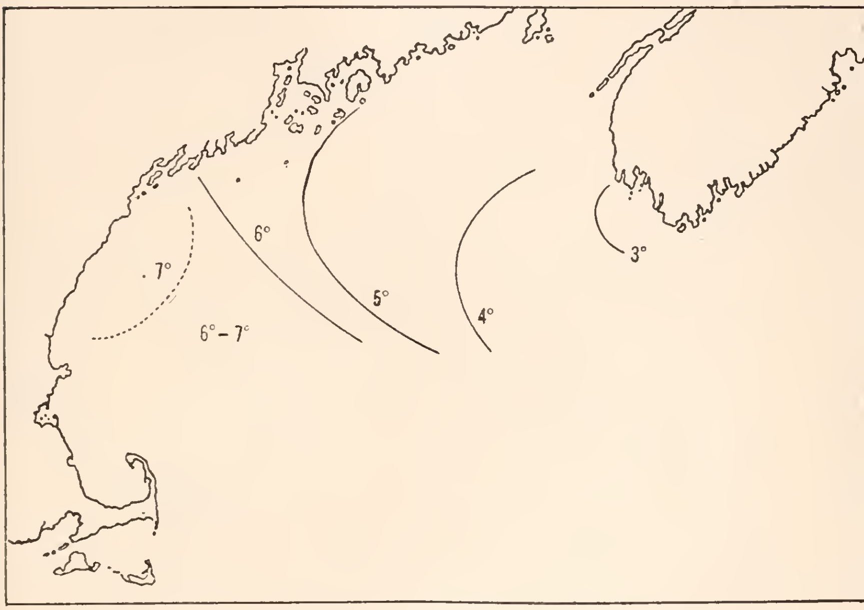

FIG. 53.— Surface temperature of the northern half of the Gulf of Maine, May, 1915.

as east of the latter, the deeper layers are at their minimum there in May instead of in midsummer. And further east, *i. e.*, off Matinicus (Fig. 48), next the coast east of Mount Desert, the eastern side of the Eastern Basin (Fig. 49, 50), German Bank (Fig. 52) and Lurcher Shoal (Stations 10272, 10315, p. 340), the entire column of water was freshest in May after which a rise in salinity took place at all depths.

The general hydrographic changes which characterize the Gulf as a whole as exemplified by the observations in 1915, are illustrated by the charts and profiles (Fig. 53–71).

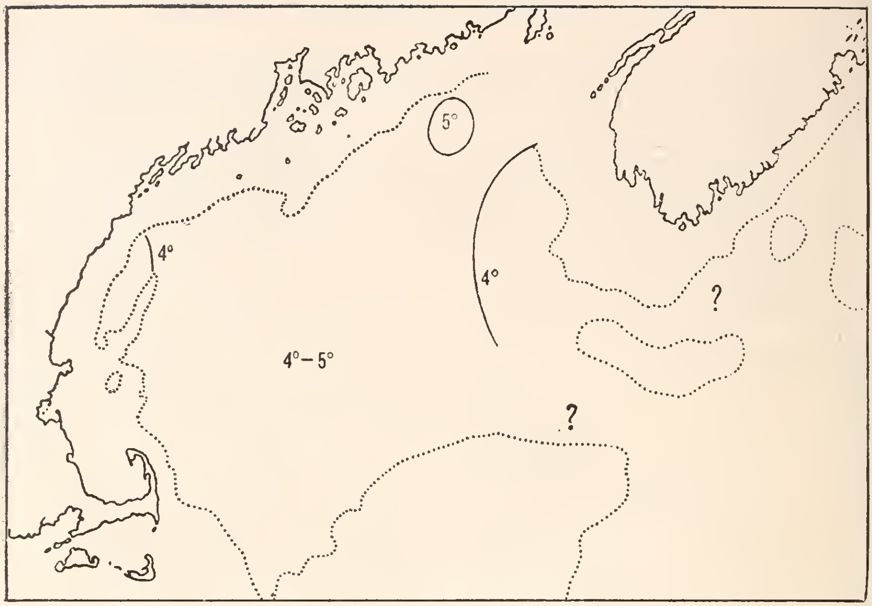

Fig. 54.— Temperature at 100 meters, May, 1915.

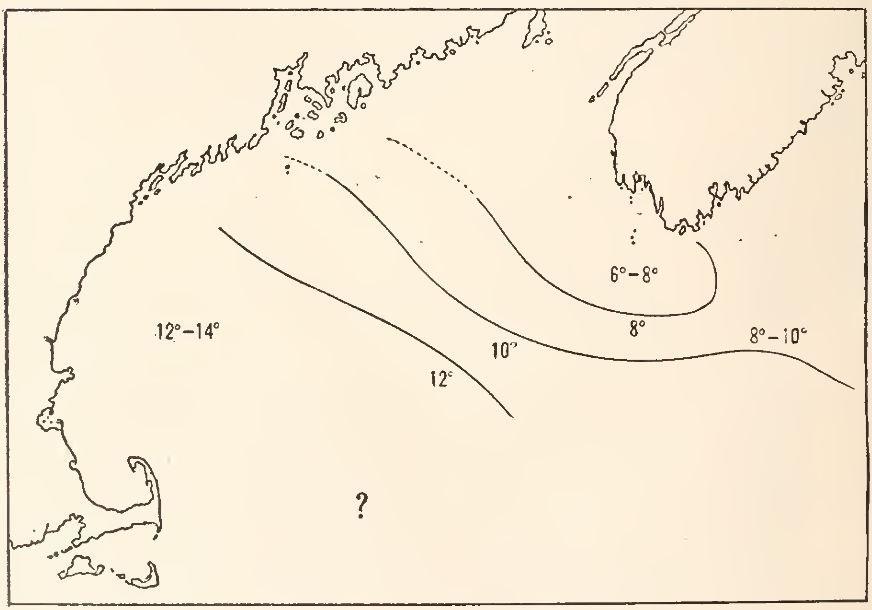

Fig. 55.— Surface temperature, June, 1915.

In early May the temperature of the upper 15 meters or so was already considerably higher than the winter minimum, much more so in the western than in the eastern side of the Gulf, with a west to east range on the surface (Fig. 53) from about 7° off Cape Ann to 3° on German Bank. But in the mid-depths, at from 40 to 100 meters, the coastal zone on the western side of the Gulf (Stations 10266, 10278), was practically as cold (3°–4°) as German Bank and its western slope (Fig. 54, 69), with warmer water in the intervening basin. The profile (Fig. 69) is also interesting both as showing that the minimum temper-

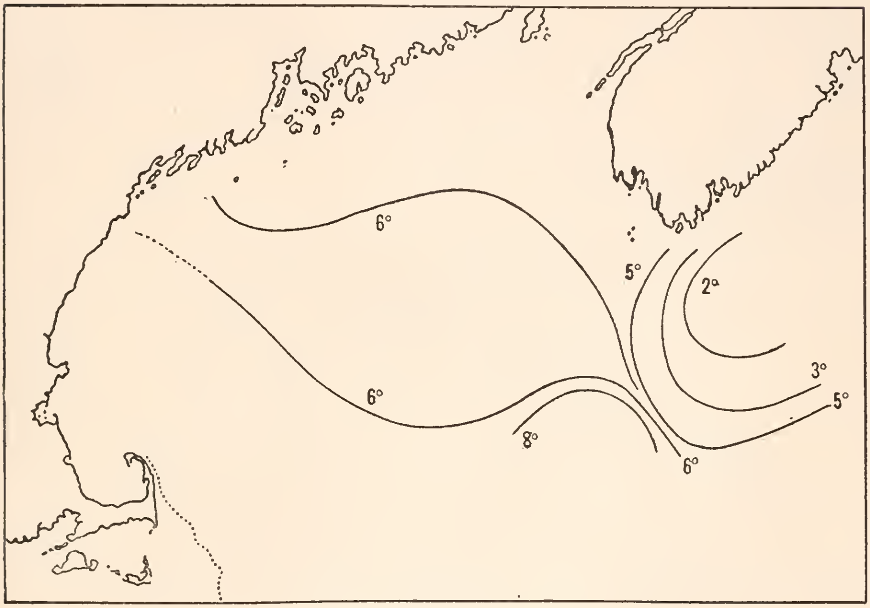

Fig. 56.— Temperature at 40 meters, June, 1915.

ature for the central part of the Gulf was at about 100 meters, with warmer water below, the thick layer of surface water warmer than 5° over the Western Basin foreshadowing the high temperature which characterizes that region in summer (p. 166), and as illustrating the mass of cool surface water (4°–) in the eastern side of the Gulf which finds its counterpart in low salinity (p. 223). With the advance of the season the temperature of the surface layers continues to rise faster in the western than in the eastern half of the Gulf, until by the

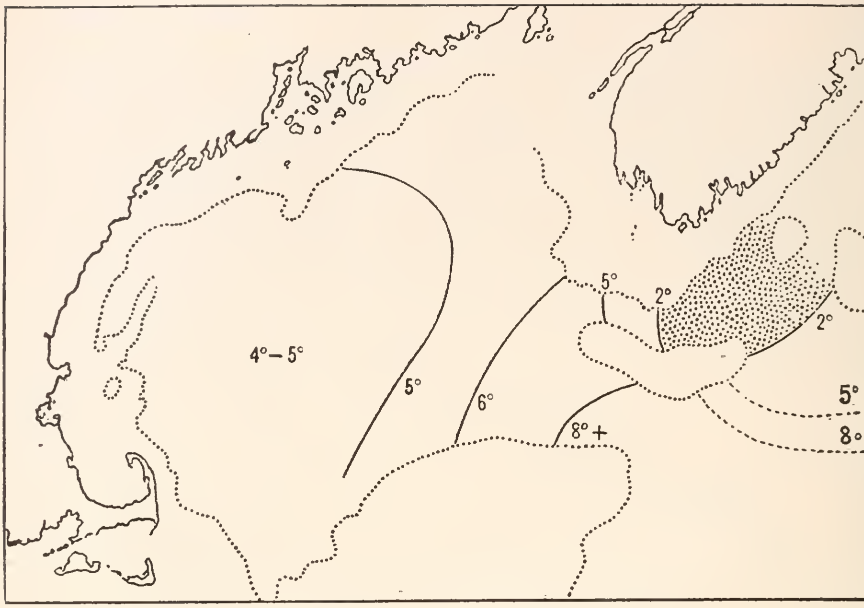

Fig. 57.— Temperature at 100 meters, June, 1915.

Fig. 58.— Surface temperatures, August 31–September 7, 1915.

middle of June the discrepancy between the surface readings on the two sides was upward of 6° (12°–14° in the Western Basin, 6°–8° on German Bank, and along the west coast of Nova Scotia, Fig. 55). But in the mid-depths, the western side of the Gulf lags behind its central and southeastern parts in summer warming (Fig. 56, 57), which results in the reestablishment of one of the most important features of summer, *i. e.* the fact that the eastern part of the Gulf is warmer than the western, except for the immediate surface.

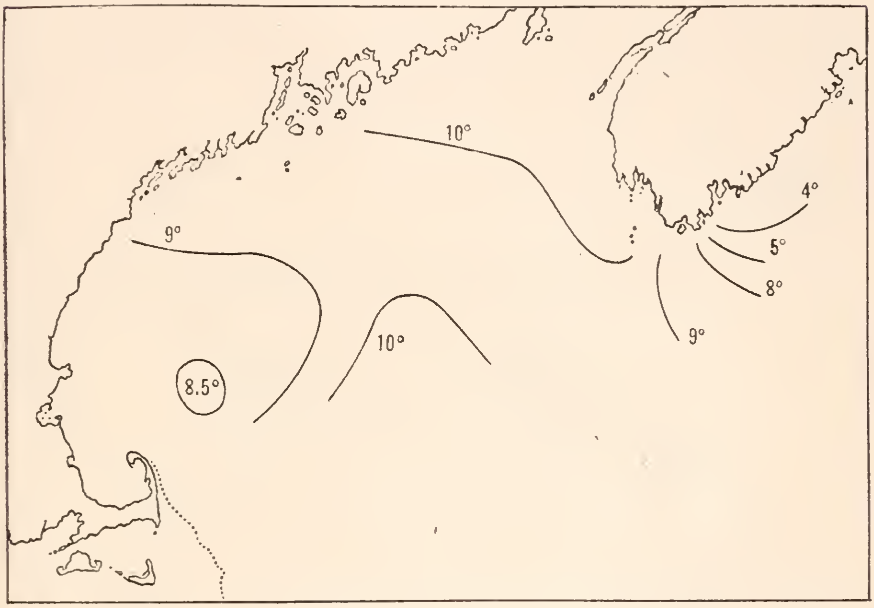

Fig. 59.— 40 meter temperature, August 31–September 7, 1915.

The deeper levels are particularly interesting at this season, because our work extended far enough east to reach the undiluted Cabot Current, which was not the case in May. At 40 meters the influence of the current was evident (Fig. 56) across the whole of the continental shelf abreast of Shelburne in very low temperature (.7°–2.87°), and in the shelf-like projection of water colder than 5° beyond the slope, at the 70–80 meter-level, with higher temperatures below, as well as above it (Fig. 73) the same as in summer (p. 174). And the tem-

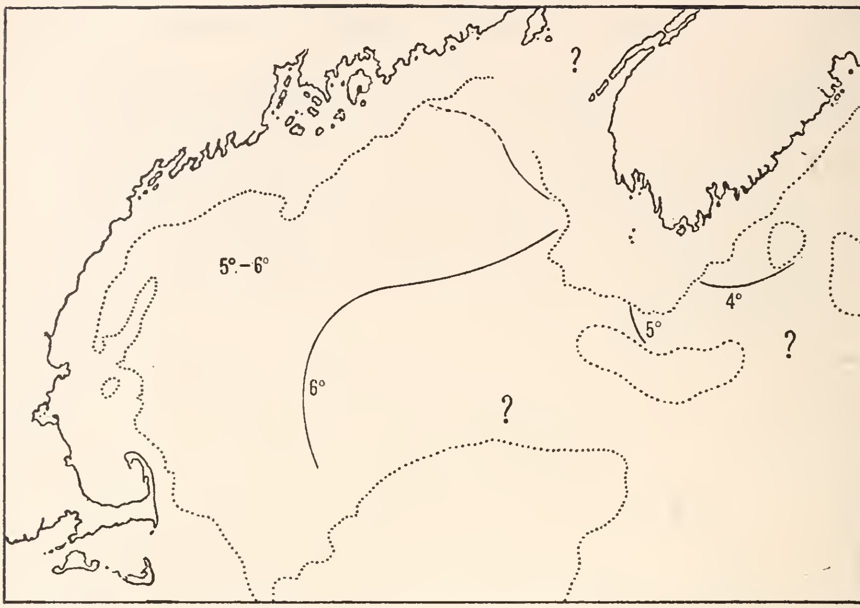

FIG. 60.— 100 meter temperature, August 31–September 7, 1915.

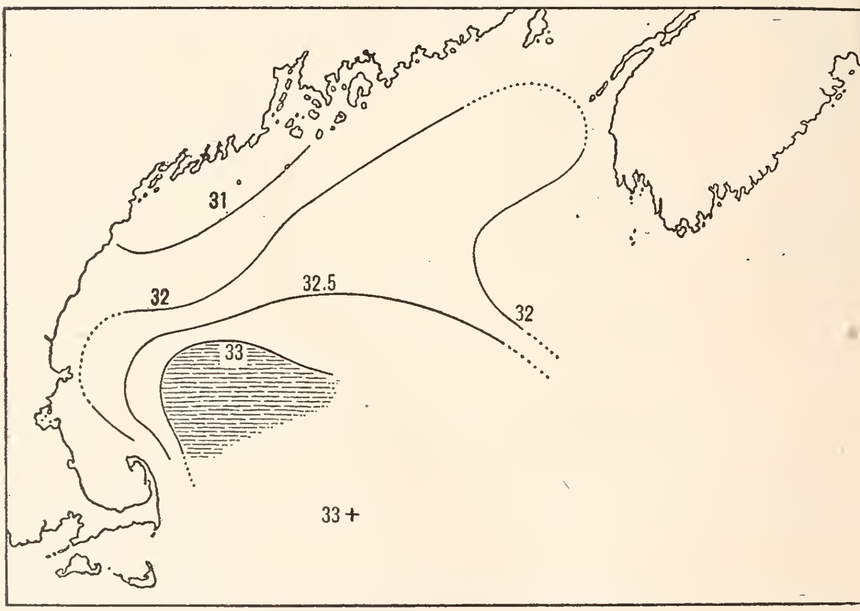

FIG. 61.— Surface salinity in May, 1915.

perature as a whole was lower along this line as well as over the slope, in June than in the preceding August, as might have been expected; while had it not been for solar warming of the previous few weeks, the surface would doubtless have been nearly as cold as the 60 meter-level, as is probably the case in winter. But in June this cold Cabot Current water has no apparent effect on the temperature of the Gulf at any depth, there being a sudden transition in the Northern Channel and over Brown's Bank from the low temperatures (2.°) of the one to warmer water of the other (Fig. 56, 57).

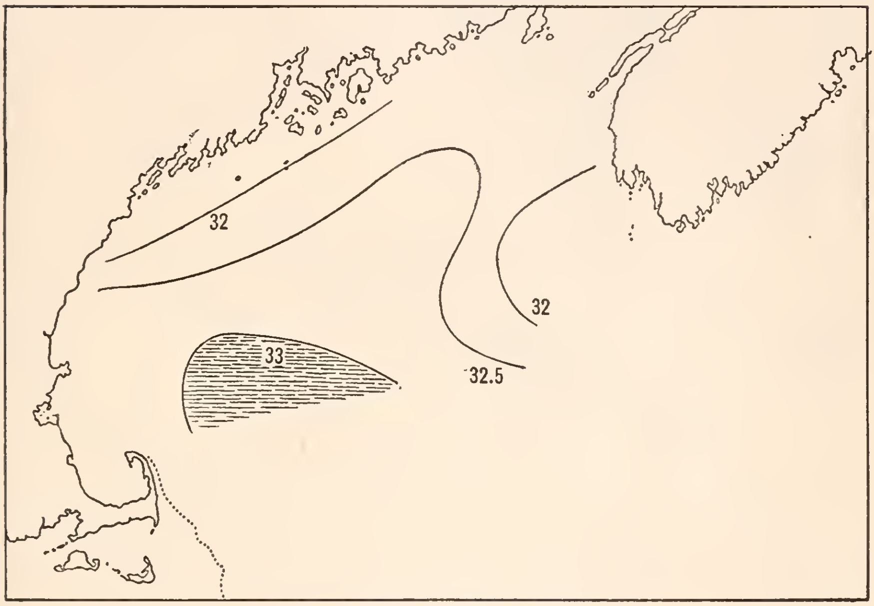

FIG. 62.— Salinity at 40 meters, May, 1915.

Judging from the experiences in past years, the temperature of the upper layers had probably passed its midsummer maximum and autumn cooling had commenced by late August, and early September, when we made our third oceanographic cruise in 1915, as is illustrated by comparing the surface temperatures for July and August, 1914 (Fig. 1) with the chart for September 1915 (Fig. 58). But while the western part of the Gulf had cooled by about 2°, cooling had not penetrated downward to any distance, for the 40 meter-level (Fig. 59)

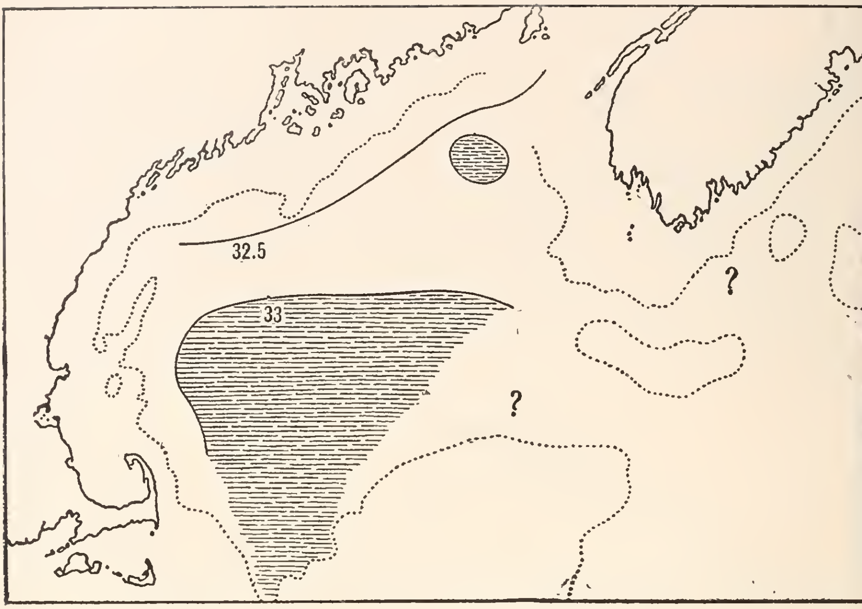

FIG. 63.— Salinity at 100 meters, May, 1915.

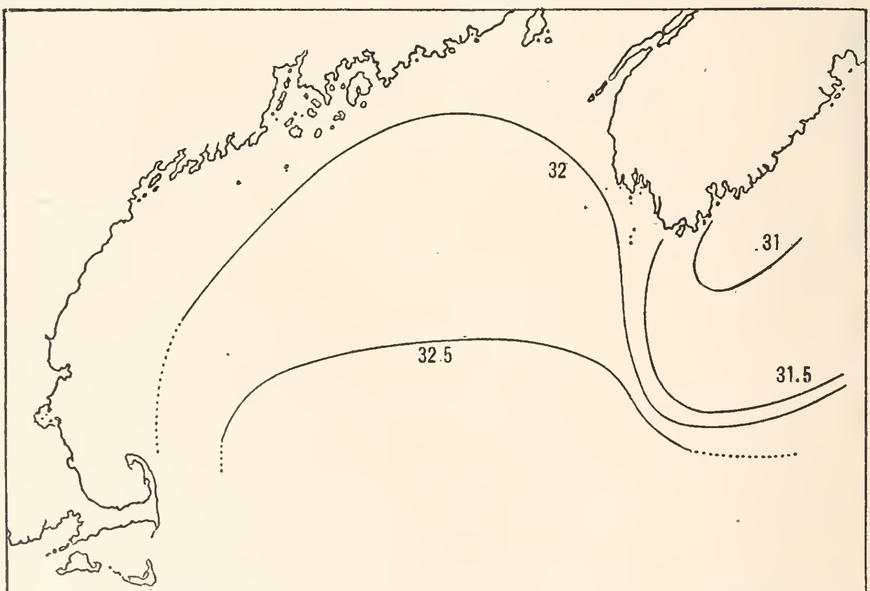

FIG. 64.— Surface salinity, June, 1915.

was slightly warmer in September, 1915, than in August, 1914, though the general distribution of temperature was the same. And this is also true at 100 meters (Fig. 60) where the western half of the Gulf was about 1°, the waters off western Nova Scotia 2°–3° warmer in September than in June. And the temperature profile across the Gulf for September (Fig. 71) corresponds fairly well with the corresponding profile for August, 1913 (1915, Fig. 71), especially in the presence of the cold layer at about 100 meters, while the banking up of bottom

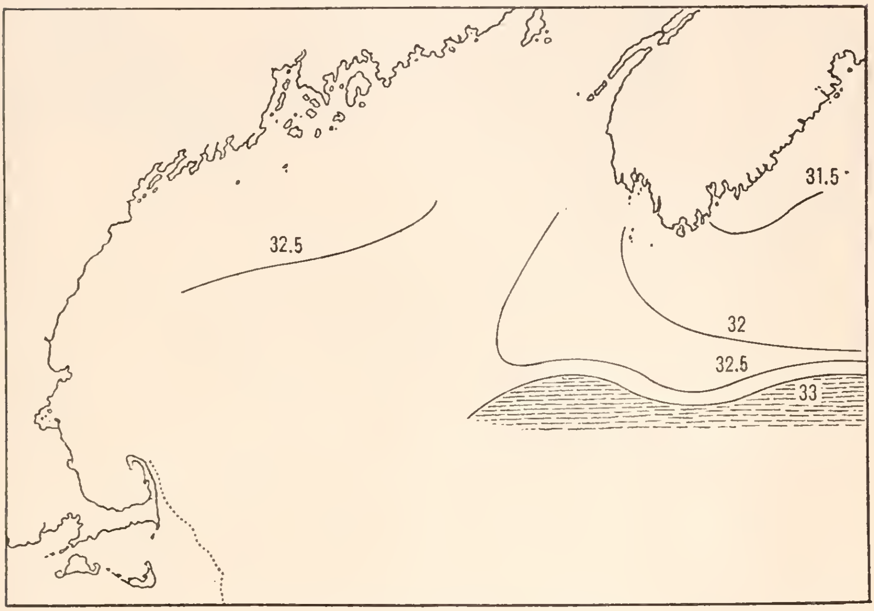

Fig. 65.— Salinity at 40 meters, June, 1915.

water warmer than 8° against Nova Scotia reproduces conditions obtaining in 1913 (1915).

In the depths of the Gulf, at and below 200 meters, there was practically no change in temperature from May to September, except off the slope of German Bank (Stations 10270, 10310) where it rose by about 1°.

The September temperatures off Shelburne (Fig. 76) are interesting, in connection with salinity, as evidence of a shrinkage of the Cabot Current (p. 242), the minimum temperature having risen from .7° to

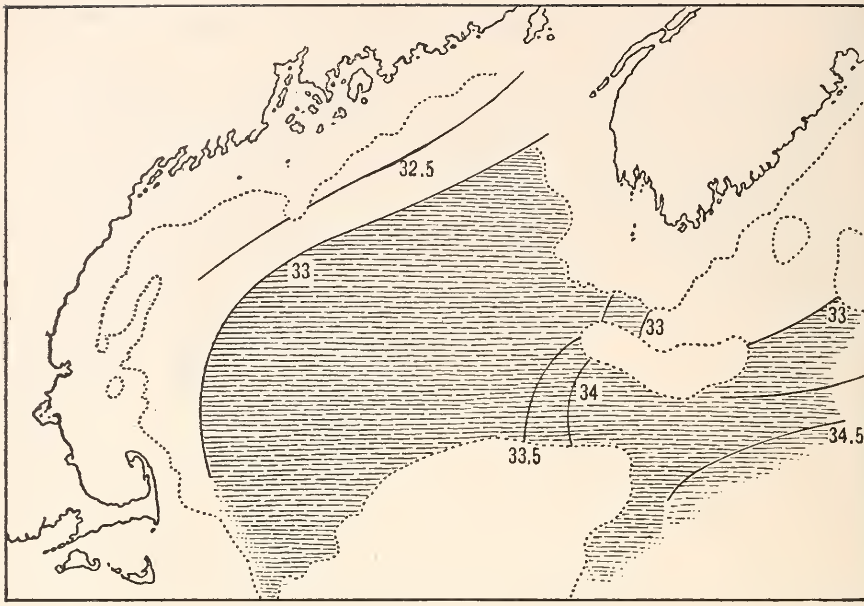

FIG. 66.— Salinity at 100 meters, June, 1915.

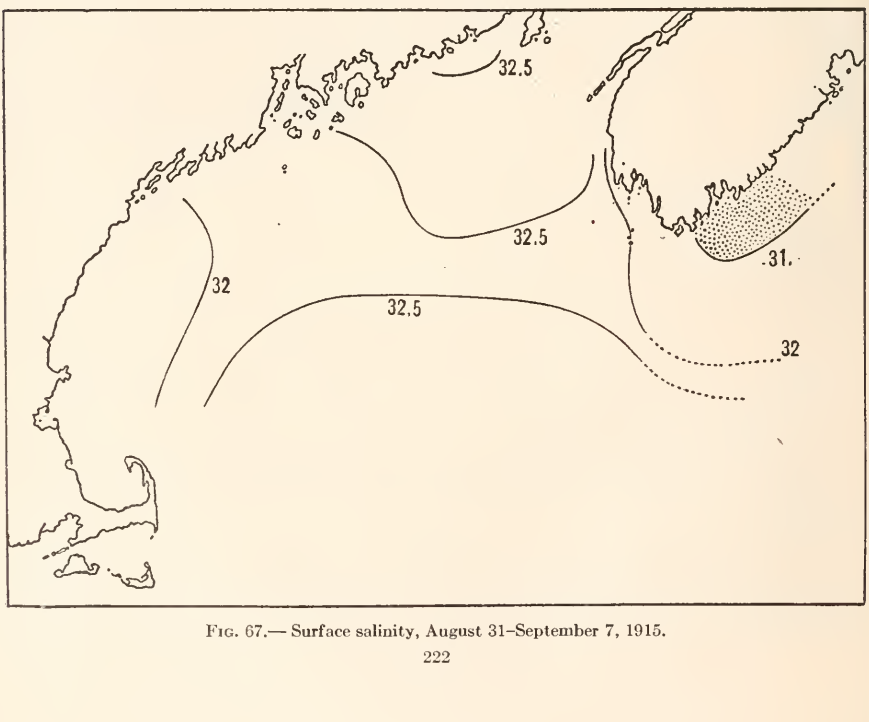

FIG. 67.— Surface salinity, August 31–September 7, 1915.

2.2° (Station 10213, 70 meters), and water as cold as 4° being confined to a narrow belt next the land both at 40 meters (Fig. 59) and 100 meters.

The general salinity cycle in the Gulf of Maine is as follows:—

In March the salinity of the whole column of water, in the western part of the Gulf, is above 33‰ (1914b): during April the spring freshets lower the surface salinity along the western shore to, or below, 32‰. However, this fresh land water does not spread far offshore in early spring, for in May we found the surface of the Western Basin

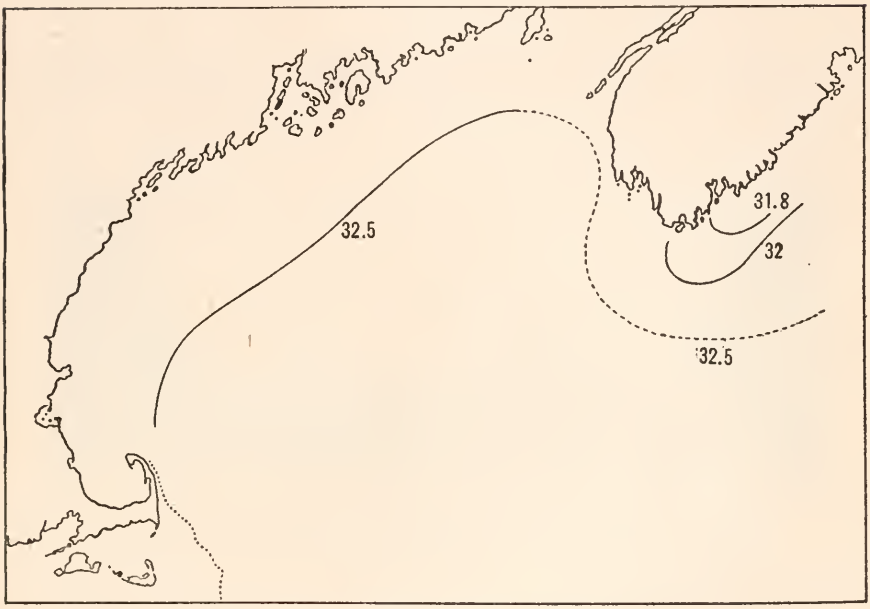

Fig. 68.— Salinity at 40 meters, August 31–September 7, 1915.

about 33‰ (Fig. 61), though the surface all around the shores of the Gulf, was then fresher than 32‰, this fresh belt spreading far enough eastward from Nova Scotia to include German Bank and the eastern part of the Eastern Basin (Station 10270).

The 40 meter chart for this month (Fig. 62) shows much this same distribution of salinity, *i. e.*, high in the center of the Gulf, 32‰ or lower along the coast of Maine and from Nova Scotia to the Eastern Basin. And the salinity profile for May (Fig. 70) is especially instructive, for the curves over the eastern slope of the Gulf reveal an intrusion of water of low salinity, from the east, of which we have found no trace in summer, and which is undoubtedly the result of an influx of the Cabot Current around Cape Sable. But at, and below 100 meters, there is no evidence of it, though even at this depth the influence of the spring freshets is apparent in the western side of the Gulf (Fig. 70). As pointed out (p. 213) the water along the coast of Maine, and the Eastern Basin of the Gulf are at their freshest in, or before, May. And by June a slight rise in salinity is apparent over the eastern half of the Gulf at all depths down to 100 meters (Fig. 64–66), the expansion of 33‰ water to the east and northeast being

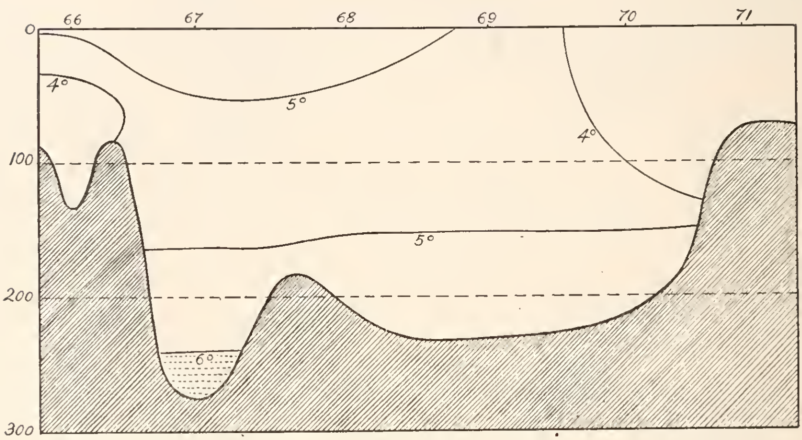

Fig. 69.— Temperature profile across the Gulf of Maine, from off Cape Ann (Station 10266) to German Bank (Station 10271), May 4–7, 1915.

especially striking (*cf.* Fig. 63, 66) at that level, though it does not yet reach the northern slope, as is the case in mid-summer (Fig. 34), nor has 34‰ water yet intruded beyond the Eastern Channel. The salinity curves off Nova Scotia show that the influence of the Cabot Current in the Gulf diminishes from May to June. On the surface it is entirely obliterated there by that time, though the salinity across the whole breadth of the continental shelf off Shelburne is still below 32‰ (Fig. 64). But at 40 meters (Fig. 65) the curve for 32.5‰ still suggests the presence of Cabot Current water as far west as the Eastern Basin. And off Shelburne (Fig. 74), the low salinities (31–32‰) of the Cabot Current and land water combined, still extend across the whole breadth of the shelf in the upper layers, though with decidedly salter water below about 80 meters, thus corroborating the corresponding temperature profile (Fig. 73).

The alteration in salinity in the western side of the Gulf from May to June, *i. e.*, a decided freshening at all depths down to about 100 meters (p. 207), resulting in the disappearance of 33‰ water down to 40 meters (Fig. 70, 72), is just the reverse of what takes place in the eastern side. Below 100 meters, however, there was very little alteration in salinity from May to June (p. 207, Fig. 45) in the Western Basin.

If our September data for 1915 represent the normal salinity for

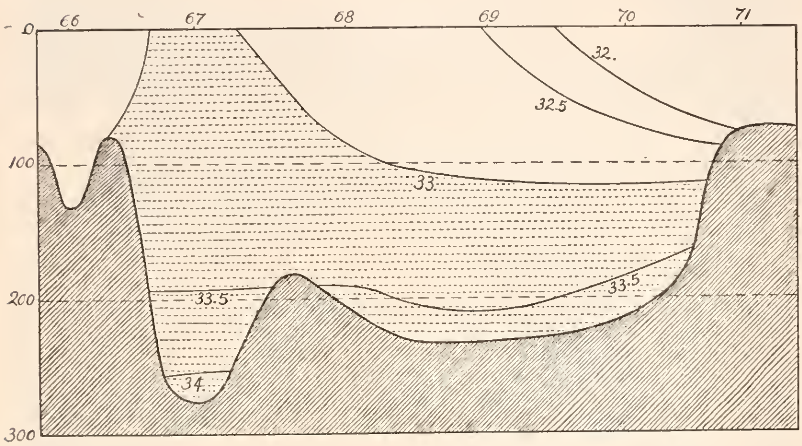

Fig. 70.— Salinity profile across the Gulf of Maine, from off Cape Ann (Station 10266) to German Bank (Station 10271), May 4–7, 1916.

that season, the summer salting of the upper layers in the eastern part of the Gulf must by then have passed its climax, and the salinity have commenced to diminish once more. On the surface, it is true, very little difference is apparent between the charts for mid-summer, and for September (Fig. 18, 67) in that region. But at 40 meters (Fig. 33, 68), the whole eastern half of the Gulf was fresher in September than in August, and there is no sign of the tongue of 33‰ water so evident in mid-summer, both in 1914 and in 1912 (1914a, pl. 2). And the same generalization holds equally for the 100 meter-level, where the September salinity of the Eastern Basin was only about 33.2‰, as against 33.6–33.8‰ in August, 1912; 33.5–34‰, in August, 1914

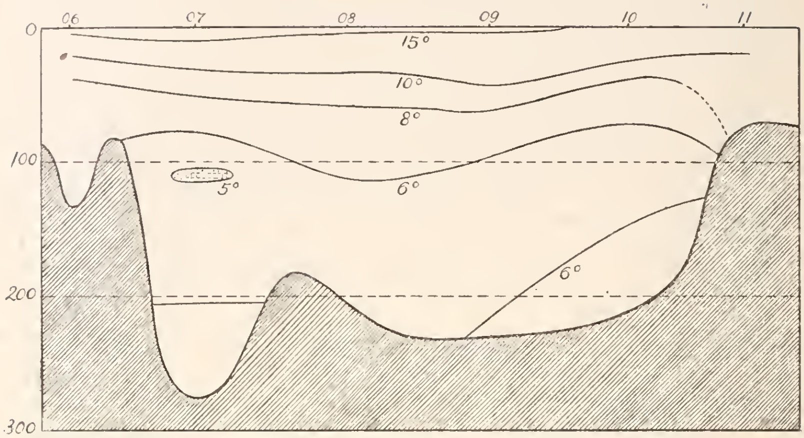

Fig. 71.— Temperature profile across the Gulf of Maine from off Cape Ann (Station 10306) to German Bank (Station 10311), August 31–September 2, 1915.

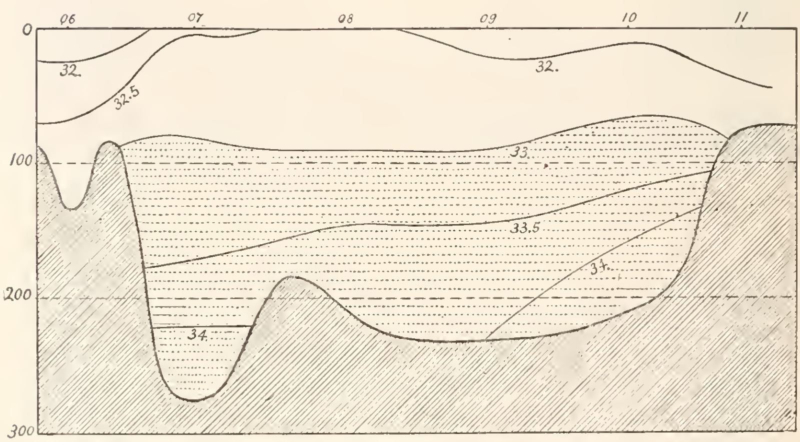

Fig. 72.— Salinity profile across the Gulf of Maine from off Cape Ann (Station 10306) to German Bank (Station 10311) August 31–September 2, 1915.

(Fig. 34, 72; 1913, Fig. 29). But this early autumn freshening (if it be a characteristic phenomenon) is confined to the eastern half of the Gulf, just the reverse being true of the western side, where the salinity of the upper layers is at, or near, its lowest in mid-summer (p. 207), with an increase of salinity already apparent on the surface by early September (Fig. 18, 42, 67). And though no great change takes place in the mid-depths from mid-summer to September, the

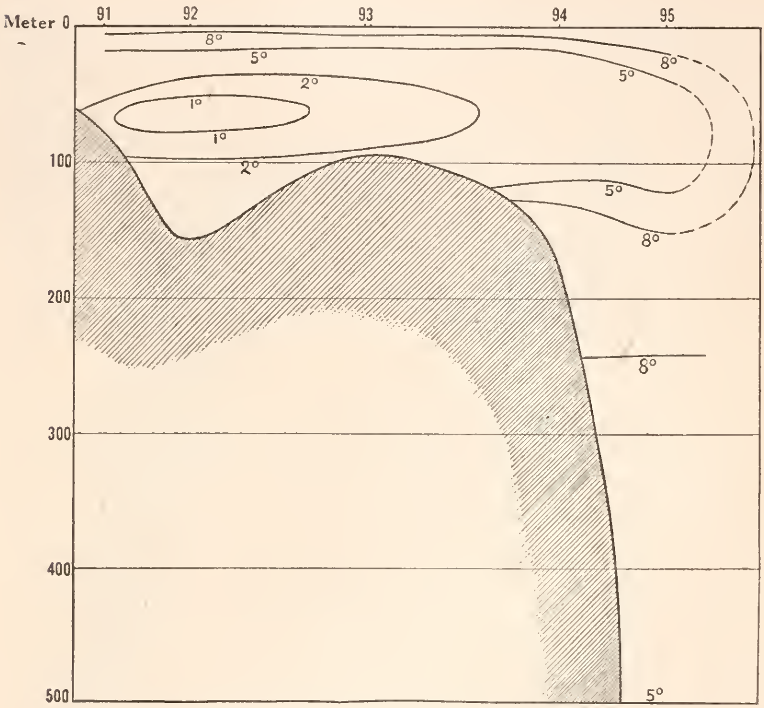

FIG. 73.— Temperature profile across the continental shelf off Shelburne, Nova Scotia, June 23, 1915 (Stations 10291–10295).

general rise in salinity characteristic of autumn and winter (p. 207) is foreshadowed, at 100 meters, (Fig. 72) by the fact that 33‰ water reaches the western slope of the basin in September, instead of being separated from it by a band of fresher water, as in June (Fig. 66). Everywhere in the depths of the Gulf, at and below 200 meters, the salinity is higher in September than in June, particularly in the

Eastern Basin, where the increase, at 200 meters, was about .6‰ in this period (33.8‰ to 34.4‰).

We have no records of seasonal changes in the eastern half of the Gulf after September; for our western stations, this has been discussed (p. 206).

Finally, I should point out that the water close to land, off Shelburne (Station 10313) was even fresher on the surface in September

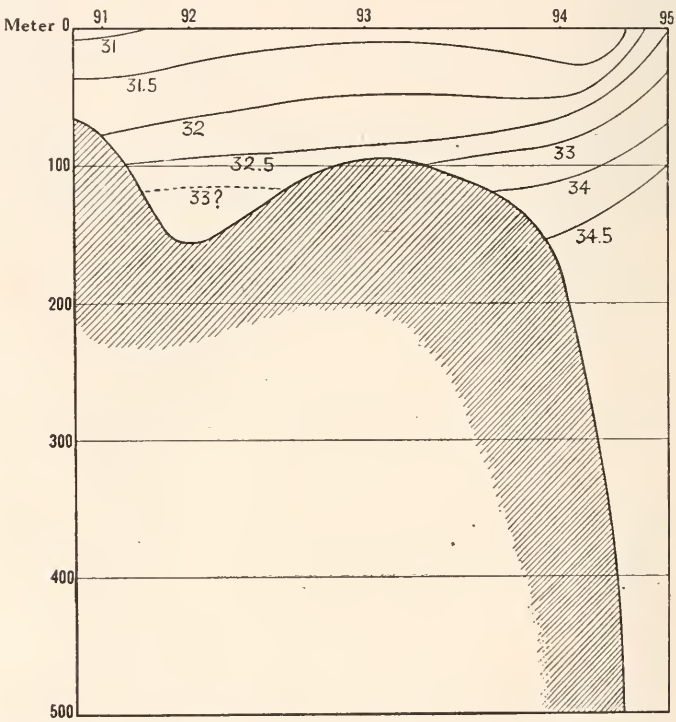

Fig. 74.— Salinity profile across the continental shelf off Shelburne, Nova Scotia, June 23, 1915 (Stations 10291–10295).

than in June; but it was considerably salter on the bottom; while a few miles further offshore (Station 10314), salinity as a whole rose considerably during the summer (Fig. 75, 76).

The most important seasonal change in density in the Gulf is the fact that the great vertical stability which characterizes the water in summer, practically disappears, as the upper layers cool, in winter,

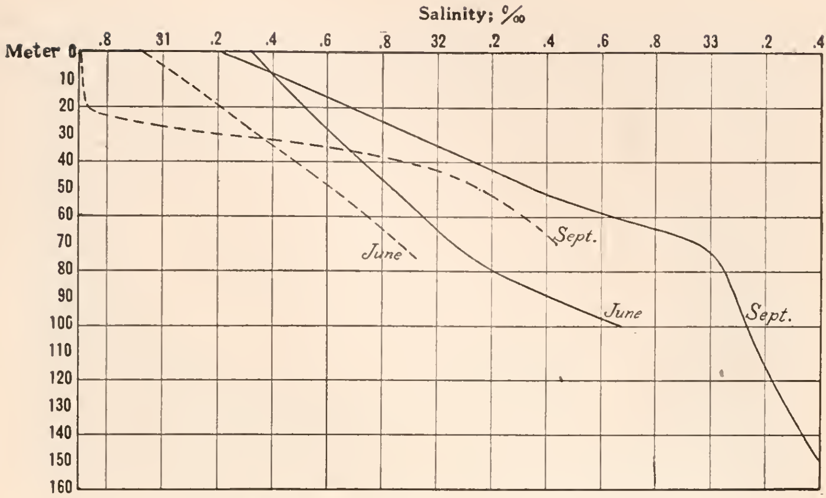

Fig. 75.— Salinity sections at corresponding pairs of localities off Shelburne, Nova Scotia, in June and September, 1915. (Stations 10291 and 10313......, 10292 and 10314, ———).

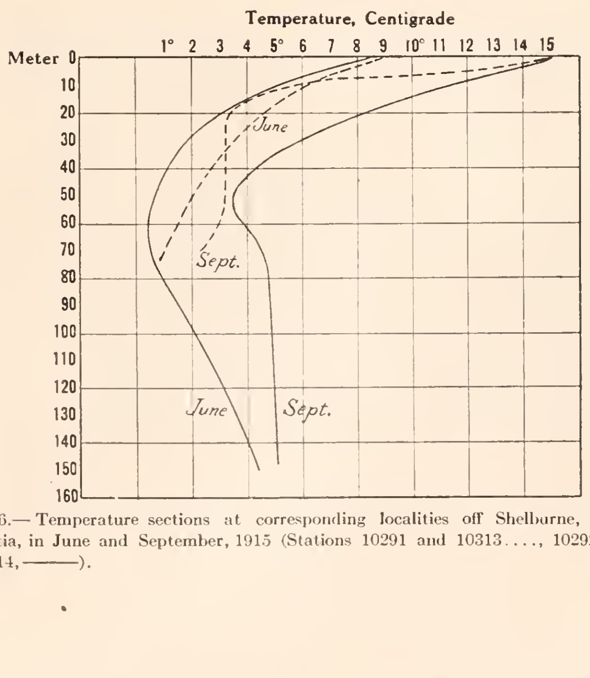

Fig. 76.— Temperature sections at corresponding localities off Shelburne, Nova Scotia, in June and September, 1915 (Stations 10291 and 10313...., 10292 and 10314, ———).

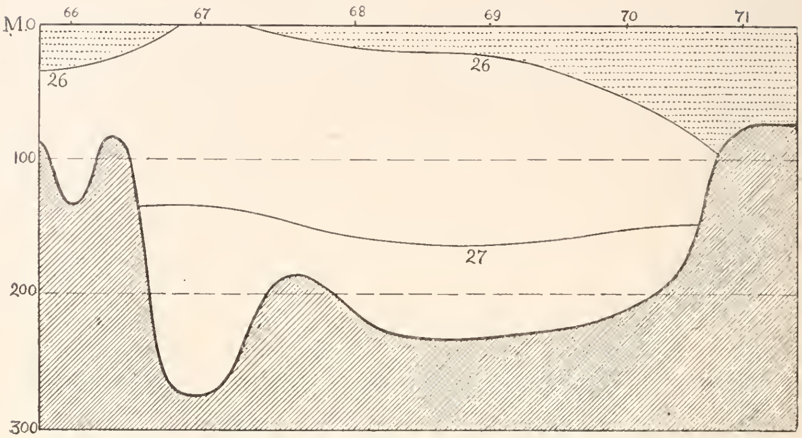

Fig. 77.— Density profile across the Gulf of Maine from Cape Ann (Station 10266 to German Bank, Station 10271), May 4–7, 1915.

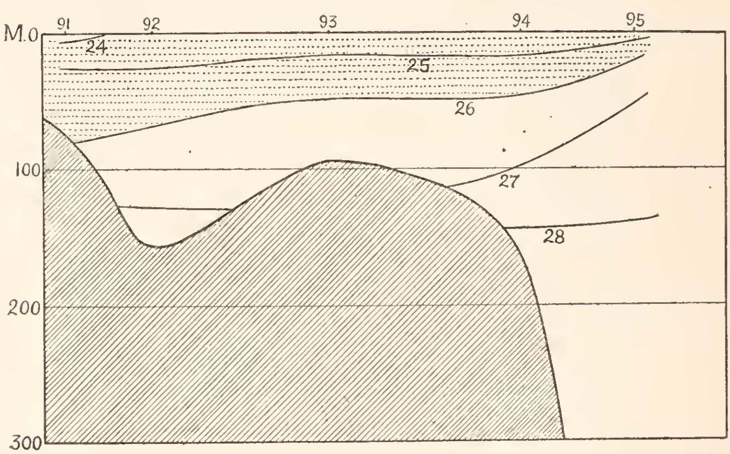

Fig. 78.— Density profile across the continental shelf off Shelburne, Nova Scotia, June 23, 1915 (Stations 10291–10295). Densities lower than 1.026, dotted.

to be gradually reestablished by the warming and freshening of the surface in spring (1914b). And density is probably comparatively uniform, horizontally, over the Gulf as a whole during the cold months, though our records for winter are limited to the neighborhood of Cape Ann. In spring, however, the inrush of land water along the northern and western shores, together with the entrance of Cabot Current water around Cape Sable (p. 224) lowers the surface density on the east and west sides of the Gulf much faster than the more gradual drop in salinity offshore, *plus* solar warming, lowers that of its center, as illustrated by a profile across the Gulf in May (Fig. 77). Particularly instructive, for its bearing on circulation (p. 242), is the fact that the cool, fresh water off Nova Scotia and on German Bank, the visible effect of the Cabot Current (p. 235), is lighter than the water it meets in the Eastern Basin of the Gulf, in spite of the higher temperature of the latter, hence floats upon it, instead of sinking into the Basin.

Even in May, the density of the bottom water of the Gulf is very uniform horizontally, west to east. And during the summer, surface density is gradually equalized until, by August a layer of water lighter than 1.026, some 70 meters thick, extends right across the Gulf (1914a, 1915).

Annual hydrographic variations in the Gulf of Maine.

The differences between the summers of 1912 and 1913 have already been discussed (1915, p. 246); in brief, the Gulf was colder and fresher in its eastern, warmer, but of about the same salinity in its western half in 1913 than in 1912.

The observations for 1913 and 1914 were made at the same season (middle of August); hence are directly comparable. But in comparing the records for 1915 with those for the preceding years, allowance must be made for seasonal change, the earlier observations having been taken in the middle of August, the most nearly comparable set for 1915 some three weeks later (September 1–19). And as pointed out (1914a), it is during just this period that the surface, in the western side of the Gulf, begins to cool, whereas on the eastern side, surface warming still continues, though the salinity of the eastern basin apparently decreases (p. 225).

On the surface the distribution of temperature was practically the same, but the absolute values were everywhere 5°–3° higher, in 1914 than in 1913 (Fig. 1; 1915, fig. 1), the only exception being locally, north of Cape Ann.

The surface salinity, on the other hand, was as a whole slightly higher in 1913 than in 1914, with a maximum difference of .8‰ off Cape Ann, .6‰ in the Western Basin, while the salt tongue which characterized the east side of the Gulf in 1913, (1915, p. 203, pl. 2), was not evident on the surface in 1914, though it was in the deeper layers (p. 196).

Taking seasonal differences into account, temperature and salinity were about the same on the surface in 1915 as the year before, the fact that the surface was considerably salter over the western basin in 1915 than in 1914 [Stations 10254 and 10255, 1914; surface salinity 31.55‰ and 31.89‰: Stations 10308 and 10307, 1915; surface salinity 32.47‰ and 32.52‰] while on German Bank and off Shelburne the reverse was true, being probably due to the difference in season between the two sets of observations; 1915 and 1914 agree in the main with 1913 in the vertical distribution of salinity and temperature, especially in the fact that the water of the central and western parts of the Gulf was coldest at about 100 meters, warmer below, instead of uniform in temperature from about 100 meters down to the bottom as in 1912 (1914a). But as a whole this vertical warming of the deeper layers was more pronounced in 1914 than either in 1913 or in 1915, as appears in the following summary of temperatures and salinities at corresponding localities from summer to summer.[1]

Off Cape Ann the salinity was lower at all depths in 1914 and 1915, which were almost exactly alike, than in 1912 or 1913, the differences between 1914 and 1912, which was the fresher of the two previous years, being .4–.5‰. But the greatest temperature difference between the three years, at any level below 20 meters, was less than 1°.

Except for the immediate surface, so subject to seasonal change, the Western Basin was warmer down to 100 meters in 1915 than in any previous year of record; below that depth the temperatures for 1915 are, as a whole fractionally cooler than those for either 1913 or 1914, warmer than 1912; though with an extreme variation of only about 2.4°. In 1913, 1914, and 1915 the water was coldest at about 100 meters (p. 167); in 1912 the temperature was uniform from 120 meters down to the bottom. Salinity here was about the same in 1913 as in 1912 (1915, p. 204); from .66‰ to .42‰ lower in the upper layers in 1914 than in 1912 or 1913 (1915, p. 204); with 1915 slightly the saltest year of the four down to 40 meters (a difference probably seasonal); below 200 meters salinity was about the same in all four years.

[1] See tables p. 333.

The center of the Gulf, near Cashe's Ledge, was 2°–3° warmer near the surface, colder below 40 meters in 1914 than in 1913, with 1915 intermediate between the two below 80 meters. But these differences may be due to varying vertical circulation at different distances from the Bank, as may the fact that the water was coldest on the bottom in 1915, instead of at 100 meters, as in 1913 and 1914. Salinity was lower here at all depths, in 1914 than in 1913, with 1915 intermediate, the extreme variation being about .46‰.

In the western side of the Eastern Basin temperatures changed only fractionally from 1912 to 1915 (apart from seasonal disturbances); but salinity decreased from 1912 to 1914, at all depths, with an alteration of .75‰ on the surface; .4‰ at 40 meters; .63‰ at 100 meters; .35‰ at 180 meters; and though 1915 apparently shows a tendency toward the reestablishment of the earlier state, being intermediate between 1914 and 1913, this may be a seasonal phenomenon (p. 225).

On German Bank both temperature and salinity were about the same in 1914 and 1915, (seasonal differences considered, p. 205) as in 1912, correspondingly warmer than in 1913 (1915).

This comparison may be further extended, for 1912, 1913, and 1914 to the northern part of the Gulf and to its northern coastal zone, where no late summer, or early autumn records are available for 1915. The northern part of the Eastern Basin was colder, down to 120 meters, in 1914 than in either 1912 or 1913, warmer, below 120 meters; as it was off Mt. Desert Rock also. It was saltest in 1914, freshest in 1913, with a difference of .64‰ at 60 meters. Along the northeast coast of Maine, however, both temperature and salinity as a whole varied but little from year to year, though the vertical range of both was greatest in 1914. But west of Penobscot Bay the water next the land was, as a whole, colder, and fresher, in 1914 than in either 1912 or 1913, as exemplified by our stations off Matinicus Island, and off Cape Elizabeth; this is also true of the deep trough west of Jeffrey's Ledge, though at that locality the difference in temperature was limited to the deeper layers, below about 75 meters.

Thus, except for the immediate surface, the upper 150 meters in the whole western, central, and northern part of the Gulf was slightly colder and considerably fresher, in 1914 than in either of the preceding years. On the contrary, the bottom of the Western Basin and the northern and eastern parts of the Eastern Basin as a whole were just the reverse, *i. e.*, warmer and salter in 1914 than in either 1913 or 1912, with still higher temperatures and salinities in the former in 1915.

In a partially enclosed basin, subject to such violent climatic changes as is the Gulf of Maine, and where waters of such different temperatures and salinities struggle for the mastery, more or less fluctuation in hydrography is to be expected from year to year. But our data are now sufficient to show that such changes as do take place are very small; and nothing has yet transpired to suggest that they ever seriously affect the waters of the Gulf one way or the other, as a biologic environment. That violent fluctuations may occur at rare intervals, is of course possible; that they do so, along the edge of the continental slope can not be disputed (1915, p. 265), but we still await evidence of such events in the Gulf.

Origin and Circulation of the Gulf of Maine Water.

The explorations in 1912 (1914a) and 1913 (1915) showed that the waters of the Gulf of Maine are complex, land water, Gulf Stream water, and St. Lawrence water all taking part in their formation, while the possibility that abyssal water might also enter, by upwelling, into this complex has also been recognized. But the data for those years was not sufficient to throw much light on the proportions in which these different waters meet in the Gulf; or to disclose the precise inflowing or outflowing currents, beyond the fact that there is an indraught on its east, and an outdraught on the west side (1914a, p. 91; 1915, p. 231). The data for 1914 and 1915 advance our knowledge of these questions, particularly as to the origin and extent of the northern current. It is clear, indeed the early records demonstrated, that the summer temperatures of the Gulf are not much affected by cold northern currents, being nearly what would be expected if it were an enclosed basin; the Gulf owes its low temperature chiefly to the cold winter climate of the neighboring land mass. But salinities, plankton, and the general set of the currents, show beyond question, that a northern current does reach the eastern side of the Gulf, though so mixed with Atlantic water that its hydrographic influence is hardly appreciable; and some information is at hand as to its seasonal variations.

One of the first, and most important conclusions, drawn from our early work was that the northern water on our coast is chiefly of Gulf of St. Lawrence, not of Labrador Current origin; and as the general theoretic reasons for this view are discussed elsewhere, 1915, p. 251, Schott, 1897, Krummel, 1911), I need only point out here how fully the records for 1914 and 1915 bear it out.

Salinities (p. 182), temperatures (p. 174), and current records (p.

203) combined, reveal an unmistakable current, flowing from northeast to southwest, along the southeast coast of Nova Scotia in August, 1914, with a velocity of 1 knot per hour, only 30 miles from the entrance to the Gulf of Maine; and though this current was both narrow (about 15 miles broad off Halifax) and superficial, it was easily distinguishable from the salter, warmer, water which bounded it on the sea side. Its most characteristic feature is, of course, its very low temperature below the level to which solar warming had penetrated (p. 171). This, with its direction of flow, and the fact that its plankton contained such typically Arctic components as *Limacina helicina* (p. 248) and *Mertensia ovum* (p. 248), shows that it actually was the southern extension of some current from the north.

In this part of the world, such fresh and at the same time icy cold, northern water can have only one of two origins, *i. e.*, from the Gulf of St. Lawrence, or from the Labrador Current. Considering that it was encountered all along the coast from Halifax to Cape Sable, hugging the land closely; and that there is an important and well-known outflow from the Gulf of St. Lawrence along the west side of Cabot Straits, the Cabot Current, (1915, p. 253, Schott, 1897; Dawson, 1896, 1913), the natural presumption would be that our Nova Scotia current is the direct continuation of the latter.

Actual hydrography further supports this contention, for both in salinity, in minimum temperature, in the degree to which solar warming progresses in summer in the surface layers, in the level at which the temperature is at its minimum, and in the superficiality of the cold water our Nova Scotia Current agrees very closely with the outflow in Cabot Straits, as well as with the neighboring parts of the Gulf of St. Lawrence (Dawson, 1913), with which it is actually continuous both in temperature (Townsend, 1901), and in salinity (Dickson, 1901). Furthermore, the fact that we found the Nova Scotia Current in the same location, and with about the same physical characters in two successive years, shows that it was not a sporadic phenomenon, but a regular characteristic of the summer hydrography of the coast. In short, the demonstration that it is a southward extension of the Cabot Current is as complete as hydrographic evidence, other than the actual drifts of bouys, can make it. This, however, does not forbid the possibility that it receives water from the Labrador Current, as the result of a southwest flow across the Grand Banks.

It is now well known that a certain amount of Labrador water enters the Gulf of St. Lawrence via the south coast of Newfoundland and the east side of Cabot Straits (Schott, 1897, 1912; Matthews, 1914). But this is so small in amount, and becomes so thoroughly mixed within the Gulf that it has no appreciable effect on the outflowing Cabot Current. Fortunately the physical characters of the latter, and of Labrador Current water are now fairly well known, thanks to Dawson's records (1896, 1913), to the work of the Scotia (Matthews, 1914), and of the Seneca (U. S. Coast Guard, 1915). According to Dawson (1913) the minimum temperature of the Cabot Current in Cabot Straits is from $-.5°$ to $+.5°$. On Banquereau Bank the minimum is about $-.1°$; off Halifax $-.2°$ to 1° in May (U. S. Coast Guard, 1915, Seneca Stations 14–17), while it is only fractionally higher (.7°–1°) off Shelburne in June (p. 217). And only a very slight warming takes place, at the level of minimum temperature, even by midsummer. The salinity of the cold water along the Nova Scotian coast is correspondingly low, and constant, that of the coldest layer (50–75 meters) 31‰–32.3‰, its average about 31.9‰.[1] The Labrador Current is even colder than the Cabot Current, its temperature being about $-$ 1.6°, when not influenced by solar warming, or by mixture with Atlantic water (Matthews, 1914); and even in July its surface warms only to about 7°. For example, at Seneca Station 74, east of the Grand Bank, July 25th, the temperature was 7.9° on the surface; about 0° at 20 fathoms, $-1.6°$ at 50 fathoms (U. S. Coast Guard, 1915, p. 60).

It is also much salter, its characteristic salinity upwards of 32.5‰, according to Matthews (1914), while even along its inner western edge, where most influenced by river-flow from the land, its surface salinity hardly falls below 32‰ (minimum about 31.9‰, Matthews, 1914). Both the Scotia and the Seneca records show that the salinity is upwards of 32.5‰ on the Grand Banks, except close to the south coast of Newfoundland where the surface is fresher owing to land drainage.

From this it appears that did any considerable amount of unadulterated Labrador water join the Nova Scotia coast current, the temperature of the latter would be lower, its salinity higher, than in Cabot Straits. True, a junction of Labrador with St. Lawrence water might take place without altering the temperature of the latter at all, were the former sufficiently mixed with warm Atlantic water, during its transit from the Grand Banks to Nova Scotia, to raise its tempera-

[1] Banquereau Bank	April	31.8‰	Seneca Station 17
Off Halifax	April	31.67–32.1‰	Seneca Station 14, 15
" "	Aug.	32.09–32.3‰	
" Shelburne	June	31.8–32‰	
" "	Aug.	31.9–32.2‰	
Sable Island Bank	April	31.7–31.9‰	Seneca Station 13

ture by 1°–2°. But this would necessarily raise its salinity as well, Atlantic water being considerably salter even than Labrador water, as demonstrated by the SENECA and SCOTIA stations off the southeast corner of the Grand Bank. Hence, if any large amount of mixed water of this sort reached Nova Scotia, its effect would be even more unmistakable, in raising the salinity of the coast current, than that of pure Labrador water, even if temperature did not betray it. But we have found nothing of the sort, low salinity prevailing all along the coast from Cabot Strait (Dawson, 1913) to Banquereau (p. 236) and thence to Shelburne (p. 182). Furthermore, the work of the SENECA failed to reveal any dominant flow to the southwest across the Grand Banks, the current there being tidal (Schott, 1897, Johnston, 1913, 1915). In short, hydrography argues against the idea that the Labrador Current exerts any direct influence on the Nova Scotian long-shore current; if it does, it is insufficient to have any appreciable effect on the salinity or temperature of the latter.

This is an appropriate place to point out, what the hydrography of the outflow from the Gulf of St. Lawrence proves, that the mere existence of a minimum temperature layer even as cold as 0° in summer at 100 meters or so, with warmer water above and below, is not a criterion for the presence of polar water. True, such a minimum temperature layer is characteristic of polar waters (Nansen, 1902; Helland-Hansen, and Nansen, 1909; Knudsen, 1899; Matthews, 1914). But it can be equally produced in partially enclosed coastal waters, where the surface layers are subject to an extremely rigorous winter climate, alternating with considerable solar warming in summer; and where at the same time, the depth of water is great enough to allow a more or less constant inflow of warmer ocean water below the depth to which winter cooling penetrates. Thus, in the Gulf of St. Lawrence, local air temperatures, without any considerable accessions of polar water (Dawson, 1907, Krummel, 1907), produce a vertical range of temperature in summer from 15°–18° on the surface to about .56° to 1.1° at 100 meters, warming to about 4.4° at 400 meters (Dawson, 1913); and a similar, though less pronounced minimum layer obtains, in some summers, even in the Gulf of Maine (p. 222), due to the same causes. But wherever such a minimum layer is colder than about −1°, as is the case in the Labrador Current (Matthews, 1914) it is positive evidence of Polar water, for nowhere, on either side of the North Atlantic, does winter cooling alone produce such a low temperature.

In the present connection the important feature of the Cabot Current is its effect on the Gulf of Maine. Although the Current is narrow and superficial (not over 20 miles broad, or 50 meters deep off Halifax in summer), its velocity is considerable, and it persists at least from spring to early autumn. Hence, since it retains its very low temperature and salinity as far west as Shelburne, only 30 miles from the entrance of the Gulf, it might be expected to produce the same subarctic hydrography all around the northern shore of the latter, as obtains off Halifax and Shelburne, did it enter the Gulf unaltered. But nothing is more certain, from our four years work than that such is not the case, the Gulf being hardly colder, or fresher, than if no northern water reached it. And, at least in summer, its eastern side, most open to the effects of the Cabot Current, is actually warmer and salter than its western. Furthermore the Cabot Current influences the hydrography of the western side of the Gulf no more in winter than in summer; and even in May, when it is apparently at its maximum, the eastern part of the Gulf is of about the same temperature, except for the immediate surface, as the western, decidedly warmer than the water is off Shelburne, only thirty miles away. The fact that the Cabot Current chills the eastern part of the Gulf so little, contrasted with the very low temperature caused by it only a few miles east of Cape Sable, suggests that such of it as enters the Gulf, is mixed with warmer water from offshore; and this is confirmed by our salinity records for 1914 and 1915. To begin with, the charts (Fig. 33, 34), show clearly that only a minor part of the current reaches the Gulf, even in June its main body swinging seaward off Shelburne (p. 217); and the smaller branch which does pass Cape Sable, mixes on German Bank with the much greater volume of warmer and salter offshore water which enters the eastern side of the Gulf in summer. And, in summer at least, the resultant mixture is as a whole, salter, and warmer than the western part of the Gulf, though the latter is less subject to disturbances from outside.

The influence of the Cabot Current, in the Gulf, is most evident at about 40 meters (Fig. 30, 33), its effect on temperature and salinity being limited to the upper 100 meters, even when at its maximum (p. 224); and it is certain that though it flows southward along the eastern slope of Brown's Bank in summer, it neither crosses the latter, nor follows it around to the west at that season, but exhibits a greater and greater tendency to recurve upon itself off Shelburne as the depth increases, the Eastern Channel being much warmer and salter.

The warm salt tongue detected in the eastern part of the Gulf in 1912 (1914a) has been confirmed by more recent studies (1915). But the fact that its salinity and temperature are both considerably below that of Gulf Stream water, though the latter is encountered in full purity close to the continental slope (p. 190), and that it does not bring with it a tropical, or Gulf Stream plankton, but only the more resistant warm-water forms, shows that it is not true Atlantic water, but the mixed-water resulting from the conflict between the inner edge of the Gulf Stream and the coast water, which takes place all along the continental slope, from Nova Scotia to Chesapeake Bay (1915). That this is the case is further supported by destiny, for mixed water, being heavier (below the level of the southern rim of the Gulf), than Gulf water (p. 202) would naturally flow into the basin of the Gulf via the Eastern Channel, by the ordinary estuarine type of circulation, and being equally heavier than Gulf Stream water at this critical level (p. 202), bars the latter from reaching the Eastern Channel. This influx, apparently at its height in late summer and early autumn, has little effect on surface temperatures or salinities. But at, and below 40 meters salinities reveal it very clearly as a tongue entering the Gulf through the Eastern Channel, crossing Brown's Bank where it meets the south and west flowing Cabot Current, thence following the eastern slope of the Gulf, to turn westward along the coast of Maine, as already described (p. 96). As depth increases it more and more nearly approaches undiluted ocean water in its characteristics. But the gradual decrease in its salinity from southeast to northwest, even in the deepest parts of the Gulf where it receives no accessions of Cabot Current water (p. 190), is evidence of a constant mixture with the fresher water of the Gulf. It is possible that pure Gulf Stream water may sporadically reach the Gulf across the western end of Georges Bank, just as it approaches the land, locally, and temporarily, west and south of Cape Cod (1915). But no actual instances of this have yet been observed, nor do the densities on the two sides, north and south, of Georges Bank, (p. 202), suggest any tendency toward it, at least in summer.

The third import source of the Gulf water is the influx from the rivers which empty into it. And as I have already pointed out (1914a, p. 96), this is so great in amount that it would of itself be sufficient to raise the level of the Gulf about half a fathom per year, were the latter an enclosed basin. Finally, the possibility of an upwelling of water from the Atlantic abyss into the Gulf, must be recognized, less because of any actual probability of it, than because circulation of this sort has often been invoked to explain the low temperature of our coast, as contrasted with Atlantic, water (1915).

That abyssal water does not enter to any great extent into our

Gulf was evident from our early work there (1914a), Gulf salinity being far too low. And on the cruise of 1913 we failed to find any upwelling of this sort west of Cape Cod (1915, p. 260); a generalization which can now be extended to the whole slope from Cape Cod east to Halifax at least in summer; for we found none of the criteria, *e. g.*, lowered surface temperature, and vertical uniformity of salinity down to the level from which upwelling takes place, which would betray such a process. On the contrary, the abyssal water all along the slope, from off Marthas Vineyard to the Eastern Channel is bounded above by a much warmer (8°–10°) and salter (35‰+) bottom zone, from 100 to 300 meters thick, (Fig. 8, 9, 14; 26, 27, 32), just such as characterizes corresponding profiles west and south of Cape Cod (1915). And this could not have been the case, had upwelling been taking place up the slope. Off Shelburne, too, the abyssal water was separated from the even colder Cabot Current by a warmer bottom zone (5°–8°) between 120 and 400 meters, both in 1914 and in 1915 (Fig. 11, 73), though the zone of high salinity did not reappear there. In short, there is no reason to suppose that abyssal water wells up the slope, on to the continental shelf, anywhere between southern Nova Scotia and Chesapeake Bay, in summer.[1] Nor do the winter temperatures and salinities of the Gulf afford any more evidence of the presence of abyssal water there at that season.

Tidal currents are so strong in the Gulf as to obscure the dominant circulation during most of the year (1914a, p. 83). But salinities, particularly the salt tongue in the east (p. 196), and plankton (p. 246) combined, suggest that the main axis of the eddy-like drift which occupies the Gulf is close to the land, which it follows, from east to north and west, sometimes with seaward expansions off Penobscot Bay and Cape Ann, the direct product of river freshets (1914a, 1915, pl. 2).

It is obvious that there must be a considerable outflow from the inshore part of the Gulf, to offset the great amount of river water, (p. 239), besides the increments of offshore and of Cabot Current water, which enter it. Our earlier work suggests that the overflow takes place chiefly along the west side, past Cape Cod; though with no definite current there, but rather a gradual fan-like drift through the South Channel, to Nantucket Shoals, and Georges Bank. But this process is not wholly restricted to the west side of the Gulf, the cool fresh band (Fig. 8), which was encountered on the eastern end

[1] Account is only taken here of the upper zone of the slope, above the 500 meter-level, *i. e.*, of upwelling which might affect the coast water.

of Georges Bank in 1914 being hard to explain, except as an outflowing current from the Gulf. Whether, however, this is a regular, or a sporadic phenomenon, is yet to be learned.

The seasonal cycle of temperature and salinity, (p. 205) indicates the following fluctuations in the relative importance of the several waters in the Gulf of Maine, from season to season.

River water is at its minimum in February and March (1914b), when the salinity, at least in the western part of the Gulf (where alone it is known at that season) is at its maximum (1914b). But, as a result of the freshets of early spring, it suddenly assumes great importance in April, as evidenced by the sudden freshening which takes place all along the coast west of Penobscot Bay (1914b), and which probably includes the coastal zone east of the latter as well; and local variations in salinity show (1914a, p. 91, 1914b, p. 402) that there is then a distinct along-shore current from northeast to southwest, the result of the successive increments of fresh water added by the various rivers, which I have myself found very noticeable as it flows past Cape Ann. The actual freshets are ended by May (though the river flow is considerable throughout the year), when salinity immediately next the land is at its minimum, (p. 213; 1914b, p. 393).

North of Cape Ann, the visible effect of the freshets hardly survives its immediate cause, as evidenced by the rise in salinity which takes place along the coast in June; and this is probably more or less true everywhere within two or three miles of land, owing to the frequent upwelling of bottom water, caused by offshore winds (1914b). But river water is increasingly evident throughout the late spring and early summer, off Massachusetts Bay, and over the Western Basin, where the immediate effects of the freshets are less pronounced, not reaching its maximum, even within 8–10 miles of Cape Ann until August (p. 207, Fig. 42); and at least in some years, it then appears as a distinct tongue extending eastward from Cape Ann (1914a, pl. 2), or as a general fresh area off Massachusetts Bay (Fig. 18). Even here, however, it dwindles very rapidly in importance in late summer and early autumn (Fig. 42, 47).

In the Gulf, river water is always most in evidence at and near the surface, as might be expected; and it has very little effect below 100 meters, except close to land.

So far as our data go, northern, like river water, is at its maximum in the Gulf in early May, when we encountered a current running westward past Cape Sable into the Gulf, unmistakably identified by its low salinity and temperature, and by the Arctic members of its plankton (p. 248), as a branch of the Cabot Current. At that season its effect is traceable as far west as the Eastern Basin of the Gulf; and its main line of dispersal was evidently west, not north toward the Bay of Fundy, neither salinity (Fig. 65), temperature (Fig. 53) nor plankton (p. 248, Fig. 81) affording any evidence of it north of Yarmouth, off the west coast of Nova Scotia. This branch of the Cabot Current dwindles rapidly as the season progresses. In June there is very little evidence of it, either in salinity or temperature, on the surface of the Gulf (Fig. 89), while the area then influenced by it in the mid-depths (32.5‰) is less extensive than in May. And in August and September no trace of it has been detected west of Cape Sable, at any depth. In the latter month the main branch of the Cabot Current still reaches Brown's Bank and the Northern Channel (p. 22). But it is so much narrower off Shelburne then than in June, or in August, as to suggest its entire obliteration there in autumn.

No satisfactory records of the winter temperatures and salinities of the eastern half of the Gulf (1914a, 1915), are yet available. But the facts that river freshets, and melting ice indicate a spring or early summer maximum for the outflow from the Gulf of St. Lawrence, and that there is nothing in the winter temperatures salinities or plankton of the western side of the Gulf (1914b) to suggest the influence of the Cabot Current, together with its fluctuations as just outlined, forbid the idea that it enters into the Gulf in appreciable amount at any season except spring.

I have already pointed out (p. 238) that the branch of the Cabot Current which reaches the Gulf is very superficial, due to its comparatively low density, hardly influencing hydrography below, say, 50 meters; and since this low density is retained by this northern water as long as it is recognizable in the Gulf, there is no reason to suppose that it ever sinks into the basin of the latter, which explains not only the comparatively high bottom temperatures of the basins, but the absence of Arctic elements in the plankton there.

The relative importance of offshore water, is, roughly, the reverse of that of river, and of the Cabot Current water, of which it is the antithesis in salinity, increasing from spring to summer as the latter dwindle. It is certain that the influx takes place chiefly in the eastern side of the Gulf (p. 238): and our records, so far as they go, suggest that in the upper layers it is at its maximum there in August (p. 225); diminishing in autumn. But we know so little about the hydrography of the eastern half of the Gulf in the latter season, or winter, that possibly other definite intrusions of the sort may occur later in the season.

In the deeper layers, particularly near the bottom, this process probably takes place more or less at all seasons. But although the salinity of the western side of the Gulf rises during the winter (p. 206; 1914b), the fact that the mean salinity is no higher off Cape Ann, or on the northwest part of Georges Bank in early spring, than off Mt. Desert in August, is good evidence that no general flooding of the Gulf by offshore, or Gulf Stream water, takes place during the winter. The hydrographic history of that season is, rather, one of general equalization, horizontal as well as vertical (1914b), the eddy-like circulation of the Gulf gradually bringing salter and salter water to its western side, as the land water gradually mixes with the higher salinities in its center. In short the Gulf is probably more nearly stagnant, if that term can fairly be applied to the open sea, in the winter than at any other time.

The comparative constancy of salinity, temperature, and character of plankton in the Gulf, since 1912 (p. 231), is good evidence that there has been no general alteration of the circulatory scheme here outlined, *i. e.*, no important sporadic floodings by either Gulf Stream or by Cabot Current water during the four year period. But the annual hydrographic variations described above (p. 231) show that there have been small fluctuations in the relative importance of these waters in the Gulf from year to year. Thus only a relatively lesser amount of offshore water can account for the low salinity of the eastern part of the Gulf in 1913 as compared with 1912, 1915. And offshore water was relatively less important in the western part in 1914 than in 1912; though it is not clear whether this was due to an increased amount of land water, to St. Lawrence water, or to an actual diminution in the inflow via the Eastern Channel. By 1915 we once more found the conditions of 1912 reestablished there.

Plankton.

General Character of the Macroplankton.— The summer plankton of the Gulf of Maine was of the same general type in 1914 as in previous years (1914a, 1915), Copepods, chiefly Calanus and Pseudocalanus, predominating, with smaller numbers of hyperiid amphipods (Euthemisto, p. 286), euphausiids (Meganyctiphanes and Thysanoessa, p. 281), pteropods (Limacina, p. 298), Sagittae (p. 294), and other boreal animals. The only important variation from this general plankton type was on German Bank (Station 10244) where we encountered the Pleurobranchia swarm which appears to characterize that locality (p. 249; 1914a; 1915); and these same copepods formed the bulk of the plankton over the continental shelf off Marthas Vineyard, and on the eastern part of Georges Bank, while they were one of its

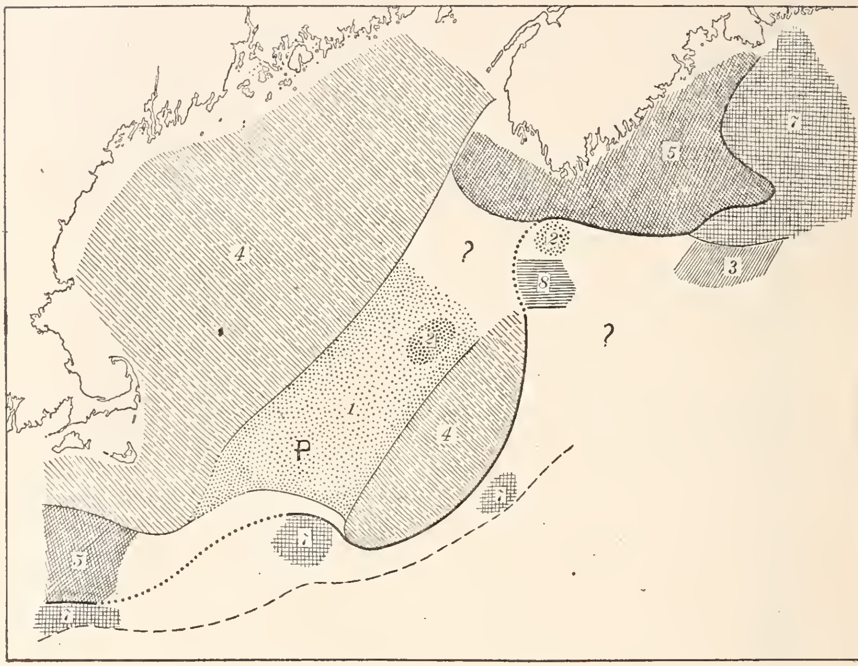

Fig. 79.— Predominant types of macroplankton, July–August, 1914.
1, Copepod and Sagitta; 2, Sagitta swarms; 3, Euphausiid; 4, Copepod; 5, Copepod and amphipod; 7, Amphipod; S, Amphipod and euphausiid; P, Pteropod swarm; ▬▬, offshore limit to copepods as an important factor: ------, Northern limit to predominant tropical plankton.

important constituents off Shelburne (Fig. 79). But very few were taken in the waters over the continental slope; in the Eastern Channel or off Halifax.

Sagittae (p. 294) were as important, faunally, as copepods, over the central part of Georges Bank and in the Northern Channel; amphipods near the land off Shelburne and Cape Sable (p. 286, Fig. 79); and the latter (Euthemisto) composed the bulk of the plankton (Fig. 79) in the waters along the outer edge of the shelf off Marthas Vineyard, on the outer part of Georges Bank and off Halifax; while euphausiids played a similar rôle on Brown's Bank, (Station 10228) and over the slope south of Shelburne (Station 10233).

Previous experience (1915) leads us to expect Gulf Stream temperatures and at least a large admixture of Gulf Stream fauna over the continental slope all the way from Chesapeake Bay to Cape Cod; and 1914 was no exception to this general rule. Thus, we encountered a tropical plankton assemblage over the slope off the west end of Georges Bank (Station 10218), including the fishes Leptocephalus and Myctophum; *Salpa fusifornis* and Doliolum; the tropical amphipods Phronima, Vibilia and Oxycephalus: the copepods Rhincalanus and Sapphirina: *Sagitta enflata, S. hexaptera* and *Pterosagitta draco* (p. 294); eleven species of tropical pteropods (p. 302) and nineteen species of tropical Medusae and Siphonophores, (p. 306); likewise Gulf weed (Sargassum), floating on the surface. And Doliolum, Phronima, a phyllosome larva and a tropical pteropod (p. 302) occurred in the otherwise typically boreal plankton on the edge of Georges Bank near Station 10219.

At the same relative position on the slope, 100 miles further east (Station 10220) the rather scanty catches were almost evenly divided between boreal organisms, (*e. g.*, Euthemistio, Aglantha, *Limacina balea*) and animals of Gulf Stream origin (Euphausia, Nematoscelis, Rhincalanus, a phyllosome larva, Phronima, Doliolum) while this Station was further noteworthy for the occurrence of several specimens of *Diphyes arctica* (p. 306), which likewise occurred over the slope off Shelburne in June, 1915.[1] The plankton over the slope off Marthas Vineyard, in August (Station 10260, 10261) was similarly divided between boreal and tropical organisms, the hauls consisting chiefly of Euthemisto, with occasional *Limacina balea*, side by side with such warm water forms as Myctophum, Phronima, and *Sagitta enflata*. But at the same relative position on the slope off Shelburne (Station 10233) the plankton was chiefly boreal, *e. g., Sagitta elegans*, Euthemisto, Clione, *Calanus finmarchicus, C. hyperboreus*, Euchaeta, *Limacina balea*, and Aglantha, as might be expected from the hydrography (p. 177), with only a minor tropical element (the copepod Rhincalanus in 1914; *Sagitta enflata* and the fishes Cyclothone and Valencienellus in June, 1915).

[1] The geographical relations of *D. arctica* are discussed (p. 306).

Tropical organisms have rarely been found in the plankton in the Gulf of Maine, the only examples, from previous GRAMPUS cruises, being as follows:— *Thysanoessa gregaria* at several localities (1914b, p. 411), *Salpa fusiformis* and *Physophora hydrostatica* near German Bank, *Salpa mucronata* off Cape Cod, and in the northeastern part of the Gulf in the summer of 1912 (1914a, p. 103, 121; 1915), and *Salpa tilesii* in Massachusetts Bay, in December, 1913. To this brief list the cruise of 1914 adds the following:— Rhincalanus in the southeast corner of the Gulf (Station 10225) and *Thysanoessa gregaria* (p. 282) in its western side (Station 10254), on Brown's Bank (Station 10228) and in the Northern Channel (Station 10229). In 1915 Rhincalanus was detected twice in the northeastern corner of the Gulf in May (Station 10272, 10273): Physalia once in the Eastern Basin (near Station 10288); and even more interesting, a bit of Gulf weed (Sargassum) was picked up on German Bank in September (Station 10211).

Three other forms, the copepods, Pleuromamma and Eucheirella, and a pteropod, *Diacria trispinosa* (1915, p. 302) while oceanic-Atlantic rather than typically tropical, (Scott, 1911; Cleve, 1900); may be classed in the latter category so far as the Gulf is concerned, since they undoubtedly enter it from the inner edge of the Gulf Stream, and, judging from their rarity, have not been able to establish themselves there. Eucheirella occurred twice in 1912, (1914a, p. 116); twice in 1913; twice in the Gulf proper in 1914; twice in 1915 (Stations 10270, 10310, a total of four specimens): Pleuromamma was taken once in 1913 (1915, p. 288): Diacria once in 1913 (1915, p. 302).

Judging from these records, visitors from the inner edge of the Gulf Stream may be expected anywhere in the Gulf, at any season. But, as the chart (Fig. 80) shows, they have been encountered most frequently in its eastern part although fewer hauls have been made there than in the west, *i. e.*, just where hydrography is most influenced by the influx of ocean water (p. 238).

The rarity of warm water animals in the Gulf of Maine contrasted with the very rich tropical fauna which inhabits the inner edge of the Gulf Stream only a short distance outside the continental shelf, is fundamentally due to their inability to survive, or reproduce in the low temperatures of the coast water. But their failure to appear there in greater numbers, sporadically or seasonably, as they do off the southern coast of New England, is evidence that the indraught of offshore water into the Gulf, is not from the Gulf Stream proper, but from the zone of mixed water along its inner edge (p. 239).

Aside from corroborating our earlier work, the plankton records for 1915 are chiefly valuable for the light they throw on the immigration of northern organisms into the Gulf of Maine, and on the seasonal changes in the relative faunal importance of the various boreal organisms there.

Previous to 1915, we had never found any unmistakable Arctic component in the plankton, for though three species common in Arctic waters, *Calanus hyperboreus, Clione limacina,* and *Eukrohnia hamata*

FIG. 80.— Localities (●) in the Gulf of Maine where tropical and subtropical plankton organism have been taken, 1912–1915.
■ = several records.

have been taken in some numbers, the first two may be endemic (p. 302), while the last is as likely to have reached the Gulf from the mid-layers offshore, as from the north (1914a, 1915). And while a few Arctic organisms have been recorded in the past, *e. g.*, the medusa Ptychogena and the ctenophore Mertensia, (Agassiz, 1865) it is not possible to connect their occurrence with hydrography. Consequently the discovery of a plankton element of unmistakable northern origin, *i. e.*, the pteropod *Limacina helicina*, the appendicularian *Oikopleura vanhöffeni*, and of Mertensia, associated with the Cabot Current water in the Gulf in May, 1915, marks a distinct advance in our knowledge. These as shown on the chart (Fig. 81) were all taken just where salinity (p. 224) and temperature (p. 215) gave clearest evidence of this northern water (Stations 10270, 10272), and each was represented by so many specimens, that their occurrence can not be looked on as accidental. The appearance of the Arctic

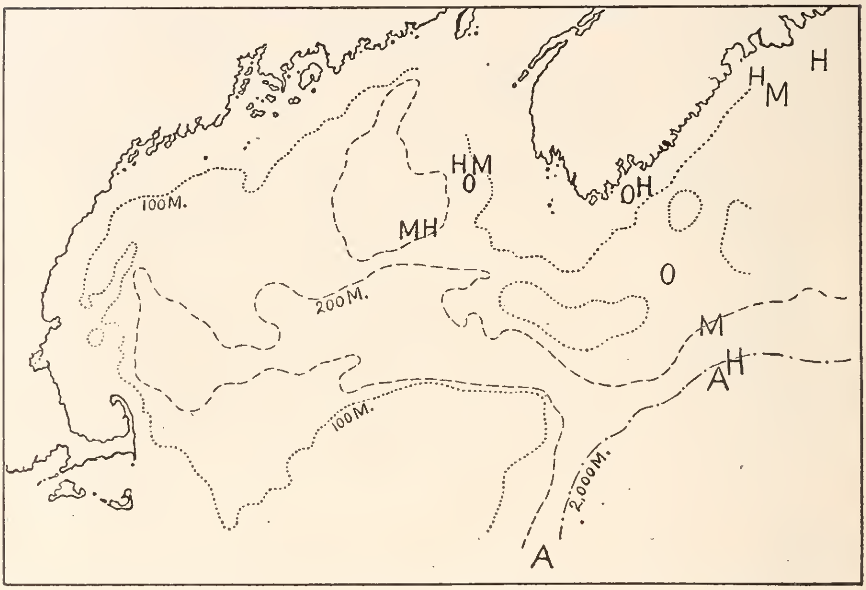

Fig. 81.— Grampus records of Arctic plankton organisms in the Gulf of Maine, 1912–1915.
H, *Limacina helicina:* M, *Mertensia ovum:* O, *Oikopleura vanhöffeni.*
Diphyes arctica is given here also (A), though its geographic origin is doubtful (p. 306).

Oikopleura in the Gulf is especially noteworthy, since it has not been recorded previously on this side of the Atlantic south of Baffins Bay, though known in European waters as far south as the Shetland Islands (Lohmann, 1896, 1910). Thanks to Lohmann's excellent descriptions and figures (1896, p. 72, taf. 14, fig. 6, 7, 10; 1910, p. 15, fig. 16, 17) it is easily recognized, its chief difference from the closely allied *O. labradorensis* being the presence of many small, dendritic, subchordal cells. Its very large size (rump-length upwards of 4 mm.) is likewise diagnostic, while the red margin of the tail makes it a conspicuous object in the water.

None of these Arctic forms were encountered in the Gulf on our later cruises (June–October), their absence coinciding with the shrinkage of the Cabot Current (p. 242). But they were all present in June across the whole breadth of the shelf off Shelburne (Mertensia, Station 10291, 10294: *Oikopleura vanhöffeni*, Station 10291, 10293: *Limacina helicina*, Station 10295).

Our records indicate a further shrinkage in the southward and westward extension of the Arctic faunal community, as the summer advances, for it hardly extended beyond Halifax in August, 1914 (*Limacina helicina*, Station 10236, 10237; Mertensia, Station 10236).

Previous records of Arctic organisms in the Gulf of Maine are too scanty to show whether there is an annual spring invasion from the Cabot Current, as was certainly the case in 1915. But judging from the hydrography of the Gulf in general and of the northern and southern currents in particular, this is probable. The mere fact that neither Mertensia, the Arctic Oikopleura nor *Limacina helicina* were found in the Gulf in the summers of 1912, 1913, or 1914, argues nothing against this view, for they were equally wanting there in the summer of 1915. And experience shows that Mertensia (A. Agassiz, 1865), apparently also Limacina, is so delicate, and so rapidly killed by unduly high temperature, that its absence at any particular time has no necessary bearing on conditions one or two months previous. The Grampus records do not indicate any greater invasion of Arctic animals in 1912, 1913, or 1914, than in 1915, though the occasional appearance of Mertensia in abundance at Eastport in September (A. Agassiz, 1865, p. 29; Fewkes, 1888), and of Mertensia and Ptychogena in Massachusetts Bay in the autumn (A. Agassiz, 1865) suggests that they are occasionally more important in the economy of the Gulf than we have found them in recent years. Unfortunately we have no records of the Gulf plankton for the year 1884, interesting because of its low temperature (1915, p. 243).

The Grampus hauls of 1915 demonstrate that, as a general rule, the plankton at any given part of the Gulf changes very little in its composition during the summer. Perhaps the most striking example of the permanence of the general plankton type is afforded by German Bank, where a swarm of Pleurobrachia (p. 306) prevailed, almost to the exclusion of other forms, from May (Station 10271) to September (Station 10290, 10311); and where we have usually found Pleurobrachia abundant, though less dominant, in other years (1914a, 1915).

Similarly the much more diversified plankton of the Eastern Basin, varied little throughout the season, September, like May hauls, consisting chiefly of *Calanus finmarchicus*, and Pseudocalanus, with smaller numbers of such other boreal forms, as *Euchaeta norvegica* (p. 292), Sagittae, Euthemisto (p. 286), *Limacina balea* (p. 298), and Thysanoessa (p. 283). In the northeast corner of the Gulf the deep hauls yielded large numbers of *Meganyctiphanes norvegica* and *Euchaeta norvegica*, besides the typical Calanus plankton, both in May (Station 10273) and in June (Station 10283), while they were similarly abundant at this locality, below about 100 meters, in the summers of 1914 (Station 10246), and 1913, 1915 (Station 10097).

In the coastal belt from Cape Elizabeth to Mount Desert a decided increase took place during the summer (p. 314) in the amount of macroplankton present in the water, coincident with the shrinkage of the diatom swarm (p. 325). But the only important change in its composition, either off Mt. Desert (Stations 10275, 10285, 10329) or off Cape Elizabeth (Stations 10277, 10326), was that the nearly pure copepod plankton (chiefly Calanus) of May grew more varied, as the season advanced, by an increase in the relative abundance of such other typical boreal organisms as Euthemisto, *Sagitta elegans*, Meganyctiphanes, Thysanoessa, and *Limacina balea*.

A similar change took place both in the Western Basin (Stations 10267, 10299, 10307) and off Cape Ann, (Stations 10266, 10306, 10324), where great numbers of young Euthemisto appeared in the August–October hauls, besides a general increase in the other boreal forms typical of the general Gulf of Maine plankton (p. 243, 1915); and off Cape Cod, where swarms of Pleurobrachia appeared in October (Station 10323).

Station 10282 in the Bay of Fundy deserves brief mention, as no deep tows had previously been made in this region. The bulk of the hauls consisted of *Calanus finmarchicus* and small copepods, with occasional Clione, Euthemisto, *Sagitta elegans, i. e.*, they were of the usual Gulf of Maine type. But there were no Euchaeta, even in the haul from 175 meters.

Our records all go to show that regional, like seasonal differences in the plankton are slight in the Gulf. In fact the only important variations from the general type so far detected are a prevalence of neritic organisms, larvae etc., close to land; a greater proportional importance of animals of oceanic, and of northern origin in the eastern part of the Gulf (the immigrants from northern and from tropical waters discussed above, p. 246, 247) and the local swarming of animals, such as Pleurobrachia, which occur in small numbers elsewhere in the Gulf.

Oceanic and neritic Plankton in the Gulf of Maine.— The influence of the coast line on the plankton is now generally recognized; and the distinction between oceanic and neritic forms has often been drawn; the latter term embracing such organisms as are actually dependent upon the bottom in shallow water, in order to pass through some stages in development (Gran, 1915). This, of course, includes forms which pass the winter, or other unfavorable seasons, on the bottom as resting spores (*e. g.*, some diatoms); the eggs and larvae of bottom-dwelling Metazoa, and Metazoa which pass through a fixed stage in development, as so many hydroid medusae do. Considering the length and complexity of the shore-line of the Gulf; its rich littoral fauna, and the very considerable amount of land water which the rivers pour into it, we might naturally expect its endemic plankton to be largely recruited from the shallow coastal zone; and it is a commonplace, for the Gulf as truly as for the eastern side of the Atlantic, that various neritic organisms often swarm near shore, particularly in the estuaries, bays, and sounds and among the numerous rocky islands.

But in our four years experience we have never found them playing a rôle of any importance in the plankton of the central parts of the Gulf; and how rare they are, except within a trivial distance of the land, may be illustrated by the following facts of distribution. We have always found neritic diatoms, of which *Thalassiosira gravida, Th. nordenskioldi, Chaetoceras debile, Asterionella japponica,* and Guinardia, may serve as examples, (Ostenfeld, 1913; Gran, 1902), practically limited to a narrow coastal zone hardly over fifteen miles broad, including the sounds and bays among the islands; and to the shallow waters over Georges Bank (p. 321).

A similar state of affairs obtains for the neritic Metazoa. For instance, one of the most striking features of our hauls has been the rarity of the neritic Scyphomedusae, Aurelia and Cyanea, in the center of the Gulf, contrasted with their abundance along shore (1914a, p. 124, pl. 6. Aurelia, in fact, is seldom seen more than a few miles from land; and though Cyanea is not so closely restricted, it is abundant only along the coastal zone, and in the shallow waters of Nantucket Shoals and Georges Bank.

Perhaps the most important index to land water among the Hydromedusae, because of its size, abundance, and the fact that its fixed stage is well known (A. Agassiz, 1865), is *Melicertum campanula*; a jelly-fish swarming in the bays and among the islands of the Gulf (1914a, p. 25). But in all our cruises we have only once found Melicertum more than fifteen miles from land, a single specimen in the Western Basin, in August, 1913 (Station 10088). The medusae of the genus Sarsia are similarly restricted to the coast, for while they are liberated in great numbers along shore, and on the shallow coastal banks in spring (1914b, p. 407) we have never taken any in the central parts of the Gulf, and only rarely more than a few miles from land.

Still another example of neritic occurrence is afforded by the hydroid colonies which float, in swarms, over Nantucket Shoals (1915, p. 306) and Georges Bank (1914b, p. 414) early in the season, but which are so closely confined to the regions where they are torn from the bottom, that we have never found them nor their free medusae, anywhere in the deep central parts of the Gulf.

There are, it is true, several medusae, with fixed stage, which do occur more or less generally over the Gulf, for example Staurophora and to a less degree *Phialidium languidum* (1914a). But this is to be explained on the assumption that their fixed stage is not confined to shallow water. They are thus in the same class as Sebastes, among fishes (p. 280) so far as their dispersal over the Gulf is concerned.

Among the Crustacea excellent examples of the neritic habit are afforded by the pelagic larval stages of the various littoral decapods, particularly the crabs; and by the phyllopod genus Evadne (Gran, 1902).

Young crabs (Cancer sp.) are produced in large numbers all along the coast line, in July; and they are usually represented in the summer hauls near land, occasionally in swarms, for example, in Ipswich Bay, and off Rye, on July 23, 1915. But they have never been detected in our offshore hauls; and what is true of crab larvae holds equally for the other metozoan larvae which are so important a part of the plankton near shore. Evadne, long recognized as one of the most important index forms of the plankton (Gran, 1902; Apstein, 1910; Herdman and Riddel, 1911), occurs regularly in summer in the Bay of Fundy off the mouth of the St. Croix river (Willey, 1913), as well as off the Nova Scotian coast (Wright, 1907). But in 1915 we detected it at only nine Stations (10287, 10302, 10303, 10313, 10317, 10318, 10319 and in Shelburne Harbor), all within ten miles of land, and most of them much nearer; and although Evadne is a seasonal organism, its absence in the more oceanic parts of the Gulf can hardly be laid to the season because the offshore work continued from spring to autumn.

It is less easy to divide the copepods than other Crustacea into the neritic and oceanic categories because they are pelagic at all stages. Hence, (barring brackish water species) what is neritic in one sea, may prove to be oceanic in another. Nevertheless, since they constitute the bulk of the plankton of the Gulf of Maine, I may point out that species which are generally classed as neritic in the North Sea region play only a very subordinate rôle, if they occur at all, in the central part of the Gulf, our lists containing only five which are so classed by Farran (1910, 1911), Scott (1911), Herdman and Ridell (1911) and Gough (1905, 1907), viz Acartia, *Tortanus discaudatus*, *Centropages hamatus*, Eurytemora, and Temora. We have only one or two records for each of the first four outside the outer islands; none from offshore parts of the Gulf (1914a, 1915). The fifth, *Temora longicornis*, is apparently less closely confined to coastal waters in the western than in the eastern side of the Atlantic for in the summer of 1913 (1915) it was generally distributed over the Gulf, though there was no corresponding expansion of other neritic organisms. But as a rule, it is common only locally near land, and over Nantucket Shoals and Georges Bank, a distribution roughly paralleling that of Cyanea (p. 251).

Finally it is justifiable to refer such fish eggs as are spawned near land. to the neritic category. Examples of this sort, in the Gulf of Maine, are afforded by the Cod and Haddock, which are very rarely encountered outside the 100 meter curve, though spawned all around the periphery of the Gulf within that depth zone (p. 251).

These facts show. that neritic organisms, strictly speaking, are closely confined to a narrow coastal zone in the Gulf of Maine in summer, and to the shallow banks that form its southern rim; none of them have ever been found in any numbers in the deep central parts of the Gulf; and most of them are unknown there. This is as good evidence as is salinity (p. 241) that at that season, *i. e.*, after the spring freshets are passed, the land water hugs the coast. In early spring, when the rivers are in flood, conditions may be different; but the water is so cold at that time, that the vernal wave of reproduction has hardly begun on the part of the littoral fauna.

The typical, endemic plankton of the center of the Gulf, is composed of species independent of the bottom, *i. e.*, "haliplankton"; most of them known to be oceanic as opposed to neritic in European waters. Thus the diatom plankton which we encountered offshore in May (p. 324) consisted chiefly of *Chaetoceras densum* and *Rhizosolenia semispina;* both so characterized by European students (Gran, 1905;

Ostenfeld, 1913; Herdman and Ridell, 1911). And the Ceratium plankton, which occupies the Gulf as a whole throughout the summer is composed of species (*Ceratium tripos*, and *C. longipes* var. *atlantica*) which are usually regarded as oceanic in the North Sea region (Paulsen, 1908; Jorgensen, 1911), and in the Norwegian Sea (Gran, 1902). The same is true of most of the Metoza characteristic of the Gulf, for example, the copepods *Calanus finmarchicus* (Damas, 1905; Gran, 1902; Farran, 1911; Herdman and Ridell, 1911), Pseudocalanus, Euchaeta and Metridia, (Farran, 1910; Herdman and Ridell, 1911): the amphipods *Euthemisto bispinosa* and *E. compressa* (Tesch., 1911; Sars, 1890–1895); the pteropod *Limacina balea* (Paulsen, 1910 "*Limacina retroversa*"); and the euphausiid *Thysanoessa inermis* (Kramp, 1913; Tattersall, 1911). Two other faunistically important members of the plankton, *Sagitta elegans* and *Meganyctiphanes norvegica* are intermediate between oceanic and neritic in the North Sea region (Apstein, 1911; Kramp, 1913). In the Gulf, however, they cover practically the same range as the more typically oceanic forms just mentioned. Furthermore, not only do these oceanic animals occur generally over the central part of the Gulf, but they constitute the bulk of the plankton even close to the land, except for a brief period in early spring, when their place is taken by the vernal diatom wave (1914b).

On the other side of the Atlantic most of these species, most characteristic of the Gulf plankton are oceanic, not only as opposed to neritic, but as inhabitants of the neighboring parts of the Atlantic Basin. This is also the case right across the North Atlantic, from the Norwegian Sea and Iceland on the east, to Newfoundland and Nova Scotia on the west (Herdman and Scott, 1908; Murray and Hjort, 1912). But thence southward, the band of cool water along our coast is a sort of *cul-de-sac* for them, the Gulf Stream limiting them on the one side, as the coast line does on the other; and most of them probably are not endemic south of New York, though they may appear there as immigrants from the northeast, in the southwest current which prevails along that part of the coast (1915).

Fish Eggs and young Fish.— The study of the fish eggs is much faciliated by the fact that comparatively few species producing pelagic eggs are common in the Gulf of Maine. Furthermore, the eggs of most of the economically important fishes, *e. g.*, Cod, Haddock, Silver Hake, Hake, Mackerel, and several of the flounders, are easily recognized; and as it happens, these species have usually composed the bulk of the fish eggs collected.

The stations, near land, or in shallow water, *e. g.*, on Georges Bank, have usually yielded fish eggs, sometimes in large numbers. But we have found very few in the deep offshore parts of the Gulf, except off the slope of German Bank (Station 10270) and in the Eastern Basin (Station 10249 in 1914, 10304, in 1915). This was especially the case in May and June, when no fish eggs of any species were taken in the central parts of the Gulf, or on the outer part of the shelf off Nova Scotia; and though the barren area is reduced in midsummer, by the occurrence of eggs in the Western and Eastern Basins, we have never found a single fish egg in the central or southern deeps of the Gulf, or in the Eastern Channel (Stations 10225, 10227, 10255 in 1914; Stations 10268, 10269, 10298, 10299, 10308, 10309 in 1915); and pelagic fish eggs are usually so rare anywhere in the Gulf over water deeper than 100 meters, even, including the narrow trough north of Cape Ann (Stations 10278, 10325), that very few can be spawned anywhere in the Gulf except along the shallow coastal zone. But the shallow waters of Georges Bank are certainly an important, perhaps our most important, spawning ground for Haddock in spring (1914b); and this is probably true for Brown's Bank also, although we have found very few eggs there in summer.

So much discussion has centered around the quantitative occurrence of pelagic fish eggs, as the basis for a census of the fish population of the North Sea, (Johnstone, 1908) that particular attention was paid to this subject during the cruises of 1914 and 1915.

In 1914 the results of the quantitative hauls were as follows:—

Station	Eggs per square meter of sea area	Station	Eggs per square meter of sea area
10213	150	10227	0
10214	0	10229	0
10215	140	10230	80
10216	0	10232	190
10218	0	10237	0
10219	0	10243	0
10223	30	10244	0
10224	0	10245	0
10225	0	10246	0
10226	10	10247	60

This agrees, essentially, with the horizontal hauls, it being only at Stations 10213, 10215, 10223, 10230, 10232, and 10247, that eggs were taken in any numbers in any of the nets.[1]

The results of the two classes of hauls, quantitative and horizontal, for 1915, were as follows:—

Egg catches, at stations where both types of hauls were made.

Station	Eggs in horizontal hauls	Eggs in quantitative hauls	Station	Eggs in horizontal hauls	Eggs in quantitative hauls
10266	12	1	10313	18	0
10270	300	14	10316	15	0
10271	0	1	10317	f	0
10275	200	5	10318	55	2
10277	19	4	10319	f	0
10278	1	0	10320	3	0
10279	75	4	10321	20	1
10281	1	0	10323	11	3
10282	0	1	10327	1	0
10284	m	0	10328	25±	0
10286	0	1	10329	3	0
10287	300+	0	10331	200+	11
10290	15	0	10332	2	0
10291	50+	1	10333	0	2
10304	45	81	10336	9	0
10306	3	27	10337	f	19
10307	2	4	10338	f	2
10310	2	0			

f = 25 — 100 m = 100 +

This table shows that there is little correspondence between the two sets of hauls; thus in two instances the vertical net caught no eggs (Stations 10284, 10287) though the horizontal hauls yielded large numbers. And on the other hand, in two instances (Stations 10304, 10306) the catches of the vertical net were larger than those of the horizontal (surface) nets. Hence to plot the abundance of eggs in the Gulf from the quantitative hauls alone would give a very erroneous result. The

[1] In 1914 fish eggs were taken at the following Stations only:— 10213, 10215, 10220, 10223, 10224, 10226, 10230, 10232, 10236, 10247, 10248, 10249.

truth of the matter appears to be that in our waters fish eggs are very streaky in occurrence; and as the surface net is usually towed for a mile, it is far more likely to encounter eggs, even in regions where they are abundant, than the vertical net. But it sometime chances that the vertical net hits, the surface net misses, a streak of eggs. In this respect, as in the irregular distribution of microplankton, (1914b), the Gulf of Maine resembles the Irish channel (Herdman, 1897, 1910); and it follows that a census of eggs in the Gulf would require a great number of vertical hauls, in proportion to the area covered.

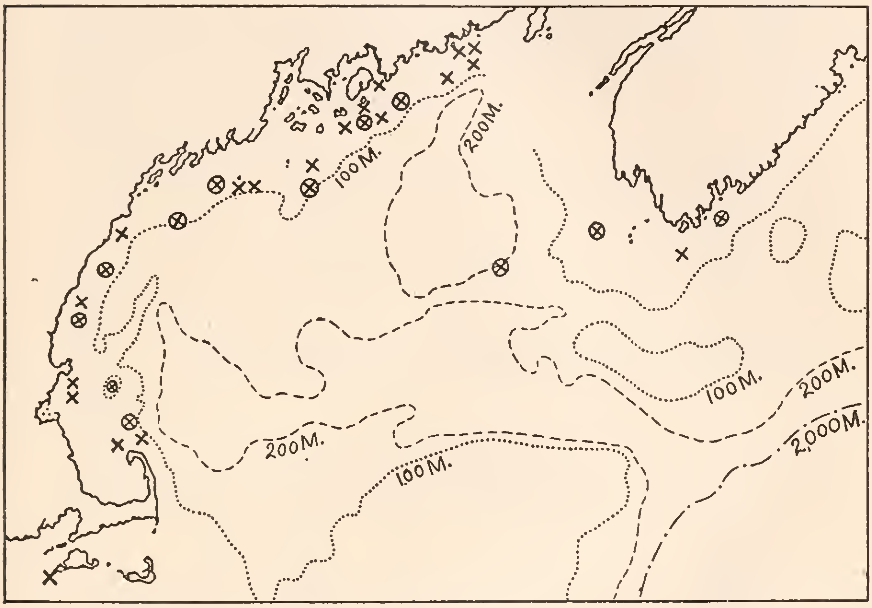

FIG. 82.— GRAMPUS records for Cod and Haddock eggs, 1912–1915. ⊗ May–June; X, July–October.

Cod and Haddock Eggs.— Eggs of Cod and Haddock, indistinguishable when newly spawned, were taken throughout the season from May to October, and there was no seasonal limitation of spawning to one, or other side of the Gulf. But as the chart (Fig. 82) shows, eggs in early stages were restricted to the zone between the coast and the 100 meter curve, except off German Bank (Station 10270); and even that locality was only fifteen miles distant from the 100 meter curve. This was the case in 1914 also; and as other fish eggs do occur in the catches made at the numerous stations in other parts of the Gulf, we can only conclude that in spring and summer, Cod and Haddock spawn only in this narrow coastal belt, just as the Cod do off the Norwegian coast (Hjort, 1914), with no spawning of any importance in the central basin of the Gulf; and our catches afford no evidence that the isolated peak of Cashe's Ledge is of any importance as a spawning ground in summer or spring, though it may so serve in winter. But Haddock are known to spawn on Georges Bank, in large numbers, in early spring (1914b, p. 415); though no Cod or Haddock eggs were taken there in summer.

The records of Cod-Haddock eggs for 1915 are given in the following table:—

1. Quantitative Hauls.

Station	Number eggs	Station	Number eggs
10266	1	10279	1
10270	14	10304	1
10271	1	10318	1
10277	1		

The other quantitative hauls (29 stations) yielded none.

2. Horizontal Hauls.

Station	Eggs in all hauls	Station	Eggs in all hauls
10266	10	10304	1
10270	m	10305	9
10277	9	10313	4
10279	f	10316	1
10280	f	10317	75+
10284	75	10318	12
10285	m	10319	21
10287	f	10320	1
10290	3	10321	1
10291	f	10323	6
10300	f	10327	1
10301	m	10328	20
10302	f	10329	2
10303	M	10330	4

Also at the following localities:— off Libbey Island; South West Harbor, Maine (many); off Petit Passage, N. S. (few).

The largest catches were off the coast of Maine, east of Penobscot Bay, and off German Bank. But no great stress can be laid on this, because the stations in the shallow water near land were not systematically located; other "rich" areas may well have been missed.

Our hauls throw very little light on the actual numbers of eggs present, there being no quantitative hauls at several of the stations *e. g.*, 10301, where the horizontal hauls were richest, and their catches as a whole being scanty, usually the minimum possible; (*i. e.*, one egg). But at least it is clear, that in late spring or summer we have never encountered anything comparable, in importance, to the spawning of Haddock in Massachusetts Bay, and along the shore from Cape Ann to Cape Elizabeth, in April and May, which was observed in 1913 by W. W. Welsh (1914b).

In Norwegian waters newly spawned Cod eggs are most plentiful over the fifty fathom contour (Hjort, 1914). But our results suggest that the distribution of spawning grounds in the Gulf is less dependent on depth, the richest hauls of eggs being at localities where the depths were, respectively, thirty meters (Winter Harbor), sixty meters (Station 10285); seventy-five meters, (off Libbey Island), and about 200 meters (Station 10270). But the stations were not close enough together, either in time or in space, to allow any precise mapping of spawning areas.

The great majority of Cod and Haddock eggs taken were either just laid, or at least so young that identification as one or the other species is impossible: the few identified specimens [1] are as follows:—

Haddock		Cod	
Station	Eggs	Station	Eggs
10278	4	10280	1
10280	5	10291	6
10291	5	10305	1
Off Petit Passage,		10313	4
Nova Scotia	1	10317	2
		10329	1

Thus eggs which can certainly be identified as Haddock occurred

[1] For details of pigment, separating Cod and Haddock before hatching, see Ehrenbaum, 1905–1909; Murray and Hjort, 1912; Hjort, 1914; Schmidt, 1905, 1906.

only in May and June, while Cod occurred throughout the season; and this, of course agrees with the well-known fact that the spawning of Haddock in the Gulf is at its height in early spring, while Cod have long been known to spawn there throughout the year.

It may, of course, be merely a coincidence that out of the hundreds of eggs examined, so few have reached an advanced stage in development. But in view of the general movement of water along the shore of the Gulf from northeast to southwest, this fact is of considerable interest, for it suggests the possibility that eggs spawned, for instance, off Cape Ann, may hatch on Georges Bank. But much more extensive data is needed to show whether such a migration actually takes place.

Oceanographically, the restriction of newly spawned eggs to the coastal zone is interesting, like the similar restriction of the ranges of other neritic Metazoa (p. 251), as evidence of how slow the interchange of water between the central and peripheral parts of the Gulf is; and conversely, the large numbers of eggs encountered over the slope of the Eastern Basin in May (Station 10270), where neither depth of water, character of bottom, nor common report of fishermen suggests the presence of Cod or Haddock in numbers, may well have been carried there, from the neighboring slope of German Bank, which is a well-known fishing ground, by the Cabot Current.

Pollock Eggs.— The spawning of Pollock (*Pollachius virens*) has long been known to reach its height, on the west side of the Gulf, in late autumn and early winter. In 1915 Pollock eggs first appeared in the tow on September 29 (Station 10321), when one was taken; and occasional eggs of this species were taken on October 1st, 18th, and 26th, (Stations 10323, 10330, 10336, 10337); about 150, all in early stages in development on October 27th.

The fact that these records are all from Massachusetts Bay, and from Cape Cod, has no bearing on the distribution of Pollock eggs in the Gulf, because no stations were located in its northern or eastern part after October 15th, *i. e.*, after Pollock spawning was well started.

Silver Hake Eggs.— In 1915 the eggs of the Silver Hake (*Merluccius bilinearis*) were found sparingly from June (Station 10284) until the middle of October (Station 10331), at the localities shown on the accompanying chart (Fig. 83). On four occasions they occurred in large numbers, *i. e.*, off Race Point, Cape Cod, July 7th (Station 10300); off Duck Island, Maine, July 19th (Station 10302); off Rye, N. H., July 23rd., and near Monhegan Island, Me., August 4th (Station 10303). Thus the Silver Hake spawns all along the shore of the Gulf and off southeastern Nova Scotia, chiefly between the land

and 50 fathom curve, just as Cod and Haddock do, though the eggs appear far less regularly than those of Cod or Haddock. So far as our scanty records go, Silver Hake do not begin to spawn in the Gulf until June, for none of their eggs were found at any of our stations in May; spawning is at its height in July and August (Stations 10300–10305); and continues, though greatly diminished, through September and the first half of October, as illustrated in the table, p. 262.

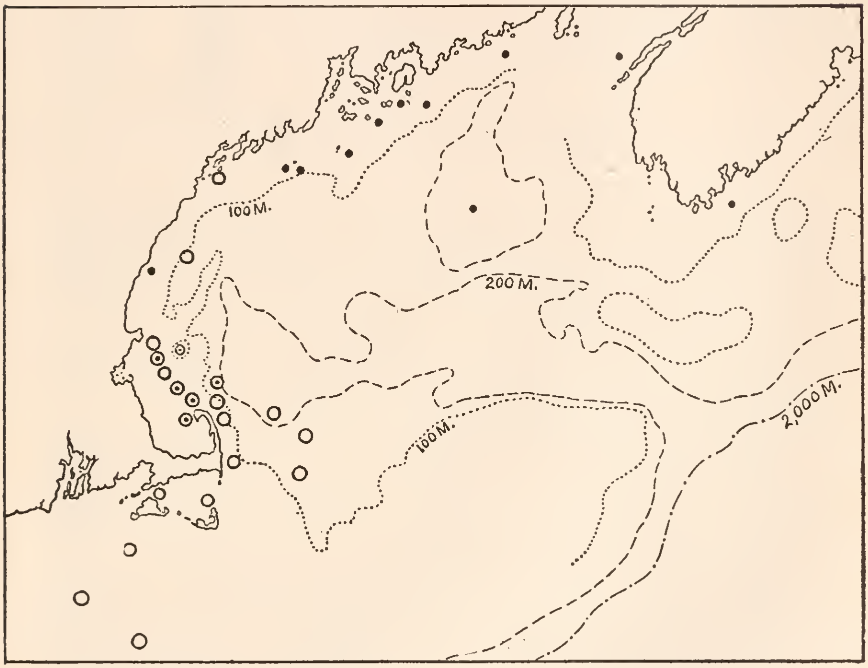

FIG. 83.— GRAMPUS records for young fry and eggs of the Silver Hake, 1912–1915: ●, eggs; ○, fry; ⊙, eggs and fry.

Unfortunately no quantitative hauls were made at the Stations (10300, 10302, 10303, 10305, off Rye, or off Wooden Ball Island), where Silver Hake eggs were most numerous, so no estimate can be made of the actual numbers present there. At the only other Station (10304), where the total catch was more than 100, the quantitative haul yielded thirty-eight eggs, *i. e.*, 190 per square meter. In only two other quantitative hauls did Silver Hake eggs occur (Station

Date	Station	Eggs in all hauls	Date	Station	Eggs in all hauls
June 10	Off Petit Passage	f	Aug. 10	Off Libbey Is.	1
" 11	10284	f	" 18	10305	*m*
" 14	10287	f	" 31	10306	3
July 7	10300	*m*	Sept. 6	10313	10
" 19	10302	*m*	" 18	10318	8
" 23	Off Rye, N. H.	*m*	" 29	10320	2
Aug. 4	10303	*m*	" 29	10321	15
" 6	10304	m	Oct. 1	10322	14
" 6	Off Wooden Ball Is.	m	" 1	10323	2
			" 22	10331	f

f = 25–50; m = 100 +; *m* = 1000 +.

10306, three eggs: Station 10323, one egg), although hauls of this type were made at seven more stations where they did occur in the surface hauls; and this agrees with the general experience that vertical hauls with small nets are of little value where the number of fish eggs present is less than fifty or so per square meter (p. 256).

Our records are too scanty to show whether spawning is fairly uniform all along the coastal zone, or is limited to particular grounds, as is the case with Cod off Norway (Hjort, 1914).

Squirrel Hake Eggs.— Very little is known about the eggs, or young, of species of Urophycis in the eastern Atlantic (Ehrenbaum, 1905–1909, p. 275); and though it is a far more important genus economically in American than in European waters, its pelagic eggs have only once been recognized off our coast, *i. e.* during the Grampus cruise of 1912 (1914a, p. 100). The identification, in that case, rested on comparison with ripe eggs taken from Squirrel Hakes (*Urophycis chus*) caught near by, and fertilized on board ship. But only newly spawned eggs were seen, hence the recent success of the Gloucester Hatchery of the Bureau of Fisheries in not only artificially fertilizing, but hatching, the eggs of this species, is very timely.

Squirrel Hake eggs, in different stages received from the hatchery, may be described briefly as follows: — they are small, ranging in diameter from .7 to .75 mm. Shortly after fertilization there are usually many small oil-globules; but these coalesce, until at 26 hours, (at a temperature of 15.5° C.) there is usually one large oil-globule, about .15–.17 mm. in diameter, with two or three tiny ones close beside it: occasionally, however, there is only one oil-globule at this stage, of about .17 mm. No pigment is yet present. At 50 hours the character of the oil-globule is much the same, but the embryo is now of considerable size, and the pigment has appeared. One of the most characteristic features of this species is the presence of black chromatophores scattered over the yolk, present there even at this early stage. At about 74 hours, not only embryo and yolk, but oil-globule as well, is pigmented. At 98 hours, the oldest stage examined, the embryo is far advanced, its length almost equal to the diameter of the yolk. The embryonic pigment consists of few large chromatophores and similar ones are scattered over both oil and yolk. Even at this stage, there are usually, but not always, several tiny globules close to the chief one.

This species is easily distinguished, in late stages, from most other pelagic eggs so far identified from the Gulf of Maine, by small size, (.7–.75 mm.) in connection with the structure of the oil-globule, and particularly the pigmented yolk. But it may prove difficult to separate it from the Rockling (*Enchelyopus cimbrius*) which has an egg of about the same dimensions, and in which, likewise, there are several oil-globules, when newly spawned, one chief one of .14–.19 mm., pigmented, with several small ones, (Ehrenbaum, 1905–1909, p. 281, fig. C). However, older Rockling eggs from the North Sea have no pigment on the yolk, hence they could not be confused with Squirrel Hake; and though the yolk is sometimes pigmented in Rockling eggs in the Baltic, this does not seem to be a characteristic feature, but only an occasional manifestation of very dense pigmentation (Ehrenbaum, 1905–1909, p. 281). If the eggs which Agassiz and Whitman (1885) provisionally referred to the rockling, [= *Motella argentea*], really belong there, the American Rockling, like the Baltic, has a pigmented yolk, hence it would be difficult to distinguish these from the eggs of the Squirrel Hake. But they say that "it is by no means certain that the species has been correctly identified" (Agassiz and Whitman, 1885, p. 391). Silver Hake eggs in early stages might also be confused with eggs of the Butter fish, (*Poronotus triacanthus*), which are of about the same size and often have two oil-globules when newly spawned. But there is no pigment on the yolk or oil-globule in late stages in eggs of this species.

Eggs indistinguishable from the 50–90 hour eggs of the Squirrel Hake, described above, first appeared on June 10 in tows off Petit Passage and were taken occasionally thereafter until September 20th (Stations 10300, 10301, 10303, 10304, 10305, 10317, 10318, 10319, off Wooden Ball Island, August 6; off Libbey Island, August 11); and they also occurred off Shelburne in August, 1914 (Stations 10230, 10232). They occurred only twice in the quantitative hauls in 1914: three eggs at Station 10304, one at Station 10318.

Mackerel Eggs.— The Mackerel is commercially so important in the Gulf of Maine, and so little is known of its spawning habits, or migrations, that any records of its eggs are worth noting (Fig. 84).

Mackerel eggs were taken, irregularly, in May, June, July, and August, as shown in the following table, p. 265.

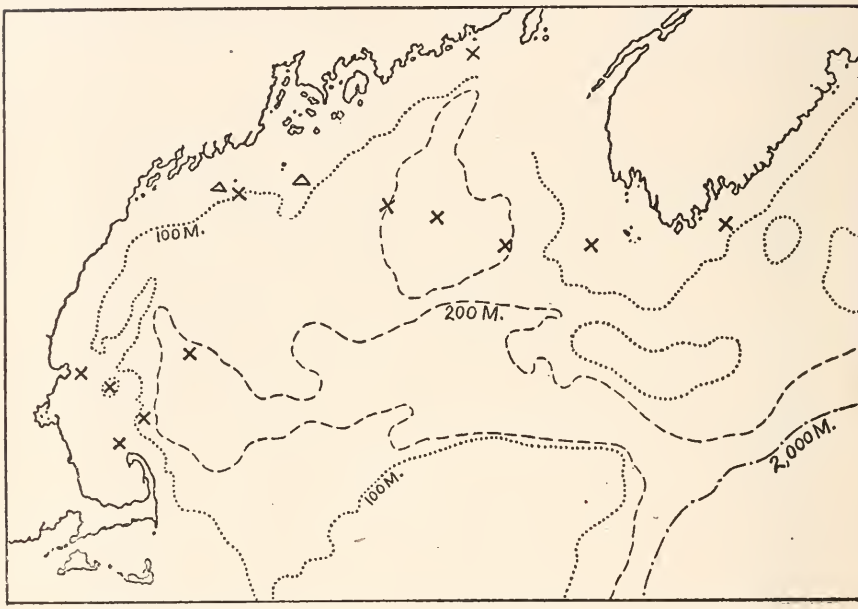

Fig. 84. Mackerel eggs, in 1915. X, records of occurrence; Δ, 50 or more in all hauls.

The quantitative hauls yielded only one egg, at Station 10291, singularly enough none, at the Station 10287 where Mackerel eggs were most numerous on the surface. At Station 10303 no quantitative haul was made.

These few records show that Mackerel spawn irregularly over the northern half of the Gulf throughout the summer. So far as they go, they suggest the region off the outer islands from Cape Elizabeth to Mt. Desert Rock, as the main spawning ground in the Gulf. But

Date	Station	Eggs in all hauls	Date	Station	Eggs in all hauls
May 6	10270	f	Aug. 7	10304	2
" 26	10279	30+	" 10	Off Libbey Is.	10
June 14	10287	200+	" 11	" "	20
" 19	10290	6	" 24	6 miles off Cape Ann	1
" 23	10291	25+	" 31	10306	3
July 7	10300	f	" "	10307	1
Aug. 4	10303	m	Sept. 16	10318	1
" 6	21 miles off Mt. Desert Rock	2			

spawning is not limited to the coastal banks, as in the case of Cod and Haddock, taking place over the basins as well; and as most of the eggs taken were newly spawned there can be no question of their having drifted from elsewhere.

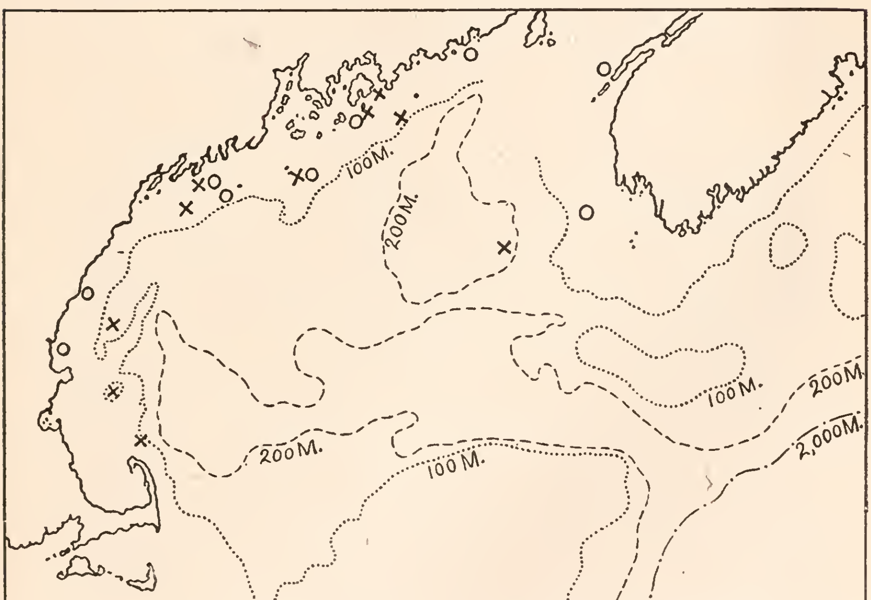

FIG. 85. GRAMPUS records for the eggs of the Sand Dab **X**, and of the Rusty Flounder **O**, in 1915.

The catches of Mackerel eggs are so small as to afford no basis for a claim that the Gulf is an important spawning area for this fish. But this may be purely accidental; Stations located a little differently in season or locality, might have yielded very different results. And caution in drawing any conclusions is especially needed in the case of a fish as erratic in its movements as the Mackerel.

Flounder Eggs.— Eggs of three of the several species of Flounders (Pleuronectidae) common in the Gulf of Maine have been detected in our hauls (Fig. 85).

The unmistakable eggs of the Sand Dab (*Hippoglossoides platessoides*) were only once taken in any numbers. The 1915 records are limited to May and June; and none were taken in July and August, 1914.

Date	Station	Eggs in all hauls	Date	Station	Eggs in all hauls
May 4	10266	4		10279	1
" 6	10270	1	May 31	10280	13
" 11	10275	204	June 2	Winter Harbor	25+
" 13	10277	13	" 11	10284	1
" 14	10278	1	" 14	10285	2
			" 14	10287	1

Apparently the spawning of this species is at its height in late spring; and as most of the shallow water stations were occupied in late summer and autumn, our records throw very little light on spawning areas, etc. Sand Dab eggs occurred in only two of the quantitative hauls, Stations 10275 and 10277, with four and three eggs respectively, *i. e.*, twenty and fifteen per square meter.

Eggs of the common Rusty Flounder (*Limanda ferruginea*)[1] occurred irregularly, May to the middle of September, but were lacking in the hauls in the latter half of that month and in October, table, p. 267.

None were taken in the quantitative hauls; but the quantitative net was not used in the coastal belt between Cape Ann and Cape Elizabeth at the time Rusty Flounder eggs were abundant there. The records for the Rusty Flounder are even more strictly limited to water shallower than 100 meters, than those for Cod and Haddock (p. 257).

[1] The only Gulf of Maine species with which newly spawned eggs of the Rusty Flounder are likely to be confused is the Cunner (*Tautogolabrus adspersus*); and the two can usually be distinguished by size, the former averaging .9 mm., the latter .75–.85 mm. in diameter.

Date	Station	Eggs in all hauls	Date	Station	Eggs in all hauls
May 26	10279	f	July 15	10301	f
" 31	10280	f	" 19	10302	f
June 10	Off Petit Passage	f	" 23	Ipswich Bay	m
" 14	10285	f	" 23	Off Rye	m
" 14	10287	f	Aug. 4	10303	2
" 19	10290	4	Sept. 11	10316	1

We did not make enough hauls near shore in the early part of the season to develop the precise spawning grounds. So far as the records go, they suggest that spawning is at its height in July, but no general conclusions are warranted.

The eggs of the "witch" (*Glyptocephalus cynoglossus*) were detected twice only, Station 10279, May 26th, twenty specimens; Station 10287, June 14th, one egg.

Cunner Eggs.— Eggs of the Cunner (*Tautogolabrus adspersus*) were taken at seven localities, always close to land (Stations 10300, 10301, 10313, 10323, off Wooden Ball Island; off Petit Passage, Nova Scotia, and in Shelburne Harbor). The absence of its eggs at the off-shore stations was to be expected, from its general distribution.

Menhaden Eggs.— The eggs of the Menhaden (*Brevoortia tyrannus*) [1] resemble those of the Pilchard (*Clupea pilchardus*) (Ehrenbaum 1905–1909, p. 374, Fig. 142) but are easily distinguished from all Gulf of Maine species, being characterized by large size (1.5–1.8 mm.); broad perivitelline space; small oil-globule (.15–.17 mm.), and very long embryo. Although the Menhaden appears in the Gulf of Maine in large numbers in summer, we have never found its eggs there. But they appeared in considerable numbers in the tows south of Marthas Vineyard (Station 10331) and in Nantucket Sound (Station 10335) in October.

Undetermined Eggs.— Among the eggs which I have not been able to identify, are a considerable number, about .85–.9 mm. in diameter, with small oil-globule (.12–.14 mm. in diameter), which much resemble eggs of the Summer Flounder (*Paralichthys dentatus*) studied by Mr. Radcliffe at Woods Hole. But since the Summer Flounder is rare north of Cape Cod, their identity is doubtful. Newly spawned eggs of this type occurred at Stations 10275, 10291, 10300, and 10316.

[1] Identified by Mr. Lewis Radcliffe, U. S. Bureau of Fisheries.

Young Fishes taken in the Tow-nets.— Identified by Mr. W. W. Welsh.

Anguillidae.

Anguilla rostrata (LeSueur).

Yarmouth Harbor,	May 9, 1915	1 specimen	56 mm.
Winter Harbor	June 2, 1915	1 "	68 mm.

Leptocephalus sp.

1914.

Station 10218	60–0 meters	1 specimen	37 mm.

Clupeidae.

Clupea harengus Linné.

1915.

Station 10273	0 meters	1 specimen	50 mm.
" 10275	0 "	3 "	39–41 mm.
" 10311	50–0 "	29 "	12–15 mm.
" 10328	40–0 "	1 "	21 mm.
" 10329	0 "	1 "	24 mm.
" 10329	40–0 "	14 "	20–29 mm.
" 10330	25–0 "	27 "	8–13 mm.
" 10337	70–0 "	13 "	13–17 mm.
" 10338	60–0 "	88 "	9–15 mm.

Clupea harengus Linné?

1915.

Station 10332	45–0 meters	108 specimens	14–19 mm.
" 10333	20–0 "	13 "	13–17 mm.

Pomolobus pseudoharengus (Wilson).

1915.

Boothbay, Maine	July 21	495 specimens	25–48 mm.
" "	August 3	160 "	23–53 mm.
" "	" 22	117 "	39–65 mm.

Brevoortia tyrannus (Latrobe).

1915.

Station 10335	8–0 meters	9 specimens	7.5–15 mm.

ALEPOCEPHALIDAE.

Alepocephalus sp. ?.

1915.

Station 10294	0 meters	3 specimens	21 mm.

MYCTOPHIDAE.

1914.

Myctophum sp.?

Station 10218	300–0 meters	1 specimen	15 mm.

Myctophum glaciale (Reinhardt).

1915.

Station 10295	500–0 meters	2 specimens	16 mm.

Myctophum species ? Larvae.

1914.

Station 10260	140–0 meters	1 specimen	20 mm.

1915.

Station 10233	70–0 meters	5 specimens	9–12 mm.

MAUROLICIDAE.

Valenciennellus tripunctulatus (Esmark).

1915.

Station 10295	500–0 meters	1 specimen	30 mm.

Maurolicus sp.? Larvae.

1914.

Station 10218	60–0 meters	1 specimen	7.5 mm.
	300–0 "	2 specimens	13.5–7.5 mm.

CHAULIODONTIDAE.

Cyclothone signata Garman.

1915.

Station 10295	500–0 meters	1 specimen	21 mm.
" 10296	60–0 "	1 "	23 mm.

GASTEROSTEIDAE.

Gasterosteus bispinosus Walbaum.

1915.

Winter Harbor	June 2	0 meters	9 specimens	38–45 mm.
Kittery "	August 2	0 "	7 "	19–29 mm.
Station 10307		230–0 "	1 specimen	30 mm.

Gasterosteus aculeatus Linné.

1915.

Winter Harbor	June 2	0 meters	1 specimen	52 mm.
Kittery "	August 2	0 "	28 specimens	19–29 mm.
Station 10307		230–0 "	2 "	39–43 mm.

Apeltes quadraticus (Mitchill).

1915.

Yarmouth Harbor	May 9	0 meters	1 specimen	34 mm.

SYNGNATHIDAE.

Siphistoma fuscum (Storer).

1915

Winter Harbor	June 2	surface	2 specimens	170 & 155 mm.

Ammodytidae.

Ammodytes americanus DeKay.

1914.

Station 10231	surface	1 specimen	63 mm.

1915.

Station 10283	surface	1 specimen	32 mm.

Labridae.

Tautogolabrus adspersus (Walbaum).

1914.

Station 10256	130–0 meters	1 specimen	10 mm.

1915.

Off Rye, N. H.	July 23	10–0 meters	110 specimens	5.5–10 mm.
Station 10319		25–0 "	2 "	7 & 8 mm.
Provincetown Harbor	Oct. 1.		18 "	26–51 mm.

Scorpaenidae.

Sebastes marinus (Linné).

1914.

Station 10226	70–0 meters	6 specimens	8–13 mm.
" 10229	80–0 "	38 "	8–11 "
" 10230	40–0 "	42 "	9–12 "
" 10231	surface	43 "	8–12 "
" 10232	60–0 "	150 "	6–12 "
" 10232	100–0 "	2 "	10 & 11 "
" 10243	40–0 "	104 "	9–15 "
" 10245	surface	6 "	12–15 "
" 10245	100–0 "	1 specimen	7 "
" 10246	50–0 "	12 specimens	11–19 "
" 10246	150–0 "	3 "	14–22 "
" 10248	50–0 "	35 "	9–14 "
" 10249	50–0 "	15 "	9–18.5 "

1915.

Station 10280	15–0 meters	1 specimen	10 mm.
" 10286	70–0 "	2 specimens	7 & 8 "
" 10303	60–0 "	many	6.5–9.5 "
" 10304	0 "	2 specimens	9 & 11 "
" 10307	0 "	20 "	18–27 "
" 10307	230–0 "	24 "	12–27 "
" 10308	0 "	swarm	14–40 "
" 10309	100–0 "	1 specimen	18 "
" 10310	130–0 "	3 specimens	10–12 "
" 10311	50–0 "	4 "	12–15 "
Southwest Harbor, Sept. 14	surface	1 specimen	17 "

Cottidae.

Myoxocephalus sp.

1915.

Station 10290	40–0 meters	2 specimens	8.5 mm.
" 10300	59–0 "	3 "	8–11 mm.

Genus ?.

1915.

Station 10311	50–0 meters	2 specimens	9 & 11 mm.

Agonidae.

Aspidophoroides monopterygius (Bloch).

1915.

Station 10280	15–0 meters	18 specimens	25 mm.
" 10290	40–0 "	5 "	26–29 "

Cyclopteridae.

Cyclopterus lumpus Linné.

1914.

Station 10224	60–0 meters	4 specimens	6–10 mm.

1915.

Station 10273	0 meters	15 specimens	23 mm.
" 10280	15–0 "	2 "	38 & 46 "
" 10281	0 "	1 specimen	8 "
" 10290	40–0 "	4 specimens	6 & 7 "

Liparidae.

Neoliparis atlanticus (Jordan & Evermann).

Station 10311	50–0 meters	2 specimens	7 & 11 mm.

Pholidae.

Pholis gunnellus (Linné).

1915.

Station 10275	0 meters	1 specimen	21 mm.
" 10290	40–0 "	35 specimens	32–28 "
" 10291	60–0 "	1 specimen	24 "

Stichaeidae.

Ulvaria subbifurcata (Storer).

1915.

Station 10281	0 meters	6 specimens	7–11 mm.
" 10291	60–0 "	1 specimen	10 "
" 10311	50–0 "	1 "	21 "
" 10319	25–0 "	2 specimens	14 & 34 "
" 10325	25–0 "	1 specimen	11 "

Cryptacanthodidae.

Cryptacanthodes maculatus Storer.

1915.

Station 10273	surface	1 specimen	40 mm.

Fierasferidae.

Fierasfer sp. Larvae.

Station 10260	140–0 meters	1 specimen	60 mm.

Merlucciidae.

Merluccius bilinearis (Mitchill).

1913.

(See Bigelow, 1915, for location of stations).

10 miles S. S. E. of Gloucester	July 7	16 specimens	5–8 mm.
Station 10057		95 "	3–13 "
" 10058		1 specimen	7 "
41° 39′ N.; 69° 15′ W.;	July 8	20 specimens	6–11 mm.
Station 10063		33 "	7–16 "
" 10070		2 "	7–9 "
" 10082		108 "	6–14.5 "
Vineyard Sound	Aug. 3	29 "	2.5–6 "
Off Cape Cod	" 4	38 "	2.5–6 "
Station 10086		120 "	3–6.5 "
" 10087		21 "	4–15 "
" 10104		37 "	4–9.5 "

1914.

Station 10256	130–0 meters	1 specimen	7.5 mm.
" 10258	25–0 "	966 specimens	4–12 "
" 10259	50–0 "	4 "	11–24 "

1915.

Station 10300	59–0 meters	38 specimens	75–10 mm.
Off Thatchers I. Aug. 24	0 "	4 "	7–8 "
Station 10306	110–0 meters	1 specimen	13 "
" 10320	50–0 "	65 specimens	5–9 "
" 10321	25–0 "	50 "	4.5–8 "
" 10321	bottom net	66 "	6–13 "
" 10323	70–0 meters	16 "	6–8 "
" 10330	25–0 "	40 "	5–8 "
" 10335	8–0 "	1 specimen	6 "
" 10336	40–0 "	15 specimens	10–19 "
" 10337	40–0 "	6 "	6–9 "
" 10337	bottom net	11 "	7–10 "
" 10338	60–0 meters	25 "	5–10 "

Gadidae.

Gadus callarias Linné.

1913.[1]

1 mile off Magnolia, Mass.		16 specimens	4–8 mm.
Station 10057		1 specimen	13 "

1914.

Station 10229	80–0 meters	1 specimen	51 mm.
" 10230	40–0 "	1 "	23 "
" 10236	65–0 "	1 "	15.5 "

1915.

Station 10300	59–0 meters	17 specimens	10–31.5 mm.

Melanogrammus aeglifinus (Linné).

1913.[1]

40° 43′ N.; 70° 12′ W.: June 5	9 specimens	16–27 mm.
43° 48′ N.; 70° 05′ W.: " 6	1 specimen	20 "
Station 10057	3 specimens	9–11 "
" 10058	2 "	29 & 64 "
" 10085	5 "	54–109.5 mm.
" 10087	1 specimen	128.5 "

1915.

Station 10300	59–0 meters	11 specimens	8–15 mm.

Brosmius brosme (Müller).

1915.

Station 10330	59–0 meters	3 specimens	7.5–8.5 mm.

Urophycis chuss (Walbaum).

1914.

Shelburne Harbor, N. S.	surface	1 specimen	72 mm.

Urophycis chesteri Goode & Bean.

1914.

Station 10258	surface	2 specimens	25 & 35 mm.
" 10258	25–0 meters	9 "	5–6 "
" 10259	50–0 "	3 "	8–10 "

[1] For the location of Stations see 1915, p. 342.

Urophycis tenuis (Mitchill).

1915.

21 miles So. of Mt. Desert Rock Aug. 6 surface 1 specimen 71 mm.

Urophycis sp.?

1915.

Station 10332	45–0 meters	9 specimens	21–32 mm.
" 10333	70–0 "	7 "	8–13 "
" 10335	8–0 "	1 specimen	6.5 "

Enchelyopus cimbrius (Linné).

1914.

Station 10251	surface	2 specimens	21 & 4 mm.
" 10256	130–0 meters	1 specimen	10 "

1915.

Station 10300	59–0 meters	1 specimen	7.5 mm.
Kittery Harbor Aug. 2	0 "	18 specimens	17–42 "
6 m. off Thatchers Island, Aug. 24	0 "	6 "	6.5–35 "
Station 10319	25–0 "	1 specimen	34 "
" 10320	50–0 "	1 "	6 "
" 10321	25–0 "	14 specimens	4.5–11 "
" 10330	25–0 "	2 "	4.5–5.5 "

Pleuronectidae.

Hippoglossoides platessoides (Fabricius).

1914.

Station 10213	50–0 meters	1 specimen	21 mm.
" 10215	70–0 "	2 specimens	10–13.5 "
" 10236	65–0 "	2 "	16.5 & 30 "
" 10237	75–0 "	2 "	19 & 21.5 "

1915.

Station 10279	60–0 meters	16 specimens	12–18.5 mm.
" 10280	15–0 "	5 "	8–10 "
" 10300	59–0 "	97 "	7–21.5 "

Limanda ferruginea (Storer).

Station 10224	60–0 meters	5 specimens	12–16 mm.
" 10258	25–0 "	2 "	12.5 & 15.5 "

Glyptocephalus cynoglossus (Linné).

1914.

Station 10258	25–0 meters	19 specimens	10–19 mm.

1915.

Station 10300	59–0 meters	109 specimens	8–23.5 mm.
" 10311	50–0 "	1 specimen	20.5 "
" 10320	50–0 "	22 specimens	10–14 "
" 10321	25–0 "	11 "	8–16 "
" 10321	bottom net	5 "	12–15 "
" 10329	40–0 meters	1 specimen	35 "
" 10330	25–0 "	1 "	9.5 "

Lophopsetta maculata (Mitchill).

1915.

Station 10337	60–0 meters	1 specimen	6 mm.

Monolena sessilicauda Goode. (Symmetrical larvae)

Station 10218	60–0 meters	1 specimen	39 mm.
" 10218	400–0 "	1 "	45 "

LOPHIIDAE.

Lophius piscatorius Linné.

Station 10321	25–0 meters	1 specimen	5 mm.

It would be premature to draw any general conclusions from the scanty data as to distribution of fish fry in the Gulf of Maine, though some features of the preceding list may be noted.

Perhaps the most interesting, certainly the most unexpected of these, is that young Cod and Haddock have appeared so seldom in the hauls, though both these species, particularly Haddock, spawn in large numbers in the Gulf; their eggs occurring more regularly in the townets than those of other fish (p. 257); and we have never taken any Mackerel fry in the Gulf, though Mackerel eggs are by no means rare there (p. 264). Since the nets in use were all adapted to the capture of the small fry, and did yield considerable numbers of other

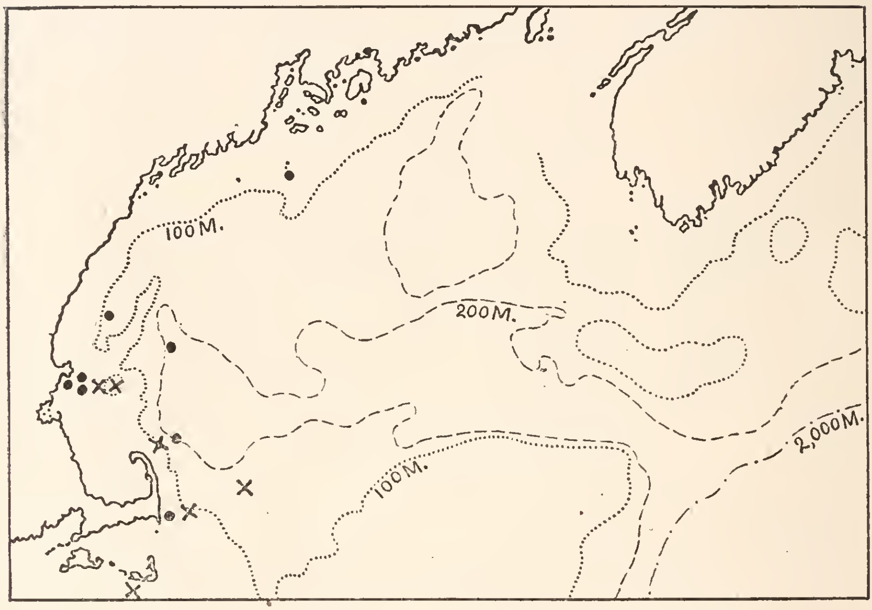

FIG. 86. GRAMPUS records for larval cod, ●, and larval haddock, X, 1912–1915.

young fish, notably Sebastes, and Merluccius, it can hardly be supposed that if Cod and Haddock larvae were as numerous as Silver Hake fry the nets would consistently miss the one, and capture the other. Consequently, even if the youngest pelagic stages of Cod and Haddock are not as rare in the Gulf as the records suggest, there is good reason to conclude that they are not abundant there during the summer. Furthermore, the few records of young Cod and Haddock are all grouped in the southwest corner of the Gulf (Fig. 86), though their eggs were as abundant in the east as in its west side; and our captures of Silver Hake fry are similarly limited to the immediate neighborhood of the coast in the southern and southwestern corner of the Gulf (Fig. 83) though its eggs occur all along the coastal zone from Cape Cod to Nova Scotia; and this has so consistently been the experience for the past four summers, during which so many hauls have been made in various parts of the Gulf, that it must be accepted as the normal condition for the summer.

All this, of course, suggests a migration, or rather drift, of the young fry, westerly and southwesterly around the periphery of the Gulf of Maine, past Cape Cod, and so either to Nantucket Shoals or Georges Bank; and, such a movement would agree very well with the circulation of the Gulf (p. 234), while, as is now well known, the young Cod in Norwegian waters perform even more extensive migrations, due to hydrographic causes (Hjort, 1914). But this suggestion must be tested much more extensively before it can be accepted as proved.

In northern European waters the European Hake is regarded as a southern or summer fish, and the distribution of the eggs and larvae of the Silver Hake, particularly the great abundance of the latter off Marthas Vineyard and further west in 1913 (Stations 10063, 10070) indicates that this is likewise true of the Silver Hake as compared with such typical boreal species as the Cod or Haddock. But though Cod and Hake have rather different faunistic relationships, when their eggs are spawned side by side in the Gulf, as is the case in summer (p. 261), they are subject to similar conditions, and would necessarily undergo similar migrations if any; and such a migration, around the Gulf, if it actually takes place, would explain, not only the geographic location of our records for the Silver Hake fry (Fig. 83); but also the fact that in summer they are so much more abundant in the Gulf than young Cod or Haddock, because the chief spawning of the latter takes place in autumn, winter (Cod), and early spring (Haddock), so that their fry would naturally have drifted out of the northern part of the Gulf by late spring and summer, when most of our work has been done. Silver Hake, on the other hand, spawn chiefly in summer in the Gulf. It is, of course, obvious that if this be a true picture, it presupposes an immigration of small fish back into the Gulf, to maintain the rich population of gadoids, both large and small, which obtains there; and it is of course possible that more or less regular supplies of Cod may reach the Gulf from the north, via the Cabot Current; though this can hardly be supposed for the Haddock.

But our actual knowledge along this line being practically *nil*, I can only point out some of the vistas which the demonstration of the existence of a drift of young fish around the Gulf, such as the results suggest, would open up. Elucidation of this general problem offers a fertile field for study, of great economic importance.

The commonest young fishes in our hauls and the most regularly recurrent in the Gulf are the larvae of the Red Fish (*Sebastes marinus*).[1]

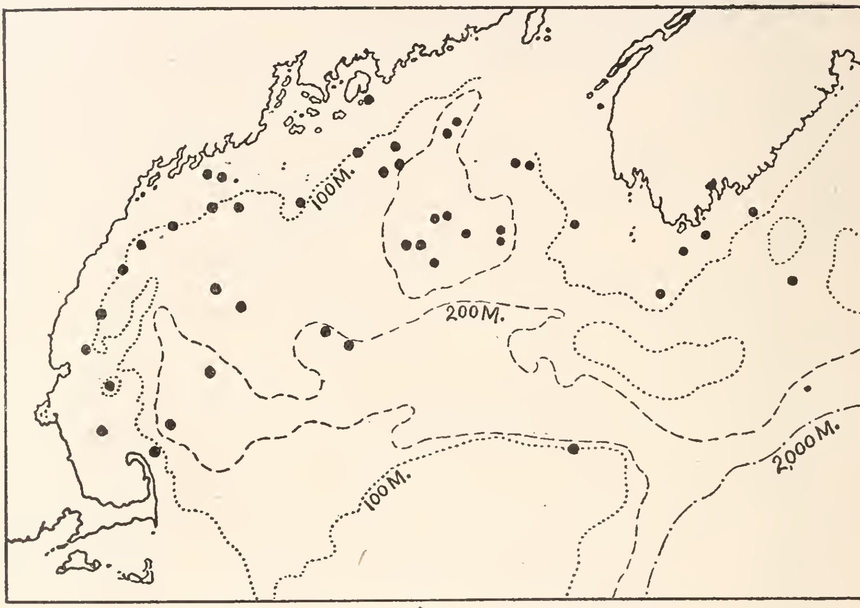

Fig. 87.— Grampus records for larval Sebastes, 1912–1915.

Enough have now been taken to show that they may be expected anywhere in the Gulf in summer (Fig. 87), especially between the coast and the 200 meter contour, and near the offshore Banks; we have even

[1] The captures of Sebastes larvae in July and August, 1913, are as follows: —

Station 10057	off Cape Cod	57 specimens
10087	" " Ann	152 "
10089	West of Cashes Ledge	19 "
10090	East of " "	224 "
10091	Jeffrey's Bank	49 "
10092	Eastern Basin	5 "
10093	" "	9 "
10097	" "	11 "
10100	Off Mt. Desert Rock	2 "
10102	" Monhegan I.	12 "

taken them in such partially enclosed waters as South West Harbor, Mt. Desert Island. Red Fish also breed on Georges Bank, where Mr. W. W. Welsh found females with young in June, 1912, though we have only once taken fry there (Station 10226); and though the young have not occurred in the hauls on Brown's, or Le Have Banks, or over the outer part of the shelf off Nova Scotia, their absence there is probably only apparent, in view of the records in the Northern Channel, near Cape Sable, and off Roseway Bank (Stations 10229, 10232, 10243). The largest catches of Red Fish larvae were made off Cape Elizabeth and on Platts Bank in 1912 (1914a); near Cashes Ledge in 1913; off Roseway Bank and Cape Sable in 1914 (Stations 10232, 10243); near Monhegan Island (Station 10303) and near Cashes Ledge (Station 10308) in 1915. Most of the records are from 40 or more meters, but they occasionally occur in large numbers on the surface. Their numbers in the Gulf, locally (*e. g.*, Station 10308) rival the swarms encountered by Schmidt [1] between Iceland and the Faroes (Ehrenbaum, 1905–1909, p. 52). The general and common occurrence of Red Fish larvae in the Gulf might at first seem an argument against the possible drift of gadoid larvae thence out onto Georges Bank (p. 279), on the ground that Red Fish would undergo a similar migration, resulting in a similar rarity of its fry in the Gulf. But when examined critically this argument loses weight, first, because Red Fish eggs are not pelagic; hence the period during which the species is subject to involuntary migrations is shorter; secondly and more important, because its reproduction takes place pretty much all over the Gulf, instead of in the coastal zone only, consequently, while the fry hatched near land are subject to the same conditions as Cod or Haddock, large numbers of Red Fish are likewise produced in the center of the Gulf outside the effective influence of its eddy-like circulation.

The occurrence of the young flounders, species of Hippoglossoides and Glyptocephalus, are interesting chiefly as indicating the spawning season (p. 276).

The only other economically or faunistically important species whose fry occur in any numbers in our hauls is the Herring (p. 268); but as this is now being made the subject of special study by the Bureau of Fisheries, the mere list of records will suffice.

Euphausiids.— The Euphausiids taken in 1914, identified by W. M. Tattersall, are listed in the following table.

[1] I have not had access to Schmidt's account, in Skifter udg, Kommission for Havundersogelser, 1904, no. 1, p. 46.

Grampus Station No.	Date. 1914.	Depth Meters	Thysanopoda acutifrons H. & T.	Meganyctiphanes norvegica M. Sars	Euphausia krohnii Brandt	Euphausia tenera Hansen	Euphausia hemigibba Hansen	Thysanoessa inermis Kroyer	Thysanoessa raschii M. Sars	Thysanoessa longicaudata Kr.	Thysanoessa gregaria G. O. Sars	Nematoscelis megalops G. O. Sars	Stylocheiron abbreviatum G. O. S.
10213	19/7	70–0		19 juv.				5					
14	19/7	100–0		5				5					
16	20/7	60–0						2			93		
20	22/7	80–0		1						6	49	3	
20	22/7	400–0			17	3	1					19	
23	23/7	60–0		2				abd.		5			
25	23/7	60–0		1									
25	23/7	240–0	5					1		8		2	
26	24/7	70–0						89					
27	24/7	180–0			10					6	4	3	
28	24/7	60–0		mod.				mod.		mod.	few	few	
29	25/7	80–0						ca 50		12	1	3	
30	25/7	40–0						ca 50					
31	27/7	0						30	4				
32	28/7	60–0		1					1				
32	28/7	100–0		–				16				2	
33	28/7	0			abd.			1					
33	28/7	100–0			abd.					mod.	few	abd.	
33	28/7	400–0				1				4		abd.	
34	29/7	75–0						23		2		2	
35	29/7	80–0						1		14			
37	6/8	75–0		1				1		4			
43	11/8	40–0						abd.					
46	12/8	150–0		181				1	1	6			
47	12/8	0						4					
48	13/8	150–0		24				7		21			
49	13/8	50–0						1		16			
49	13/8	175–0		3				9	1	32		6	
50	14/8	120–0						2		5			
53	22/8	80–0		4				abd.		few			
54	22/8	0		13				12					
54	22/8	75–0		38				11		15	12		
54	22/8	225–0		50				16		35	7		
55	22/8	150–0								5			
56	23/8	0		8							2		
56	23/8	130–0		35				25		18	4	15	
58	25/8	25–0						2					
59	25/8	50–0						abd.	2	1			
61	26/8	400–0			47					10	6		2

Euphausiids, though taken at most of the stations both in 1914 and in 1915, seldom formed an important constitutent of the plankton. However, the haul on Brown's Bank in July, 1914 (Station 10228, p. 245, Fig. 79) at 60 meters yielded 500 cc. of small individuals of three species of *Thysanoessa*, *T. gregaria*, *T. longicaudata*, and *T. inermis*, with a few *Nematoscelis megalops*, and large *Meganyctiphanes norvegica*. A few days later we again found a euphausiid plankton, over the continental slope off Shelburne, Nova Scotia (Station 10233, p. 245, Fig. 79) where half hour hauls on the surface, at 100 meters and at 200 meters yielded respectively 125 cc., 500 cc., and 250 cc., with very little else. In this case the surface catch consisted of *Euphausia krohnii*, the catch at 400 meters being *Nematoscelis megalops*, with a mixed swarm of the two at 100 meters. Swarms of euphasiid larvae were likewise taken on the surface off Cape Cod in August, of that year (Station 10264) in company with great numbers of large Calanus, while at Stations 10246 and 10254, the nets yielded a swarm of *Meganyctiphanes norvegica*.

In 1915 we again found Nematoscelis and Euphausia in large numbers over the slope off Shelburne (Station 10295), though the hauls on Brown's Bank (Station 10296) yielded none at all. The most notable occurrence of euphausiids during that summer was the reappearance of *Meganyctiphanes norvegica*, associated with the large copepod Euchaeta, in the northeast corner of the Gulf, where it was abundant in the deep haul (125–0 meters) in May (Station 10273); swarmed at about 100 meters in June (Station 10283) and was plentiful in the deep water (150–0 meters) in August (Station 10304). But although it was abundant at this same locality both in 1913 and 1914, not a single specimen was taken there in 1912 (1914a). At only two other localities in 1915 did euphausiids (*Thysanoessa inermis* in each case) form a large part of the catch, in the Eastern Basin in May (Station 10270) and off Cape Ann in August (Station 10306).

Thysanoessa inermis [1] is the commonest euphausiid in the Gulf of Maine, occurring at most of the stations there in 1914 (p. 282), and at twenty stations in 1915 (Stations 10270, 10271, 10273, 10275, 10277, 10279, 10283, 10288, 10290, 10291, 10293, 10304, 10306, 10307, 10309, 10310, 10318, 10329, 10332, 10333). But it was lacking in the hauls over the southern edge of Georges Bank, in the Eastern Channel, and at all the stations outside the continental slope, except for a single specimen at 10233. Hansen (1915) [2] records it from off Cape Cod,

[1] I follow Hansen (1911) in including both *Th. inermis* and *Th. neglecta* under this name.

[2] Hansen, in this paper, lists all the earlier captures by the various vessels of the U. S. Bureau of Fisheries in this region.

Brown's Bank, the coastal water south of Nova Scotia, the Woods Hole region, and over the continental shelf south of Marthas Vineyard; but not from the continental slope. His failure to find it in the large collections from outside the 100 fathom curve off Marthas Vineyard can hardly be accidental, as hosts of other euphausiids have been taken there on many occasions. In short, *T. inermis* is a characteristic inhabitant of the cold coastal water from southern Nova Scotia, as far west as Long Island. But it is evidently not at home in the high temperatures outside the continental slope, though of course it may be accidentally swept out into the Gulf Stream by the mixture of the two waters which takes place there. Its rarity or absence off Halifax in 1914 reflects the local rarity of the group and poverty of the macroplankton as a whole (p. 309).

Thysanoessa longicaudata, likewise a boreal species (Kramp, 1913, Zimmer, 1909) is as generally distributed in the Gulf as *T. inermis*. But it occurred less regularly, and at fewer stations in 1912, 1914, and especially in 1915 (when it was detected only once, Station 10304). On the other hand, it was taken at three deep stations over the slope, though not at the one (Station 10218) where salinity and temperature were most characteristically oceanic, and Hansen (1915) likewise records it from many stations over the continental slope, and the edge of the Gulf Stream south of Marthas Vineyard. Apparently it is less definitely associated with the coast water than is *T. inermis*.

Thysanoessa raschii, likewise a northern form (Kramp, 1913, Zimmer, 1909), is much less common in our waters in summer than either of the preceding species, for it was not represented at all in the hauls in July 1912; appeared at only five stations in 1914 (two in the Gulf, two in the cold water off southern Nova Scotia, Stations 10231, 10232, one off Marthas Vineyard, Station 10259); and at three Stations (10277, 10318, 10329) in 1915. But it swarmed in the western part of the Gulf during the early spring of 1913 (1914b). Hansen's (1915) records are chiefly from the Gulf of St. Lawrence. But they include one station on Brown's Bank, August 1877, and one off the northern end of Cape Cod, August 1881. Apparently the Gulf of Maine is the extreme southern limit for this species in summer.

The occurrence of *Thysanoessa gregaria*, side by side with *T. inermis* and *T. raschii* is, as Dr. Tattersall writes me, an interesting phenomenon, because, unlike them, it is a typical subtropical form (Zimmer, 1909), its presence, like that of Salpa, and other tropical animals, indicating the presence of southern, *i. e.*, ocean, waters in the Gulf (p. 239). *Thysanoessa gregaria* is much less common in the Gulf than *T. inermis,* but the records for 1912 (1914a, p. 412), 1914 (p. 282) and 1915 (Stations 10306, 10307, 10308, 10310, 10318) show that it may be expected anywhere there, likewise on Brown's and Georges Banks, in the Eastern Channel, and in the waters outside the continental slope. Its absence in the cold coast water off Nova Scotia is explained by its southern origin. Hansen (1915) records it at two oceanic stations south of Marthas Vineyard. Our data, particularly its occurrence in 1915, when it was not detected until August, suggest that it increases in numbers, and penetrates further and further into the Gulf, as summer advances.

The captures of *Meganyctiphanes norvegica* in 1912, 1913, 1914, and 1915 show that it may be expected anywhere in the Gulf of Maine and in the cold water off southern Nova Scotia. The GRAMPUS did not find it in Massachusetts Bay in 1912, 1914, or 1915 but Hansen (1915) records it there; and although we did not take it in any of the oceanic hauls, he lists it in small numbers from many stations outside the continental slope south of Marthas Vineyard, for the summers of 1880–1894, and once off the southern edge of Georges Bank. Off this coast Meganyctiphanes appears to be most abundant near land, though it also extends seaward to the zone of mixture between coastal and Gulf Stream water, which agrees with its general occurrence on the other side of the north Atlantic (Kramp, 1913; Tattersall, 1911). But while in European waters it is generally most abundant in regions where the depth is as great as 150 fathoms (Holt & Tattersall, 1905; Tattersall, 1911; Kramp, 1913), in the Gulf of Maine it often swarms in the shallow water of harbors and bays.

Nematoscelis and Euphausia are typical oceanic species (Holt & Tattersall, 1905; Tattersall, 1911; Kramp, 1911). The former was taken once in 1912 (1914b, p. 411); and in 1914 it was encountered only twice in that part of the Gulf covered by previous cruises (1914a, 1915). But it likewise occurred in small numbers in the southeast corner of the Gulf, in the Eastern Channel, off the southeast face of Georges Bank, on Brown's Bank, and on Le Have Bank. It was abundant in the deep hauls over the slope south of the latter, both in 1914 (p. 282) and in 1915 (Station 10295, p. 283). Hansen (1915) does not record Nematoscelis from the Gulf of Maine, from Georges Bank nor indeed from the continental shelf north and east of Cape Cod; but he lists it from many localities over the continental slope, particularly south of Marthas Vineyard.

Euphausia krohnii is apparently even more oceanic in our waters than Nematoscelis, for it was only in the Eastern Channel and over the continental slope (Stations 10233 and 10261, in 1914, Station 10295 in 1915) that it was taken; and Hansen's (1915) numerous records are all either from the oceanic water outside the continental slope, or from the outer part of the shelf. Its abundance at Station 10233, and its bathymetric distribution there relative to that of Nematoscelis is noted above (p. 283).

Hyperiid Amphipods.— Hyperiid amphipods are chiefly represented in the collections by two species of Euthemisto, *E. compressa* and *E. bispinosa.* In 1914 these two combined, formed a considerable portion of the volume of the horizontal hauls over the continental shelf as a whole south of Nova Scotia; on the southern and western parts of Georges Bank; and on the shelf south of Marthas Vineyard (p. 245), being especially numerous off Cape Sable (Station 10229), west of Le Have Bank (Station 10232), south of Marthas Vineyard (Station 10259) and along the southern half of Georges Bank (Stations 10216–10219); and one or the other, or both, occurred at every one of the Stations.

While exact numerical results can not be expected from horizontal hauls, it may be of interest to note that about 1000 cc. of large Euthemisto were taken in a half-hour haul on the surface in a 1 meter-net on Brown's Bank (Station 10228); 750 cc. on the surface off Shelburne; and about 1000 cc. of medium sized specimens at 40 meters off Cape Sable (Station 10243) in hauls of the same duration. This abundance is apparently characteristic of these waters, for Euthemisto again formed a considerable part of our catches on the shelf south of Nova Scotia (Stations 10291–10294); on Brown's Bank (Station 10296) and off Marthas Vineyard (Stations 10332, 10333) in the summer of 1915. Euthemisto is more or less seasonal in its occurrence in the Gulf, for only occasional specimens were taken in May; and it was not until June 19 (Station 10288) that it appeared in any numbers in the tow.

Very large adults, with eggs, were taken very generally over the whole area both in 1914 and in 1915. But the chief breeding areas, as indicated by relative abundance, are over the continental slope, (Station 10220, 10261); the central and northwestern parts of Georges Bank (Station 10215, 10216, and 10219); on Brown's Bank (Station 10228), and off Shelburne (Station 10231). In fact, young larvae were numerous on the surface, adults, with eggs, in the deep haul, both on Georges Bank in 1914, (Stations 10215 and 10219), and off Shelburne (Station 10293) in 1915. But there is no apparent correlation between these spawning areas and hydrography, since they cover nearly the entire range of both salinity and temperature for the general area under study.

The proportionate abundance of the two species [1] in the summer of 1914 is shown in the following table, which gives the relative numbers in samples from each haul.

Stations and Depths in Meters.

	10213 70–0	10214 100–0	10215 50–0	70–0	10216 60–0	10218 60–0	300–0	10219 0	80–0	10220 80–0	400–0	10223 60–0	10224 60–0	10225 60–0	10226 70–0	10227 180–0	10228 0	60–0
compressa	12	7	11	6	6	2	6	S[2]	5	9	15	0		17	22	4	4	21
bispinosa	0	9	13	3	13	2	1		14	8	4	86		3	6	5	35	14

	10229 0	80–0	10230 40–0	10231 0	10232 60–0	100–0	10233 0	100–0	300–0	10234 75–0	10237 75–0	10242 0	10243 40–0	10245 0	10245 100–0	10246 0	50–0	150–0
compressa	4	20	9	25	10	23	3	25	5	16	6	S[2]	4	4		11	13	8
bispinosa	29	2	8	14	5	11	1	17	4	14	18		15	17		8	8	5

	10217 0	10218 50–0	150–0	10249 50–0	175–0	10250 120–0	10253 80–0	10254 0	75–0	225–0	10255 150–0	10256 130–0	10258 25–0	10259 50–0	10260 140–0	10261 400–0
compressa	2	3	7	9	11	7	4	3	3	2	7	8	0	0	4	19
bispinosa	3	0	9	22	19	6	0	0	3	6	1	4	30	20	36	3

[1] Identifications follow Sars, 1890–1895.

[2] S, = Swarm of the two species combined.

For distributional purposes we may divide the stations into three classes:— first those where *E. compressa* was twice as numerous as *E. bispinosa,* at one level at least, and about equal to it in numbers at the other; second, the reverse; and thirdly stations where the two were either nearly equal in numbers, or where one greatly predominated at one, the other at another depth. On this basis *E. compressa* predominated in the southwest part of the Gulf of Maine, and locally in its northeast corner (Stations 10246, 10248), on the northeast edge of Georges Bank (Station 10226), over the outer part of the shelf south of Shelburne, Nova Scotia; and probably all along the continental slope (Stations 10218, 10220, 10233, 10261). *E. bispinosa* outnumbered *E. compressa* in the eastern part of the Gulf, in the Northern Channel, on Brown's Bank, locally off Halifax (Station 10237), and over the southern part of Georges Bank.

In 1915 *E. compressa* was the more numerous of the two in the Gulf in May and June; but in the latter month *E. bispinosa* predominated over the outer part of the shelf off Shelburne (Station 10294) as well as on Brown's Bank (Station 10296). In August *E. bispinosa* predominated in the Western and Eastern Basins (Stations 10307, 10310) and on German Bank (Station 10311), while it outnumbered *E. compressa* locally off Marthas Vineyard (Stations 10331–10333), off Cape Cod and in Massachusetts Bay in October (Stations 10336, 10337). These records suggest that while *E. compressa* is a permanent and characteristic inhabitant of the Gulf, *E. bispinosa* is absent, or at least rare, there in spring, appearing in summer, when it may locally outnumber *E. compressa,* particularly in the eastern half of the Gulf. But it is very rarely as numerous as *E. compressa* in the coast water of the western side of the Gulf, and that only in autumn, as just noted, and in winter (1914b, p. 410).

In the coast waters off Nova Scotia *E. bispinosa* is faunistically more important, usually equalling if not outnumbering *E. compressa,* particularly over the outer part of the shelf. We have always found it the predominant member of the pair in the shallow waters south of Marthas Vineyard, and on the southern part of Georges Bank. In the coast water east of Cape Cod, *E. bispinosa* is apparently the more oceanic of the two. But the difference between the two, in this respect, is one of relative abundance only, for they occur together in most of our hauls, and it is difficult to correlate the predominance of one, or the other with hydrography, or with depth, though *E. bispinosa* has more often outnumbered *E. compressa* in deep, than in shallow hauls, especially at localities where both species are abundant.

The occurrence of hyperiid amphipods other than Euthemisto, in 1914, is given in the following table.

	10218 60–0	300–0	10219 80–0	10220 400–0	10231 0	10233 0	10235 80–0	10237 75–0	10248 50–0	10260 140–0	10261 400–0
Oxycephalus sp.		3									
Hyperoche abyssorum						2	1	1	1		
Parathemisto oblivia					1			5			
Phronima sedentaria		4	1	2							6
" atlantica	51	17	1							1	
Phrosina semilunata	25										
Phronimella elongata	3										
Vibilia sp.		2									

In 1915 *Parathemisto oblivia* was taken again off Shelburne (Station 10291, five specimens); *Hyperoche* and *Hyperia* at several stations in the Gulf: Phronima on Brown's Bank (Station 10296) and off Marthas Vineyard (Station 10333).

The rarity of Parathemisto reproduces our experience in previous years (1914a, 1914b, 1915), and its repeated occurrence close to the southern coast of Nova Scotia suggests that when it does reach the Gulf, it is brought thither by the St. Lawrence water.[1] Hyperoche was much more common in 1912 and 1913 than in 1914 or 1915 and more generally distributed; and neither of the two species of Hyperia, *H. galba* and *H. medusarum*, was found in 1914, though both were common in previous summers. Especially interesting is the large haul of oceanic warm water species at Station 10218. Two of these, Phronimella and Phrosina, are now recorded for the first time from our waters so far as I can learn (Holmes, 1895). But as both are widely distributed in the Atlantic (Bovallius, 1889) there is nothing remarkable in their occurrence in the inner edge of the Gulf Stream.

Copepods.— Our records for this group in the Gulf of Maine add little except in the way of verification, to those for 1912 (1914a) and 1913 (1915).

In 1914 and 1915 as in previous summers, *Calanus finmarchicus*

[1] Parathemisto is recorded from the Gulf of St. Lawrence by Whiteaves, 1901.

was universal, not only in the Gulf but on Georges Bank, and in the coastal waters south of Nova Scotia, occurring not only at every station, but in practically every haul; by far the most important individual member of the plankton.[1] But it occurred only in small numbers over the continental slope (Stations 10220, 10233, and 10261); and was wanting both in the Gulf Stream plankton off the southwestern edge of Georges Bank (Station 10218) and over the outer part of the shelf south of Marthas Vineyard (Station 10259).

Second only to *Calanus finmarchicus* numerically, though much less important economically because of its small size, is *Pseudocalanus elongatus*, which was again found at every station in the Gulf in both years (p. 243), and on Georges Bank; as well as at most of our stations in the cold waters off southern Nova Scotia (Stations 10229–10232; 10234–10243), and locally on the shelf south of Marthas Vineyard (Station 10260). But it was lacking at all our deep stations over the continental slope, and on Brown's Bank (Station 10228) as well, which agrees with its absence in the inner edge of the Gulf Stream in 1913 (1915).

The records in 1914, for copepods other than *Calanus finmarchicus* and *Pseudocalanus elongatus*, as identified by Dr. C. O. Esterly, are listed in the following table. Only a preliminary examination has yet been made of the copepods taken in 1915.

	10213 70–0	214 100–0	215 70–0	218 60–0	300–0	219 80–0	220 400–0	223 100–0	224 60–0	225 240–0	227 80–0	228 60–0	229 80–0	230 40–0
Calanus hyperboreus	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Rhincalanus nasutus	....	....	....	×	×	....	×	....	....	....	....	....	....	....
" *cornutus*	....	....	....	×	....	....	....	....	....	....	....	....	....	....
Eucalanus attenuatus	....	....	....	×	×	....	....	....	....	....	....	....	....	....
" *elongatus*	....	....	....	×	×	....	....	....	....	....	....	....	....	....
Eucheirella rostrata	....	....	×	×	....	×	....	....	....	×	....	....	....	....
Euchaeta norvegica	×	×	×	....	....	....	....	....	....	×	....	....	....	....
Centropages typicus	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Temora longicornis	....	×	....	....	....	....	....	....	×	×	....	....	....	....
Metridia lucens	×	....	....	....	....	....	....	×	....	×	×	×	×	×
Heterorhabdus spinifrons	....	....	....	....	×	....	×	....	....	....	....	....	....	....
Anomalocera pattersoni	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pleuromamma gracilis	....	....	....	....	....	....	×	....	....	....	....	....	....	....
" *robustum*	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" *abdominalis*	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Acartia longiremis	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Candacia Sp.?	....	....	....	....	....	....	....	....	....	....	....	....	....	....

[1] The numerical occurrence of Calanus is discussed elsewhere, p. 317.

	10232 100–0	233 60–0	400–0	240 50–0	245 0	100–0	246 0	50–0	150–0	247 0	248 150–0	249 50–0	175–0
Calanus hyperboreus	×	....	....	....	....	....	....	....	....	....	....	×	....
Rhincalanus nasutus	....	....	....	....	....	....	....	....	....	....	....	....	....
" *cornutus*	....	....	....	....	....	....	....	....	....	....	....	....	....
Eucalanus attenuatus	....	....	....	....	....	....	....	....	....	....	....	....	....
" *elongatus*	....	....	....	....	....	....	....	....	....	....	....	....	....
Eucheirella rostrata	....	×	....	....	....	....	....	×	....	....	....	....	....
Euchaeta norvegica	×	×	....	....	....	×	....	....	×	×	×	×	×
Centropages typicus	....	....	....	....	....	....	×	....	....	....	....	....	....
Temora longicornis	....	....	....	....	....	....	....	....	....	....	....	....	....
Metridia lucens	....	×	×	×	×	×	....	×	×	×	×	....	×
Heterorhabdus spinifrons	....	....	....	....	....	....	....	....	....	....	....	....	....
Anomalocera pattersoni	....	....	....	....	×	....	×	....	....	×	....	....	....
Pleuromamma gracilis	....	....	....	....	....	....	....	....	....	....	....	....	....
" *robustum*	....	....	×	....	....	....	....	....	....	....	....	....	....
" *abdominalis*	....	....	....	....	....	....	....	....	×	....	....	....	....
Acartia longiremis	....	....	....	....	....	....	....	....	....	....	....	....	....
Candacia Sp.?	....	....	....	....	....	....	....	....	....	....	....	....	....

	10250 120–0	251 0	253 80–0	254 0	25–0	75–0	255 150–0	256 0	130–0	258 25–0	259 50–0	260 140–0	261 400–0
Calanus hyperboreus	....	....	....	....	....	....	....	....	....	....	....	....	....
Rhinacalanus nasutus	....	....	....	....	....	....	....	....	....	....	....	....	....
" *cornutus*	....	....	....	....	....	....	....	....	....	....	....	....	....
Eucalanus attenuatus	....	....	....	....	....	....	....	....	....	....	....	....	....
" *elongatus*	....	....	....	....	....	....	....	....	....	....	....	....	....
Eucheirella rostrata	....	....	....	....	....	....	....	....	....	....	....	....	....
Euchaeta norvegica	....	....	....	×	×	×	....	×	×	....	....	....	....
Centropages typicus	....	....	....	×	....	....	....	....	....	....	....	×	....
Temora longicornis	....	....	....	....	....	....	....	....	....	....	....	....	....
Metridia lucens	×	....	×	....	....	....	×	×	×	....	....	×	....
Heterorhabdus spinifrons	....	....	....	....	....	....	....	....	....	....	....	....	....
Anomalocera pattersoni	×	....	....	×	....	....	....	....	....	×	×	....	....
Pleuromamma gracilis	....	....	....	....	....	....	....	....	....	×	....	×	×
" *robustum*	....	....	....	....	....	....	....	....	....	....	....	....	....
" *abdominalis*	....	....	....	....	....	....	....	....	....	....	....	....	....
Acartia longiremis	....	×	....	....	....	....	....	....	....	....	....	....	....
Candacia Sp.?	....	....	×	....	....	....	....	....	....	....	....	....	....

Calanus hyperboreus belongs fundamentally to the Arctic community (Farran, 1910, Murray and Hjort, 1912). Its occurrence in the Gulf of Maine agrees with its general distribution in so far as it was most abundant at the season (May and June) when northern water is at its maximum there; and its fluctuations off southern Nova Scotia, where it was about as numerous as *C. finmarchicus* in June, lacking in August, correspond with those of the Cabot Current. Hence, its numbers in the Gulf must receive annual accessions from the North. But its sporadic appearance here and there in the Gulf, at all seasons, together with the fact that even in spring it was rare or absent just where Cabot Current water was most in evidence (Stations 10270–10272), suggests that it may also be endemic in the Gulf of Maine.

Metridia lucens was practically universal in the Gulf of Maine in 1914, as in past years, though never abundant there. It was as generally distributed over the Gulf throughout the spring and summer in 1915, though much less numerous in that year when it was detected at only about half the stations.[1]

In 1914 it occurred in several surface hauls, instead of being restricted to depths of 25 meters or more, as was the case the year before (1915, p. 295).

Euchaeta norvegica played much the same rôle in the Gulf in 1914 and 1915 as in 1912 and 1913 (Fig. 88), occurring in most horizontal hauls deeper than 100 meters, sporadically at higher levels; and even on the surface both in the Gulf (Stations 10247, 10254, 10256) and off Shelburne (Station 10294). But although the surface hauls have occasionally yielded considerable numbers of Euchaeta (*e. g.*, Station 10032 in 1912; 1914a, p. 104) it is far more numerous and regular in its occurrence in the depths of the Gulf, of which it is one of the most characteristic inhabitants; as it is of the mid-layers of the Norwegian Sea (Gran, 1902); and almost all the records for Euchaeta have been from outside the 100 meter curve, no matter at what depth the specimens were taken. As a rule Euchaeta occurs in small numbers only, so much so that it seldom appears in the vertical hauls. But it was abundant in the northeast corner of the Gulf both in 1914 and in 1915 (p. 250).[2]

Temora longicornis and *Anomalocera pattersoni* have markedly diminished in the Gulf of Maine since 1913 (p. 290). The latter, a species so conspicuous, both in life and after preservation, that it is not likely

[1] *Metridia lucens* occurred at the following Stations in 1915: 10270, 10272. 10273, 10278, 10279, 10282, 10283, 10284, 10286, 10294, 10295, 10299, 10304, 10306, 10307, 10308, 10309, 10311, 10314, 10315, 10318, 10324, 10325.

[2] In 1915 Euchaeta was taken at Stations 10270, 10273, 10276, 10282, 10283, 10286, 10293, 10294, 10304, 10306, 10307, 10309, 10310.

to be overlooked, was detected at only four stations in 1915 (Stations 10303, 10307, 10308, 10314), instead of being widely distributed as in former years (p. 295). On the other hand the 1915 hauls add one species, *Eucalanus elongatus*, to the list of the Gulf of Maine copepods (Station 10253), interesting because it is a typical warm water, oceanic form (Farran, 1911), not previously recorded from the general region. The records of *Rhincalanus nasutus* (Station 10272, 10273), *Eucheirella rostrata* (p. 246, Stations 10270, 10294, 10310) and *Pleuromamma abdominalis* in the Gulf (p. 246) are likewise worth noting, because of their oceanic origin.

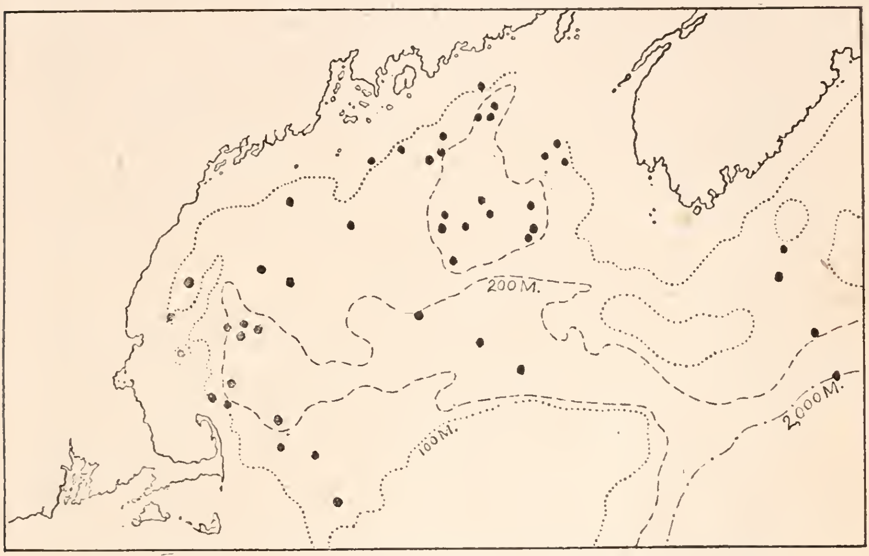

Fig. 88.— Locality records for *Euchaeta norvegica* in the Gulf of Maine and off Nova Scotia, 1912–1915.

Copepods practically disappear from the western side of the Gulf in April (1914b). But very little is known of the manner of their reappearance, *i. e.*, whether the copepod fauna is reestablished, more or less evenly over the Gulf, by the multiplication of the few which survive during the barren season; or whether it is recruited from local centers of reproduction, or by migration from outside waters. The great regional variation in number of copepods in May (p. 314), and the subsequent equalization which takes place during the summer, shows that in 1915 at least there were two distinct centers for copepods in spring, one on the western, the other on the eastern side of the Gulf;

and the fact that the richness of these decreased, while that of the nearby stations increased, is good evidence that copepods were actually dispersed from them throughout the neighboring waters.

The May swarm off Cape Ann (Station 10266) consisted chiefly of very young stages of Calanus, with occasional older stages, and of Pseudocalanus; *i. e.*, it was an actual growth center, not an evidence of immigration, and this agrees with our earlier observations that copepod nauplii appear in swarms in Gloucester Harbor in early May followed by great numbers of young Calanus in the adjacent waters later in the month (1914b, p. 407). The May swarm in the Eastern Basin (Station 10270) contained a much larger proportion of adult *Calanus finmarchicus*, with comparatively few very early stages; hence, so far as internal evidence goes, it might either have represented an immigration, or a late stage in a local reproductive cycle, the unmistakable influence of the Cabot Current in this region (p. 224) giving the first of these alternatives an *a priori* probability. But as there are no records from the waters further south or east in May, and it is not known whether copepods dwindle almost to the vanishing point in the eastern half of the Gulf in early spring as they do in the western, indeed nothing is known of the plankton there from September to May, and the question remains open.

Sagittae.— Sagittae were taken at nearly all stations, both in 1914 and in 1915; but the quantitative importance of this group, in the plankton as a whole, differed greatly in different regions. Thus in July 1914, Sagittae swarmed on the northeastern edge of Georges Bank (Station 10224, Fig. 79) and again in the Northern Channel (Station 10229), where the meter-net, at 100 meters, yielded upwards of three liters. The opposite extreme was found on Brown's Bank (Station 10228), off Shelburne (Station 10231), off Halifax (Station 10237), and off Penobscot Bay (Station 10250), where the catches were respectively, two, seven, five, and two specimens; while none were taken in the basin north of Le Have Bank (Station 10235). In 1915 Sagittae formed a considerable portion of the catch off Lurcher Shoal in May (Station 10272) and near Shelburne (Stations 10291, 10295) in June; while they swarmed in Massachusetts Bay late in September (Station 10321) and off Marthas Vineyard in October (Station 10232). But nowhere in that year were they as abundant as the local swarms of the preceding season.

Our experience has been that *Sagitta elegans* and *S. serratodentata*[1]

[1] Identifications follow Ritter-Zahony 1911 and Michael, 1911.

are always, and everywhere, the most abundant chaetognaths in the Gulf of Maine (1914a, 1915), and that of the two, *S. elegans* is invariably predominant in its western part (fig. 89). In the summer of 1914 *S. elegans* was the only Sagitta taken on the northern and northwestern parts of Georges Bank, (Stations 10215, 10224), off Massachusetts Bay and Cape Cod, both in July and in August (Stations 10213, 10214, 10253, 10256, 10264); and in the Northern Channel (Station 10229). It greatly outnumbered *S. serratodentata* on the

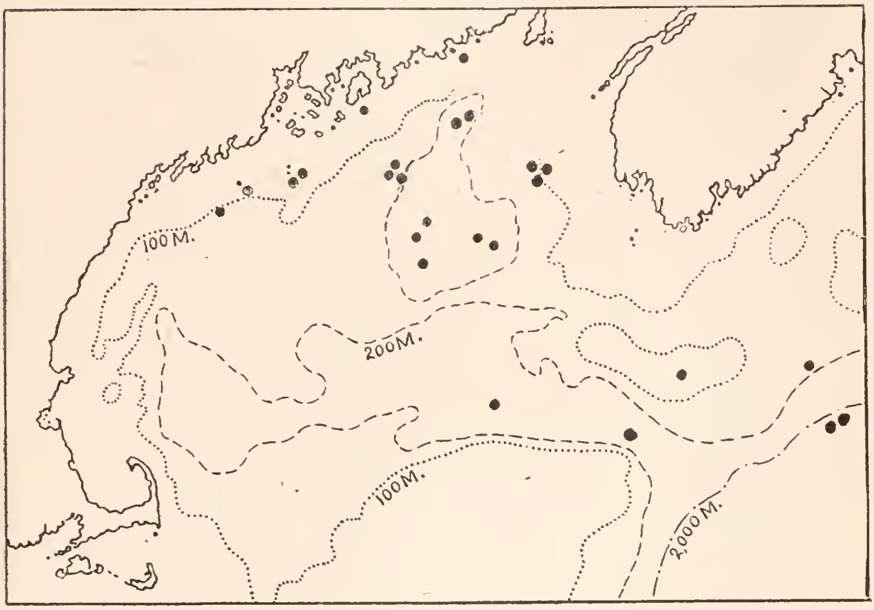

FIG. 89.— Localities indicating *Sagitta serratodentata* as abundant as, or outnumbering, *S. elegans*, 1912–1915. Only those stations where sufficient Sagittae were taken for their proportional numbers to be significant, are included.

southwestern part of Georges Bank (Station 10216), and in most of the hauls on the continental shelf south of Nova Scotia (Stations 10236, 10234, 10232).

In that year the catches off the coast of Maine (Stations 10248, 10250, 10251), on the southeastern part of Georges Bank (Station 10223), and locally off Nova Scotia, contained the two in roughly equal numbers. *Sagitta serratodentata* was much the more numerous of the two in the deep hauls in the eastern and southeastern parts of the Gulf (Stations 10225, 10245, 10246, 10249), in the Eastern Channel (Station 10227), on the southern edge of Georges Bank (Station 10219), and over the continental slope (Stations 10218, 10220, 10233). It was predominant in 1915, only locally, in the eastern and northern parts of the Gulf as illustrated by the following table, and chart (Fig. 89).

Station	Species present	Species predom.	Station	Species present	Species predom.
10266	E		10304	E,	
10270	E		10306	E, S	E
10271	E		10307	E, S	E
10272	E, S	E	10309	E, S	S
10273	E, S	E	10310	E, S	S
10275	E		10311	E, S	E
10277	E		10316	E	
10279	E		10317	E, S	E
10281	E, S	E	10318	E, S	E
10282	E, S	E	10319	E	
10286	E, S	E	10320	E, S	E
10287	E		10321	E, S	E
10288	E, S	E	10323	E, S	E
10290	E		10327	E, S	E
10291	E		10328	E, S	E
10293	E		10330	E	
10294	E, S	equal	10332	E	
10295	E, S	"	10333	E, S	S
10296	E, S	S	10337	E	
10303	S		10338	E, S	E

E = elegans. S = serratodentata.

The records for 1915, together with data previously acquired show that while *S. elegans* occurs very generally all over the Gulf probably at all seasons, (1914a, 1915), the distribution of *S. serratodentata* depends largely upon the season. Thus in May and June it was found only in the eastern part of the Gulf, in the Bay of Fundy, and off southern Nova Scotia (Fig. 90); and in four years it was detected only once (1914a, Station 10019) in the western and southwestern parts of the Gulf prior to August 1. In late summer and autumn, on the other hand, it was found at most of the stations there, and in Massachusetts Bay (Fig. 90). *Sagitta serratodentata* is the prevalent Sagitta in the coastal water south and west of Cape Cod (1915).

But in the Gulf of Maine *S. elegans* plays that rôle, except locally, in its eastern side (Fig. 89).

These facts support the general thesis that while *S. elegans* is endemic in the boreal waters of the Gulf, *S. serratodentata*, a more southern species, is carried thither and to Nova Scotian waters by the current from the southwest.

Six more species of chaetognaths have so far been detected in the collections of 1914 and 1915. *Sagitta lyra* occurred sparingly in the deep hauls in the Gulf and Eastern Channel in 1914 (Stations 10225,

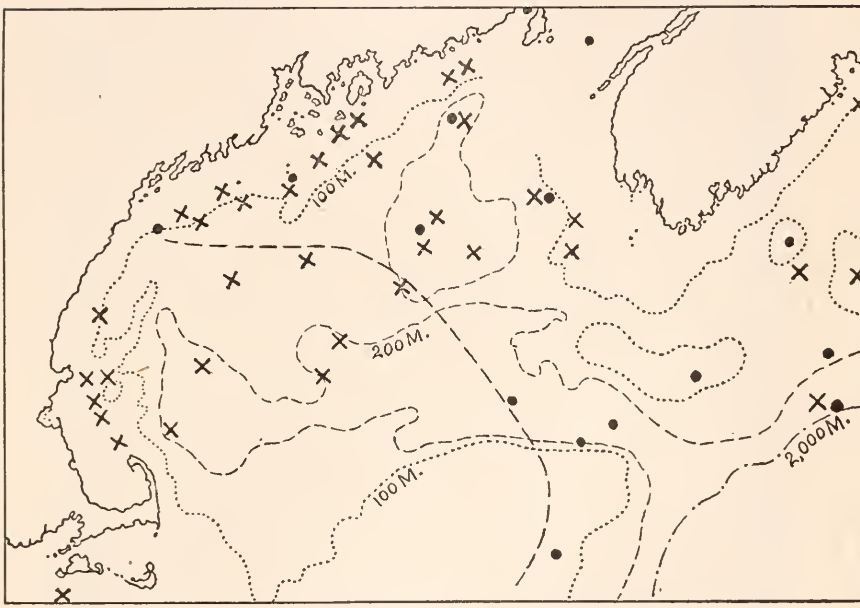

FIG. 90.— GRAMPUS records for *Sagitta serratodentata*, 1912–1915. ●, records for May–July 15; X, July 15; ....February; ------, western limit, May to August.

225–0 M; 10227, 180–0 M; 10248, 150–0 M; 10254, 225–0 M; in 1914: Station 10310, 100–0 M; in 1915), and at most of the stations over the continental slope (Stations 10220, 10233, 10261, 10295) in hauls at 400–500 meters. But it was lacking in all shallow hauls even at these same stations. *Sagitta hexaptera* has been detected in one haul only (Station 10245, 100–0 meters, one specimen).

The warm water *S. enflata*, which is common south of New York

(1915, p. 300), appeared, with other tropical organisms, in the tows over the continental slope in 1914 (Stations 10218 and 10220); off Marthas Vineyard in 1915 (Station 10333, one specimen); and *Pterosagitta draco*, similarly tropical in origin, was represented by about fifty specimens in the 60 meter haul at Station 10218, a record worth noting as it has not been found before in this region, though known south of New York (1915, p. 297).

Eukrohnia hamata was taken at one station in 1912; at nine stations in the Gulf in 1913; at six stations in 1914, four in the Gulf (Stations 10225, 10246, 10248, 10254) two on the continental slope (Stations 10220, 10233). In 1915 it was taken only twice in the Gulf (Stations 10304 and 10310 in hauls from 150 and 130 meters respectively); but it also occurred in the shallow waters on Brown's Bank (Station 10296), and was abundant over the slope off Shelburne (Station 10295). The depths of the hauls range from 60–0 meters at Station 10296 to 400–0 meters at Stations 10220 and 10233; the total number of specimens being about 120. It is interesting that no *E. hamata* were taken in the 60 meter haul at Station 10225, or the 50 meter hauls at Stations 10240 and 10248, since it occurred at other depths at those localities. The largest catches were on the slope, and in the southeastern corner of the Gulf (Station 10225). I have discussed the faunal significance of this species elsewhere (1915, p. 301).

Pteropods and Heteropods.— In 1914 and 1915, as in previous years (1915, p. 303), the only members of these groups which attained any faunal prominence in the Gulf of Maine were *Limacina balea* and *Clione limacina*. In the summer of 1914 the former was numerous off Cape Cod (Station 10264), and swarmed over the northwest edge of Georges Bank (Station 10215), where about 125 cc. were taken in a haul at 50 meters. Considerable (though much smaller) catches of Limacina were likewise made at Stations 10216 and 10259; in the Eastern Channel; in the northeast corner of the Gulf (Stations 10246, 10247); and at three of the four stations on the slope (Stations 10220, 10233, 10261). But only one specimen was taken at the oceanic Station (10218) where the plankton as a whole was tropical, and at the time of our 1914 cruise it was equally wanting in the northwestern part of the Gulf (Stations 10251, 10253, 10254), though this was its chief center of abundance in 1912 (1914a). It was likewise rare, or absent in August 1914 in the waters south and southwest of Halifax (Stations 10235, 10236, 10237, 10242); on Brown's Bank (Station 10228); in the Eastern Channel (Station 10227); on the eastern and southern edges of Georges Bank (Stations 10226, 10219), and on the southern edge of the continental shelf south of Marthas Vineyard (Station 10260).

In 1915 swarms of *Limacina balea* were encountered on three occasions, first over the outer edge of the continental shelf south of Shelburne, Nova Scotia, June 23 (Station 10294); off Marthas Vineyard, October 22 (Station 10333) and again in Massachusetts Bay, October 27 (Station 10338), while it occurred, in smaller numbers, at about 50% of the stations in the Gulf.[1]

Although *Limacina balea* is a characteristic member of the Gulf plankton, and though it has now been taken in all parts of the Gulf, it is far less regular in its occurrence than Calanus, Euthemisto, or *Sagitta elegans.* Thus it swarmed on German Bank in August 1912, and in August 1913; but was not found there in August 1914, or in either May, June, or September of 1915, though it occurred only a few miles away (Stations 10270, 10310). At several localities, too, it was present during one cruise in 1915, absent on the next, or *vice versa,* for example, off Monhegan Island (Stations 10303, 10318); off Matinicus (Stations 10276, 10287), and in the northeast corner of the Gulf (Stations 10273, 10287). And neither in 1912, 1914, nor 1915, was it as generally distributed in the Gulf as it was in 1913 (1915, p. 303, fig. 72). In spite of these anomalies, however, there is some evidence that Limacina approaches the western and northern coasts of the Gulf as the summer advances, for in 1915 none were taken in the numerous hauls along the Maine coast until September; and it appeared in summer off Cape Ann (Station 10306) and off Matinicus (Station 10287), where it was lacking in May (Stations 10266, 10276).

We have usually found *Limacina balea* most abundant in hauls from 30–60 meters (1915, p. 305), absent on the surface. But it occurred on the surface at four stations, twice in considerable numbers in 1914 (Stations 10247, 10264); at five in 1915 (Stations 10294, 10295, 10308, 10329, 10333), twice in swarms (Stations 10294, 10333). However, these surface catches were made at night, and it was never found on the surface between sunrise and sunset. Apparently Limacina, like other plankton organisms performs a more or less regular vertical migration, rising toward the surface at night, sinking again at daylight.

The salinities at which Limacina was numerous in 1914 and 1915 range from about 31.06‰ (Station 10295) to at least 35‰ (Stations

[1] *Limacina balea* was taken at the following stations in 1915: 10269, 10270, 10272, 10273, 10278, 10279, 10287, 10288, 10291, 10294, 10295, 10306, 10307, 10308, 10309, 10310, 10317, 10318, 10320, 10321, 10328, 10329, 10330, 10331, 10332, 10333, 10337, 10338.

10220 and 10261); the temperature from about 5°–6°; to about 16.6° (Station 10264, surface), *i. e.*, it was scarce, or absent both in the coldest and warmest, and in the very freshest and saltest, water; which corroborates the previous records (1915, p. 305). Its rarity in Gulf Stream water (Station 10218), while it was common at other stations on the slope where hydrography and plankton were less purely oceanic (Stations 10220, 10261), indicates that the junction of coast and oceanic waters is its normal southern limit, at least in the upper layers, which agrees with the experience in 1913 (1915, p. 305) as well as with its distribution in other regions; and its absence in the southeastern part of the Gulf, in the Eastern Channel and in the area off Halifax is explicable on this basis, these regions being occupied by unmistakable, though diluted tongues of offshore water (p. 196). Similarly, its absence, or rarity, in the very cold water of the Cabot Current, off Shelburne, certainly suggests that it does not reach the Gulf by that route.

But hydrography offers no apparent explanation for the irregularity and sporadic nature of its occurrence within the Gulf. Hence, if its distribution there be dependent on the physical environment, as is no doubt the case in the last analysis, it probably is neither temperature nor salinity alone which limits the existence of the adult, but a complicated set of interacting phenomena. Possibly too high temperature and salinity may directly prevent its reproduction: it may be food supply which is the limiting factor; or warm or cold ocean currents may act as actual physical barriers to its dispersal.

Limacina helicina being as good an index of Arctic water (Meisenheimer, 1905b; Murray and Hjort, 1912, p. 640) as *L. balea* is for boreal, its occurrences in our waters are of great interest. It has never been found in the Gulf of Maine in summer (1914a, 1915); nor in the western half of the latter at any season. But on our May cruise, in 1915, it occurred at the two stations on the eastern side where salinity (p. 224), temperature (p. 215), and other Arctic organisms (p. 248) gave unmistakable evidence of Cabot Current water (Station 10270, 150–0, and 50–0 meters, two specimens; 10272, 60–0 meters, seven specimens).

We did not find it again in the Gulf; but in June it occurred at two stations off Shelburne, one close to the land (Station 10291, 85–0 meters, five specimens), the other over the continental slope (Station 10295, 500–0 meters, two specimens). In August, 1914, it occurred twice near land, off Halifax (Station 10236, 65–0 meters, two specimens; Station 10237, 75–0 meters, two specimens).

The third characteristic pteropod of northern waters, *Clione lima-*

cina, appears to occupy a rôle intermediate between *Limacina balea* and *L. helicina* in the Gulf, occurring irregularly, usually in small numbers. But though it never attains the faunal prominence there that it does further north, and has been decidedly rare in recent years (1914a, 1915), it is recorded by Wood as swarming in Portland Harbor in May, 1868, when "the water appeared to be alive with them" (Wood, 1869, p. 185). However, such occurrences are certainly exceptional, as is its occasional appearance, in numbers, as far west as New York (De Kay, 1843, p. 6). Whether they are due to invasions by northern water, or to local propagation, is an open question.

The summer records (1914a; 1915) show that Clione may be expected anywhere in the Gulf; and it is no more regular in its occurrence in the eastern than in the western side, contrary to what might be expected of a cold-water organism, and to what is actually the case with *Limacina helicina* (p. 300). But it was distinctly seasonal in 1915, for while it was taken at most of the stations in May, (Stations 10266, 10269, 10270, 10271, 10272, 10276, 10277, 10278, 10279, 10280), it occurred at only about half the June stations (Stations 10281, 10282, 10284, 10286, 10287, 10288, 10293, 10294), and while we have occasional records for July and August (1914a, 1915), it was not taken in September or October, 1915; nor off Massachusetts Bay November or December, 1912 (1914b, p. 404), though it reappeared there in small numbers in January and February, 1913. Our records added to Wood's account, point to spring as its season of greatest abundance in the Gulf.

Clione is one of the most prominent members of the macroplankton of the Arctic Ocean (Meisenheimer, 1905b; Damas and Koefoed, 1907, Paulsen, 1910); and it swarms in the polar waters of the Labrador Current off the east coasts of Newfoundland and Labrador, where I myself found it in great numbers among the floe ice, in the summer of 1900. The apparent correspondence between its seasonal maximum, and the seasonal fluctuations of the Cabot Current in the Gulf of Maine, suggests that its numbers there are recruited from the north. But its distribution within the Gulf does not correspond to the northern water there, as does that of *Limacina helicina* (p. 300), Mertensia (p. 248), or the Arctic Oikopleura. On the contrary, Clione was as numerous in the western as in the eastern part of the Gulf (p. 248) even in May. It was rare in the Cabot Current off southern Nova Scotia in summer (Stations 10233, 10235, 10243, a total of four specimens in 1914: Station 10294, one specimen in 1915).

In reality, as Damas and Kofoed point out (1907, p. 361), *Clione limacina* is not the sure index to Arctic water that many have supposed, for it is quite as abundant in the Atlantic water south, as in the Arctic water north, of Iceland (Paulsen, 1909, p. 42, Murray and Hjort, 1912, p. 107); and is common south of Ireland (Massy, 1909). The true explanation is that though Clione reaches its maximum size, and abundance in Arctic waters, its normal range reaches the northern boreal waters as well. In the Gulf of Maine it is probably endemic in small numbers which may receive additions annually from the north.

Two other species of pteropods were taken in the Gulf of Maine in 1914, a Pneumoderma too young for specific determination (Station 10245); and two specimens of *Limacina inflata* off Cape Cod (Station 10213), the latter no doubt stragglers from the south.

The stations on the continental slope, on Georges Bank, and off Marthas Vineyard, yielded the following tropical pteropods and heteropods (identified by W. F. Clapp): —

	10216, 60–0 meters	10218, 60–0 meters	300–0 meters	400–0 meters	10219, 80–0 meters	10220, 400–0 meters	10261, 400–0 meters
Limacina rangii d'Orb.						4	
Crescis conica Eschscholtz				1			
" *acicula* Rang.				1			
Hyalocylis striata Rang.				1			
Cuvierina columnella Rang.				2			
Diacria trispinosa Lesueur				1			
Cavolina tridentata Forskål					1		2
" *longirostris* Lesueur				1			
" *uncinata* Rang.		1					
Peracle reticulata d'Orb.				1			
Corolla calceola Verrill		1		1			
Pterotrachea keraudrenii Souleyet	2						
Firoloida desmarestia Lesueur			1				
Pleurobranchea tarda Verrill			2				

Pelagic Coelenterates. The Medusae, Siphonophorae, and Ctenophorae taken on the cruises of 1914 and 1915 fall into two well-marked geographic groups, Boreal-Arctic, and Tropical. The records for the former for 1914 are given in the following table: —

	10213	10214	10215	10216	10219	10220	10224	10225	10227	10228	10229	10230	10231	10232	10233
HYDROMEDUSAE															
Hybocodon pendula	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lymnorea borealis	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....
Leuckartiara octona	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Catablema vesicaria	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Melicertum campanula	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Staurophora mertensii	....	×	....	....	....	....	×	....	....	....	....	....	....	....	....
Mitrocoma cruciata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Obelia sp.	....	....	×	....	×	×	....	....	....	....	....	....	....	....	....
Phialidium languidum	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Aequorea tenuis	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....
Aglantha digitale	....	....	....	×	....	×	....	....	....	....	×	×	×	×	....
SIPHONOPHORES															
Diphyes arctica	....	....	....	....	....	×	....	....	....	....	....	....	....	....	
Stephanomia cara	×	....	....	....	....	....	....	×	....	....	....	....	....	....	....
SCYPHOMEDUSAE															
Cyanea capillata	....	×	×	....	....	....	×	....	....	....	....	....	....	....	....
Aurelia aurita	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
CTENOPHORES															
Mertensia ovum	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pleurobrachia pileus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Bolinopsis infundibulum	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Beroe cucumis	....	....	....	....	....	....	....	×	×	×	....	....	×	×	×

	10234	10235	10236	10237	10243	10245	10246	10247	10248	10249	10250	10251	10253	10254	10256
HYDROMEDUSAE															
Hybocodon pendula	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lymnorea borealis	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....
Leuckartiara octona	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....
Catablema vesicaria	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....
Melicertum campanula	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....
Staurophora mertensii	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....
Mitrocoma cruciata	....	....	....	....	....	....	×	....	....	....	×	....	....	....	....
Obelia sp.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Phialidium languidum	....	....	....	....	....	×	×	×	×	×	×	×	×	×	....
Aequorea tenuis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Aglantha digitale	....	....	×	×	....	×	×	....	×	....	×	....	....	....	....
SIPHONOPHORES															
Diphyes arctica	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Stephanomia cara	....	....	....	....	....	....	....	....	....	....	....	....	....	×	×
SCYPHOMEDUSAE															
Cyanea capillata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Aurelia aurita	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....
CTENOPHORES															
Mertensia ovum	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....
Pleurobrachia pileus	....	....	....	....	×	....	×	....	×	....	....	....	....	....	....
Bolinopsis infundibulum	....	....	....	....	....	....	....	....	....	×	×	....	....	....	....
Beroe cucumis	×	×	×	×	×	....	×	....	×	....	....	....	....	....	....

Most of these species have been recorded from the Gulf of Maine, (A. Agassiz, 1865; Bigelow, 1914a, 1914b, 1915). The Grampus records add little to previous knowledge, either systematic or geographic.

Perhaps the most interesting feature of the Grampus collections is the general scarcity of coelenterates at all of the Gulf stations, at any distance from land, except for the following species, *Phialidium languidum, Mitrocoma cruciata, Aglantha digitale,* and *Pleurobrachia pileus.* The records for these in 1915 are: —

	10270	271	272	276	278	281	282	286	287	288	290	291	293	294
Mitrocoma cruciata	×	×	....	....	×	....	×	×	×	×	×	×	×	....
Phialidium languidum [1]	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Aglantha digitale	×	....	×	×	....	×	....	....	....	....	×	×	....	×
Pleurobrachia pileus	....	×	×	....	....	....	....	....	....	....	×	....	....	....

	10295	301	303	304	306	310	311	317	318	321	323	327	328	329
Mitrocoma cruciata	....	×	×	....	....	....	....	....	....	....	....	....	....	....
Phialidium languidum [1]	....	....	....	×	....	....	....	×	×	....	....	×	×	×
Aglantha digitale	×	....	....	....	×	....	....	....	....	....	....	....	×	....
Pleurobrachia pileus	....	....	×	×	×	×	×	×	....	×	×	×	×	×

The presence or absence of Aurelia and Cyanea is always worth noting, because they are such typically neritic organisms (1914a, Damas, 1909) that their occurrence is a sure index of coast water. Their rarity over the whole offshore parts of the Gulf, and off Nova Scotia, except close to land, in which the records for 1914 and 1915 agree with previous experience is discussed above. Phialidium is less closely restricted to the shore than either Cyanea or Aurelia (p. 251), hence probably is not limited to such shallow water during its fixed stage. However, none of the captures of Phialidium have been far outside the 100 fathom curve; nor more than fifty miles from land, and most of the records are much nearer the shore. On each of the

[1] Also abundant in Kittery River and off Rye, N. H., July 23.

cruises in the Gulf Phialidium was found swarming, but each time in a different place; near Mt. Desert Rock and off the Kennebec river in 1912; off Penobscot Bay in 1913; over the Eastern Basin (Station 10249) in 1914; and in Kittery River, and off Rye in 1915. Our experience has always been that Phialidium is most numerous at or near the surface; and this is well illustrated at Station 10249, where only a few were taken in the 50 meter, none in the 175 meter haul, though it was very numerous on the surface. As yet it has not been found on Georges Bank on the one hand, nor off the south coast of Nova Scotia on the other; and it is probable that the Gulf of Maine is the northern limit to its abundance. The earliest records for Phialidium are in July and it is usually most numerous during August.

The comparative abundance of *Mitrocoma cruciata* in May and June 1915, and its absence during summer and autumn, explains its rarity during the July and August cruises of previous years (p. 304; 1915, p. 316). This agrees with Alexander Agassiz's statement that it is frequently found in Massachusetts Bay during early summer (1865, p. 102). As the table shows, its period of abundance hardly overlaps that of Phialidium.

Staurophora mertensii has been found, in past years, in most parts of the Gulf, (1914a, 1915). But so far as the hauls can be trusted, there has been a steady decrease in its numbers since 1912. Thus Staurophora was taken at many stations in that year, often in swarms: at seven stations, usually in small numbers, in 1913: in 1914 it was found at three stations, only once (Station 10214) in any numbers, although the work was done at about the same time of year; and in 1915, it was taken at four stations, a total of only four specimens. Staurophora has not been taken on Georges Bank, nor south of Cape Cod: but it is recorded from Woods Hole (Hargitt, 1905).

The other neritic Medusae occur so rarely and irregularly in the hauls that I need only note that the Obelia on the northern part of Georges Bank were no doubt associated with the Obelia hydroids found floating there (p. 252, 1915).

Only one oceanic Medusa, *Aglantha digitale*, occurs with any regularity in our waters; and enough records for this species have now been accumulated to show that it may be expected anywhere in the Gulf; though never abundant there. It is also taken in hauls in the zone of mixed water over the continental slope, often in some numbers (1915); but so far has not been recorded from undiluted Gulf Stream water (*e. g.* it occurred at Stations 10220 and 10233, but not at 10218).

The only siphonophore which occurs in any numbers in the Gulf is *Stephanomia cara;* but unfortunately it is so fragile that the specimens captured are usually in the most fragmentary state imaginable. The identification of the records listed (p. 303) depends on the shape of the nectophores and the presence of the oil-globule in the palpons (Fewkes, 1888), no tentilla being intact.

The captures of *Diphyes arctica* at Station 10220 in 1914, and again off Shelburne (Station 10295) in 1915, are of interest because this siphonophore has not been recorded previously from American waters. In these specimens all the superior nectophores are in such good condition and agree so well both with Chun's (1897) figures and with the Behring Sea series which I have studied (1913) that the identification was easy. At the moment the geographic status of *D. arctia* is doubtful, for though it was formerly thought to be a typical Arctic form (1911, Chun, 1897, Romer, 1901), it has recently been captured in deep hauls by the GAUSS off Cape Verde (Moser, 1915). Certainly, however, it does not belong to the surface waters of the Gulf Stream; and so far as American coast waters are concerned it can safely be ascribed a northern origin. The local swarming of *Pleurobrachia pileus* has already been noted (p. 242); as has also the occurrence of the Arctic ctenophore *Mertensia ovum* in the Gulf of Maine in May and off Shelburne in June, 1915 (Stations 10271, 10272, 10291, 10294, p. 249).

The following warm-water coelenterates were taken in the inner edge of the Gulf Stream off Georges Bank, in July 1914 (Station 10218).

Medusae	60–0 meters	300–0 meters	Siphonophores	60–0 meters	300–0 meters
Stomotoca pterophylla	×	×	*Hippopodius hippopus*		×
Toxorchis kellneri	×	×	*Diphyes spiralis*	×	
Laodicea cruciata	×	×	" *appendiculata*	×	
Rhopalonema funerarium		×	" *bojani*		×
" *velatum*	×	×	*Diphyopsis dispar*	×	×
Liriope scutigera	×		" *mitra*	×	×
" *tetraphylla*		×	*Agalma elegans*	×	×
Aglaura hemistoma	×	×	*Anthophysa formosa*	×	
Nausithoe punctata	×		*Physalia physalis*	×	

Physalia was also seen floating near Stations 10258 and 10262, as well as over the outer part of the shelf south of Marthas Vineyard in 1914; near Brown's Bank (Station 10296) and in the Eastern Basin of the Gulf (Station 10288) in 1915 (p. 246).

These siphonophores, and most of the Medusae, are oceanic species which might be expected anywhere in the Gulf Stream or the subtropical Atlantic. But two of the medusae, Stomotoca and Toxorchis, are neritic West Indian forms, not previously known north of Florida. Their occurrence at Station 10218 exemplifies the efficacy of the Gulf Stream current as a carrier of tropical organisms. Laodicea is likewise neritic, but ranges at least as far north and east along the coast as Woods Hole.

Finally, a single specimen of *Diphyes truncata*, from Station 10220 is worth noting, because this species was not known from American waters, though it is probably cosmopolitan (1913, Moser, 1915).

Quantitative Distribution of Plankton, 1914, 1915.

Only on the supposition that the plankton is uniform horizontally, over considerable areas, could a satisfactory quantitative survey be expected from vertical hauls as far apart as those of the Grampus; and this is far from true of the plankton of the Gulf, organisms of one sort or another often occurring in streaks, or swarms, for example diatoms in the spring of 1913 (1914b), fish eggs (p. 257), Sagittae (p. 294), and pteropods (p. 298).

However, this seems to be less often the case with copepods, which are, on the whole, the most important constituent of the Gulf plankton; and since the quantitative hauls show a certain consistency from year to year and from season to season, while nothing whatever was known up to 1912 as to the amount of plankton present in the Gulf, the general results are worth recording.

The quantitative distribution of plankton may be measured in several ways, the most obvious unit being the total bulk of plankton present from surface to bottom, usually in terms of a column one square meter in cross section. (The area of the mouth of the Hensen quantitative net used in 1914 is .1 square meter: in 1915 we used a Michael Sars net .5 m. in diameter, *i. e.*, with mouth area of approximately .2 square m.). Volume, it is true is a very rough measure (Steuer, 1910), different types of plankton packing down more or less densely; but it still remains the most convenient index to the comparative abundance of the plankton as a whole, as distinguished from its various individual components.

The volumes of the quantitative hauls of 1914 (measured as in previous years, 1914a, 1915), are as follows: —

Station	Depth meters	Vol. cc.[1] per square meter	Station	Depth meters	Vol. cc. per square meter
10213	110–0	210	10234	95–0	25
10214	175–0	120	10236	70–0	10
10215	70–0	60	10237	75–0	5
10216	70–0	30	10243	55–0	100
10218	500–0	50	10244	50–0	15
10223	75–0	170	10245	110–0	60
10224	55–0	240	10246	190–0	200
10225	260–0	30	10247	30–0	10
10226	85–0	200	10248	190–0	100
10227	220–0	50	10249	220–0	105
10229	100–0	170	10250	145–0	350
10230	50–0	140	10253	140–0	60
10231	50–0	20	10254	260–0	200
10232	140–0	50	10255	175–0	70

The stations may be grouped in three classes, rich, with 100 cc. or more; intermediate, with 30 to 100 cc.; and barren, with less than 30 cc. The horizontal hauls at Stations 10228 and 10258, where no quantitative hauls were made, put them in the "rich" class; while the same test classes, Stations 10233, 10251 and 10260 as intermediate, 10220, 10235 and 10261 as barren. On this basis (Fig. 91) the plankton under each square meter of the sea surface was rich over a belt running from off the mouth of the Bay of Fundy southwest to Massachusetts Bay and the southwestern basin of the Gulf; probably also covering Nantucket Shoals and following the coast as far west as Marthas Vineyard, with other "rich" areas on the northeastern part of Georges Bank, in the Northern Channel, on Brown's Bank, and off Cape Sable. On the other hand it was very scanty (30 cc. or less)

[1] No attention is paid here to the coefficient of filtration of the net, which being the same for all hauls, does not effect their comparative value.

along the southern slope of Georges Bank, in the northeastern and southeastern corners of the Gulf; and generally south and southwest of Halifax. In the northwestern, central, and eastern parts of the Gulf as a whole, on the northwestern part of Georges Bank, in the Eastern Channel, and over the whole breadth of the continental shelf off Shel-

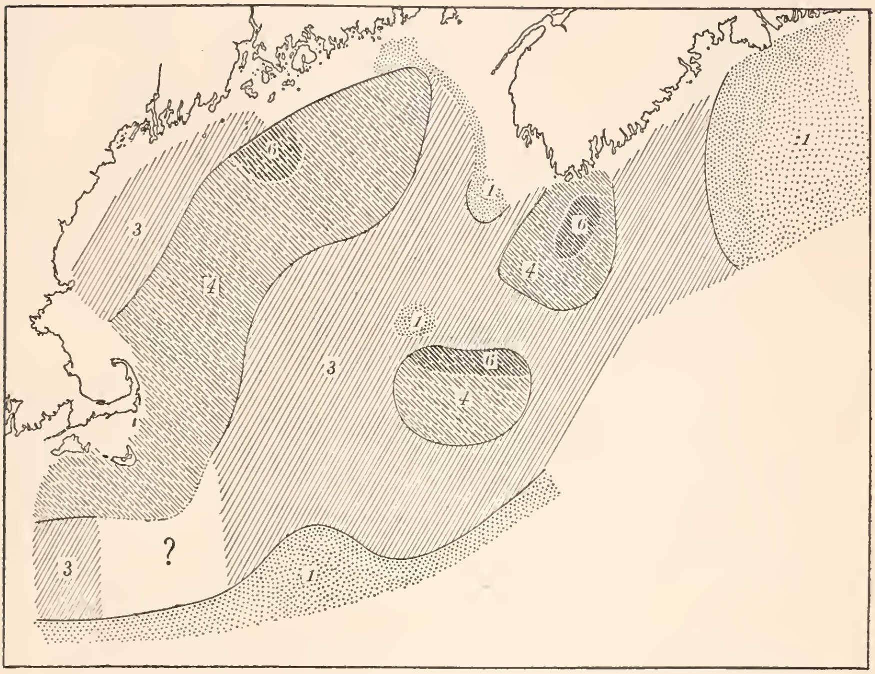

Fig. 91.— Volumes of plankton per square meter of sea area, July–August, 1914.

6, very rich,	170 + cc.	per square meter.
4, rich,	100 + cc.	"
3, intermediate,	30 – 100cc.	"
1, scanty	30 – cc.	"

burne, Nova Scotia, plankton volumes were intermediate between these extremes.

The volume of plankton, however, is no index to its regional density, which is after all the most important question before us, because the amount of water filtered varies with the depth at various stations; a better criterion is the volume per cubic meter.

Volume of Plankton per Cubic Meter, 1914.

Station	Vol. cc. per cubic meter	Station	Vol. cc. per cubic meter
10213	1.9	10234	.26
10214	.68	10236	.14
10215	.85	10237	<.1
10216	.43	10243	1.8
10218	.1	10244	.3
10223	2.2	10245	.54
10224	4.3	10246	1.
10225	.11	10247	.33
10226	2.3	10248	.52
10227	.22	10249	.48
10229	1.7	10250	2.4
10230	2.8	10253	.42
10231	.4	10254	.77
10232	.35	10255	.4

Horizontal hauls class the stations where no quantitative hauls were made, as follows: — rich, Stations 10229, 10258: intermediate, 10233, 10235, 10245: barren 10220, 10251, 10260, 10261. According to the table Stations 10248 and 10249 are intermediate; but they are treated here as rich because the horizontal hauls show that the density of the plankton was much greater than the quantitative hauls suggest.

In the western part of the Gulf, on the northeastern corner of Georges Bank where it is high (.6+), and off the southern and southeastern coasts of Nova Scotia, volume per cubic meter, *i. e.*, density, corresponds fairly well with the volumes per square meter. But density was comparatively greater than volume on the western part of the Bank, and in the northeastern corner of the Gulf, while in the southeastern part, the reverse was true. The barren area (.3— cc. per cu. m.) was continuous with the sparse plankton of the deep water over the continental slope (Fig. 92). The plankton was densest on the northeastern part of Georges Bank, off Cape Sable, and locally off Penobscot Bay.

Were the plankton uniformly distributed vertically, the foregoing calculation would be satisfactory; but our previous experiences in the

Gulf of Maine have shown that it is usually more or less stratified. In 1913 the greater part of the plankton was condensed in the upper 100 meters or so; and while no such general rule can be laid down for 1914, because sometimes the deeper haul (Stations 10215, 10246, 10248, 10254), sometimes the shallower (Stations 10214, 10233, 10249,) yielded

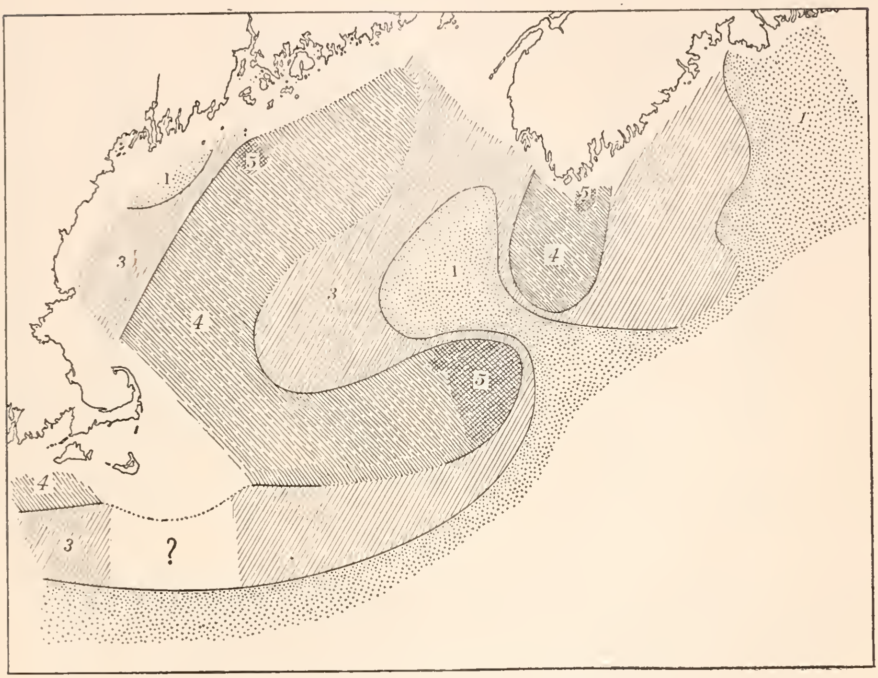

FIG. 92.— Plankton volume per cubic meter, July–August, 1914.

5, very rich	1 + cc.	per cubic meter
4, rich	.6 + cc.	"
3, Intermediate	.3 − .6 cc.	"
1, scanty	.3 − cc.	"

the largest catch when two subsurface hauls were made at different levels, usually one was much larger than the other, as illustrated by the following table of catches in the horizontal hauls, reduced to a column 1 square meter in cross section. Duration of hauls, ½ hour. The depth is the level at which the major part of each haul was made.

Station	Depth meters	Volume cc.	Station	Depth meters	Volume cc.
10213	70	1000	10235	80	125
10214	30	3550	10236	50	250
	150	250	10237	60	125
10215	30	150	10242	0	1500
	60	375	10243	40	1250
10216	50	125	10245	100	125
10219	60	600	10246	50	150
10223	50	375		150	1000
10224	40	2500	10248	50	150
10225	60	150		150	1250
	240	125	10249	50	2180
10226	60	2500		175	500
10227	180	125	10250	120	125
10228	0	1250	10251	100	125
10229	80	3750	10253	80	375
10230	40	2500	10254	75	150
10231	0	337		225	625
10232	50	125	10255	150	125
	100	125	10256	130	375
10233	0	150	10258	25	1000
	100	610	10260	60	150
	300	250		120	125
10234	75	125	10261	400	125

As a whole the water was richer in plankton above 100 meters than below that depth, the mean volume of all the catches taken above 100 meters (909 ccm.) being almost three times the mean of all the deeper hauls (350 ccm.); while it was only above 100 meters that exceptionally large catches (2000 ccm. or more) were taken. Consequently, the volumes per cubic centimeter as calculated from the quantitative hauls must be used with discrimination. They represent the actual density fairly well at stations where no stratification is apparent from the horizontal hauls (*e. g.* Stations 10225, 10232); and approximate the truth in shallow waters, particularly where mixed vertically by tidal currents. But they greatly understate the actual maximum density in deep water where the plankton is stratified, making such regions appear much less prolific, as feeding grounds for pelagic fishes than they actually are, while crediting to their barren layers a richness which they do not possess.

Some information as to the seasonal fluctuations in the amount of plankton present in the Gulf is afforded by the work done in 1915. In May of that year the volume of plankton, both per square meter (Fig. 93) and per cubic meter, was greatest in the east and west sides of the Gulf. But though the rich area extended right across the Gulf

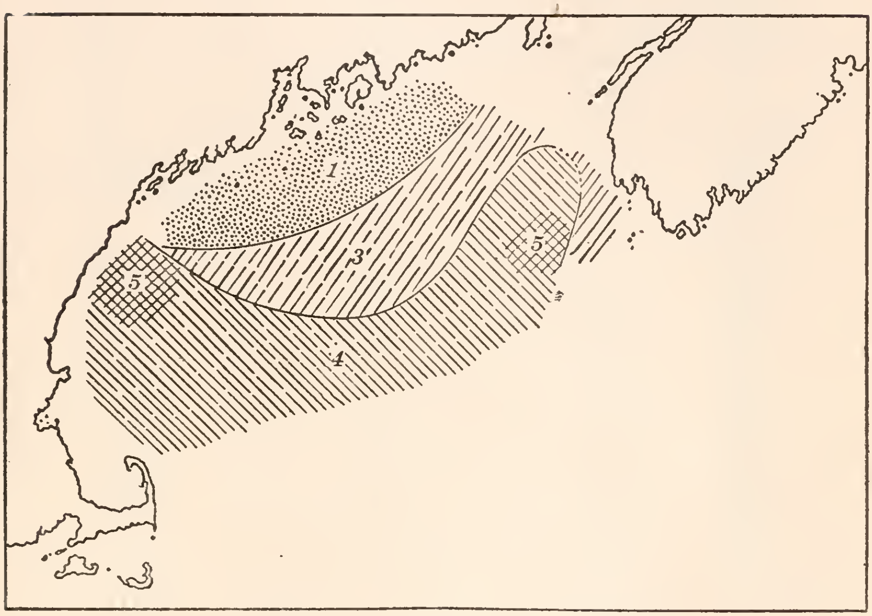

Fig. 93.— Plankton per square meter of sea area, May 1915.

5, very rich	300 + cc.
4, rich	100 + cc.
3, intermediate	30 – 100 cc.
1, scanty	30 – cc.

it[1] was indented on the north by less prolific water; and the zone along the northern coast, *i. e.*, just where the diatom swarm was at its maximum, was very barren of large organisms, as illustrated by the following table of volumes per square, and per cubic meter for that year. These, however, are not directly comparable with the data for 1914, since a different net was used.

[1] Its continuity depends on the richness of the horizontal surface haul at Station 10268.

Station	Vol. per sq. meter	Vol. per cu. meter	Station	Vol. per sq. meter	Vol. per cu. meter
	cc.	cc.		cc.	cc.
10266	270	2.1	10309	425	2.12
10267	250	1.	10310	225	1.18
10269	70	.4	10311	45	.7
10270	370	2.	10313	50	.7
10271	75	1.	10315	50	.6
10272	170	2.1	10316	12.5	.2
10275	20	.4	10318	25.	.3
10276	10	.1	10319	30.	.85
10278	325	2.1	10320	50.	.7
10279	250+	3.8	10321	30.	.75
10281	10	.1	10323	37.5	.47
10282	50	.2	10324	150	1.
10283	100	.55	10325	225	1.3
10284	15	.18	10326	150	.1
10286	15	.18	10327	20	.33
10287	50	.7	10328	30	.5
10288	150	.7	10329	100	1.6
10290	40	.6	10331	75	2.5
10291	125	1.7	10332	100	2.
10294	100	.6	10333	100	1.3
10298	50	.4	10336	125	2.5
10299	200	1.	10337	100	1.6
10304	275	1.37	10338	250	3.1
10306	110	.78	10339	75	1.
10307	165	.7			
	Average 115	1.1			

From May to June the amount of macroplankton present increased off Matinicus and over the northern part of the Eastern Basin, decreased in the Western Basin, a change resulting in much the same conditions as in August 1914. But in September, as in May, plankton was most abundant in the sink north of Cape Ann, and again over the Eastern Basin; with a band of decidedly barren water all along the coast of Maine from Cape Elizabeth to Grand Manan Channel. The average volume of plankton, both per square and per cubic meter was greatest in May (181; and 1.5 cc. respectively). least in June (80 cc. and .4 cc.), with the September volumes intermediate (145 cc.; and about 1 cc.); and in that month the richest haul was made (425 cc.

per square meter at Station 10309). But not enough hauls were made in any month, in 1915, for these averages to be more than a general index to abundance.

Number of Copepods. The work during 1914 strengthens the view that copepods are the only important members of the macroplankton of which the quantitative hauls yield an approximately complete catch (1914a, 1915), for comparatively few Sagittae, amphipods or schizopods were taken in the Hensen net even at stations where they were very abundant (*e. g.* the Sagitta swarm at Station 10224). For this reason the copepods alone are treated numerically here.

The numbers of copepods per square, and per cubic meter, disregarding the coefficient of filtration of the net, is given in the following table for 1914.

Station	Copepods per sq. meter	Copepods per cu. meter	Large Calanus per sq. meter	Large Calanus per cu. meter
10213	189500	1722	90000	818
10214	53500	306	50000	285
10215	71000	1014	6450	92
10216	11000	157	2450	35
10218	6500	13	5000	10
10223	74000	986	35000	465
10224	6000	109	600	10
10225	15000	58	6000	57
10226	81500	959	77000	900
10227	25000	114	8500	38
10229	227000	2270	32500	190
10230	59000	1180	22000	440
10231	11000	220	5500	110
10232	29500	211	18000	128
10234	10500	110	3500	36
10237	4000	53	3750	50
10243	167000	3036	55660	1012
10244	38500	770	1920	38
10245	17500	159	5800	52
10246	71000	373	50000	260
10248	51500	270	25000	250
10249	49500	225	45000	204
10250	99500	686	25000	172
10253	64500	460	41500	296
10254	94000	361	90000	345
10255	63500	363	45000	257

Copepods were most numerous, per square meter (70,000) over a V-shaped region, with one arm extending from Cape Cod toward Penobscot Bay, the other to the northern part of Georges Bank; off Cape Sable; in the extreme northeast corner of the basin of the Gulf; and south of Marthas Vineyard (Fig. 94), with maxima off Cape Cod, off Cape Sable, and in the Northern Channel (Stations

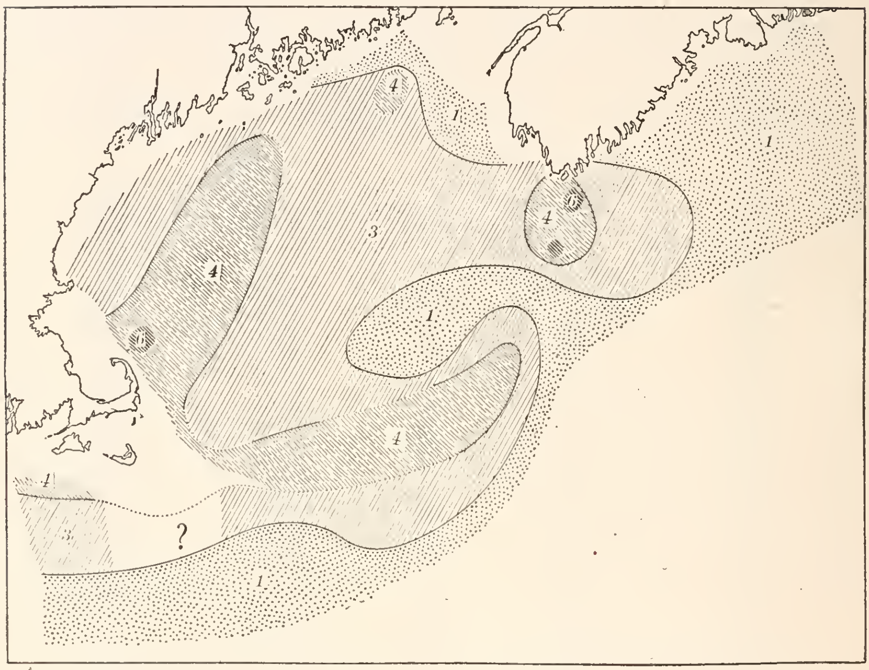

Fig. 94.— Copepods, per square meter of sea area, July–August 1914.

6, very rich	150, 000 +
4, rich	70,000–150,000
3, intermediate	20,000–70,000
1, scanty	less than 20,000

10213, 10243, 10229). But there were very few copepods in the extreme northeastern corner of the Gulf; in the oceanic water south of Georges Bank; in the Eastern Channel and southeastern part of the Gulf; or in the waters southwest of Halifax; and distribution of copepods, on the basis of numbers per cubic meter was practically the same (Fig. 95), except that the region northwest of Cape Cod was relatively less productive.

The hauls for the past three years show that copepods must be by far the most important summer food for pelagic fishes in the Gulf of Maine. But the number of these animals as a whole is not a fair index to the fertility of different regions as feeding grounds, because

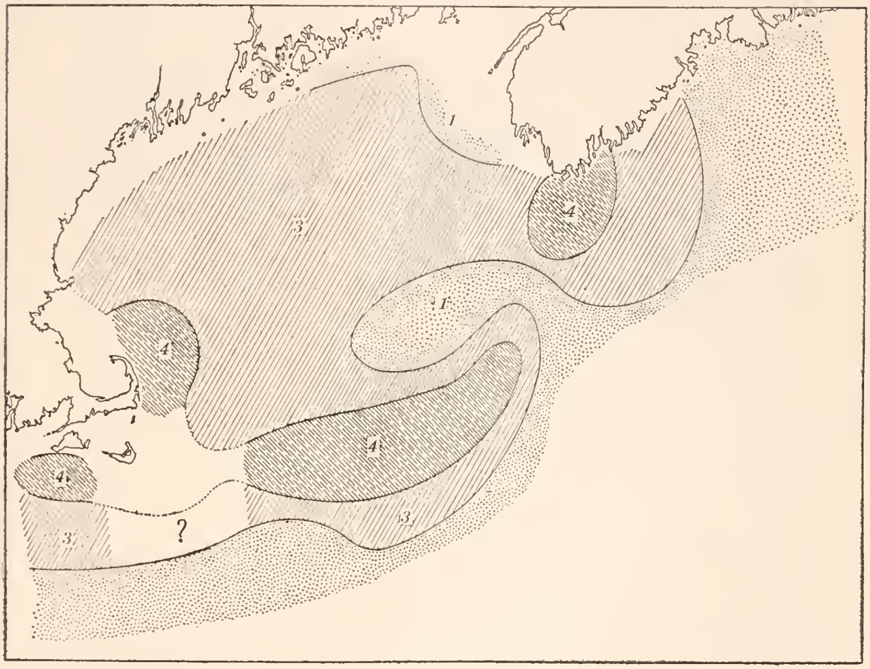

Fig. 95.— Copepods per cubic meter, July–August 1914.

4, rich	900 +
3, intermediate	200–900
1, scanty	less than 200

of the great difference in size between different species; one large Euchaeta or adult Calanus, for example, being equivalent to many young Calanus, Pseudocalanus or Temora, (Farran, 1911). Large Calanus were abundant (30,000+) per square meter over the whole western and southwestern parts of the Gulf, extending northeastward to Station 10246 on the one hand, and probably around Cape Cod to connect with the "rich" water off Marthas Vineyard (Station 10258) on the other (Fig. 96); and there was a second "rich" area over the northeastern part of Georges Bank, a third off Cape Sable. On the other hand the northeastern, eastern, and southeastern parts of the Gulf, including the Eastern Channel, the extreme northern edge of

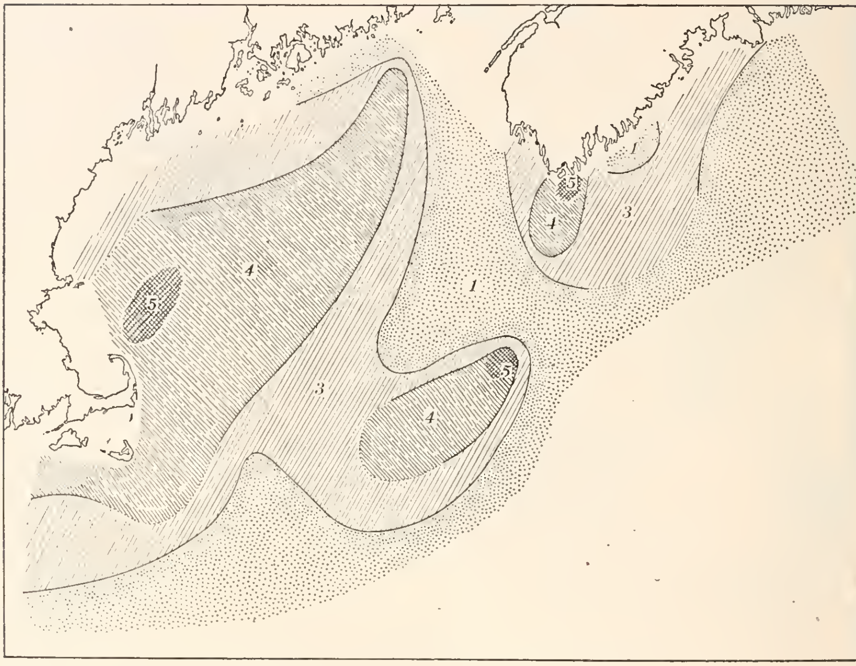

FIG. 96.— Large Calanus per square meter of sea area, July–August, 1914.

5, very rich	50,000 +
4, rich	30,000–50,000
3, intermediate	10,000–30,000
1, scanty	10,000 –

Georges Bank, Brown's Bank, the outer part of the continental shelf south and southwest of Halifax, and the oceanic water on the continental slope were very barren.

The numbers of copepods as a whole, and of large Calanus, per square meter, in 1915 is listed in the following table: —

Station	Copepods per square meter	Large Calanus per square meter	Station	Copepods per square meter	Large Calanus per square meter
10266	511000	8000	10307	104000	94000
10267	50000	19500	10309	173000	162000
10269	48000	9500	10310	114500	77000
10270	411500	95500	10311	41000	500
10271	11050	750	10313	67000	6500
10272	55000	12000	10315	47000	4500
10275	1000	500	10316	159000	250
10277	7500	1000	10318	14750	3250
10278	175000	56000	10319	66500	6000
10279	189000	38000	10320	42500	205000
10282	10000	8500	10321	45500	1000
10283	21000	12000	10323	77000	22000
10284	2500	1000	10324	112500	40000
10286	11500	3000	10325	158500	65500
10287	35000	9000	10326	86000	39000
10288	55500	20000	10327	30750	500
10290	21500	500	10328	57000	9500
10291	15500	2000	10329	49000	9500
10293	20000	5000	10331	234000	500
10294	65500	13000	10332	319500	7000
10296	9500	8500	10333	204000	6000
10298	11000	5500	10336	205000	44000
10299	43000	39500	10338	244500	97000
10304	234500	40000	10339	50500	5000
10306	51500	34000			

The copepod population of the Gulf for May differs from that of midsummer chiefly in greater local variation, the rich regions being richer, the barren ones even more barren. Thus, the range, was from 1000–500,000 per square meter in May; from 17000–189000 in July and August 1913; 27000–123000 in August 1914. Probably this is a regular seasonal phenomenon, for in 1915 local differences were much smaller in autumn, the number of copepods decreasing in the rich, increasing in the barren portions of the Gulf during the summer. Thus the extraordinarily dense copepod population of the waters off Cape Ann dwindled from 500,000 per square meter early in May, to about 50,000 at the end of August, rising again to 112,000 in October. The swarm over the eastern part of the Eastern Basin underwent a similar change, diminishing from about 400,000 per square meter in May (Station 10270) to about 114,000 in September (Station 10310).

On the other hand, copepods increased on German Bank from 11,000 in May to 21,000 in June, and 41,000 in September; in the western part of the Eastern Basin from 48,000 in May to 173,000 in September; in the Western Basin from 50,000 in May to 104,000 in September; near Mt. Desert Island, from only 1,000 in May to 57,000 in October; off Cape Elizabeth from 7,500 in May to 86,000 in October.

These data point to the waters off Cape Ann and Cape Cod in the west, and off Cape Sable in the east; and to the northern part of Georges Bank, as the richest parts of the Gulf; both for copepods as a whole and for large Calanus (p. 315). But this does not fairly represent the comparative value of our waters as feeding grounds for pelagic fishes, because it neglects two important groups, amphipods and schizopods, which are not adequately represented in the quantitative hauls. Neither of these were of much faunal importance in the Gulf proper (p. 283); but the presence of large numbers of very large amphipods in the waters over the shelf south and southwest of Halifax; and of swarms of schizopods on Brown's Bank and at Station 10233 (p. 283) shows that these localities were more fertile feeding grounds than the small volume of plankton and numbers of copepods would indicate.

Annual Variation in Amount of Plankton. The volume of plankton, and number of copepods per square meter for corresponding localities in the Gulf for August–September 1913–1915, was as follows: —

Locality	Stations			cc. per sq. meter		Copepods per sq. meter		
	1913	1914	1915	1913	1914	1913	1914	1915
Off Cape Ann	10087	10253	10306	180	60	50500	64500	51500
Western Basin	10089	10254	10307	80	200	31000	94000	104000
Near Cashe's Ledge	10090	10255		120	70	43500	63500	
Eastern Basin, west side,	10092	10249	10309	160	105	96500	49500	173000
German Bank	10095	10244	10311	60	15	31500	38500	41000
Off Lurcher Shoal	10096	10245	10315	120	60	70000	17500	47000
North east corner of Basin	10097	10246			200	87000	71000	
Off Petit Menan I.	10098	10247		70	10	40000	few	
Off Mt. Desert Rock	10100	10248		220	100	123500	51500	
Off Matinicus Rock	10101	10250		100	350	75000	99500	
Average				123	117	63772	61055	

This table shows that local differences were considerable from year to year, both in volume and in number of copepods; for example, the latter were three times as numerous in the Western Basin in 1914 as in 1913, while at other localities the reverse was true, the counts made off Lurcher's Shoal in 1913 being four times as large as those of 1914. As a whole, copepods were more numerous in the western half of the Gulf (Stations 10250, 10253, 10254, 10255) in 1914, in the eastern half in 1913. Plankton volumes were greatest in 1913, at all but two stations. But the fact that the averages, both of copepods and plankton volumes, differ but little, suggests that these local differences do not indicate any general change in the amount of plankton present in the Gulf from 1913 to 1915; though this is apparently an increase from 1912 (1915).

Microplankton.

The records are of interest chiefly as illustrating the general characters of the microplankton over the whole breadth of the continental shelf east of Cape Cod, instead of for the Gulf of Maine only, as in previous years (1914a, 1915), and for the information they afford as to seasonal variations in the Gulf.

During the summer of 1914, diatom plankton was encountered at three widely separated localities (Fig. 97) viz., off Marthas Vineyard (Station 10258); on the northern edge of Georges Bank (Station 10224); and near land off Penobscot Bay (Station 10250). These hauls were as far apart in composition as they were geographically, the former consisting of Rhizosolenia (chiefly *R. hebetata semispina*) [1]; the Georges Bank (Station 10224) haul chiefly of *Guinardia flaccida*, with smaller numbers of Rhizosolenia; while the microplankton off Penobscot Bay was mainly Chaetoceras, with smaller numbers of Rhizosolenia and Thalassiosira. At all these stations there were a few Ceratium among the diatoms.

Mixed plankton (diatom and Ceratium) occupied the outer part of the shelf south of Marthas Vineyard and the southern edge of Georges Bank, and the coastal zone in the northeastern corner of the Gulf, both off Maine and Nova Scotia, the three diatom swarms thus influencing the plankton over considerable areas (Fig. 97).

At Stations 10253 and 10254, off Cape Ann, the plankton consisted chiefly of an acantharian radiolarian, Acanthometron, and it reap-

[1] For an account of the marine diatoms of northern waters, see Gran, 1908.

peared in large numbers off southern Nova Scotia and locally in the center of the Gulf in 1915 (Stations 10309, 10313).

Elsewhere in the coast water, as well as over the continental slope off Nova Scotia a typical "Ceratium" plankton prevailed (Fig. 97). But the very scanty catches at the three oceanic stations further west

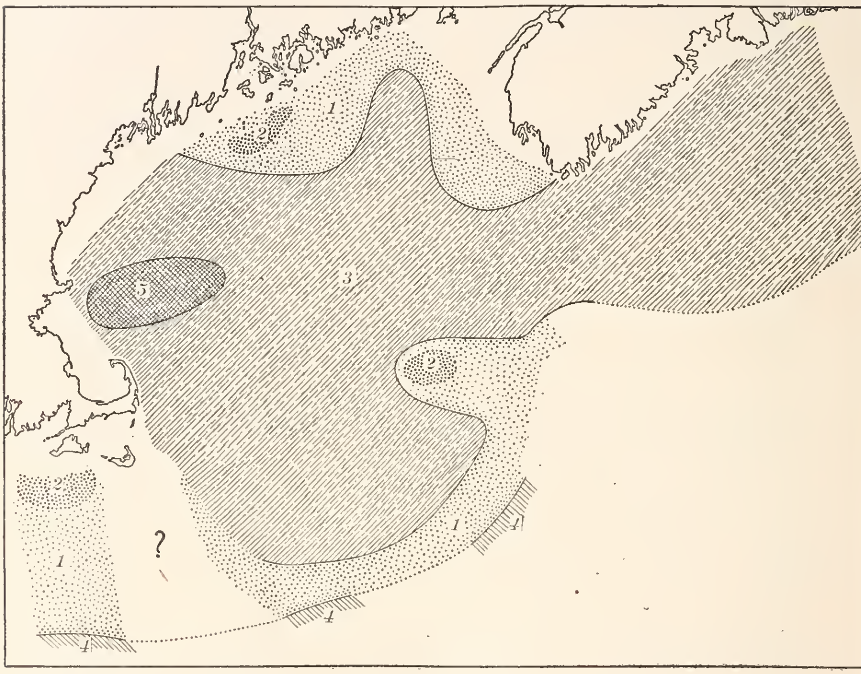

Fig. 97.— Microplankton types, July–August 1914.
3, Ceratium plankton
1, Mixed Ceratium and diatom
2, Diatom
5, Radiolarian
4, Tropical, characterized by Trichodesmium

(Stations 10218, 10220, 10261) were characterized by the presence of the tropical Alga, Trichodesmium.

In 1914, as in 1913, the Ceratium plankton consisted chiefly of two species of Ceratium, *C. tripos* and *longipes* (Paulsen, 1908). In July the latter was much the more numerous of the two in the Gulf, and off southern Nova Scotia (Stations 10229–10243), while *C. tripos* was predominant off the southeastern slope of Georges Bank (Station 10220), and in the coast waters off Marthas Vineyard. In August, however, these proportions were reversed in the central and western parts of the Gulf, as is illustrated by the following table of the two, in samples from representative stations.

Station	C. longipes	C. tripos	Station	C. longipes	C. tripos
10213	50	1	10245	105	2
10216	38	14	10246	62	4
10223	21	1	10248	29	1
10225	9	4	10249	13	47
10227	34	1	10250	32	2
10229	21	1	10251	115	1
10230	60	0	10253	2	10
10233	42	3	10254	4	50
10234	51	0	10255	0	50
10235	63	0	10256	5	76
10236	45	0	10258	1	11
10237	69	4	10264	1	23
10242	91	1			

A third species of Ceratium, *C. arctica*, belonging to frigid waters as its name implies (Murray & Hjort, 1912; Paulsen, 1908; Jørgensen, 1911; Gran, 1902), occurred in small numbers off Nova Scotia (Stations 10230, 10231, 10233, 10236, 10237, 10242; Shelburne Harbor) and at one Station (10248) in the northeast corner of the Gulf of Maine. *C. arctica* has not been recorded previously from the Gulf, so far as I am aware. But it is apparently a characteristic member of the spring plankton of the north Atlantic, for in April, 1910, Jørgensen, on a run from Scotland to Chesapeake Bay, found it regularly from Lat. 48° 50′ N., Long. 35° W., to the neighborhood of the American coast, where it was replaced by *C. longipes.*

Ceratium fusus was as widespread in the Gulf of Maine in 1914 as in 1913, occurring in small numbers at most of the stations. It likewise appeared in the hauls on Georges Bank, Brown's Bank, off Nova Scotia, off Marthas Vineyard, and over the continental slope, (Stations 10214–10216, 10218–10223; 10228, 10229, 10232–10234; 10237, 10242–10245; 10248–10254; 10256, 10259, 10260, 10264).

The oceanic species *C. macroceras,* appeared in small numbers outside the continental slope at our oceanic Stations (10218, 10220, 10261), and in the coastal waters off Marthas Vineyard (Stations 10258–10260). But it has not been detected in the tow over the slope south of Cape Sable (Station 10233), or anywhere on Georges Bank, in the Gulf of Maine, or on the continental shelf south of Nova Scotia, which supports the thesis that it is distinctively a warm water species off this coast.

Though no quantitative hauls were made for microplankton, the horizontal hauls give a rough index to its abundance, when this varies as greatly, from place to place, as it does in our coastal waters in summer. Microplankton was very scanty indeed along the southern edge of the continental shelf, over the slope, in the southeast corner of the Gulf of Maine, (Station 10225); the Eastern Channel, and on Brown's Bank (Stations 10227, 10228). The Nova Scotian waters (Stations 10229–10237) were, if possible, even more barren, a half-hour's haul usually yielding a mere trace. On the other hand the hauls off Lurcher Shoal (Station 10245); off Mt. Desert (10248); off Penobscot Bay (10250); off Cape Ann (10253) and near Marthas Vineyard (10258) were very productive; for example, the volume of the catch of the no. 20 net, 24 ccm. in diameter, towing one half hour, was 40 cc. at Station 10245; 25 cc. at Station 10248; 75 cc. at Station 10250; 80 cc. at Station 10253, 35 cc. at Station 10258. Elsewhere in the Gulf of Maine (Stations 10213–10215, 10246, 10247, 10249, 10254–10256), the volumes of the catches ranged from about 5–10 cc.

The data for 1915 are chiefly valuable as outlining the seasonal fluctuations in the two most important groups, diatoms and Ceratium. In the western part of the Gulf, diatoms swarm in early spring (1914b) when they fill the water almost to the exclusion of other plankton, just as is the case in the Irish Sea (Herdman and Ridell, 1911), in the Skagerak and in the North Sea (Gran, 1915), though it is not known whether the swarm then extends to the eastern shore of the Gulf. In May, 1915, diatoms were still swarming over a triangular area in the central part of the Gulf extending from Cape Elizabeth to the Grand Manan Channel, (Fig. 98), and from the coast of Maine south at least as far as Cashes Ledge. But they had already been replaced by Ceratium off Massachusetts Bay, while Ceratium likewise occupied the waters over the coast bank west of Nova Scotia.

Even the most cursory examination of the diatom swarm of May shows that different genera predominated in different localities. Along the shore of the Gulf (Stations 10275, 10276, 10277), the nets yielded almost pure catches of *Thalassiosira gravida* and *Th. nordenskioldi* as was the case in April 1913 (1914b, p. 405), with smaller numbers of the spirally coiled *Chaetoceras debile* intermingled with the long rod-like *Thalassiothrix longissima,* and an occasional Coscinodiscus. But both Thalassiosira and *Chaetoceras debile* were lacking in the central part of the Gulf, being replaced there by other species of Chaetoceras, especially *C. densum* and *C. boreale,* while the diatom component of the mixed plankton in the eastern side of the Gulf was chiefly *Rhizosolenia semispina* and Chaetoceras. By the middle of

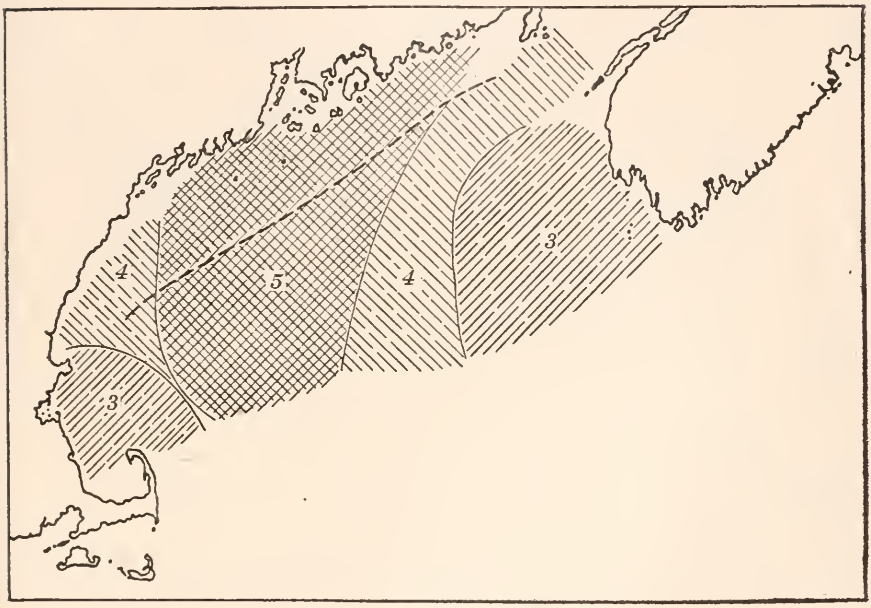

Fig. 98.— Microplankton types, May 1915.
5, Diatom
3, Ceratium
4, Mixed diatom and Ceratium
- - - - - -, offshore limit to Thalassiosira

June (Fig. 99) pure diatom plankton had dwindled to a small area off Mt. Desert (Station 10285), *i. e.* was no more extensive than in the preceding August (p. 322, Fig. 97). Diatoms had now practically disappeared from the southwestern and central parts of the Gulf (Stations 10298, 10299), where they had constituted the bulk of the plankton a month earlier, while *Thalassiosira gravida, T. norden-*

skioldi, and *Chaetoceras debile* were restricted to a narrow coastal zone (Fig. 99).[1]

Diatoms diminished still more during the summer, till by September there was no longer any pure diatom plankton at any of the stations; while even mixed plankton was limited to a narrow belt from off Penobscot Bay, to the mouth of the Bay of Fundy (Fig. 100), and to

FIG. 99.— Microplankton types, June 1915.
5, Diatom
3, Ceratium
4, Mixed diatom and Ceratium
------, offshore limit to Thalassiosira

the mouth of Massachusetts Bay where Skelatonema was the predominant genus. Thalassiosira had practically vanished, except for an occasional example at one Station (10317), its place being taken off the coast of Maine by various species of Chaetoceras and Rhizosolenia.

In the Gulf the seasonal history of Ceratium is the reverse of that

[1] Thalassiosira was taken at Stations 10275, 10276, 10277, 10278, 10281, 10284, 10285, 10287, 10302, 10303, 10317.

of diatoms, just as in the waters off northwestern Europe (Gran, 1915). When the diatom swarm is at its height in April, Ceratium plays only a subordinate rôle in the plankton of the Gulf (1914b). But by May the waters on the two sides of the Gulf were occupied by Ceratium plankton (Fig. 98); and in June Ceratium had not only replaced the diatoms right across the southern half of the Gulf, from west to east, but also occupied the whole breadth of the continental

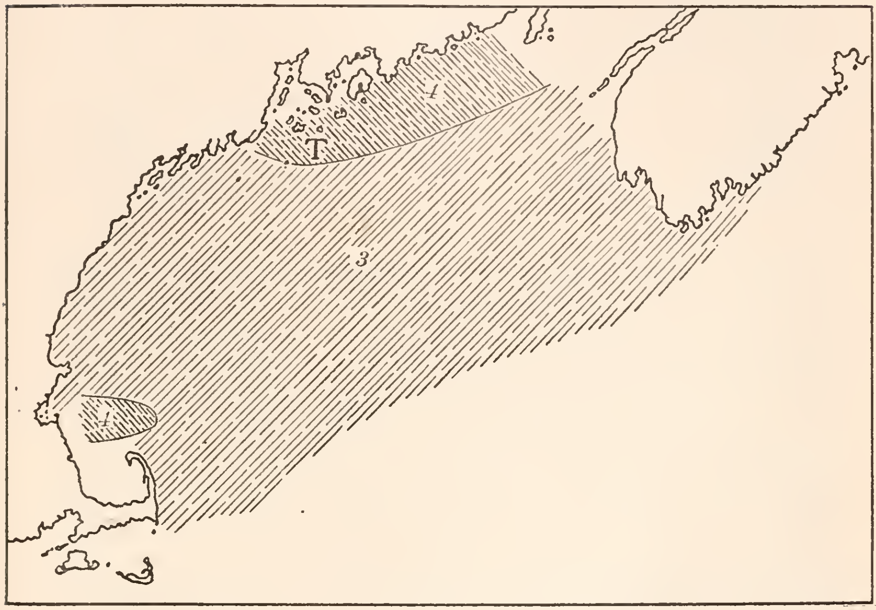

Fig. 100.—Microplankton types, August–September 1915.
3, Ceratium
4, Mixed diatom and Ceratium
T, Occurrence of Thalassiosira

shelf off southern Nova Scotia (Fig. 99), just as is the case in midsummer (p. 322). In September (Fig. 100) the entire Gulf, except for small regions of mixed plankton off the coast of Maine and off Massachusetts Bay, was occupied by Ceratium.

The several species of Ceratium, like the prominence of the genus as a whole, undergo a definite seasonal fluctuation in the Gulf. In May, the predominant Ceratium at all the stations (except Stations

10267, 10268, 10275, and 10277, where none were detected) was one or other variety of *C. longipes* (Paulsen, 1908); *C. tripos* occurring at three stations only, as illustrated by the following table: —

Station	C. longipes	C. arctica	C. tripos	C. fusus
10266	39	8	1	4
10269	30	5	0	1
10270	20	1	0	1
10271	100+	100+	0	0
10272	18	6	1	0
10273	11	3	0	0
10276	100+	0	0	0
10278	12	1	0	0
10279	100+	0	3	1

Ceratium longipes was still the prevalent species in June, *C. tripos* being no more abundant than the month before. But by September *C. tripos* was as abundant as *C. longipes*, or outnumbered it, everywhere, except locally near the coast of Maine, (Stations 10317, 10318); and it greatly predominated over *C. longipes* off Cape Cod and in Massachusetts Bay in October (Stations 10330, 10336, 10337, 10338).

Ceratium arctica, like other typical northern species, was far more numerous in the Gulf in May than we have ever found it there in summer. But though it was most common where Cabot Current water was most in evidence (Station 10271), it occurred in small numbers at most of our other stations as well.

In June *Ceratium arctica* was limited to the extreme northeast corner of the Gulf (Stations 10283, 11284, 10286, Petit Passage), and to the waters off Shelburne. In September and October it was not detected at all.

According to Jørgensen (1911) the presence of *C. arctica* is a sure index of polar water. But while this is true for European waters, off our coast an almost equally cold habitat exists in the Gulf of St. Lawrence; and though Herdman, Thompson, and Scott (1898) did not detect *C. arctica* there, its presence in the Cabot Current off southern Nova Scotia suggests that it reaches the Gulf of Maine by that route, not from the Banks of Newfoundland, as Jørgensen supposes.

The genus Peridinium almost always occurs in the Ceratium plankton of the Gulf of Maine. In summer it usually plays a very subordinate rôle, except locally (*e. g.*, Stations 10215, 10216); but in May it not only occurred at every station where Ceratium was present, but even rivalled the latter in numbers in the eastern part of the Gulf (Stations 10270, 10272, 10273); and in September it was about as numerous as Ceratium off Swan's Island, (Station 10317) and near Matinicus Island (Station 10329).

Among the other organisms which appear in the catches, Halosphaera deserves special notice, because now recorded for the first time from the Gulf of Maine. This pelagic alga was widely distributed over the Eastern Basin of the Gulf in May (Stations 10269, 10270, 10271, 10272, 10273) though nowhere abundant; and it occurred locally off Mt. Desert in June (Stations 10284, 10286); at one Station (10310) in August. It was likewise found across the whole breadth of the continental shelf, south of Nova Scotia, in June (Stations 10291, 10293, 10294, 10296) and off Shelburne in September (Station 10313).

Halosphaera being widely distributed over the North Atlantic, (Ostenfeld, 1910), and common at Canso, Nova Scotia, in summer (Wright, 1907), was to be expected in the Gulf waters; it may have been overlooked in the hauls of earlier years. So far as our few records go they suggest that it is at its maximum in our Gulf in May, practically disappearing during the summer, which parallels its seasonal occurrence in the North Sea (Ostenfeld, 1910).[1]

Tintinnids (Cyttarocylis) are apparently never an important constituent of the plankton of the Gulf; though the records for 1914 and 1915 (so far detected at Stations 10271, 10272, 10276, 10298, 10304, 10310, 10317, 10318, 10319 in 1915) show that they may be expected anywhere there. But they sometimes appear in large numbers in the cold water along the south coast of Nova Scotia (Stations 10233, 10234, 10236, 10237, 10242; Wright, 1907). The northern distribution of this genus, and the fact that some forms are characteristically neritic, others oceanic, (Brandt, 1910), lends interest to them. But so numerous and so closely allied are the races, or species (Jørgensen, 1899) that they must be left to the specialist.

[1] For an account of the biology of Halosphaera in the Norwegian Sea see Gran, 1902, p. 12.

Table of Stations.

Abbreviations for nets.

A. = 4 ft. "stramin."
B. = Meter "stramin."
C. = Meter silk, "Sars."
D. = 30 cm. stramin and ※5 silk.
E. = 24 cm.; ※5 silk.
F. = 24 cm., No. 20 silk.
G. = 24 cm. "stramin."
H. = Helgoland.
Q. = Hensen quantitative net.
V. = $\frac{1}{2}$ meter vertical quantitative net.
$\frac{1}{2}$M. = $\frac{1}{2}$ meter horizontal net.

Cruise of 1914.

Station	Lat.	Long.	Date	Depth meters	Nets	Depth of hauls, meters
10213	42°11′	69°59′	July 19	128	F.E.B.H.Q.	0, 0, 40–0, 90–0, 110–0
214	41°49′	69°21′	" 19	201	F.E.D.H.B.Q.	0, 0, 40–0, 125–0, 125–0, 175–0
215	41°19′	68°42′	" 20	80	F.E.C.H.Q.	0, 0, 40–0, 60–0, 70–0
216	40°38′	68°20′	" 20	78	F.E.B.H.Q.	0, 35–0, 40–0, 60–0, 70–0
217	40°20′	68°13′	" 21	150		
218	40°6′	68°6′	" 21	550+	F.C.H.B.Q.	0, 70–0, 400–0, 300–0, 500–0
219	40°39′	67°28′	" 21	98	F.B.H.Q.	0, 40–0, 60–0, 90–0
10220	40°54′	66°13′	" 22	700+	F.C.B.H.	0, 80–0, 300–0, 400–0
221	41°07′	66°20′	" 22	183		
222	41°20′	66°19′	" 22	93		
223	41°35′	66°37′	" 23	82	F.H.Q.	0, 50–0, 75–0
224	42°03′	66°57′	" 23	64	F.H.Q.	0, 40–0, 55–0
225	42°22′	67°11′	" 23	274	F.C.H.Q.	0, 60–0, 240–0, 260–0
226	42°08′	66°14′	" 24	91	F.H.Q.	0, 60–0, 85–0
227	42°19′	66°02′	" 24	220	F.H.Q.	0, 180–0, 220–0
228	42°34′	65°51′	" 24	95	F.H.A.	0, 60–0, 0
229	42°55′	65°41′	" 25	113	F.A.C.	0, 0, 100–0
10230	43°19′	65°23′	" 25	54	F.C.Q.	0, 30–0, 50–0
231	43°37′	64°57′	" 27	58	F.B.Q.	0, 0, 50–0
232	43°12′	64°27′	" 28	146	F.C.H.Q.	0, 50–0, 100–0, 140–0
233	42°41′	63°58′	" 28	450+	F.B.C.H.	0, 0, 100–0, 300–0
234	43°08′	63°57′	" 29	100	F.H.Q.	0, 75–0, 95–0
235	43°43′	63°54′	" 29	219	F.C.	0, 80–0
236	44°17′	63°52′	Aug. 2	100	F.H.Q.	0, 50–0, 70–0
237	44°25′	63°19′	" 6	84	F.E.H.Q.	0, 0, 60–0, 75–0

Cruise of 1914 (continued).

Station	Lat.	Long.	Date	Depth meters	Nets	Depth of hauls, meters
238	44°11′	63°07′	Aug. 6	173		
239	43°54′	62°53′	" 7	256		
10240	43°19′	62°43′	" 7	91		
241	43°22′	63°02′	" 7	102		
242	43°22′	63°28′	" 7	146	F.D.	0, 0
243	43°18′	65°27′	" 11	64	F.E.Q.H.	0, 0, 55–0, 40–0
244	43°22′	66°26′	" 12	56	F.E.H.Q.	0, 0, 40–0, 50–0
245	43°49′	66°51′	" 12	126	F.E.H.Q.	0, 0, 100–0, 110–0
246	44°15′	67°23′	" 12	201	F.E.C.H.Q.	0, 0, 50–0, 160–0, 190–0
247	44°21′	67°28′	" 12	67	F.E.Q.	0, 0, 30–0
248	43°46′	67°58′	" 13	201	F.E.C.H.Q.	0, 0, 50–0, 150–0, 190–0
249	43°17′	67°40′	" 13	228	F.E.C.H.Q.	0, 0, 50–0, 175–0, 220–0
10250	43°39′	68°49′	" 14	155	F.E.H.Q.	0, 0, 120–0, 145–0
251	43°27′	69°39′	" 14	155	F.E.H.	0, 0, 100–0
252	42°57′	70°18′	" 15	140		
253	42°29′	70°18′	" 22	157	F.E.H.Q.	0, 0, 80–0, 140–0
254	42°37′	69°38′	" 22	268	F.E.C.H.Q.	0, 0, 75–0, 225–0, 260–0
255	42°27′	68°30′	" 23	182	F.E.H.Q.	0, 0, 150–0, 175–0
256	41°55′	69°25′	" 23	192	F.E.H.	0, 0, 130–0
257	41°39′	69°49′	" 24	27		
258	41°03′	70°51′	" 25	34	F.E.H.	0, 0, 25–0
259	40°34′	70°46′	" 25	62	F.E.H.	0, 0, 50–0
10260	40°03′	70°41′	" 26	148	F.E.C.H.	0, 0, 60–0, 120–0
261	39°54′	70°43′	" 26	450+	F.E.C.H.	0, 0, 400–0, 400–0
262	40°02′	70°26′	" 26	192		
263	41°12′	70°57′	" 27	32		
10264	42°09′	70°	" 28	128	F.E.	0, 0

Cruise of 1915.

10266	42°30′	70°20′	May 4	137	F.E.H.V.	0, 0, 50–0, 125–0
10267	42°38′	69°36′	" 5	273	F.E.H.V.	0, 0, 85–0, 260–0
10268	42°51′	68°43′	" 5	196	F.E.	0, 0
10269	43°04′	67°56′	" 6	191	F.E.H.V.	0, 0, 85–0, 175–0
10270	43°14′	67°07′	" 6	201	F.E.C.H.V.	0, 0, 50–0, 150–0, 175–0
10271	43°26′	66°28′	" 7	73	F.E.H.V.	0, 0, 60–0, 70–0

Cruise of 1915 (continued).

Station	Lat.	Long.	Date	Depth meters	Nets	Depth of hauls, meters
10272	43°52′	66°41′	May 10	94	F.E.H.V.	0, 0, 60–0, 80–0
10273	44°05′	67°32′	" 10	232	F.E.H.	0, 0, 125–0
10274	44°13′	67°51′	" 10	87		
10275	44°09′	68°09′	" 11	54	F. 9 ft.C.V.	0, 0, 30–0, 50–0
10276	43°44′	68°50′	" 12	84	F.E.H.V.	0, 0, 60–0, 75–0
10277	43°32′	69°46′	" 13	101	F.H.V.	0, 60–0, 75–0
10278	43°	70°12′	" 14	182	F.E. 9 ft. V.	0, 0, 60–0, 150–0
10279	42°17′	70°07′	" 26	75	F.E.H.V.	0, 0, 60–0, 65–0
10280	43°45′	69°32′	" 31	28	F.E.C.	0, 0, 15–0
10281	44°48′	66°55′	June 4	87	F.E.C.V.	0, 0, 50–0, 80–0
10282	44°25′	66°32′	" 10	194	F.E.C.H.V.	0, 0, 75–0, 175–0, 180–0
10283	44°15′	67°23′	" 10	209	F.E.H.V.	0, 0, 100–0, 180–0
10284	44°09′	67°54′	" 11	91	F.E.C.V.	0, 0, 70–0, 80–0
10285	44°09′	68°09′	" 14	54	F.½M.	0, 5–0
10286	43°59′	68°15′	" 14	95	F.½M.C.V.	0, 3–0, 70–0, 80–0
10287	43°44′	68°50′	" 14	78	F.½M.C.V.	0, 3–0, 50–0, 70–0
10288	43°28′	67°30′	" 19	227	F.½M.C.H.V.	0, 0, 85–0, 200–0, 200–0
10289	43°27′	66°51′	" 19	153		
10290	43°24′	66°22′	" 19	64	F.½M.C.V.	0, 0, 40–0, 60–0
10291	43°29′	65°08′	" 23	78	F.½M.C.V.	0, 0, 60–0, 70–0
10292	43°19′	64°59′	" 23	157		
10293	42°59′	64°43′	" 23	87	F.½M.C.V.	0, 0, 60–0, 75–0
10294	42°36′	64°27′	" 23	176	F.½M.C.V.	0, 0, 100–0, 170–0
10295	42°22′	64°16′	" 24	500+	F.½M.C.	0, 0, 500–0
10296	42°28′	65°37′	" 24	89	F.C.	0, 50–0
10297	42°17′	66°03′	" 25	236	F.	
10298	42°26′	67°45′	" 25	245	F.V.	0, 200–0
10299	42°32′	69°14′	" 26	219	F.C.V.	0, 200–0, 200–0
10300	Off Race Point, Cape Cod		July 7	59	F.C.	0, 59–0
10301	44°31′	67°24′	" 15	73	F.½M.C.	0, 0, 50–0
10302	44°08′	68°15′	" 19	53	F.½M.C.	0, 0, 40–0
10303	43°46′	69°23′	Aug. 4	80	F.½M.C.V.	0, 0, 60–0, 70–0
10304	43°32′	67°35′	" 6–7	219	F.E.C.V.	0, 0, 150–0, 200–0
10305	44°08′	68°15′	" 18	63	F.E.C.	0, 0, 40–0
10306	42°31′	70°19′	" 31	147	F.½M.C.H.V.	0, 0, 40–0, 110–0, 140–0
10307	42°40′	69°34′	" 31	245	F.½M.C.H.V.	0, 0, 220–0, 220–0,235–0
10308	42°52′	68°40′	Sept. 1	185	F.½M.H.	0, 0, 50–0

Cruise of 1915 (continued).

Station	Lat.	Long.	Date	Depth meters	Nets	Depth of hauls, meters
10309	43°08′	67°52′	Sept. 1	221	F.½M.C.V.	0, 0, 130–0, 200–0
10310	43°15′	67°03′	" 2	201	F.½M.C.V.	0, 0, 175–0, 190–0
10311	43°22′	66°17′	" 2	73	F.½M.C.V.	0, 0, 50–0, 60–0
10312	43°14′	65°37′	" 2	58		
10313	43°28′	65°06′	" 6	78	F.½M.C.V.	0, 0, 50–0, 70–0
10314	43°20′	64°59′	" 6	164		
10315	43°49′	66°44′	" 7	97	V.	80–0
10316	44°32′	67°22′	" 11	64	F.½M.C.V.	0, 0, 30–0, 60–0
10317	44°05′	68°26′	" 15	31	F.½M.C.V.	0, 0, 20–0, 28–0
10318	43°43′	69°17′	" 16	78	F.½M.C.V.	0, 0, 50–0, 70–0
10319	43°28′	70°16′	" 20	54	F.½M.C.V.	0, 0, 25–0, 35–0
10320	42°25′	70°33′	" 29	82	F.½M.C.V.	0, 0, 50–0, 70–0
10321	42°10′	70°22′	" 29	48	F.½M.S.C.V.	0, 0, 48–0, 25–0, 40–0
10322	42°04′	70°16′	Oct. 1	27	F.½M.C.	0, 0, 15–0
10323	42°17′	70°07′	" 1	87	F.½M.C.V.	0, 0, 70–0, 80–0
10324	42°31′	70°19′	" 1	158	V.	150–0
10325	43°	70°12′	" 4	183	V.	175–0
10326	43°24′	69°53′	" 4	155	V.	145–0
10327	44°32′	67°20′	" 9	62	F.E.C.V.	0, 0, 40–0, 60–0
10328	44°06′	68°14′	" 9	66	F.½M.C.V.	0, 0, 40–0, 60–0
10329	43°44′	68°51′	" 9	69	F.½M.C.V.	0, 0, 40–0, 60–0
10330	42°34′	70°37′	" 18	47	F.½M.C.	0, 0, 25–0
10331	41°19′	70°55′	" 22	34	F.½M.C.V.	0, 0, 25–0, 30–0
10332	40°51′	70°55′	" 22	53	F.½M.C.V.	0, 0, 45–0, 50–0
10333	40°26′	70°56′	" 22	82	F.½M.C.V.	0, 0, 65–0, 75–0
10334	40°09′	71°	" 22	165		
10335	41°26′	70°17′	" 25		F.½M.C.	0, 0, 8–0
10336	41°42′	69°53′	" 26	51	F.½M.C.V.	0, 0, 40–0, 50–0
10337	42°05′	70°18′	" 26	62	F.½M.C.V.	0, 0, 40–0, 60–0
10338	42°19′	70°30′	" 27	82	F.½M.C.V.	0, 0, 60–0, 80–0
10339	42°31′	70°36′	" 27	75	V.	75–0

Table of Temperatures, Salinities and Densities.

Density is at the temperature *in situ*, and = specific gravity at T°, compared to distilled water at 4° C, × 1000. The density readings are connected for pressure by Ekman (1910) Table IV alone, this being sufficiently accurate for the small depths involved. They are given only for selected stations (p. 200).

1914.

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10213	0	16.83°	31.17	24.35
	20	9.06°		
	40	5.38°	32.34	25.67
	100	3.97°	32.74	26.49
	120		32.95	
	130	4.41°		
10214	0	17.5 °	31.80	23.12
	20	15.75°		
	40	7.25°	32.25	25.48
	100	4.22°	32.92	26.64
	150	5.12°	33.28	
	190	5.53°	33.49	27.4
10215	0	16.68°	32.09	23.53
	20	12.24°		
	40	10.43°	32.81	25.47
	70	9.62°	32.88	25.67
10216	0	18.6 °	33.10	23.87
	20	13.9 °		
	40	13.04°	33.58	25.52
	70	10.64°	34.88	27.21
10217	0	17.3 °	32.74	23.82
	20	10.64°		
	40	9.15°	33.60	26.24
	100	11.80°		
	150	10.63°	35.23	27.87
10218	0	20.48°	34.42	24.37
	40	17.7 °	36.04	26.52
	100	14.87°	35.82	26.59
	200	10.85°	35.32	28.18
	300	9.46°	35.14	28.63
	400		34.96	
	500	5.25°	34.90	29.95

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10219	0	18.9 °	33.55	23.68
	20	17.33°		
	40	16. °		
	90	10.28°	34.65	
10220	0	19.98°	33.82	23.9
	40	15.35°	34.97	26.17
	100	11.2 °	35.23	27.46
	200	8.18°	35.01	28.27
	300	6.9 °	34.94	28.78
	400	5.55°	34.87	
	500	5.02°	34.87	30.12
10221	0	16.5 °	32.74	24.05
	40	16.18°	34.78	25.79
	100	12. °	35.16	27.18
	160	10.78°	35.25	27.93
10222	0	14.67°	32.48	24.28
	90	8.98°	34.18	26.95
10223	0	13.33°	32.59	24.57
	20	10.86°	32.63	
	40	8.90°	32.78	25.61
	75	7.92°	33.03	26.1
10224	0	11.11°	32.47	24.84
	30	10.76°	32.54	25.03
	55	10.78°	32.61	25.18
10225	0	15.28°	32.16	23.81
	40	10. °	33.17	25.76
	100	9.53°	34.69	27.36
	150	9.33°	35.05	27.89
	200	8.4 °	35.08	28.32
	250	7.93°	35.08	28.51
10226	0	15.28°	32.25	23.88
	40	12.6 °	32.34	25.51
	85	6.6 °	33.03	26.42
10227	0	15.11°	32.47	24.06
	40	9.3 °	33.04	25.82

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10227	80	8.91°	34.18	26.9
	130	8.8 °	34.78	27.59
	170	7.15°	34.99	
	220	6.95°	35.03	28.49
10228	0	14.72°	32.20	23.84
	40	8.35°	33.40	26.33
	85	8.5 °	34.25	27.10
10229	0	11.44°	32.01	
	40	6.17°	32.38	25.7
	100	5.96°	32.92	26.4
10230	0	10.28°	31.47	24.24
	30	3.03°	32.07	25.78
	50	3.14°	32.34	25.98
10231	0	6.62°	31.62	24.85
	30	1.81°	31.98	25.77
	50	1.91° / 1.97°	32.20	25.95
10232	0	15. °	31.26	23.12
	40	4.38°	31.74	25.42
	100	2.88° and 3.45°	32.88	26.68
	140	5.55° and 5.76°	33.64	
10233	0	16.95°	31.22	22.85
	40	7.34°	32.90	25.99
	100	7.59°	34.16	27.26
	200	7.74°		
	300	7.62°	34.96	28.72
	400	5.3 °	34.92	
	500	4.98°	34.83	29.89
10234	0	14.72°	31.29	23.15
	40	3.13°	31.80	25.56
	95	2.8 °	32.88	26.66
10235	0	14.17°	30.95	23.09
	40	5.52°	31.91	25.44
	100	5.26°	33.60	27.10
	220	8.26°	34.56	28.00

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10236	0	12.78°	30.90	23.24
	40	3.38°	31.71	25.47
	85	0.76°	32.09	26.11
10237	0	14.44°	30.86	22.91
	30	3.5 °	31.35	
	50	2.15°	31.80	
	75	1.10°	32.34	
10238	0	15.56°	31.53	23.23
	40	6.92°	32.01	25.34
	80	3.35°	32.97	26.68
	120	6.7 °	33.93	27.25
	165	8.87°	34.81	27.76
10239	0	15. °	31.22	23.09
	40	5.55°	32.10	24.81
	100	5.89°	33.82	27.13
	150	8.82°	34.78	
	200	8.84°	34.92	28.03
	250	8.35°	34.92	
10240	0	15. °	31.98	23.70
	20	11.9 °	32.21	
	40	5.55°	33.28	26.54
	60	5.72°	33.69	
	80	5.8 °	33.78	
10241	0	16.67°	31.18	22.74
	40	5.19°	32.34	25.78
	90	8.77°	34.45	27.63
10242	0	15.83°	31.29	23.15
	40	4.4 °	32.07	25.69
	100	6.15°	33.75	27.07
	140	7.92°	34.45	
10243	0	13.61°	31.67	23.77
	30	7.47°	31.67	
	55	3.51°	31.98	
10244	0	10. °	32.84	25.31
	30	9.64°	32.86	25.5
	55	9.60°	32.90	25.71

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10245	0	14.44°	32.52	24.21
	40	9.44°	33.42	26.10
	80	8.75°	33.87	26.65
	120	8.54°	34.11	27.11
10246	0	14.44°	33.06	24.64
	40	8.35°	33.35	26.19
	100	6.28°	33.57	26.91
	150	7.58°	34.05	
	190	8.17°	34.47	27.8
10247	0	10.44°	32.52	24.97
	30	8.97°		
	60	8.88°	32.84	
10248	0	13.33°	32.65	24.51
	40	8.45°	32.97	25.91
	100	7.18°	33.51	26.74
	150	6.04°	33.64	
	190	8.34°	34.49	27.82
10249	0	17.5 °	31.91	23.04
	40	6.38°	32.74	25.97
	100	5.31°	33.06	26.64
	150	6.04°	33.55	27.15
	220	5.83°	33.48	27.2
10250	0	13.05°	32.52	24.5
	40	8.59°	32.92	25.87
	100	7.04°	33.24	26.55
	145	6.26°	33.39	
10251	0	16.56°	31.92	23.34
	40	5.65°	32.38	25.81
	100	4.41°	32.70	26.41
	145	4.93°	33.24	
10252	0	16.22°	31.64	23.2
	40	7.8 °	32.39	25.45
	90	4.64°	32.56	26.29
	130	3.66°	32.79	26.74
10253	0	18.89°	31.29	22.23
	40	6.47°	32.29	25.63
	100	4.64°	32.43	26.23
	140	4.49°	32.50	

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10254	0	20. °	31.55	22.17
	40	5.75°	32.43	25.75
	100	4.36°		
	150	5.51°	33.42	27.11
	200	6.8°	34.11	27.7
	260	7.09°	34.23	28.09
10255	0	19.17°	31.89	22.71
	40	7.81°	32.52	25.55
	100	3.95°	32.81	26.53
	150	5.13°	33.33	
	175	6.24°	33.87	
10256	0	19.56°	31.80	22.55
	40	6.57°	32.38	25.74
	100	4.24°	32.88	26.61
	150	5.38°	33.51	
	180	5.68°	33.64	
10257	0	20. °	32.05	
	25	6.8 °	32.09	
10258	0	19.72°	32.16	
	15	14.29°	32.43	
	30	12.09°	32.52	
10259	0	21.95°	33.69	
	25	14.83°	33.53	
	55	9.67°	33.60	
10260	0	22.89°	33.78	
	40	13.67°	34.09	
	100	11.63°	35.23	
	140	11.45°	35.41	
10261	0	23.5 °	34.11	
	100	13.06°	35.46	
	200	11.99°		
	300	9.91°	35.16	
	450	7.26°	35.16	
10262	0	21.89°	33.64	
	40	13.07°	33.89	
	100	11.34°	35.14	
	180	10.35°	35.26	

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10263	0	17.89°	32.12	
	17	13.30°	32.45	
10264	0	16.67°		
	30	7.34°	32.05	
	80	5.65°	32.48	

1915.

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10266	0	6.11°	32.32	25.51
	50	3.55°	32.68	26.22
	130	3.55°	32.81	26.84
10267	0	6.1 °	33.03	26.04
	50	5. °	33.15	26.48
	130	4.69°	33.17	26.94
	260	6.59°	34.02	27.99
10268	0	6.1°	32.79	25.85
	50	4.78°	32.81	26.2
	100	4.47°	33.04	26.69
	190	5.6 °	33.53	27.10
10269	0	4.4 °	32.50	25.83
	50	4.28°	32.68	26.21
	100	4.44°	32.95	26.67
	185	5.82°	33.22	27.04
10270	0	3.6 °	31.78	25.3
	50	3.04°	32.03	25.78
	100	3.9 °	32.86	26.59
	190	5.95°	33.58	27.37
10271	0	3. °	31.89	25.43
	35	3.24°	31.94	25.61
	70	3.27°	31.94	25.8
10272	0	3.9 °	32.05	
	50	3.42°	32.09	
	90	3.6 °	32.30	
10273	0	4.7 °	32.23	
	50	4.81°	32.57	

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10373	100	5.1 °	33.03	
	150	4.98°	33.28	
	225	6.28°	33.66	
10274	0	4.2 °		
	40		32.20	
	80	3.97°	32.23	
10275	0	4.4 °	31.51	
10276	0	5. °	31.8	
	40	4.22°	32.34	
	80	4.22°	32.43	
10277	0	7.8 °	29.58	
	50	4.18°	32.38	
	95	4.15°	32.45	
10278	0	7.8 °	32.03	
	50	4.04°	32.63	
	100	3.45°	32.7	
	175	3.7 °	32.94	
10279	0	10. °	31.89	
	40	5.2 °	32.68	
	70	3.82°	32.68	
10280	0	6.9 °	31.56	
	25	5.56°	31.83	
10281	0	4.4 °	31.82	
	40	4.63°	31.82	
	80	4.58°	31.83	
10282	0	6.4 °	31.89	
	50	5.71°	32.41	
	100	5.2 °	32.83	
	180	5.25°	33.06	
10283	0	5.4 °	31.98	
	50	5.27°		
	100	5. °	32.70	
	180	3.54°	33.66	

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10284	0	5.4 °	32.07	
	40	5.11°	32.21	
	80	5.14°	32.45	
10285	0	8. °	31.76	
10286	0	7.5 °	32.16	
	40	5.44°	32.30	
	80	5.18°	32.41	
10287	0	7.8 °	31.94	
	35	5.83°	32.16	
	70	4.66°	32.36	
10288	0	9.7 °	32.41	
	50	5.6 °	32.50	
	100	4.86°	33.06	
	150	5.6 °	33.46	27.21
	220	6.21°	33.95	27.81
10289	0	7.8 °	32.25	
	50	5.9 °	32.66	
	100	5.7 °	33.24	
	150	5.87°	33.48	
10290	0	6.1 °	32.07	
	25	5.9 °	32.09	
	60	5.85°	32.12	
10291	0	8.9 °	30.93	23.93
	30	3.47°	31.36	25.16
	75	.96°	31.92	25.94
10292	0	8.6 °	31.33	24.35
	50	.7 °	31.83	25.77
	75	.7 °	32.12	
	100	2.02°	32.68	26.62
	150	4.32°		
10293	0	10. °	31.36	24.15
	40	1.54°	31.91	25.75
	85	1.6 °	32.50	26.41

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10294	0	9.7 °	31.06	23.98
	40	2.85°	31.83	25.59
	80	2.12°	32.79	26.62
	120	7.5 °	34.34	27.42
	170	8.28°	34.67	27.85
10295	0	11.1 °	32.39	24.78
	80	3.63°	34.27	27.67
	200	8.15°	34.97	28.24
	300	7.3 °	34.94	28.73
	500	4.91°	34.94	29.98
10290	0	10. °	31.44	
	40	2.8 °	32.29	
	80	7.36°	33.49	
10297	0	10. °	32.56	25.08
	40	8.2 °	33.31	26.19
	100	8.14°	34.18	27.14
	150	7.72°	34.67	27.89
	225	7.2 °	34.92	28.43
10298	0	12.5 °	32.56	24.66
	50	5.18°	32.59	26.05
	100	5.02°	33.04	26.63
	150	5.68°	33.48	27.15
	225	6.91°	34.60	28.17
10299	0	13.6 °	32.50	24.41
	50	6.22°	33.04	26.28
	100	4.6 °	33.08	26.70
	210	5.67°	33.82	27.56
10300	0	16.6 °	31.4	
	50	6.7 °	32.2	
10301	0	8.9 °	31.58	
	60	7.16°	32.03	
10302	0	11.6 °	31.83	
	20	7.97°	31.98	
	45	7.24°	32.16	

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10303	0	11.6 °	31.87	
	35	8.01°	32.14	
	75	5.96°	32.41	
10304	0	11.4 °	32.63	
	50	8.26°	32.67	
	100	6.22°	33.12	
	150	4.78°	33.73	
	200	6.89°	34.16	
10305	0	10.8 °	31.94	
	25	9.37°	32.05	
	50	8.79°	32.34	
10306	0	16.1 °	31.24	22.89
	50	7.24°	32.39	25.63
	100	5.97°	32.50	26.08
	140	5.78°	32.57	26.33
10307	0	17.6 °	32.47	23.39
	50	7.77°	32.81	25.91
	100	5.01°	33.12	26.7
	150	5.1 °	33.28	27.06
	200	5.7 °	33.75	27.37
	235	6.36°	34.23	28.08
10308	0	15.8 °	32.52	23.88
	40	9.02°	32.59	25.46
	90	6.36°	33.03	26.47
	165	5.63°	33.69	27.37
10309	0	15.5 °	32.47	23.99
	50	9.44°	32.66	25.4
	100	5.72°	33.1	26.62
	150	5.77°	33.60	27.25
	210	5.98°	33.60	27.44
10310	0	13.3 °	32.41	24.42
	50	7.05°	32.88	26.02
	100	5.56°	33.26	26.74
	190	7.1 °	34.33	27.82
10311	0	9.4 °	32.23	24.9
	30	10.28°	32.47	25.1
	65	10.1 °	32.56	25.36

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10312	0	13.3 °	31.49	
	25	9.4 °	31.73	
	50	7.38°	32.	
10313	0	15. °	30.7	
	20	3.38°	30.73	
	50	3.33°	32.16	
	70	2.22°	32.43	
10314	0	15. °	31.22	
	25	7.89°	31.82	
	50	3.3 °	32.34	
	75	4.95°	33.01	
	100	5. °	33.12	
	150	5.05°	33.40	
10315	0	12.2 °	32.88	
	50	11.2 °	33.19	
	90	10. °	33.42	
10316	0	10.28°	32.3	
	60	9.95°	32.43	
10317	0	11.6 °	32.5	
	28	10.95°	32.52	
10318	0	13.6 °	32.30	
	35	10.1 °*	32.27	
	70	8.61°	32.56	
10319	0	15.5 °		
	25	10.5 °	31.83	
	50	8.5 °	32.12	
10320	0	10.5 °	31.91	
	35	10.7 °*	31.98	
	70	7. °	32.30	
10321	0	11.4 °	31.73	
	20		31.83	
	40	11.22°		

*Approximate only.

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10322	0	13.4 °	31.38	
	25	12.95°	31.60	
10323	0	11.4 °	32.07	
	40	11. °*	32.25	
	80	6. °	33.06	
10324	0	10.3 °	32.21	
	40		32.25	
	80	7.11°	32.5	
	120	7.2 °*	32.57	
	150	6.78°	32.66	
10325	0	11.6 °	32.21	
	50	7.33°	32.39	
	100	6.4 °	32.81	
	175	5.28°	33.22	
10326	0	11.9 °	32.41	
	50	7.61°	32.9	
	100		32.9	
	145	5.39°	33.48	
10327	0	9.4 °	32.75	
	30		32.74	
	60	9.83°	32.77	
10328	0	9.4 °	32.66	
	30		32.70	
	60	10.1 °	32.79	
10329	0	10. °	32.47	
	30	10.3 °	32.56	
	60	8.95°	32.84	
10330	0	11.4 °	31.8	
10331	0	14.4 °*	32.1	
	30	14.5 °	32.14	
10332	0	13.9 °	32.32	
	25		32.45	
	50	13.1 °	32.92	

*Approximate only.

Station	Depth meters	Temp. Cent.	Salinity ‰	Density
10233	0	13.3 °	32.65	
	25	13.2 °	32.74	
	50		32.97	
	80	11.89°	33.68	
10334	0	15.5 °	33.86	
10335	0	13. °	32.09	
10336	0	10.5 °	32.	
	25		32.03	
	50	9.39°	32.41	
10337	0	11.1 °	31.89	
	30		31.94	
	60	10.39°	32.14	
10338	0	11. °	31.82	
	40	9.4 °*	32.2	
10339	0	10.8 °	31.91	
	35		32.2	
	70	7.28°	32.43	

Table of Temperatures and Salinities at corresponding Localities, 1912–1915.

In part these are taken directly from the tables of temperature and salinity (p. 333: 1914a, 1915), in part reconstructed from the temperature and salinity sections.

Sink off Cape Ann.

	Temperatures				Salinities			
Depth meters	1912 10002 July 10	1913 10087 Aug. 9	1914 10253 Aug. 22	1915 10306 Aug. 31	1912 10002 July 10	1913 10087 Aug. 9	1914 10253 Aug. 22	1915 10306 Aug. 31
0	18.33°	16.67°	18.89°	16.11°	31.74	32.09	31.29	31.24
20	9.44°	10.56°	11.2 °	10.5 °	32.05	32.48	31.93	31.95
40	6.56°	6.67°	6.47°	8. °	32.36	32.69	32.29	32.3
60	5. °	5.44°	5.4 °	6.7 °	32.61	32.74	32.36	32.42
80	4.61°	5.28°	4.8 °	6.3 °	32.82	32.76	32.4	32.44
100	4.61°	5.17°	4.64°	6.15°	32.9	32.77	32.43	32.5
120		5.17°	4.5 °	6. °	32.92	32.76	32.47	32.52
140			4.49°	5.9 °			32.5	32.57

*Approximate only.

Western Basin.

Depth meters	Temperatures 1912 10007 July 15	1913 10088 Aug. 9	1914 10259 Aug. 22	1915 10307 Aug. 31	Salinities 1912 10007 July 15	1913 10088 Aug. 9	1914 10254 Aug. 22	1915 10307 Aug. 31
0	17.78°	19.17°	20. °	17.22°	31.62	32.21	31.55	32.47
20	11.72°	12.56°	11.5 °	12.5 °	31.95	32.5	32.04	32.6
40	8. °	8.72°	5.75°	9. °	32.3	32.72	32.43	32.74
60	6. °	6.39°	4.9 °	7. °	32.6	32.9	32.69	32.88
80	5. °	5.44°	4.5 °	5.7 °	32.9	33.08	32.88	33.1
100	4.67°	5.17°	4.36°	5.15°	33.14	33.24	33.05	33.12
120	4.61°	5.56°	4.7 °	5.2 °	33.33	33.39	33.2	33.2
140	4.61°	5.89°	5.3 °	5.25°	33.49	33.55	33.35	33.24
160	4.61°	6.17°	5.9 °	5.7 °	33.6	33.71	33.55	33.39
180	4.61°	6.28°	6.5 °	5.8 °	33.69	33.85	33.8	33.62
200	4.61°	6.28°	6.8 °	5.87°	33.75	33.96	34.11	33.75
220	4.61°	6.28°	7. °	6.2 °	33.78	34.05	34.19	34.
240		6.28°	7.04°	6.4 °		34.13	34.21	34.2
260		6.28°	7.09°			34.23	34.23	

Center of Gulf, near Cashe's Ledge.

Depth meters	Temperatures 1913 10090 Aug. 10	1914 10255 Aug. 23	1915 10308 Sept. 1	Salinities 1913 10090 Aug. 10	1914 10255 Aug. 23	1915 10308 Sept. 1
0	16.11°	19.17°	15.8°	32.56	32.89	32.52
20	11.11°	12.2 °	11.2°	32.7	32.25	32.55
40	7.22°	7.81°	9.1°	32.86	32.52	32.59
60	6.56°	5.7 °	7.7°	33.	32.68	32.75
80	6.44°	4.3 °	6.8°	33.15	32.74	32.93
100	6.39°	3.95°	6.3°	33.27	32.81	33.1
120	6.44°	4.1 °	6. °	33.4	33.	33.3
140	6.44°	4.7 °	5.8°	33.53	33.21	33.45
160	6.50°	5.5 °	5.7°	33.7	33.52	33.64
180	6.56°	6.3 °		33.83		
200	6.61°					

West side of Eastern Basin.

Depth meters	Temperatures 1912 10027 Aug. 14	1913 10092 Aug. 11	1914 10249 Aug. 13	1915 10309 Sept. 1	Salinities 1912 10027 Aug. 14	1913 10092 Aug. 11	1914 10249 Aug. 13	1915 10309 Sept. 1
0	15. °	16.67°	17.5 °	15.56°	32.66	32.59	31.91	32.47
20	9.22°	8.95°	9.1 °	12.5 °	32.91	32.86	32.4	32.53
40	7.78°	6.67°	6.38°	10.3 °	33.14	33.05	32.74	32.6
60	7.39°	5.76°	5.7 °	8.5 °	33.36	33.14	32.84	32.75
80	7.22°	5.56°	5.3 °	6.8 °	33.56	33.21	32.95	32.9
100	6.95°	5.89°	5.31°	5.9 °	33.69	33.33	33.06	33.1
120	6.61°	6.05°	5.5 °	5.8 °	33.76	33.46	33.29	33.3
140	6.17°	6.05°	5.9 °	5.9 °	33.81	33.62	33.49	33.5
160	6.05°	6.05°	6.1 °	5.9 °	33.86	33.77	33.55	33.64
180	6. °	6.11°	6. °	6. °	33.89	33.89	33.54	33.75
200		6.11°	5.9 °	6.1 °		33.99	33.51	33.8
220		6.05°	5.83°			34.08	33.48	
240		6.05°				34.14		

German Bank.

Depth meters	Temperatures 1912 10029 Aug. 14	1913 10095 Aug. 12	1914 10244 Aug. 12	1915 10311 Sept. 2	Salinities 1912 10029 Aug. 14	1913 10095 Aug. 12	1914 10244 Aug. 12	1915 10311 Sept.2
0	10.33°	8.89°	10. °	9.44°	32.7	32.79	32.84	32.23
20	9.83°	8.67°	9.85°	10. °	32.75	32.92	32.85	32.4
40	9.67°	8.61°	9.64°	10.1 °	32.8	32.93	32.88	32.5
60	9.61°	8.56°	9.65°	10.1 °	32.92	32.94	32.90	32.55

Off Lurcher Shoal.

Depth meters	Temperatures 1912 10031 Aug. 15	1913 10196 Aug. 12	1914 10245 Aug. 12	1915 10315 Sept. 7	Salinities 1912 10031 Aug. 15	1913 10196 Aug. 12	1914 10245 Aug. 12	1915 10315 Sept. 7
0	13.33°	12.12°	14.44°	12.22°	32.84	32.75	32.52	32.88
25	11.8 °	10.5 °	10.3 °	11.3 °	33.	32.97	32.95	32.99
50	10.7 °	9.4 °	9.2 °	10.11°	33.44	33.35	33.57	33.19
75	10.97°	8.6 °	8.8 °	9.9 °	33.64	33.4	33.84	33.36
100	8.5 °	7.4 °	8.6 °		33.76	33.41	33.97	

Northeast corner of Gulf.

	Temperatures			Salinities		
Depth meters	1912 10036	1913 10097	1914 10246	1912 10036	1913 10097	1914 10246
0	10.56°	12.78°	14.44°	32.75	32.75	33.06
20	10.17°	11.67°	10. °		32.76	33.14
40	9.33°	10.44°	8.35°		32.77	33.35
60	8.89°	9.17°	7.25°		32.8	33.34
80	8.61°	8.39°	6.57°		32.91	33.5
100	8.28°	7.72°	6.28°		33.08	33.57
120	8.00°	7.28°	6.57°		33.24	33.76
140	7.61°	6.67°	7.25°		33.45	33.95
160	7.44°	6.5 °	7.8 °		33.65	34.17
180	7.44°	6.22°	8.0 °	34.31	33.87	34.38
200		6.00°	8.17° (at 190m.)		34.09	34.47

Off the Northeast Coast of Maine.

	Temperatures			Salinities		
Depth meters	1912 10033 Aug. 16	1913 10098 Aug. 13	1914 10247 Aug. 12	1912 10033 Aug. 16	1913 10098 Aug. 13	1914 10247 Aug. 12
0	10.61°	10.28°	10.44°	32.68	32.47	32.52
20	10.11°	9.56°	10.15°	32.68	32.55	32.62
40	9.72°	9.33°	8.92°	32.68	32.62	32.73
60	9.61°	9.11°	8.88°	32.68	32.7	32.84
80						

Off Matinicus.

	Temperatures			Salinities		
Depth meters	1912 10039 Aug. 22	1913 10101 Aug. 14	1914 10250 Aug. 14	1912 10039 Aug. 22	1913 10101 Aug. 14	1914 10250 Aug. 14
0	13.33°	11.95°	13.05°	32.5	32.68	32.52
20	11.28°	10.05°	10.2 °		32.81	32.75
40	9.33°	9.44°	8.59°		32.94	32.92
60	8.89°	8.95°	7.9 °		33.06	33.04
80	8.67°	8.67°	7.4 °		33.19	33.14
100	8.33°	8.39°	7.04°		33.29	33.24
120	7.89°		6.6 °			33.3
140	7.28°		6.2 °	33.6		33.37

Off Cape Elizabeth.

Depth meters	Temperatures 1912 10019 July 29	1913 10103 Aug. 14	1914 10251 Aug. 14	Salinities 1912 10019 July 29	1913 10103 Aug. 14	1914 10251 Aug. 14
0	13.89°	16.11°	16.56°	31.92	31.83	31.92
20	11.05°	11.33°			32.38	
40	8.33°	8.72°	5.65°		32.64	32.38
60	6.89°	7.39°			32.74	
80	5.83°	6.95°			32.8	
100	5.67°	6.67°	4.41°	32.97	32.84	32.60
120						
140			4.9°			33.2

Trough between Jeffrey's Ledge and Coast.

Depth meters	Temperatures 1912 10011 + 12b July 17–23	1913 10104 Aug. 15	1914 10252 Aug. 15	Salinities 1912 10011 + 12b July 17–23	1913 10104 Aug. 15	1914 10252 Aug. 15
0	15. °	17.22°	16.22°	31.92	31.85	31.64
20	8.33°	9.61°	12. °	32.23	32.25	32.12
40	6.11°	7.78°	7.8 °	32.52	32.56	32.39
60	4.78°	6.61°	6.2 °	32.69	32.84	32.48
80	4.61°	5.83°	5. °	32.71	33.	32.54
100	4.61°	5.22°	4.3 °	32.77	33.06	32.6
120	4.61°	4.83°	3.8 °	32.85	33.08	32.72
140		4.56°	3.66°	32.95	33.1	32.79
160	4.11°	4.33°	(At 130m.)	33.01		
180				(at 150m.)		(at 130m.)

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