BELOW THE SURFACE

In the northern and western parts of the Gulf of Maine, to which the chilling effect of the cold Nova Scotian water does not reach and which are only indirectly affected by the shoreward and seaward oscillations of the warm oceanic water outside the edge of the continent, the superficial stratum, down to say 20 meters, is sensibly warmer by mid-May than in April. The surface, also, warms so much faster than the water only a few meters down that a temperature gradient of several degrees develops over all this part of the gulf by the end of May as the first step in the transformation from the homogeneous state that characterizes the upper 100 meters at the end of the winter (p. 523) to the very steep gradient of summer (p. 596).

Thus, the mean temperature of the 20-meter level of Massachusetts Bay was only about 1° higher on May 20 to 22, 1925 (about 5.5°), than it had been on April 21 to 23, the difference between this depth and the surface having now increased to about 3° to 5°, except around the shores of Cape Cod Bay, where tidal stirring was active enough to maintain a more homogeneous state (*Fish Hawk* cruise 13, stations 6 and 7). Local differences of this sort, in the rate at which heat is transferred downward into the bay during the spring, were responsible for a regional variation of about 6° (from 4° to 9.9°) in the temperature of its 20-meter level at this date, and for a regional distribution (warmest in Cape Cod Bay) paralleling the surface (fig. 28); but evidently they had not yet been effective much deeper than 20 meters, because the temperature of the bay still continued virtually uniform from station to station at the 40-meter level and at nearly the same values (3.3° to 3.8°) as it had a month earlier.

While the deepest water of the bay (at 70 to 80 meters level) had warmed by about 0.2° meantime, the source of heat in this case was probably the bottom water offshore. Similarly, the 40 to 60 meter level of the bay warmed by only 0.6° in 1920 between April 9 (station 20090, 2.3°) and May 16 (station 20124, 2.9°); the bottom water in 100 to 120 meters by only about 0.4° (from 2.3° to 2.7°), although the surface temperature rose by about 6.4° meantime. In short, seasonal warming is negligible at depths greater than 25 to 30 meters until after the third week of May in the Massachusetts Bay region.

This statement applies equally to Ipswich Bay north of Cape Ann, where the 20-meter level warmed from 1.94° to 4.18° between April 9 and May 7 to 8, 1920, and the 40-meter level only from 2.45° to about 3.1° (stations 20092 and 20122), with no appreciable change at depths greater than 60 meters, so that the vertical range of temperature between the surface and 40 meters increased from only about 1° to nearly 5° during the 4 weeks' interval (fig. 33).

In the basin off the northern part of Cape Cod, just outside the 100-meter contour, the 40-meter temperature rose from 2.2° on March 24 (station 20088) to 3.78° on May 16 (station 20125), while the temperature at 100 meters hardly changed appreciably during this interval of nearly 8 weeks. Below that depth the water, which had cooled slightly from March to April, then warmed fractionally, so that the curves for March and May fall close together (fig. 3) at 140 meters (about 3°–4°). In the southwestern part of the basin, where no observations were taken in April, a similar difference obtains between records for May 17 and February 23, 1920, showing a warning of about 4° at the surface (7.22° to 8.33° in May, according to the locality), but with very little change at 100 meters.

Turning now to the opposite side of the gulf, Mavor's (1923) tables show the central part of the Bay of Fundy warming only fractionally at any level from April 9 to May 4, 1917 (whole column then between 1.9° and 2.8°), but then more rapidly to 8.18° at the surface, 4.68° at 30 meters, and 3.92° at 100 meters on June 15.

Assuming, from the character of the winters preceding, that the mean temperature at 40 meters ranged about 1° lower at the beginning of spring in 1920 than in 1915, the difference between the April and May readings, just summarized, suggests that

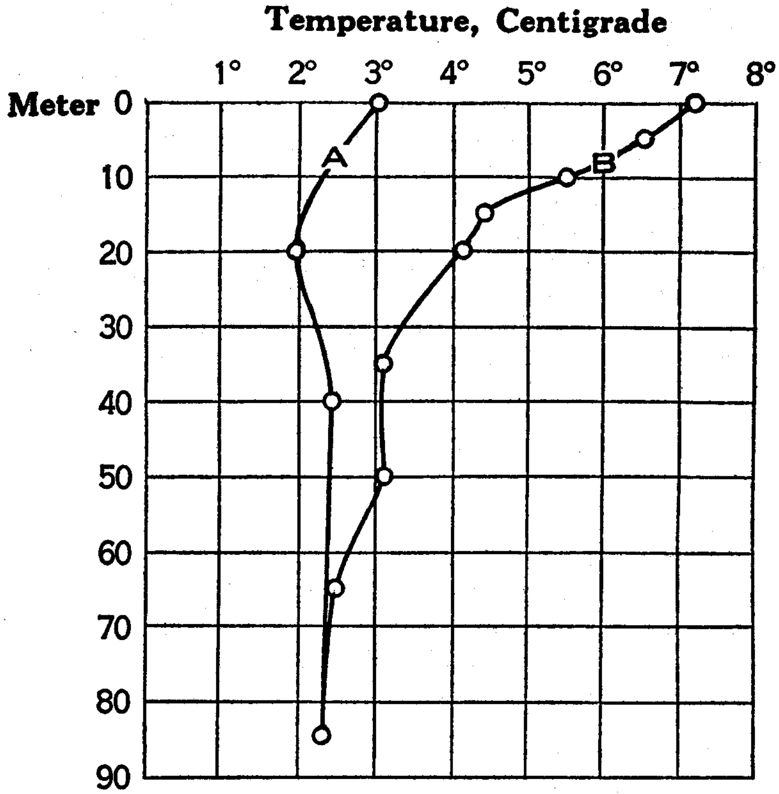

FIG. 33.—Vertical distribution of temperature in Ipswich Bay on April 9, 1920 (A, station 20092), and on May 7 and 8, 1920 (B, station 20122)

this level normally warms by about 1° during the interval from mid-April to mid-May in the parts of the gulf where the change is most rapid.

Taking the open gulf as a whole, the 100-meter readings for April, 1920 (a cold year), so closely reproduced the May readings for 1915 (a warm year)[18] that the temperature of the mid-depths may be described as virtually stationary during this part of the spring.

As the result of the two contrasting processes—vernal warming in the western side of the gulf and the inflow of cold water into the eastern—the regional distribution

[18] Maximum divergence at this level, for pairs of stations, was only from 3° in the western basin on Apr. 18, 1920, station 20115, to 4.8° on May 4, 1915 ,station 10267.

of temperature at the 40-meter level alters from April (fig. 24) to mid-May (fig. 34) by a shift of the coldest area (1.58° to 2.1° in April, 1920; 3° to 3.25° in May, 1915) from the western and northwestern sides of the gulf to the eastern side. Similarly, the warmest center shifts from the eastern arm of the basin, where the April readings were highest in 1920, to the western, with the coastal sector from Massachusetts Bay to Cape Elizabeth (4.5° to 5.1°, May 4 to 14, 1915), with about equal temperatures along the southwestern edge of Georges Bank (5.4° to 5.6° on May 17, 1920, stations 20128 and 20129).

The mid-stratum of the gulf, as illustrated by the 100-meter level, continues through May as regionally uniform in temperature as it is in April (fig. 25), with an extreme recorded range of only 2.45° within the gulf for the two years 1915 and 1920 (2.65°, Massachusetts Bay, station 20124, to 5.1° northeastern part of the basin, station 10273) and slightly warmer (7.5°) along the southwestern slope of Georges Bank (station 20129). Within the basin of the gulf the 100-meter readings for May have been highest (4.4° to 5.1°) in the central and northeastern parts, lowest in the western (2.6° to 3.5°) and eastern sides (about 4°). This last reading perhaps reflects the chilling effect of the Nova Scotian current from above; but there is no reason to suppose that the latter influences the spring temperature much deeper than this, because the 150-meter readings for March 2 and 23, for April 17, 1920, and for May 6, 1915, all fall within 0.2° of one another (about 5° in temperature) in the eastern side, and are nearly as uniform over the gulf, generally, for all the May cruises, as appears from the following table:

1915		1919		1920	
Station	Approximate temperature	Station	Temperature	Station	Temperature
	° C.		° C.		° C.
10267	5.2	Ice patrol 20[1]	4.35	20125[2]	4.04
10268	5	Ice patrol 21	4.4	20126	4
10269	5.1			20127[1]	3.8
10270	5				
10273	4.98				
10278	3.5				

[1] At 146 meters. [2] At 140 meters.

Thus the open basin of the gulf may be described as virtually uniform in temperature from side to side at the 150-meter level in May, though the precise readings may be a degree or so warmer or colder from one year to the next. The readings at the four deepest stations for May, 1915, also fall within 0.2° of one another at 185 to 190 meters (5.6° to 5.9° at stations 10267, 10268, 10269, and 10270).

The graphs for individual stations (figs. 3 to 11) show that in May (as is the case throughout the spring) the horizontal uniformity in temperature in the deep strata of the gulf usually is associated with a considerable rise in temperature with increasing depth, from the 50 to 100 meter level downward. As an example, I may cite a station off Cape Ann, occupied on May 4, 1915 (station 10267), when the 130-meter reading was 4.69°, with 6.59° at 260 meters depth. During the month the 200-meter level has averaged slightly warmer than the 100-meter level in the open basin of the gulf. In the Bay of Fundy, however, access to which for the inflowing bottom drift is hindered by the contour of the sea floor (p. 691), the temperature was virtually uniform from the 75-meter level downward on May 10, 1918 (about 2°), while in 1917 it was slightly lower (2.11°) at 175 meters than at 75 to 100 meters (2.2° to 2.8°) on the 4th of the month (Mavor, 1923). The deep sink inclosed by Jeffreys Ledge (recalling the Bay of Fundy in the contour of its floor, though smaller in area) was likewise nearly uniform in temperature from 100 meters (3.45°) down to 175 meters (3.7°) on May 14, 1915 (station 10278).

Whether the bottom water of the gulf basin cools or warms slightly from April through May, or whether the temperature remains virtually constant there, depends on the pulses just discussed (p. 555) and on the quantity and temperature of water

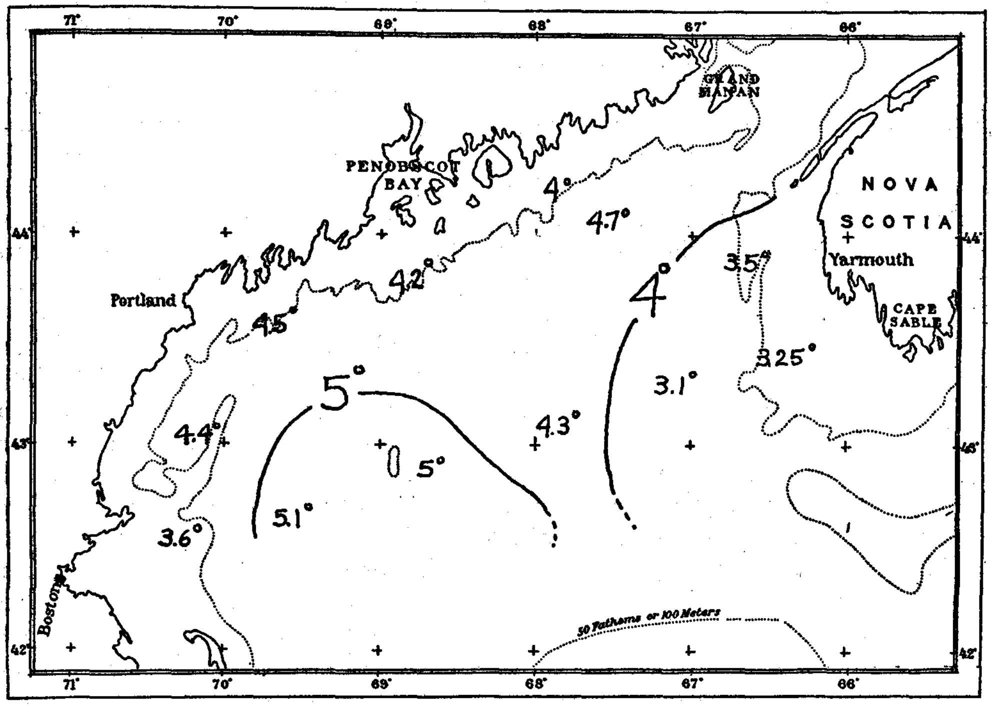

FIG. 34.—Temperature at a depth of 40 meters, May 4 to 14, 1915

brought in by them. If the inward drift over the bottom continues comparatively constant, little or no change is to be expected in the bottom temperature. If, however, the flow slackens or ceases, vertical circulation, from which no part of the gulf is free, will tend to equalize the temperature vertically; that is, to cool the deepest water while warming the overlying stata as they mix together. A pair of stations in the southwestern part of the basin for February and May, 1920, illustrate just this change, the slight rise in temperature with increasing depth from 100 meters downward to bottom in 150 meters, which was recorded for February 23 (station 20048), giving place to perfect vertical homogeneity by May (station 20127), while the 140 to 150 meter level cooled from 4.87° to 3·8° and the 100-meter level warmed from 3.54° to 3.8° during the interval.

The spacial distribution of temperature in May may be illustrated in a more connected way by three west-east profiles of the gulf—the first for April 28, 1919 (fig. 35), the second for May 4 to 7, 1915 (fig. 36), and the third for May 29 to 30, 1919 (fig. 37).

The first of these is interesting chiefly as it outlines the extension of the cold Nova Scotian current into the eastern side of the gulf, indenting like a shelf into the warmer water of the basin (isotherm for 4°, fig. 35). Water almost equally cold, washing the slope of Cape Cod at 60 to 120 meters in the opposite side of the profile, is reminiscent of the previous winter's cooling *in situ;* and the definite separation of these two cold masses by slightly higher temperatures in the central part of the basin deserves emphasis. Unfortunately no readings were taken deep enough in the basin to show what relationship the temperature of the bottom stratum bore to that of the mid depths at the time. So far as they go, however, they point to a homogeneous state at depths greater than 100 meters.

Although the May profile for 1915 (fig. 36) was run only a week later in date, the presence of a lenticular mass of 5° to 6° water over the western part of the basin, with maximum thickness of about 50 meters, illustrates a considerable advance in the seasonal cycle, reflecting the penetration of solar heat downward from the surface into the underlying water. Below it the cold coastal band that skirts the western side of the gulf earlier in the spring (the product of local chilling) is still represented at the mouth of Massachusetts Bay by temperatures of 3.5° to 4° at depths greater than 20 meters.

Whether the cold water of Nova Scotian origin in the eastern side of the gulf assumed a shelflike outline earlier in that particular spring, as it certainly did in 1919, is not known. If so, its tip had been eaten away by mixture with the surrounding water until its limiting isotherm (4°) had come to assume the more nearly vertical course shown on the profile (fig. 36). In actual temperature, however, this cold water mass was very nearly the same in 1915 as the ice patrol found it in 1919, one of the many illustrations that might be cited of the surprising constancy of the gulf in temperature from year to year. The presence of appreciably warmer (4° to 5°) water below it in both these years illustrates how strictly the inflow past Cape Sable into the gulf is confined to the upper stratum above the 100 to 120 meter level, a phenomenon resulting from the distribution of density in this side of the gulf (p. 946). As a consequence, the surface is the coldest level there in May, or at least the lowest readings will be had only a few meters down.

Figure 37 illustrates still a later stage in the thermal cycle, the Nova Scotian current having slackened and the two cold water masses that hug the two sides of the gulf earlier in the season having merged into the general stratum of minimum temperature (4° to 5°) at the 50 to 120 meter level. Vernal warming is illustrated further on this profile by a rise in the temperature of the upper 10 meters from about 5° at the end of April (5° to 6° on May 4 to 6, 1915) to 8° to 9°. In the deeps of the gulf a rise in temperature from about 4.5° to 5.6° to 6° during the preceding four weeks (cf. fig. 37 with fig. 35) is evidence of a considerable movement of slope water through the Eastern Channel into the gulf during the interval. However, the nearly horizontal course of the isotherm for 5 degrees across the basin on May 28 (fig. 37),

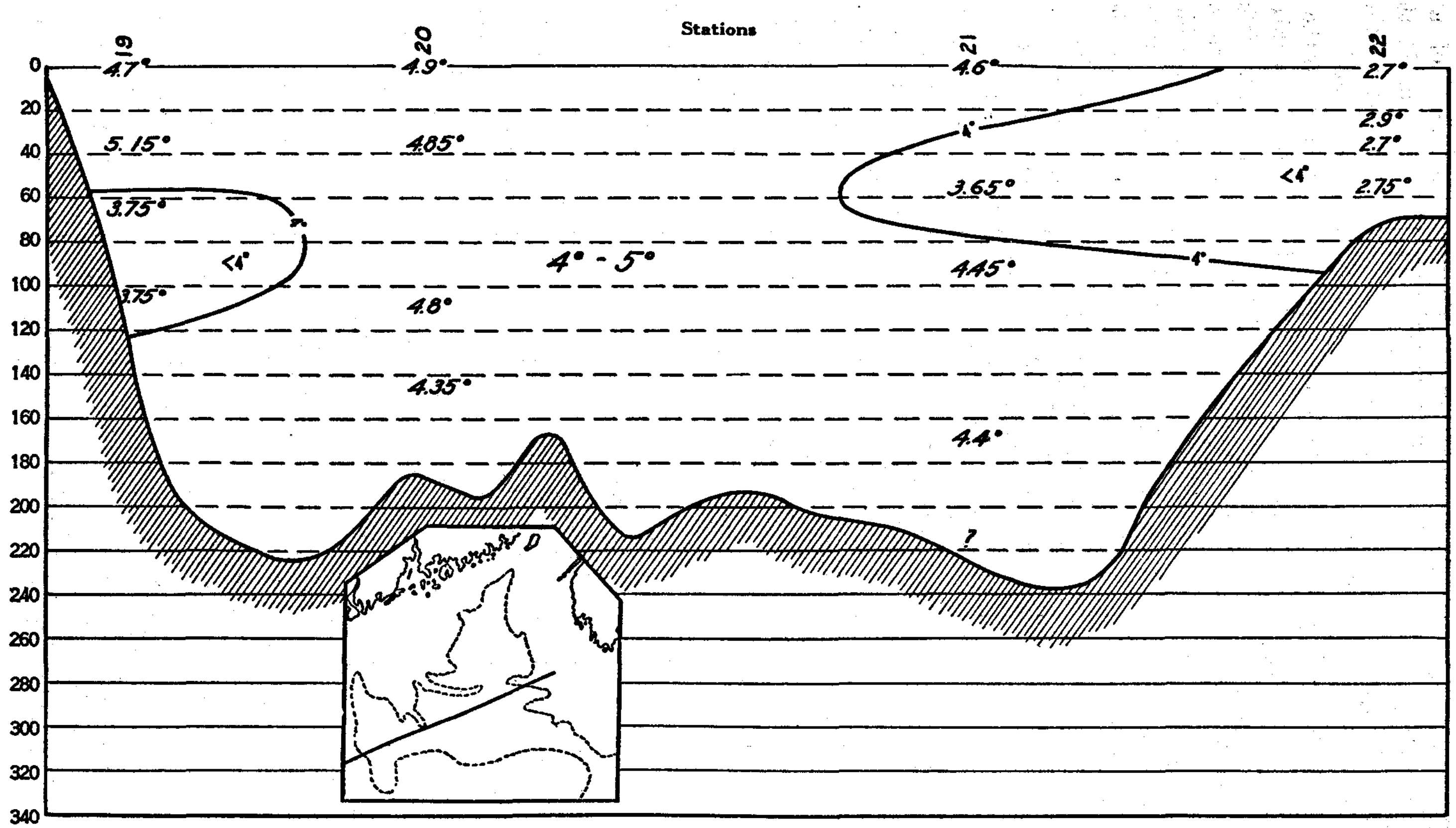

FIG. 35.—Temperature profile from a point a few miles off Cape Cod to German Bank, April 28, 1919 (ice patrol stations 19 to 22)

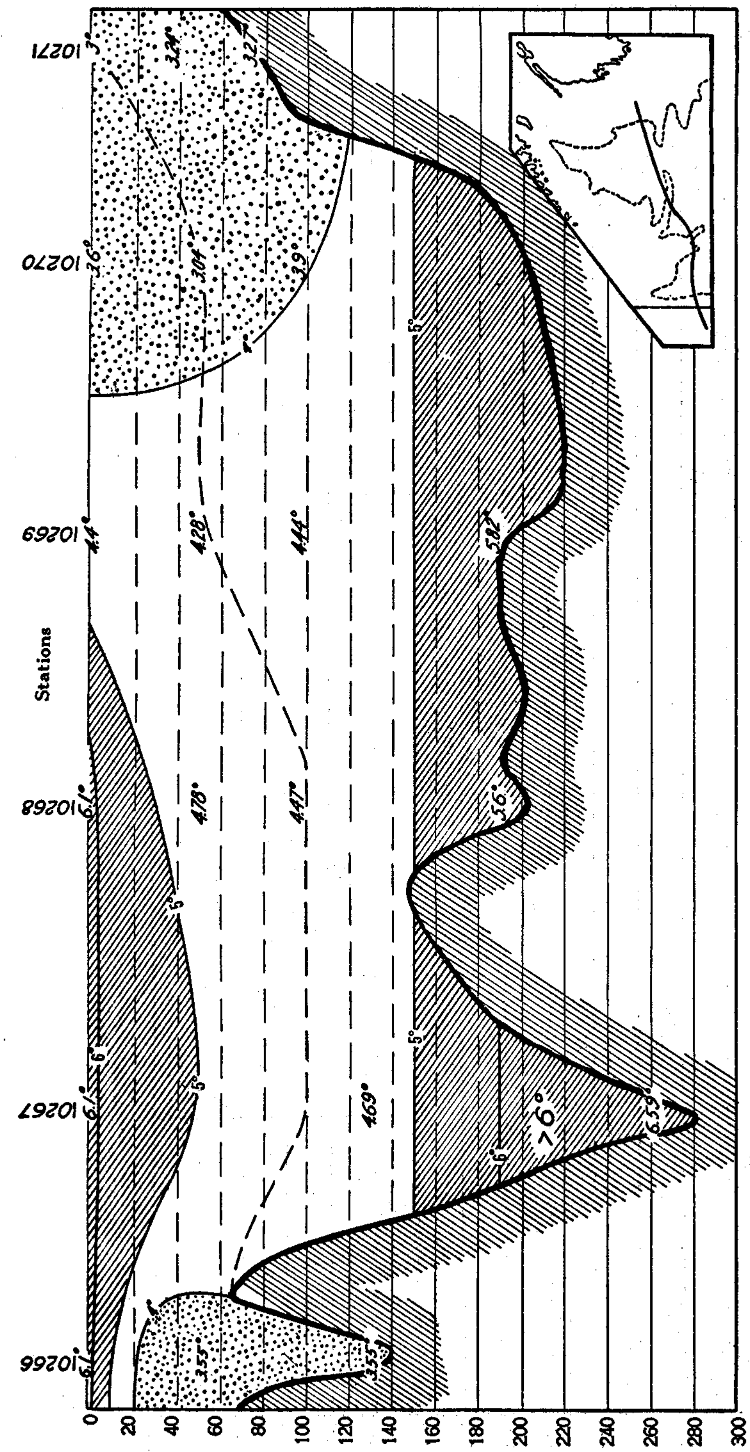

Fig. 36.—Temperature profile crossing the gulf from the mouth of Massachusetts Bay to German Bank for May 4 to 7, 1915

evidence of a static condition in the bottom water rather than one of active circulation, marks the precise date when this profile was run as falling between two of the pulses by which this indraft is believed to progress (p. 558), not as coinciding with one of them. Whether such a pulse annually succeeds the slackening of the Nova Scotian current remains to be learned, but this is not unlikely.

In 1920 the general increase in temperature that involves the gulf proper and the western part of its offshore rim from April to May, did not extend to the seaward slope of the latter. There, on the contrary, a change of the reverse order took place from about the 40-meter level right down to the bottom in 150 to 200 meters (fig. 38), illustrated by a decrease in the bottom temperature from 11.5° on February 22 (station 20045, 150 meters) to 8.28° on May 17 (station 20129, 160 meters). Accompanied, as it was, by a corresponding freshening at the bottom, this cooling is clear evidence that the warm, highly saline oceanic water that bathed this part of the slope in February, as it usually does in summer (p. 617), had receded offshore by May. Lacking data farther eastward along the slope for this season, it is impossible to state the precise cause of this event further than that it probably represented a dynamic alteration (p. 936) rather than a direct extension of Nova Scotian water in this direction (p. 825).

Whatever its cause, however, the fact that so great a chilling of the bottom water undoubtedly did occur in just this location in 1920 (and may, perhaps, every spring) is of great interest biologically, as events of this sort necessarily limit the permanent bottom dwellers of the eastern part of the so-called "warm zone" to such

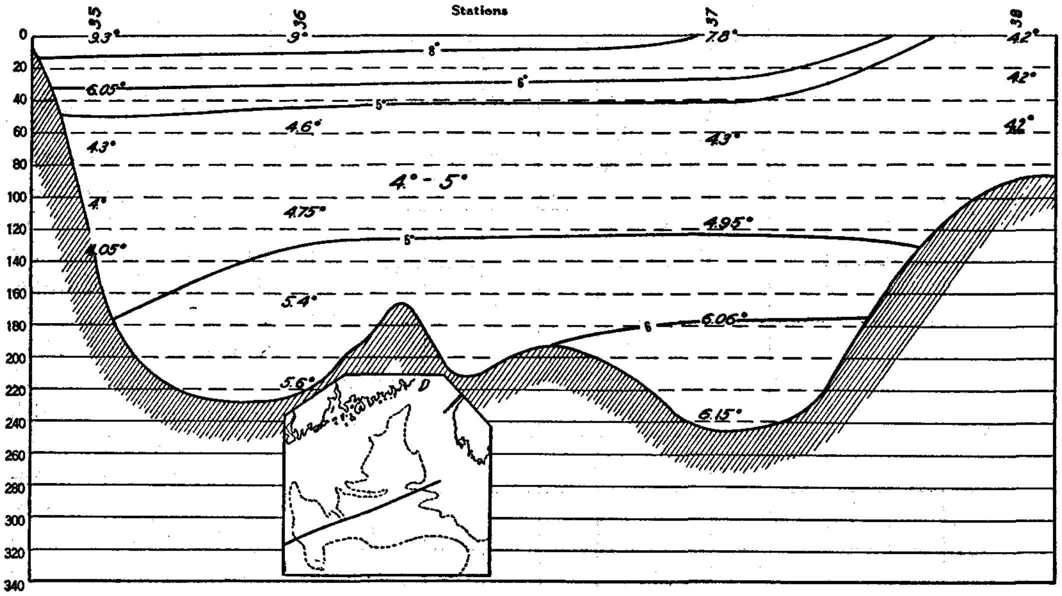

FIG. 37.—Temperature profile from a point a few miles off Cape Cod to German Bank, for May 29 and 30, 1919 (ice patrol stations 35 to 38)

animals as can survive temperatures as low as 7° to 8°. Unfortunately no readings were taken there during the only spring (that of 1884) when a serious mortality is known to have taken place among its inhabitants—invertebrates as well as fishes (notably the tilefish)—but in very cold years the temperature there may fall several degrees lower, perhaps, than happened in 1920. Tentatively, mid May may be set as the coldest season on bottom along this part of the continental slope—three months later than in the inner waters of the Gulf of Maine.

JUNE

I am not able to present as satisfactory a thermal picture of the gulf for June as for the spring, no measurements of temperature having been made in the western side of the basin, along shore between Cape Ann and Cape Elizabeth, nor on Georges Bank during that month. On the other hand, our June cruise of 1915 led far enough east past Cape Sable to cross-cut the Nova Scotian current before it passes that promontory. The *Fish Hawk*, also, made a general survey of Massachusetts and Cape Cod Bays on June 16 and 17 in 1925. A few temperatures were taken by the *Halcyon* near Gloucester on the 6th in 1924, in the Nantucket Shoals region during the first half of the month in 1925, and Dawson (1922) also took a considerable number of June readings along Nova Scotia in 1904 and 1907.

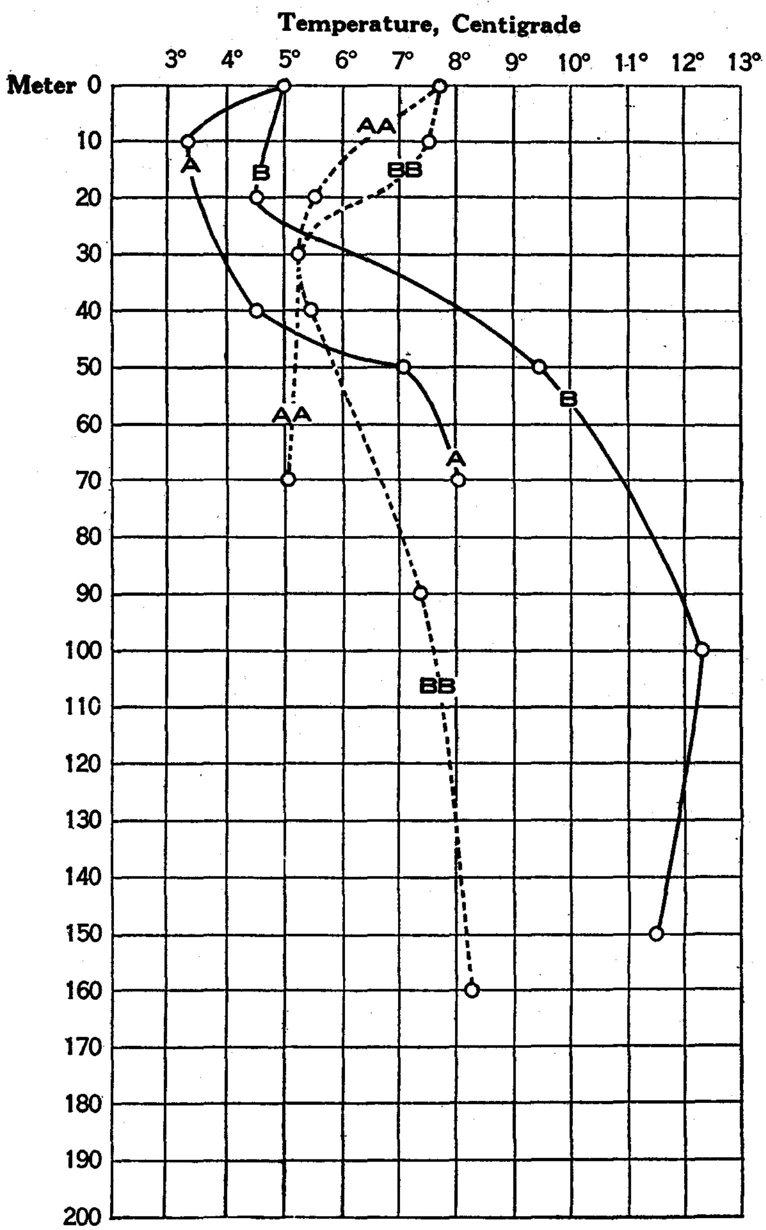

FIG. 38.—Vertical distribution of temperature on the southwestern slope of Georges Bank to show cooling of the bottom water, but warming at the surface, from February to May, 1920. A and B, February 22 (stations 20046 and 20045); AA and BB, May 17 (stations 20128 and 20129)

RATE OF WARMING

Progressive warming is to be expected, of course, over the whole area throughout the month of June. Thus, the surface had warmed to 10.56° at a station 8 miles off Gloucester on the 6th in 1924, and to 12.1°–15.2° over Massachusetts Bay generally by the 16th or 17th in 1925, an average change of about 5 degrees since May 20 to 22. At the 20-meter level these mid-June temperatures averaged about 7.8° (18 stations), contrasting with about 5.5° in May (p. 564), with the readings for June 6, 1924 (6.2°) intermediate, as the date would suggest. These Massachusetts Bay stations for 1925 also illustrate interesting regional differences in the rate at which heat penetrates downward into the water during the late spring and early days of summer, depending chiefly, it would seem, on differences in the extent to which the water is stirred by the tides and on the freedom of interchange of water between the coastal zone and offshore—perhaps to some degree on upwellings.

In midwinter the Plymouth shore and Cape Cod Bay to the southward see winter chilling more rapid than in any other part of the Massachusetts Bay region (fig. 81). With the advance of spring, however, the regional relationship is reversed, so that by May we find the surface water warmest in Cape Cod Bay (p. 557, fig. 28). During the last week of that month, however, and the first half of June, the western side of Massachusetts Bay had caught up with Cape Cod Bay in the progression of temperature, so that all this area (inclosed by the isotherm for 15° on fig. 39) was now nearly uniform (15 to 15.2°) in surface temperature, except for one station off Plymouth Harbor, where vertical circulation of some sort was responsible for a slightly lower reading (14.43°).

Considerably lower surface temperatures (12.1° to 13.3°), right across at the mouth of the bay, show that the offshore waters had lagged behind the coastal belt in warming; and still lower readings (12° to 13°), along the north shore of the bay deserve emphasis because the 20-meter level was warmest here, coldest at the mouth of the bay, and with a rather surprisingly wide range in temperature (12.03° to 4.56°) from station to station. Active vertical stirring is clearly responsible by bringing the upper 20 meters within the immediate effect of the sun's rays, to warm nearly uniformly along the northern shore. At the same time it is probable that the warming of the upper stratum in this particular region is forwarded during June by a more or less constant drift of the surface water—already warmed to 12° to 14° temperature—around Cape Ann and westward into the bay. Consequently, a somewhat higher mean temperature for the upper 20 meters may be expected to prevail along its northern shore than in its central parts in June, just as was actually recorded in that month in 1925 (*Fish Hawk* cruise 14, stations 35 to 37), instead of a lower mean temperature, as is the case later in the summer.

More rapid warming of the surface along the Plymouth shore and in Cape Cod Bay, but a slower rise in temperature at 20 meters, points to a less active overturning by the tides; and the fact that the surface and 20-meter readings both averaged 2° to 3° higher there than over the deep sink off Gloucester (*Fish Hawk* station 31) is evidence that the interchange of water between the open basin of the gulf, on the one hand, and the western and southern parts of Massachusetts and Cape Cod Bays, on the other, had been so slow for some weeks previous that the latter had acted as a more or less isolated center of local warming. On the other hand, the low temperatures (5 to 6°) at the 20-meter level along the eastern side of Stellwagen Bank, at the mouth of the bay, point to a certain amount of upwelling over the slope of the latter, bringing up cold water from greater depths offshore.

These regional differences in the June temperatures for 1925 are smoothed out over the Massachusetts Bay region with increasing depths. At 40 meters, for example, the extreme range of temperature was then only from about 3.5° to about 6.1°, with the mouth of the bay uniformly 4° to 4.5°, and the 40-meter temperature (about 3.6°) off Gloucester for the 6th of the month, for 1924 (station 10653), falls within this range. At 75 to 94 meters the temperatures of Massachusetts Bay were also about the same in 1924 (3.13°, station 10653) as in 1925 (3.97° and 4.04° at *Fish Hawk* stations 30 and 32).

Out in the open basin, off Cape Ann, the surface warmed from 6.1° on May 4, 1915 (station 10267), to 13.6° on June 26 (station 10299), or at about the same rate

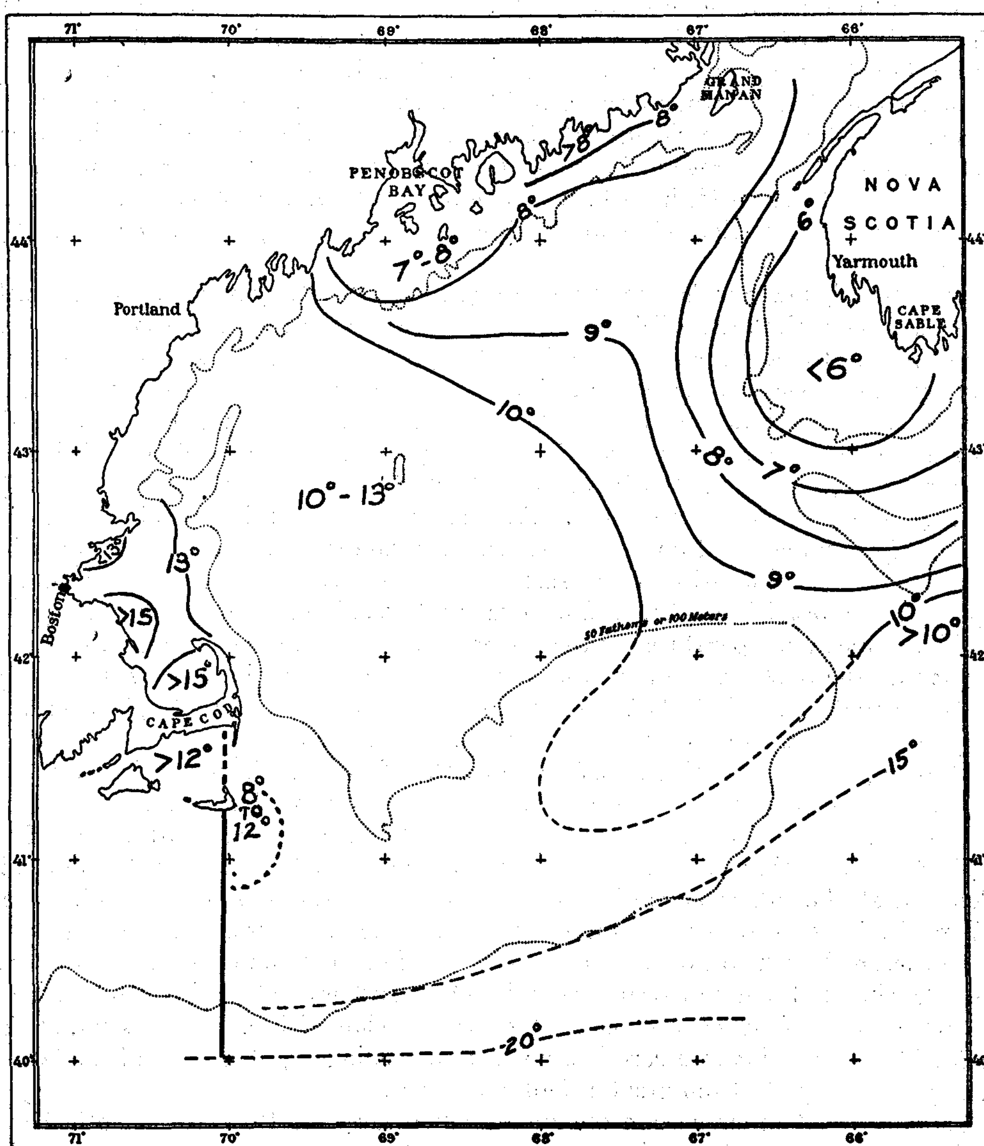

FIG. 39.—Surface temperature in mid-June from all available sources. The dotted curves are based on Dixon's (1901) tabulation

as in Massachusetts Bay in 1925. The 40-meter temperature, however, rose by only 1.5° during the interval (from about 5.2° to about 6.8°), while virtually no change took place at 90 meters or deeper (fig. 5). It is probable, also, that the seasonal succession illustrated by these two stations is characteristic of that side of the basin in general.

No observations have been taken in the western side of the gulf in June, or on Nantucket Shoals, on the cruises of the Bureau of Fisheries' vessels, except those just mentioned; but the daily data tabulated by Rathbun (1887) for several lighthouses and lightships partially fill the gap for the coast sector between Cape Ann and the Mount Desert region, and are consistent with the serials taken of late years in the northeastern part of the gulf, in the Bay of Fundy, and in Massachusetts Bay.

Approximate temperatures (°C.) at the surface on June 15, from Rathbun's (1887) tables[1]

Locality	1881	1882	1883	1884	1885	Average
Pollock Rip lightship	14.2	9.7	12.2	11.7	10.6	11.7
Thatchers Island (Cape Ann) light	13.2	------	12.2	------	------	12.7
Boon Island light	10	8.3	10.6	11.4	10.3	10.1
Seguin Island light	9.8	10.9	11.9	11.4	9.4	10.7
Matinicus Rock light	8.3	8.3	7.2	8.3	7.5	7.9
Petit Manan light	7.6	8.9	10.3	10.6	10.1	9.5

[1] Given only to nearest 0.1°.

The 10-day averages for Gloucester and Boothbay for 1920 (figs. 29 and 30) show that the water warms only slightly faster in inclosed locations of this sort than off the open coast (compare 13° at Gloucester and about 12° at Boothbay on June 15 with Rathbun's record of 12° to 13° at Thatchers Island, off Cape Ann, and of 9° to 11° at Seguin Island. A temperature about 3 degrees lower at Matinicus Rock, at the mouth of Penobscot Bay, than at Seguin Island, some 34 miles along the coast to the westward, probably reflects some local retardation of vernal warming by the spring freshets from the Penobscot River. Conversely, the comparatively high temperature at Petit Manan suggests that readings as warm as 10° are to be expected by June 15 after a few days of warm weather, in sheltered locations along shore in shallow water, to the east as well as west of Mount Desert. In fact, Doctor McMurrich records almost as high surface temperatures (9° to 9.5°) at St. Andrews by June 15 in 1916. Lubec Narrows, however, open to the Grand Manan Channel and with a great volume of water rushing through on every tide, had warmed to only about 6° by this date in 1920 (fig. 31).

Earlier in the season, and up to mid May, the vertical distribution of temperature in the upper 150 meters or so is of one type throughout the inner waters of the gulf, though the actual values differ slightly from station to station. During late May and June, however, very important differences develop between the state just described for the western side of the gulf (where the rapid warming of the upper stratum by the sun, coupled with the sudden establishment of a high degree of vertical stability, causes the development of a steep temperature gradient in the upper 40 to 50 meters, overlying water more nearly homogeneous) and the northeastern part of the gulf, where more active stirring by the tides spreads the warmth received from the sun through a thicker stratum of water. Furthermore, we find the rate of warming decreasing from west to east as we follow around the coast line of the gulf, even after this regional difference in the downward dispersal of the heat received has been allowed for. Thus, the surface had warmed only from 5° on May

12 (station 10276) to 7.8° on June 14 (station 10287) off Penobscot Bay; the 40-meter level from 4.2° to about 5.8°, while the courses of the curves suggest that no appreciable change in the temperature of the water is to be expected at or below 80 meters off this part of the coast during the month of June.

In the immediate vicinity of Mount Desert Island the surface temperature rose by about 1° from May 10 to 11 (stations 10274 and 10275, 4.2° and 4.4°) to June 10 to 11 (stations 10283 and 10284, both 5.4°); but four days later surface readings of 7.5° to 8° were had at three stations (10285 to 10287) a few miles to the westward. The graphs (fig. 7) for these stations, as compared with May 10 (station 10274), show that the whole column, down to the bottom in 80 meters, warmed at a nearly equal rate there up to June 10, instead of most rapidly at the surface, as happens off Penobscot Bay and in the Massachusetts Bay region, no doubt because of the stronger tidal currents to the east than to the west of Penobscot Bay (p. 678).

Near Mount Desert Island this vertical stirring is sufficiently active to bring the whole column of water uniformly under the effect of the sun's rays during the early spring, resulting in the uniform rate of warming from surface to bottom just noted. During June, however, the surface receives heat so rapidly there, coupled with a corresponding freshening (p. 747), that the column is stabilized vertically, though the deeper layers are never so insulated here as in the less actively stirred waters to the west of Penobscot Bay and to the south of Cape Elizabeth.

In 1915 this establishment of stability in the Mount Desert region evidently fell between June 10 and June 15, because the surface warmed more rapidly there between these two dates (a change of about 2°) than it had during the preceding month, though the 30-meter and deeper temperatures rose by only about 0.2° meantime.

Data are not available for a general survey of the temperature of the Bay of Fundy for the month of June, but very considerable local differences in the rate of vernal warning are to be expected there during the early summer to correspond with regional differences in the activity with which the water is stirred by the violent tidal currents. The Grand Manan Channel stands at the one extreme, with the whole column of water warming uniformly, or nearly so, through June down to 100 meters, and correspondingly slowly at all depths. Thus, on June 4, 1915, the whole column of water in the western end of the channel abreast the north end of Grand Manan (station 10281; 80 meters) was about 4.5° in temperature, pointing to a rise of about 2° at all levels from the minimum of the preceding winter, and the channel continues homogeneous in temperature from surface to bottom into August (p. 599).

In the central parts of the Bay of Fundy, however, vernal warming essentially parallels the account just given for the Mount Desert region, with a similar seasonal relationship between successive monthly curves (fig. 40) constructed from Mavor's (1923; *Prince* station 3) records for the spring of 1917, though the actual temperatures differ somewhat at the two localities. Thus, this Fundy station warmed from 2.96° to 8.18° at the surface between May 4 and June 15; from 2.01° to 4.13° at 50 meters; from 1.87° to 3.92° at the 100-meter level; and from 1.75° to 2.08° at 150 meters;

so that the temperature curves for the two dates recall those off Mount Desert for May 10 and June 14, 1915, in their mutual relationship. A similar seasonal relationship also obtains between serials taken in the Fundy Deep near by on March 22, 1920 (station 20079), and June 10, 1915 (station 10282).

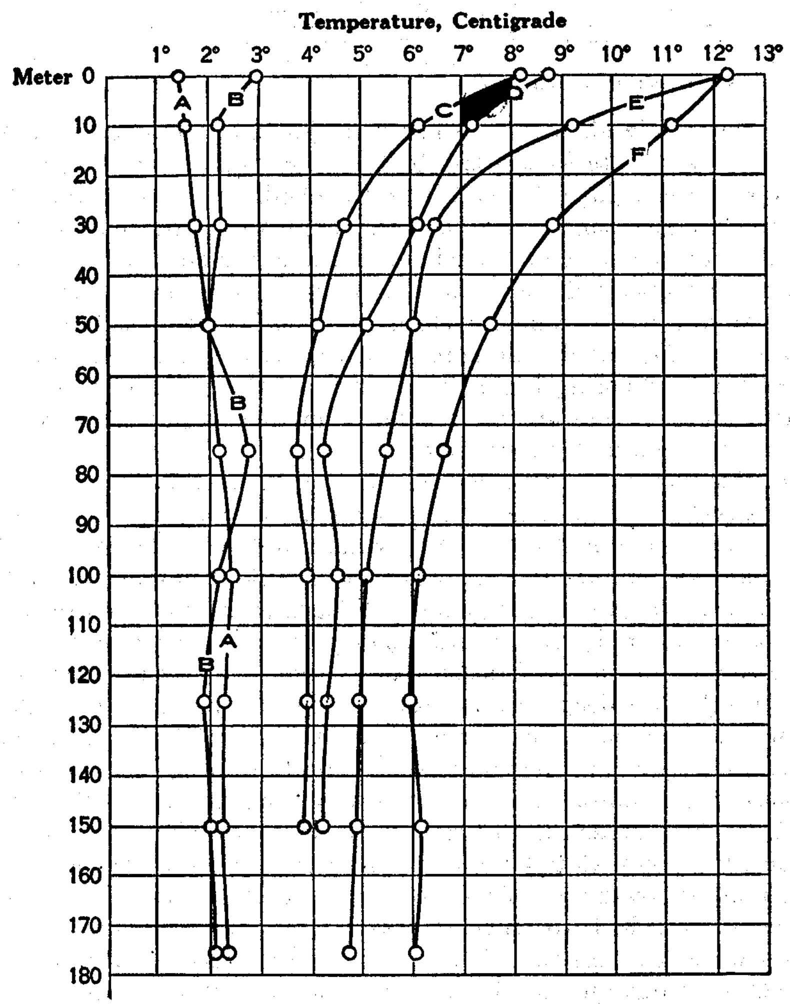

FIG. 40—Vertical distribution of temperature in the Bay of Fundy in 1917, from Mavor (1923, *Prince* station 3, 1916–17). A, February 28; B, May 4; C, June 15; D, July 4; E, July 31; F, September 4.

In 1917 the surface temperature had risen only to 8.68° at the *Prince* station by July 4 (Mavor, 1923, p. 375); the 50-meter level to 5.06°, the 100-meter level to 4.5°, and the 150-meter level to 4.21°; but warming either took place more rapidly in the Bay of Fundy in 1904, or the temperature did not fall so low there during the preceding winter, because Dawson (1922, p. 82, station F) found the deeper strata of the Fundy Deep about 2° warmer than this a week earlier in the season, as follows:

Serial temperatures (° C.) in Fundy Deep for June, 1904, after Dawson (1922)

Depth	June 23, 1904	June 29, 1904 [1]	Depth	June 23, 1904	June 29, 1904 [1]
Surface	8	11.1	27 meters	6.7	8.6
9 meters	7.5	9.7	55 meters	6.4	7.5
18 meters	7	9.4	91 meters	6.4	6.4

[1] Dawson's records are given to the nearest 0.5° F.

Surface water only about 4° warmer than the 50 to 60 meter level at these Bay of Fundy stations, as late as the last half of June, is an interesting contrast to the coastal sector between Cape Cod and Cape Elizabeth, where the surface temperature rises to 7° to 8° higher than 50 to 60 meter temperature by that season; nor does this regional divergence reach its maximum until late in summer (p. 596).

The most interesting phase of the June temperatures for 1915 is the light which they throw on the hydrographic cycle in the southeastern parts of the gulf. As stated above (p. 561), actual chilling takes place over the banks west of Nova Scotia, and out into the neighboring basin, from April to May, while the icy water of the Nova Scotian current is flowing into the gulf from the east past Cape Sable, although vernal warming is well under way elsewhere.

In 1915 this flow had become so weak during the last half of May (if it had not ceased altogether) that it no longer offset the normal tendency of the water to warm at this season. Consequently the temperature of the whole column of water on German Bank rose from about 3° on May 7 to about 6° on June 19 (station 10290). Unfortunately, the neighboring station in the basin (10270) was not revisited in June; but the surface a few miles northward also warmed from a temperature of 4° to 5° in mid May to 9.7° on June 19 (station 10288), though with a rate so rapidly decreasing with depth that the deep water, at 100 to 180 meters, was only 0.4° to 1° warmer on the later date than on the earlier one. As this rise of temperature in the deeps was accompanied by a corresponding rise in salinity (p. 755), it is to be credited to a renewed pulse in the inflow through the Eastern Channel, and 1919 seems to have been a still "earlier" season in this respect, as described above (p. 558).

Off Shelburne, only 25 to 30 miles to the eastward of Cape Sable, by contrast, the 50 to 75 meter stratum continued very cold next the coast (0.7° to 0.9°) until the last week of June in 1915 (Bigelow, 1917a, stations 10291 and 10292), and was only slightly warmer at the end of July of that year (Bjerkan, 1919) or in July, 1914 (station 10231). Consequently, it would not be surprising to find the water along western Nova Scotia temporarily chilled by a renewed pulse from this icy reservoir at any time during June, either at the surface or a few meters down. Serial readings taken off Yarmouth, also off Cape Sable, by Dawson in 1907 (1922, p. 82, stations M and S), show that some such event did take place that year, made evident by a drop in the bottom temperature (55 meters) in the offing of Yarmouth, Nova Scotia, from 4.7° on June 17 to 1.1° on June 25, although the surface water continued to rise in the normal seasonal advance.

Temperatures (°C.) 17 miles southwesterly from Cape Fourchu in 1907, from Dawson (1922, p. 82)

Depth	June 17	June 21	June 25
Surface	5.6	6.4	8.9
9 meters	5	6.1	6.9
18 meters	5	4.7	3.9
27 meters	4.7	4.7	2.8
55 meters	4.7	4.7	1.1

The source of this cold indraft is found near Cape Sable—by Dawson's records 10 miles south from Brazil Rock on the 26th and 27th, quoted below—which also shows an interesting variation in temperature at different stages of the tide.

Temperatures (°C.) 10 miles south of Brazil Rock (from Dawson)

Depth	June 26, high water	June 27, low water
Surface	8.6	7.8
9 meters	4.7	7.5
18 meters	2.8	4.7
27 meters	2.5	3.9
55 meters	1.4	1.9

It is probable that when belated overflows of the cold Nova Scotian water into the gulf do occur after early June they are of brief duration, for we have found no evidence of such an event later in the season on our recent cruises.

Dawson's June temperatures likewise afford an interesting illustration of the rate at which the surface water may be expected to warm along the Nova Scotian coast sector between Yarmouth and Cape Sable during the month of June. Thus, the surface there was 4.4° to 5° on the 7th of the month in 1904, though it had already risen to 6° at the mouth of Yarmouth Harbor by that date. In 1907 the surface was 5° to 6° in the offing of Yarmouth on the 11th to 15th; 6° to 7.8° on the 22d (warmest close in to the land); 6.5° to 8° to the eastward of Cape Sable by the end of that month; but the tide-swept region close to the cape was still only 4.2° to 5°, and this cold pool reappears on our charts for August (p. 592).

In 1915 the temperature of the surface water had risen to 10° over Browns Bank and the Eastern Channel (stations 10296 and 10297) by June 24 to 25, which is 3.5° cooler than the expectation for Massachusetts Bay at that date, and the water that filled the trough of the channel at depths greater than 100 meters was about 1 to 2 degrees warmer (7° to 8°) than on April 16, 1920 (station 20107). On Browns Bank, too, the temperature of the bottom water was about 4° higher at the June station than at the April station (stations 10296 and 20106), but the 40-meter reading was actually lower in June (2.8°)—colder, in fact, than any June reading in the inner parts of the Gulf of Maine. The presence of a cold mid stratum at this particular locality sandwiched between water of 7.36° on bottom at 80 meters, 10° at the surface, is unmistakable evidence of an extension of the cold Nova Scotian water from the eastward out over the bank, indenting into the higher temperatures that may be expected to prevail there earlier in the season. The profile run across the shelf abreast of Shelburne, Nova Scotia, the day before (stations 10291 to 10295, June 23 and 24, 1915) corroborates this apparent tendency for the cold Nova Scotian current to swing offshore abreast Cape Sable at the time, instead of flowing past the cape into the eastern side of the Gulf of Maine, as it does earlier in the season. This profile (fig. 41) lies outside the geographic limits of the present discussion; it will be enough, then, to point out that it cuts across a lenticular mass of water colder than 2°, occupying the whole breadth of the continental shelf at the 40 to 100 meter level, with a minimum reading of only 0.7° (station 10292, 50 and 75 meters) in the trough between the land and La Have Bank.

The high temperatures recorded for the Eastern Channel in June, 1915, prove Browns Bank the westerly boundary for the icy water at the time; but it may extend across the Eastern Channel to Georges Bank earlier in the month in some years, a question discussed below in connection with the July temperatures of the bank (p. 919).

Unfortunately, no temperatures have been taken below the surface on any part of Georges Bank in June. It is probable that the vernal expansion of the cold Nova Scotian current maintains temperatures lower than 10° on the eastern part of the bank until the first of the month, and Dickson (1901) so represents it on his chart of surface temperatures for June, 1897, contrasting with temperatures higher than 12° in the western side of the gulf, on the one hand, and outside the continental edge, on the other. July temperatures (p. 594), however, suggest that the surface on the western end of the bank may be expected to warm to 10° to 11° by mid June, except locally, where strong tidal currents and rips sweep around its shoalest portions. Considerable variations develop in the temperature gradient on Nantucket Shoals by that month, however, according to the local activity of the tidal stirring, for the *Halcyon* found the temperatures almost exactly the same on bottom in about 30 meters depth (8.3°) as at the surface near Round Shoal on June 7, 1925, but the bottom more than 5° colder than the surface[19] in water of about 40 meters depth only 6 miles to the eastward.

Judging from daily readings made at Nantucket lightship in the years 1881 to 1885 (Rathbun, 1887), and from the *Halcyon* temperatures just cited, surface temperatures of 10° to 12° (varying somewhat from year to year) are to be expected in the Nantucket Shoals region generally by the middle of June.

GENERAL DISTRIBUTION OF TEMPERATURE

A graphic picture of the June state for the gulf as a whole results from combining the June stations for the various years (fig. 39). Unfortunately, the observations not only include possible annual differences, but cover too long a space in time for this surface chart to be as satisfactory as might be wished at a season when the water is absorbing heat from the sun as rapidly as happens through June. It will serve, however, as an indication of the regional distribution and approximate values that may be expected in various parts of the gulf at the middle of the month. Its feature of chief interest is that the temperature is higher in the western side than

[19] Surface 11.7°; bottom 6.4°.

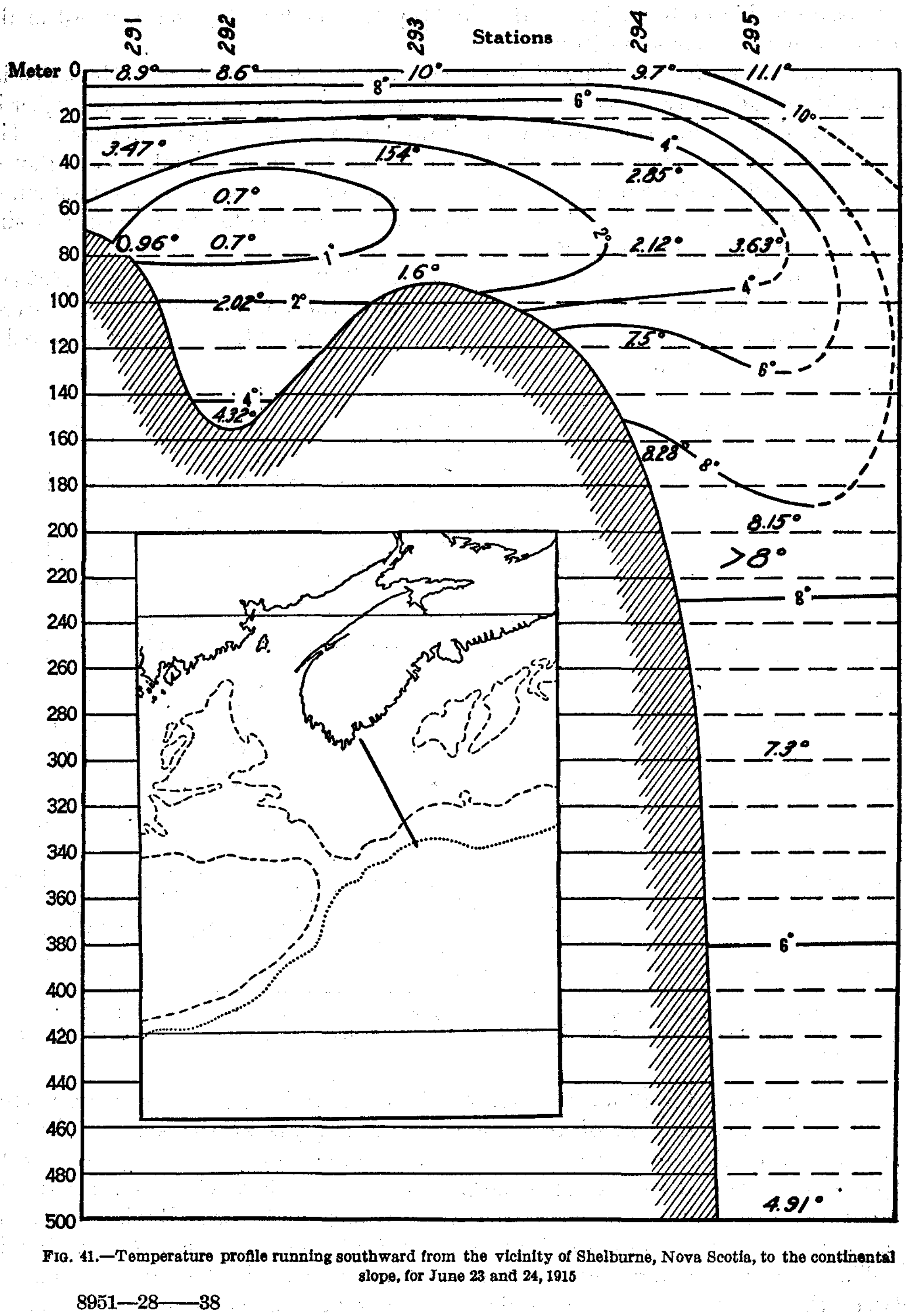

FIG. 41.—Temperature profile running southward from the vicinity of Shelburne, Nova Scotia, to the continental slope, for June 23 and 24, 1915

in the eastern side in June, just as it is in May (p. 556, fig. 27), and warmest in the inner part of Massachusetts Bay.

In June the surface of the gulf is coldest over the shallows west of Nova Scotia, with rather a sudden transition from surface temperatures of 8° to 9° and higher in the eastern side of the basin to readings lower than 7° to 8° next the land. The comparatively warm core (8° to 9°) extending up the deep trough of the Bay of Fundy, outlined by the curve for 8° on this surface chart, also deserves mention, as does the slightly cooler zone (7° to 8°) extending westward along the coast of Maine across the mouth of Penobscot Bay.

In the offshore side of the picture, Dickson's (1901) data for the years 1896 and 1897 locate the isotherm for 15° as following along the continental edge of Georges Bank, with surface water of 20° separated from the edge of the continent by a wedge of cooler water increasing in breadth from west to east.

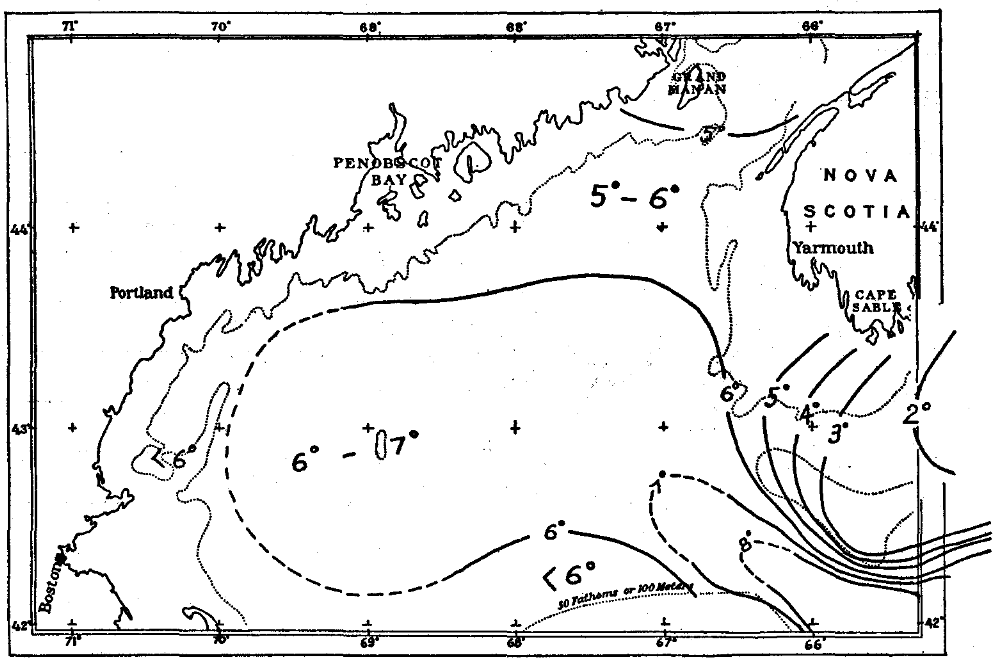

FIG. 42.—Temperature of the eastern side of the gulf at a depth of 40 meters, last half of June, 1915. The Bay of Fundy temperature is according to Mavor (1923); the temperatures along western Nova Scotia are from Dawson (1922)

The June chart for 40 meters (fig. 42) shows a gradation in temperature across the gulf from west to east of the same sort as appears at the surface (fig. 39). The influence of the Nova Scotian current on temperature at the 40-meter level is graphically illustrated by an expansion of water colder than 3° from the coast off Shelburne, Nova Scotia, out across the western part of Browns Bank, contrasting with higher temperatures (5° to 6°) on German Bank and along western Nova Scotia.

The most interesting feature of this 40-meter chart is the sudden transition between the cold water on Browns Bank to the much higher temperature (8.2°) in the Eastern Channel (a horizontal dislocation of 5° in a distance of only about 15 miles) and its demonstration that the latter is clearly a tonguelike intrusion from offshore. The records are not sufficient to outline exactly how far 7°-water then penetrated the southeastern part of the gulf; but the temperatures at such of the stations as lie in the course usually followed by the inflowing current (6.3° and 6.1° at 40 meters at stations 10288 and 10299) suggest that readings as high as 7° would not have been found farther west in the basin than is outlined on the chart at any time during June, 1915. Undoubtedly, however, wide fluctuations occur from year to year in this respect.

If the data for the two years 1915 and 1925 can justly be combined, as seems allowable because the preceding winters were not unusually severe, slightly higher temperatures are to be expected over the eastern and central parts of the basin generally than either in the northeastern corner of the gulf (including the Bay of Fundy), on the one hand (40-meter level about 4° to 5°), or off Massachusetts Bay, on the other, where the *Fish Hawk* recorded 40-meter temperatures of 3.5° to 4.5° at most of her mid June stations in 1925. A 50-meter reading of 5.18° in the southern side of the basin as late as June 25, 1915 (station 10298), suggests that the 6° to 7° water then takes the form of a pool, as it is shown in the chart, entirely surrounded by slightly lower temperatures except for its connection with still warmer water outside the edge of the continent, via the Eastern Channel. A regional distribution of temperature of this sort is interesting as evidence that the influence of the indraft through the Eastern Channel may raise the 40-meter temperature of the central parts of the gulf slightly higher in late June than the figure (4° to 5°) to which solar warming, unassisted, would bring it by that date.

At a depth of 100 meters (fig. 43) the isotherm for 5° shows a tendency on the part of this indraft to follow the eastern slope of the basin and to eddy to the westward around its northern side, but this drift seems not to have been active between the dates covered by this cruise (June 10 to 26) because not as clearly outlined as in March, 1920 (fig 13), but showing a gradation in temperature from 8° in the Eastern Channel to 5° at the mouth of the Bay of Fundy. Had water been flowing actively inward through the channel at the time, a uniformly high temperature (7° to 8°) naturally would have resulted over a considerable area in the eastern side of the gulf. A transition of the opposite sort along the Northern Channel, from 6° to 7° at its western end to 2° to 3° at its eastern end, is evidence equally clear that no general movement of the water was taking place through this trough, either westward into the gulf or vice versa.

Unfortunately, no data are available on the subsurface temperatures along the seaward slope of Georges Bank for June, but our Shelburne profile for June 23, 1915 (fig. 41), showed the warmest (8°) bottom water separated from the edge of the bank by a much cooler (about 4°) wedge at 100–120 meters, as seems always to be the case to the eastward of the Eastern Channel.

The temperature of the bottom water in the deeps of the gulf is always interesting because of the light it throws on the inward pulses (p. 922). During the last half of June, 1915, this was fractionally warmer than 6° in the eastern and south central parts of the basin at depths greater than 175 to 185 meters (stations 10288 and 10298), underlying a cooler stratum (4° to 5°) at 50 to 150 meters; and although no record was obtained of the bottom temperature in the western arm of the basin on this cruise, the presence of 6°-water there on May 4 (p. 566) at depths greater than 225 to 230 meters, and again on August 31 of the same year (station 10307), makes it almost certain that this was also the case in June.

The relationship which this warm bottom stratum bears to the cooler water above it and to the indraft from outside the edge of the continent, is made more graphic by the accompanying profile, running from the Eastern Channel westward and inward along the basin (fig. 44).[20] Obstructed on the north by the topography of the sea floor, this warm bottom water reaches the western part of the basin off Cape Ann via the southern branch of the trough, a route that entails its rising over the intervening ridge to within 190 to 200 meters of the surface.

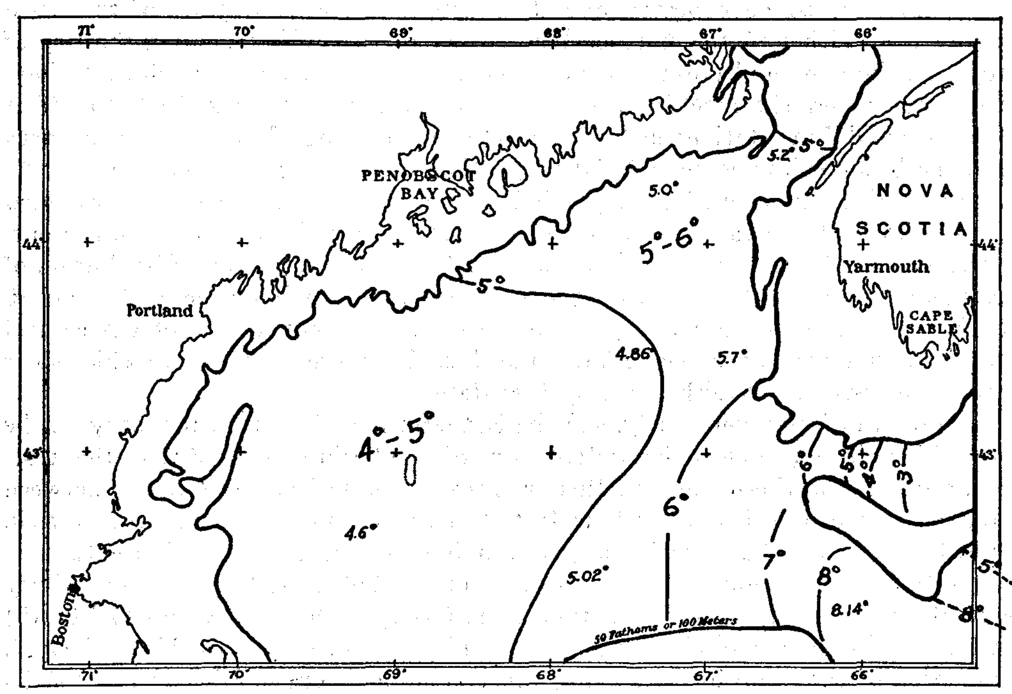

FIG. 43.—Temperature at a depth of 100 meters, last half of June, 1915. (The Bay of Fundy is according to Mavor, 1923.)

It is probable that overflows of this sort are intermittent—frequent enough, however, to maintain the bottom temperature of the western bowl fractionally above 6° for most of the year. The greater thickness of the warm bottom stratum in the southeastern side of the basin (into which the Eastern Channel opens) than elsewhere in the gulf corresponds to the proximity of the source of supply; and it is not unlikely that bottom temperatures of 7° or higher would have been found there at the end of June had readings been taken in depths greater than 275 to 300 meters.

In horizontal plan the bottom water of 6° takes the form of a Y, following the outlines of the trough of the gulf; its approximate outlines for May and June, 1915, are shown in the accompanying chart (fig. 45).

[20] The deepest readings in the western side of the basin are borrowed from the May station (10267).

JULY AND AUGUST

The vessels of the Bureau of Fisheries have taken a large number of observations within the gulf during the months of July and August since 1912. July and August temperatures have been recorded in various parts of the Bay of Fundy region under the auspices of the Biological Board of Canada over a series of years.[21] The tidal survey of Canada (Dawson, 1905 and 1922) likewise has gathered a considerable body of thermal information for the Fundian region and along the Nova Scotian side of the open Gulf of Maine. With such a wealth of material available, the chief difficulty in establishing the normal midsummer state of the gulf has been to appraise the importance of the annual and sporadic fluctuations that confuse the record.

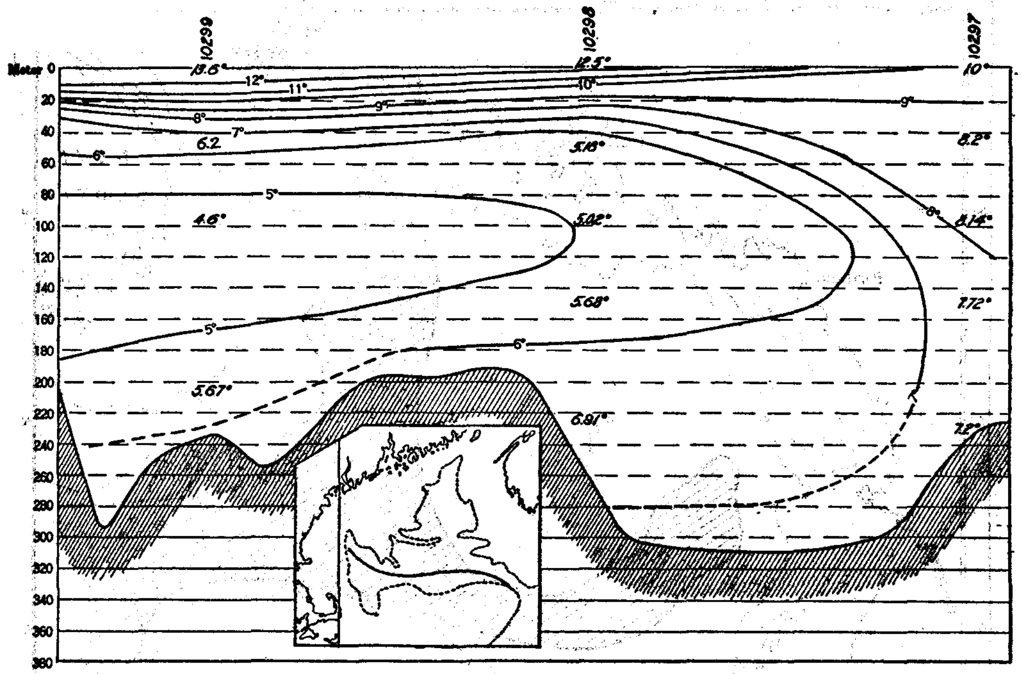

FIG. 44.—Temperature profile running easterly from the basin off Cape Ann along the trough of the gulf to the Eastern Channel for June 25 and 26, 1915

SURFACE

As the result of continued warming by the sun, the surface of all parts of the gulf is considerably warmer in July and August than it is in June, in most years rising nearly to its maximum by the last week of July over most of the gulf. The graphs for Gloucester and Boothbay Harbors (figs. 29 and 30) show that in inclosed situations of this sort the surface water is warmest then, mirroring the air temperature; but in the open waters outside warming continues slowly until well into August, depending on the weather, with the readings highest some time during the

[21] See Copeland (1912); Mavor, Craigie, and Detweiler (1916); Craigie (1916 and 1916a); Craigie and Chase (1918); Vachon (1918); and Mavor (1923).

last half of the month. On the whole, the surface temperature of the gulf may be described as more nearly stationary from July 25 to the end of August than over any equal interval during the spring, on the one hand, or during the autumn, on the other.

The surface chart for late summer (fig. 46) represents the average state during the last week of August. Deviations in one direction or the other from the precise values there given are to be expected, however, according as the year is warm or cold, the season forward or tardy (p. 626).

The surface temperature within the gulf rises highest over the western and southwestern parts of the deep basin, at the mouth of Massachusetts Bay, and in

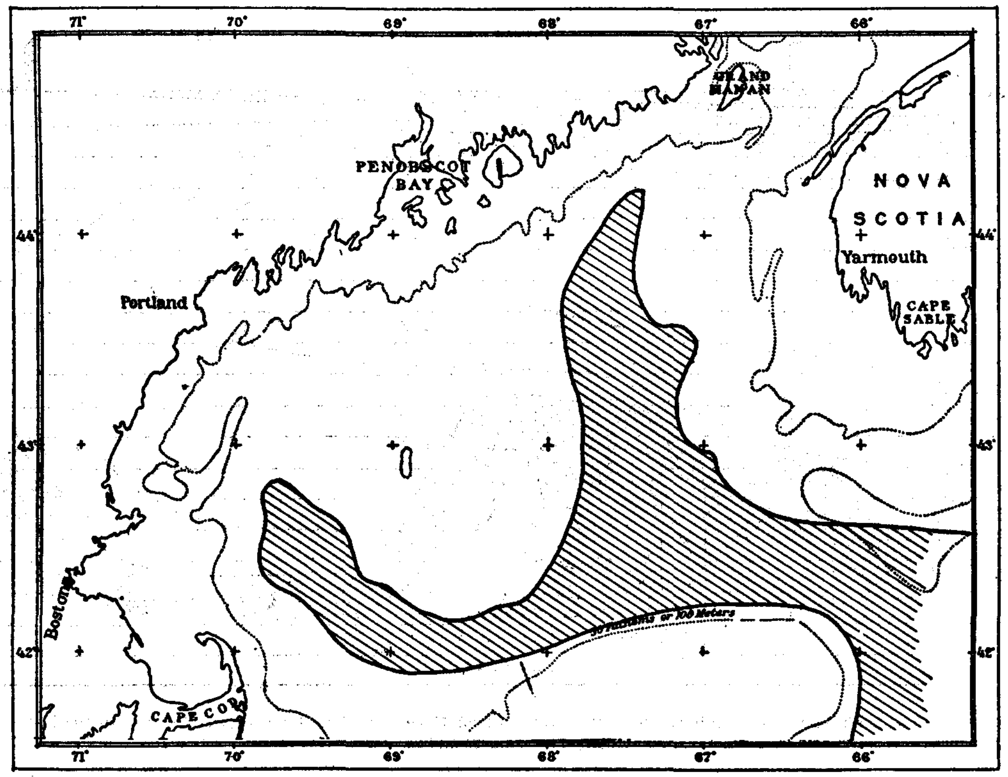

FIG. 45.—Extent of bottom water warmer than 6°, last half of June, 1915

Cape Cod Bay, as outlined by the isotherm for 18°. Within this area readings of 20° have been reported on three occasions, namely, twice by Doctor Kendall in the last week of August, 1897, and more recently on August 22, 1914 (station 10254). On the other hand, the lowest surface reading so far recorded for the last week of August in this warm subdivision, more than a few miles out from land, was 17.6° in the western basin on August 31, 1915 (station 10307). The data from the cruises of 1912, 1913, and 1914, compared with readings taken in August, 1922, and by Doctor Kendall in 1897, show that the temperature first reaches 18° at the mouth of Massachusetts Bay and out over the neighboring part of the basin in its offing, whence the limiting isotherm (18°) spreads south as well as north, to the confines laid down on the chart, as the summer draws to its close.

We have invariably had surface readings higher than 18° in the outer half of Massachusetts Bay after the first week of August, and in Cape Cod Bay; but off

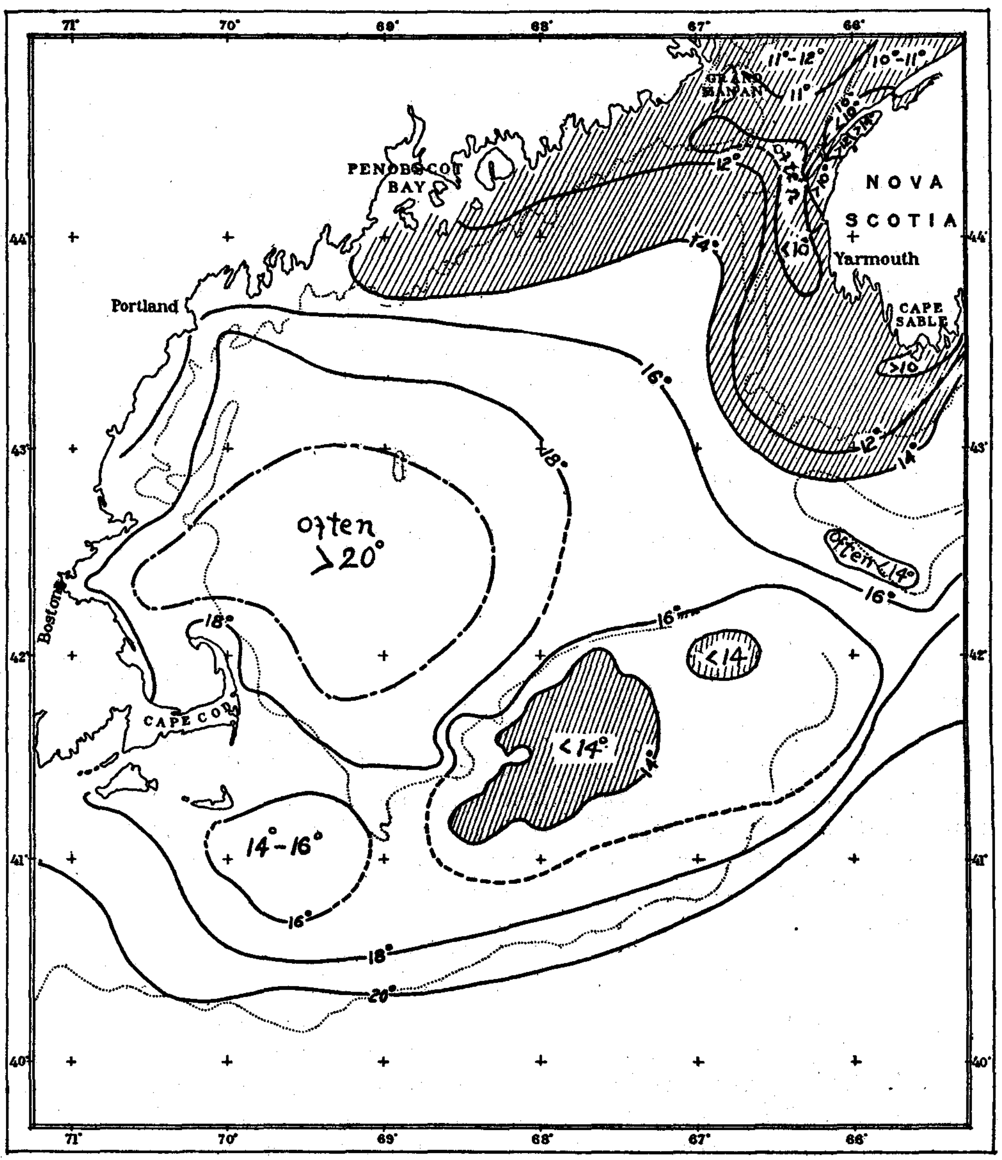

FIG. 46.—Normal surface temperature for mid-August, based on a combination of the recent station records with Rathbun's (1887) tabulation at lighthouses, the Canadian records, Dickson's (1901) data, and the daily surface readings, at Gloucester, Boothbay, and Lubec (figs. 29 to 31). (Close to Cape Sable, read < 10° for > 10°.)

the tip of Cape Cod, where tidal currents run strong, the surface is usually cooler locally, as is the general rule in such locations, with readings of 17° to 18° for the last half of August. For this same reason the coastal belt around the western and northern shores of Massachusetts Bay usually remains cooler than 18° on the surface throughout the summer, though warmer than 15°; but as every bather knows, continued onshore winds sometimes drive the warm offshore water right in to the beach there, though in a surface film so thin that one's legs may be in decidedly lower temperatures while swimming. On the other hand, when westerly winds drive the surface water out to sea, cooler water wells up from below, locally lowering the surface temperature. Upwellings of this sort, combined with local stirrings by the tides, are so common an event along the northern shore of the bay that usually this is fringed by a zone, a few miles wide, where streaks of surface water warmer than 16° alternate irregularly with patches cooler than 14° to 15°, and where we have occasionally had surface readings as low as 12° in July, with 10° reported to us in August. Cold streaks of this sort are most often to be expected about the bold promontory of Nahant and along the rocky shore between Gloucester and Cape Ann.

At Thatchers Island (the tip of Cape Ann) tidal disturbances may cause considerable and irregular fluctuations in the temperature of the surface from day to day, witness readings varying from 15.6° to 17.5° during the warmest periods of the summer of 1881 (Rathbun, 1887); but a temperature of 19.4° at the cape late in July, 1882, shows that the warm surface water from offshore may touch the coast line there during calm periods or after onshore winds, as it does elsewhere.

It appears from what little precise evidence is available, and from general reports by seaside dwellers, that similar fluctuations prevail all along the coast line in August, from Cape Ann northward about to Cape Porpoise; but the surface of the coastal belt averages 1° to 2° colder in this sector than in Massachusetts Bay—usually below 16°.

It is unfortunate that daily records are not available for any station along this stretch of coast line or for the Isles of Shoals, which occupy a commanding position off the mouth of the Merrimac River. Most of our August passages, also, to and fro, have followed courses outside the 100-meter contour. Rathbun's (1887) record of maxima of 15.6° to 16.7° at Boon Island for the summers of 1881 to 1885, with our own stations between Cape Elizabeth and Cape Ann, suggest 15° to 16° as the usual maximum for the coastal sector between the Isles of Shoals and Cape Elizabeth, out to the 100-meter contour, with temperatures 1° to 3° higher a few miles farther out at sea.

The rise in surface temperature experienced as one runs offshore from Cape Elizabeth is illustrated by the following readings taken by W. C. Schroeder on the *Halcyon* on a trip to Platts Bank, July 20, 1915: 8 miles out from Cape Elizabeth, 16.1°; 17½ miles out, 19.44°; 20 miles out, 19.44°; on Platts Bank, 30 miles out, 18.9°. This agrees closely with the gradation indicated for this region on the charts (figs. 46 and 47); also with the state of the surface on August 7, 1912, when the temperature rose, progressively, from 15.6°, at a point 8 miles off the cape, to 17.8° on Platts Bank (Bigelow, 1914, p. 46).

It has long been common knowledge that the coastal waters along eastern Maine and in the Bay of Fundy are cold in summer, with a maximum difference of almost 10° C. (18° F.) between the surface there and in the offing of Cape Ann. This cold area, outlined by the isotherm for 12° on the chart (fig. 46), also includes the whole eastern side of the gulf, off western Nova Scotia, out to the 100-meter contour, in an undulating outline more easily represented graphically than verbally.

The transition from warm to cool is often very noticeable as one runs from the offing of Cape Elizabeth, across the mouth of Casco Bay, to the neighborhood of

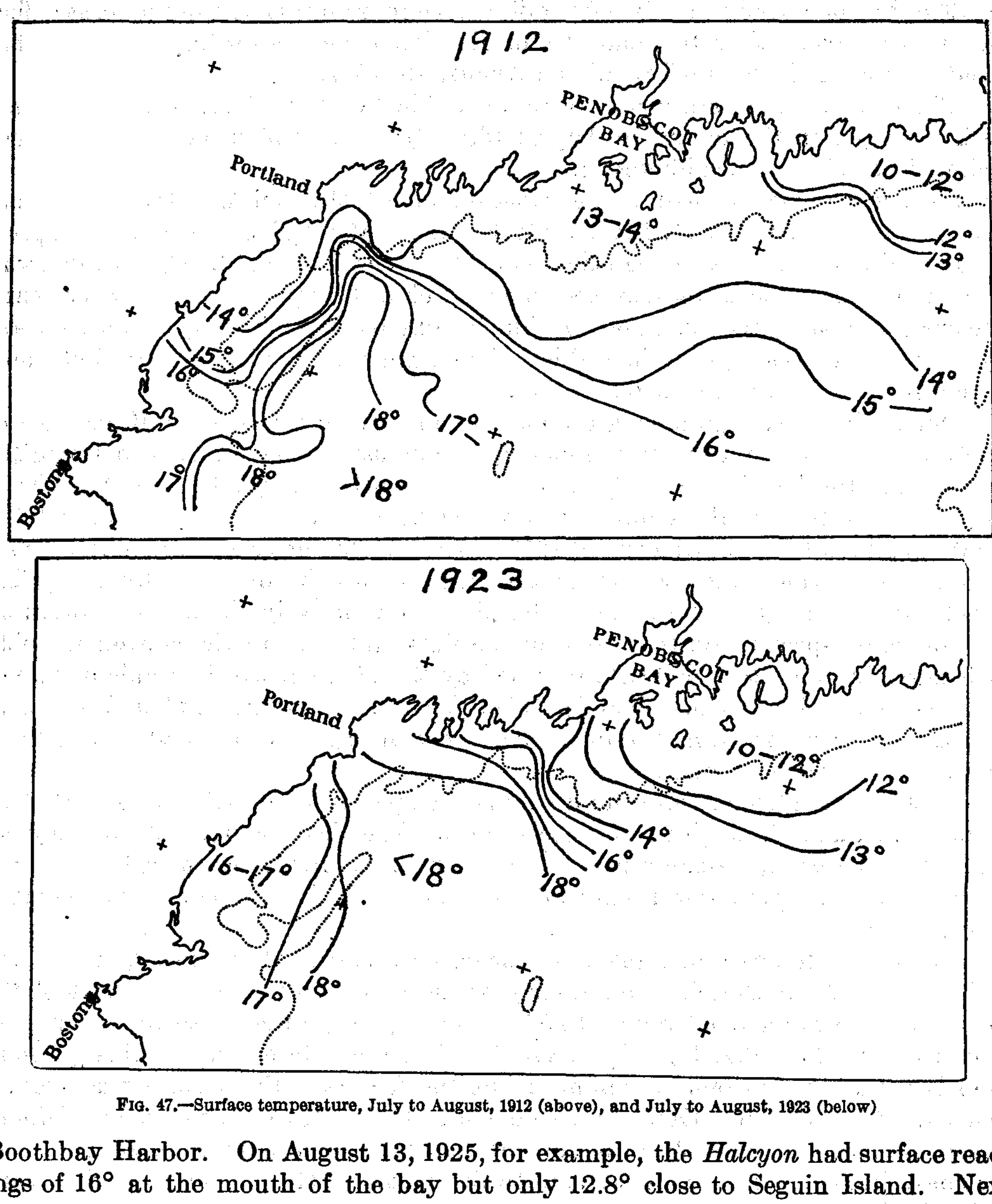

FIG. 47.—Surface temperature, July to August, 1912 (above), and July to August, 1923 (below)

Boothbay Harbor. On August 13, 1925, for example, the *Halcyon* had surface readings of 16° at the mouth of the bay but only 12.8° close to Seguin Island. Next the shore surface temperatures ranging from 13° to 15.3° have been recorded between Casco Bay and Penobscot Bay in August; usually cooler than 14°, but with much local variation as the tide swirls around the islands and ledges. The maximum temperatures at Seguin Island Lighthouse for the years 1881 to 1885 (Rathbun, 1887), were, respectively, 13.3° to 13.9°, 13.3° to 13.9°, 13.9° to 14.4°, 13.9° to 14.4°, and 14.4°. This agrees with readings of 13.9° at two localities within a few miles of the island on August 22, 1912, and with 12.8° to 14° in that general neighborhood on July 18, 1925; but one need run only a few miles offshore from this part of the coast to find the surface warmer than 16°, and Doctor Kendall records a reading of 16.7° within about 8 miles of the land off Seguin on August 16, 1897.

The surface temperature rises to 16° to 18° in Boothbay Harbor during the last week of July and the month of August (fig. 30); equally high, no doubt, in other sheltered bays in this neighborhood.

Surface readings taken on a line across the mouth of Penobscot Bay ranged from 12.8° to 13.9° on August 21, 1912, while Rathbun (1887) gives maximum temperatures of 11.7° to 12.2° at the lighthouse on Matinicus Rock at the western gateway to the bay, where the water may be somewhat chilled by the swirling tidal currents. The surface in sheltered situations within Penobscot Bay may warm to a temperature several degrees higher than this before autumnal cooling sets in, but information is scant for this particular region.

Our surface readings among the outer islands along the coast of Maine, east of Penobscot Bay, and out to the 100-meter contour usually have ranged between 10° and 12° for the last half of July and for the month of August (fig. 47). After a few calm, warm days the temperature of this zone may rise locally to 13° (12.78° off Mount Desert Island, August 13, 1913, station 10099, has been our highest record there). The surface water is considerably warmer up the bays, locally, depending on the topography of the bottom as determining how actively the water is stirred by the tide, and especially on the extent of the flats laid bare to the sun on the ebb. Surface readings of 10.6° to 11.7°, recorded by the *Halcyon* within a mile or two of Great Duck and Little Duck Islands, Bakers Island, and Long Island on August 8 to 11, 1925, cover the usual midsummer range close in to the islands and among them for the Mount Desert region.

Rathbun (1887) gives maximum summer temperatures of 11.6° to 13.3° at Petit Manan light, and although the surface water off Machias was only 8.9° on July 15, 1915 (station 10301), probably it is always as warm as 10°, or warmer, there during the last half of August, and usually 11° to 12°, except where some local upwelling is taking place.

The hourly temperatures taken off the eastern coast of Maine during the last half of August, 1912, are especially interesting because they suggest a movement of the coldest surface water (colder than 13.5°) offshore (i. e., to the southwest), out past Mount Desert Rock (fig. 47). Unfortunately I can not state whether this phenomenon is regularly recurrent in summer; but the fact that the surface was slightly cooler (9.3°) near Mount Desert Rock on September 15, 1915, than close in to Mount Desert Island (9.8° to 10.8°), near Petit Manan Island a few miles eastward along the coast (10.5°), or near Swans Island to the westward (10.8°), suggests that some such distribution of surface temperature is at least not unusual for that general region.

On August 17, 1912, and again on the 19th, we had readings of 10 to 11.7° as the *Grampus* sailed lengthwise through the Grand Manan Channel; and it is probable that this is about the highest temperature attained in the tide-swept Lubec Channel, because the highest 10-day average was about 10° there during the last of August and first of September of 1920 (fig. 31). The highest mean temperature recorded at Eastport for a 10-day period for the years 1878 to 1887 was 10.7° (Moore, 1898) in the second week of September.

The surface temperature of the greater part of the open Bay of Fundy likewise ranges from 10° to 12° in August, rising above 12° only exceptionally and locally (Huntsman, 1918; Vachon, 1918). Thus, Mavor (1923) records a range from 9.44° to 12° at 19 stations on three traverses of the bay inward from Grand Manan on August 22 to 27, 1919, warmest along the New Brunswick shore, coldest (9° to 10°) near Digby Neck on the Nova Scotian side. A similar gradation is described by Dawson (1922) for the first half of August, 1907. The records given by Craigie (1916), Craigie and Chase (1918), and Vachon (1918) for the open bay, with a maximum of 12.68°, a minimum of 8.93°, in July and August, are consistent with this on the whole.

Dawson (1922, p. 92) records surface temperatures somewhat higher (14.17° to 13.33°) than this on a run from Digby to the middle of the bay on the meridian of St. John, New Brunswick (his station A), for July 22, 1907, but this may have been an unusually warm summer in the bay. At any rate, temperatures so high were briefly transitory, for the surface at his outer station had cooled to 13.6° by the next day and to 12.8° three days later (Dawson, 1922, pp. 88–92), when the surface temperature along the land from Digby Gut to Brier Island was only 8° to 9°. With a variation from 10° to 11.7° over the Fundy Deep for the three-day period, August 23 to 25, 1904, independent of the stage of the tide (Dawson, 1922, p. 95), slight changes evidently are to be expected in the bay from day to day, perhaps governed by the roughness of the sea.

Many records of temperature, surface and subsurface, have been published for the Passamaquoddy Bay region by Copeland (1912), by Craigie and Chase (1918), and by Vachon (1918), showing a considerable regional variation in the temperature to which the surface attains by the end of the summer. Copeland found the surface warmest (13.9° to 15.6°) in the northern part of the bay, coldest (10.4° to 11°) near Deer Island and in Letite Passage, with the central and western parts of the bay ranging from 11.1° to 15°. Vachon (1918, station 4), likewise records the surface of the center of the bay as warming from 11.4° on July 20 to 15.9° on July 27 in 1916, cooling to 11° on August 3 and 17, but warming again to 12.48° on the 25th and to 14.91° on the last day of the month. In the mouth of the St. Croix River, however, the water is kept so thoroughly stirred by the strong tides that Vachon's highest reading was 13.4°, the lowest 10.95°, for the period July 17 to August 31, coolest after northwest winds. Low surface temperatures also rule in Friar Roads between Campobello Island and Eastport, where Vachon reports 8.7° to 10.3° between August 2 and September 17, with 9.5° to 12.62° in the western passage between Deer Island and the coast of Maine, and with about this same range of temperature at a station near St. Andrews.

Vachon's and Copeland's records, combined, show that the temperature of the surface of the northwestern part of Passamaquoddy Bay may be expected to reach 15° for a brief period in August in warm summers, though perhaps not every year. At the other extreme, the surface water in the channels between the islands of western New Brunswick, where tidal stirring is more thorough, is seldom warmer than 11° to 11.5°. Considerable fluctuations are also recorded within brief periods in the central part of the bay, where the surface temperature is intermediate between these two extremes, and in the mouth of the St. Croix River, connected with the direction of the wind and with the stage of the tide.

It is interesting to find that no part of the surface of the Bay of Fundy,[22] with its much stronger tides, is as warm as the greater part of Massachusetts Bay, though the maximum readings for these two areas differ by only about 3° (15° for Passamaquoddy and about 18° to 19° for Massachusetts Bay).

Craigie and Chase (1918) found the surface about as cold (9° to 11°) in the outer part of the Annapolis basin on July 23 to 24, 1915, as it is along the Nova Scotian side of the Bay of Fundy outside, but progressively warmer, passing inward, to 15.33° near the head. According to Huntsman (1924), Minas Basin, at the head of the Bay of Fundy, also warms faster than the latter in summer, but the definite values have not yet been published for it.

Dawson's (1922) very considerable list of surface temperatures for 1904 and 1907, with our yearly stations off Lurcher Shoal, on German Bank, and near Cape Sable, unite to show that a cool surface is characteristic of the whole coastal zone along western Nova Scotia out about to the 100-meter contour, usually with the readings falling between 9° and 12°, as outlined by the isotherm for 12° on the chart (fig. 46). More specifically, our own surface records for the Lurcher Shoal and German Bank stations have been as follows:

Locality and date	Station	Surface temperature
Near 100-meter contour, off Lurcher Shoal:		°C.
Aug. 15, 1912	10031	13.33
Aug. 12, 1913	10096	12.22
Aug. 12, 1914	10245	14.44
Sept. 7, 1915	10315	12.20
German Bank, outer part:		
Aug. 14, 1912	10029	10.44
Do	10030	11.11
Aug. 12, 1913	10095	8.89
Aug. 12, 1914	10244	10.00
Sept. 2, 1915	10311	9.40

The constant difference between these two localities shows that surface temperatures lower than 12° do not reach offshore beyond the 100-meter contour in the offing of Lurcher Shoal, but on August 12, 1913 (station 10094), we found the surface as cold (8.89°) 12 miles out from the edge of German Bank as it was over the latter (station 10095).

As Dawson (1922, p. 99) has remarked, "as a rule, the temperature nearer shore becomes higher when the weather remains quiet," his data showing that the

[22] For further details regarding the Bay of Fundy the reader is referred to the extensive tables given by Copeland (1912), Craigie and Chase (1918), and Vachon (1918).

water close in to the western coast of Nova Scotia warms to 10° to 12° by August from St. Marys Bay to Yarmouth. Yarmouth Harbor he found only slightly warmer (12° to 12.5°) than the open waters at its mouth, and it had about this same temperature on September 8, 1916,[23] but the surface of St. Marys Bay rises to a considerably higher temperature. The maximum for this bay can not be stated, data for the inner part of the bay for August being lacking. Craigie and Chase (1918), however, found its surface progressively warmer, passing inward, from 9° to 10° at the mouth to about 11° abreast of Petite Passage, 13° to 13.5° off Weymouth, and to 14.8° at the head during the second week of July in 1915; and as Vachon (1918) again had readings of 11.08° abreast of Petite Passage and 12.92° off Weymouth on September 4 to 5, 1916, it is not likely that August sees the surface temperature rise much above 15° anywhere in St. Marys Bay.

A coastal belt skirting Cape Sable, 12 to 15 miles wide, like the vicinity of Lurcher Shoal, is characterized by surface temperatures lower than 10° throughout July. This, no doubt, results from thorough stirring by the tides, which proverbially run strong around the cape, causing a mixture in varying amount with the icy water that persists until midsummer in the deeper strata next the coast, a few miles to the eastward (p. 681).

Near the cape Dawson (1922, p. 85, station Q) had surface readings of 5.3° to 7.5° (usually from 0.5° to 1° higher at high water than at low water) during the first half of July, 1907. By the last week of that month he found that the mean surface temperature 12 miles out from the cape had risen to about 9° at high tide and to about 8.4° at low, with a slightly greater difference between high and low tide temperatures (average about 9° and 7.2°) closer in to the land, and with a maximum of 11.95° at the high-water slack and a minimum of only 5° at low-water slack on the 20th. Our own more recent record of 10.28° near by on July 25, 1914 (station 10230), falls well within these extremes.

These temperatures suggest that the flood current, flowing westward past the cape, draws warmer surface water toward the land from offshore, but that the ebb, flowing to the eastward, carries out water that has been thoroughly mixed by the currents swirling around the cape.

Surface readings of 10° to 12° on several lines along the coast sector between Yarmouth, Nova Scotia, and the cape, for the middle of July (Dawson, 1922), show that this narrow cold pool off Cape Sable becomes entirely isolated from the low temperatures about Lurcher Shoal before the last of that month by the development of a warmer surface over the intervening area, but is continuous with still lower temperatures to the eastward along the outer coast of Nova Scotia until August, witness a surface reading of 6.62° at low water a few miles off Shelburne on July 27 in 1914 (station 10231), no doubt reflecting some updraft of the icy water from below with the outflowing tide. In 1915, however, the Canadian Fisheries Expedition found no surface water colder than 9.7° off this part of the coast on July 21 (Bjerkan, 1919). On September 6 of that year (station 10313) the surface was 15° 10 miles off Cape Roseway, 13.3° 10 miles south of Cape Sable on September 2 (station 10312), and 13.6° near by on August 11, 1914 (station 10243). Apparently, then, if the cold surface persists as late as August off the Cape, it becomes reduced to an isolated pool

[23] Varying from 11.3° to 12.7° during that day (Vachon, 1918).

not more than half a dozen miles wide by the end of the summer, persisting only as a reflection of purely local activity of tidal stirring.

Our Gulf of Maine cruises have not crossed the southeastern part of the area in August; hence the isotherms for this region (fig. 46) are only tentative for that month, combined from the July cruise of the *Grampus* in 1914, the Canadian Fisheries Expedition stations off southern Nova Scotia for July, 1915, temperatures taken by the *Albatross* in August, 1883, and July, 1885 (Townsend, 1901), and from scattering records from other sources. These combine to show a rather abrupt transition in surface temperature in the region of the Northern Channel between the cool area along western Nova Scotia (12°) and somewhat higher readings (14° to 16°) on Browns Bank, but make it unlikely that the surface normally warms above 16° over the latter at any season. It is probable, too, that much local variation in temperature exists on Browns Bank, with cool and warm streaks caused by tidal mixings, especially along its southwestern edge fronting the Eastern Channel, where the *Albatross* had surface readings of 12.78 to 13.3° at four stations on August 31, 1883.

The surface temperature in the center of the Eastern Channel was 15.1° on July 24, 1914 (station 10227), but readings of 12.8°, 16.1°, 14.2°, and 13.3° at four successive stations on a line crossing the deep water from Georges Bank to Browns Bank on August 31, 1883, suggest that while the central core of the channel is usually fractionally warmer than 16° by the end of the summer, vertical stirrings or upwellings are sufficiently active along the edges of the two banks to maintain narrow lanes there colder than 16° on the surface.

It is probable that the surface is from 1 to 3 degrees cooler over the eastern, northern, and central parts of Georges Bank, as a whole, than in the basin of the gulf to the north throughout the summer, and certainly it is considerably cooler than the oceanic waters outside the edge of the continent to the south, just as it is in June (fig. 39). Thus, Dr. W. C. Kendall had surface readings of 12.8° to 15.3° (averaging about 14.5°) at 55 stations along the northwestern edge of the bank on August 21 to 25, 1897, and the isotherm for 16° for this region is located on the chart (fig. 46) from these observations.

This part of the bank offers an excellent illustration of the chilling of the surface that follows when cooler water from below is brought up over and around shoals by the tides, with the surface averaging 1° to 3° cooler over the shoal ground than elsewhere on the bank and (generally) coldest (13° to 14°) over the shoalest part, where the water is less than 50 meters deep. Even small isolated shoal spots may cause cool pools at the surface in this region, and the effect of projecting submarine promontories or ridges may be made evident for some miles by lowered surface temperature. Where the water is not only shoal, but the topography of the bottom is broken and tidal currents run strong, considerable variations in surface temperature also are to be expected from ebb to flood, as Dawson found to be the case near Cape Sable (p. 593). Doctor Kendall records several such alterations on Georges Bank, notably a drop of about 1.5° at a station on its northern edge during a period of a few hours on August 21. A few yards' sailing may also be enough to bring the vessel from a cool streak into a warm one, or vice versa, the explanation for which is apparent enough on calm days when the lines of contact between different runs of tide are often made visible by miniature rips, oily slicks, or by the accumulation of floating débris of one sort or another. In all this, Georges Bank, in the south of the gulf, agrees with the coastal belt generally in the northeast, as it does in being colder at the surface than is the intervening basin where "the water moves to and fro in an unbroken sheet, clear of obstruction," as Dawson (1905, p. 15) expresses it.

Doctor Kendall's temperatures, added to readings taken by the *Grampus* in July, 1908 (Bigelow, 1909), and from the *Halcyon* in the summer of 1923, show that the surface is correspondingly cool (12° to 16°) in August over the shallow broken bottom south of Nantucket, with similar fluctuations within short distances and at different stages of the tide, due to the same disturbing influence of tidal mixings. Thus, the *Halcyon* had surface readings varying from 11.6° to 15° in August, 1923, as she fished at various locations within a mile or two of Round Shoal bouy; 13.3° to 16.4° over Rose and Crown Shoal; 15.5° over the slightly deeper channel between Round Shoal and Rose and Crown Shoal; and 13.8° to 15.5° on the Great Rip fishing ground 12 miles southeast of the island of Nantucket. Unfortunately, it is not yet known whether this cold area is separated from the equally low surface temperatures of Georges Bank by a band of warm surface water along the so-called "south channel," as seems probable, or whether the cool surface forms an unbroken band, west to east, from the one shoal ground to the other.

In 1913 the surface to the seaward of the 50-meter contour off Nantucket had warmed to upward of 19° by the last week in August (Bigelow, 1915, p. 350, fig. 2, stations 10107 to 10112). This was true also of the whole breadth of the shelf abreast of Marthas Vineyard on the 26th of the month in 1914, except close in to the land (station 10263), where a surface reading of only 17.9° probably reflected some tidal disturbance or other. With this same exception, Doctor Kendall likewise had 18° to 19° at every station off Marthas Vineyard early in September, 1897, paralleling Libbey's (1891) record of surface warmer than 19° over this part of the continental shelf during August, 1889.

These data locate the isotherm for 18° as following the southern and western edges of Nantucket Shoals around into the submarine bight west of the latter, but with cool pools next the southern shores of Marthas Vineyard, as just noted.

It is probable that the surface temperature rises higher than 20° over the outer part of the continental shelf off southern New England every August, and Libbey's (1891) extensive data show that in some years temperatures slightly higher than 20° are to be expected within a few miles of Marthas Vineyard. But his records also show that a considerable variation in surface temperature is to be expected within short periods of time over the inner half of the shelf, where a sudden cooling of the surface would be the natural accompaniment of any unusual stirring of the water or of the upwellings that so often follow offshore winds.

There is also considerable variation in the surface temperature off Marthas Vineyard from year to year. In 1914, for example, the isotherm for 20° included only the outer half of the continental shelf on August 21 at longitude 71° (fig. 46).

In spite of these fluctuations, it is safe to say that the surface is invariably warmer than 20° along the edge of the continent in the offing of Marthas Vineyard and Nantucket Island by the end of August. To find the surface warming to upward of 22° to 23° it is only necessary to sail seaward a few miles farther.

Passing eastward from the longitude of Nantucket, we find a more sudden transition from the comparatively cool water (18°) over the southwestern part of Georges Bank to the high temperature of the oceanic water outside the 200 meter contour, accompanied, however, by such irregularities as might be expected along the zone of contact of waters differing in salinity as well as in temperature. At times the north–south gradation in surface temperature along this sector of the edge of the continent is also interrupted by a cooler band. On July 20 to 21, 1914 (stations 10216 to 10218),[24] this was indicated by surface readings of 18.6°, 17.3°, and 20.48° at three successive stations from north to south on a line crossing the southern slope of the bank.

Such data as are available point to an abrupt increase in the breadth of the cool wedge eastward from Georges Bank between the edge of the continent and the warm oceanic temperatures of >20°, to the seaward of the latter. Thus the surface was only about 17° at our outermost station off Shelburne on July 28, 1914 (station 10233), while the Canadian Fisheries Expedition crossed a band of 17° to 19.7° water some 70 miles wide outside the 200-meter contour in the offing of Cape Sable on July 22, 1915 (Bjerkan, 1919; *Acadia* stations 41 to 44). Unfortunately no temperatures have been taken off the slopes of Georges or Browns Banks during the last half of August of late years, but even if the isotherm for 18° should encroach a few miles farther inward by the end of the month than is represented on the chart (fig. 46), there is no reason to suppose that the surface temperature rises higher than 20° inside the 100-meter contour on the banks anywhere east of Nantucket Shoals at any season, except possibly for brief periods following persistent southerly winds.

TEMPERATURE GRADIENT IN THE UPPER 100 METERS

A differentiation in the vertical distribution of temperature between the western and eastern sides of the gulf begins to develop in June, widening with the advance of summer, until the extremes, as represented by the western basin on the one hand and by the Bay of Fundy and coastal banks off western Nova Scotia on the other, yield graphs differing widely in the upper 100 meters by August.

The most striking feature of the western type, as exemplified by the basin off Cape Ann (fig. 48) and by the bowl at the mouth of Massachusetts Bay off Gloucester (fig. 4), is that the water cools very rapidly from the surface down to a depth of 40 to 50 meters, succeeded by only a slight fall in temperature down to the 100-meter level. Whether increasing depth is accompanied by a further slight cooling or by a slight warming depends on the locality, the topography of the bottom, and to some extent on yearly fluctuations, as discussed later (p. 602). In August we have found the 40-meter level averaging from 10° to 14.5° cooler than the surface in the western side of the basin and 9° to 13° cooler at the mouth of Massachusetts Bay (figs. 4 and 5), illustrating the remarkably sudden change that any animal would experience there, from warm water to cold, by sinking down for a few meters only. Observations taken farther up the bay on August 22 to 24, 1922 (stations 10630 to 10645), showed a similar vertical chilling down to 50 meters or so, except that the

[24] This cool band is more clearly marked, by temperature, at deeper levels, as described on page 608.

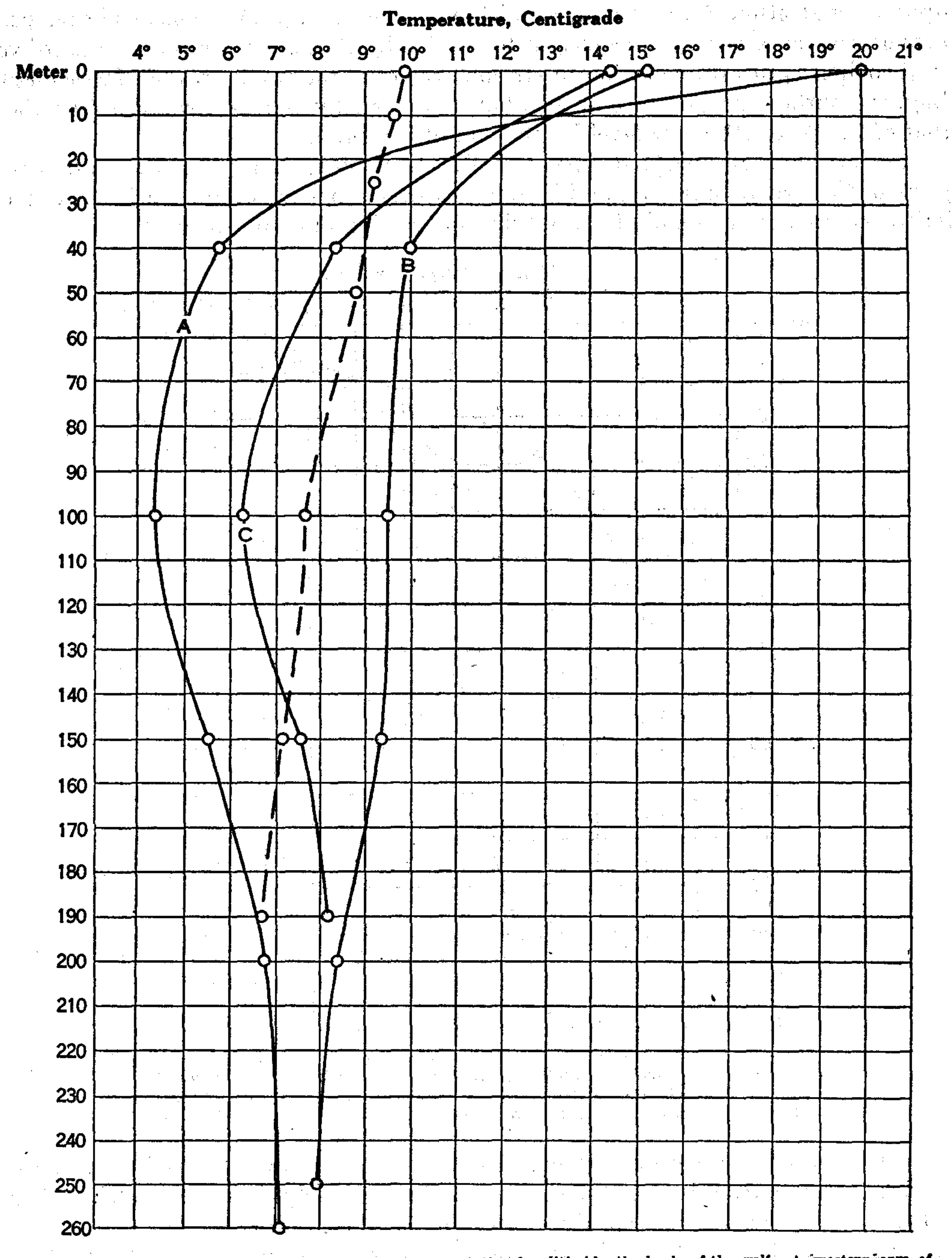

FIG. 48.—Vertical distribution of temperature at representative localities in the basin of the gulf. A, western arm of basin, off Cape Ann, August 22, 1914 (station 10254); B, southeastern part of the gulf, July 23, 1914 (station 10225); C, northeastern arm of the basin, August 12, 1914 (station 10246). The broken curve (D) is for Mavor's (1923) station 24, off the western end of Grand Manan Island, August 27, 1919

uppermost stratum, 5 to 10 meters thick, was then nearly homogeneous in temperature at several of the stations closest to the land. Although the precise rate of vertical cooling varies from station to station even over the small area of Massachusetts Bay, the surface temperature of its whole area usually warms upward of 10° above that of the 20 to 50 meter level by the end of the summer.

Serials have also yielded curves of this same general type in the west-central parts of the basin, generally, and in the northwestern part of the gulf between the latitudes of Cape Ann and of Cape Elizabeth during July and August.

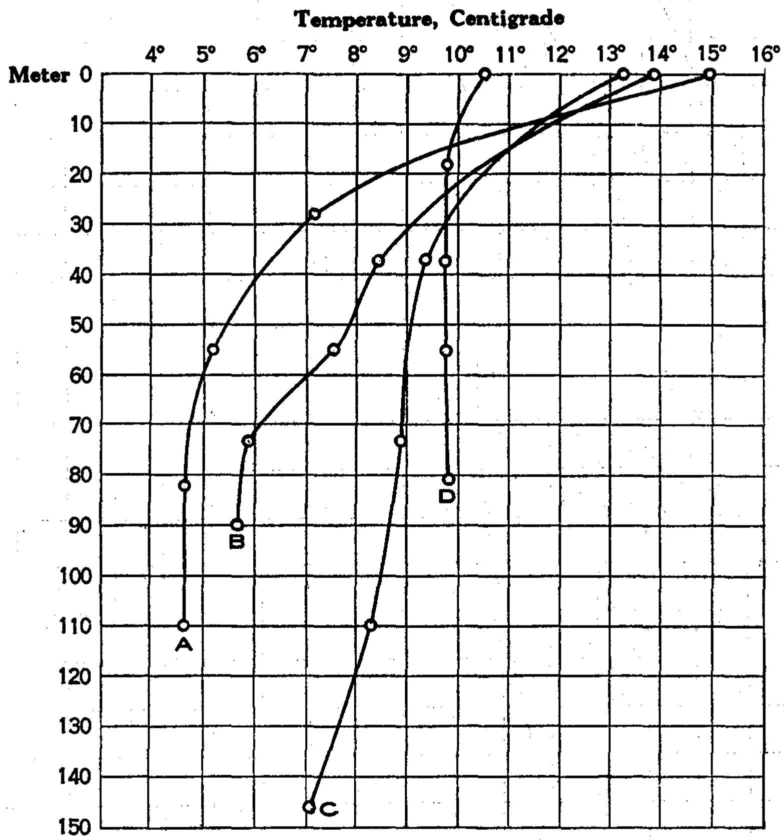

FIG. 49.—Vertical distribution of temperature at successive stations, from Cape Ann to Grand Manan, in July and August, 1912. A, near the Isles of Shoals, July 17 (station 10011); B, off Cape Elizabeth, July 29 (station 10019); C, off Penobscot Bay, August 22 (station 10039); D, off the western entrance to the Grand Manan Channel, August 19 (station 10035)

Our first summer's cruise (Bigelow, 1914, p. 51), however, proved that the difference of temperature between the surface and the underlying water (which is nearly uniform, depth for depth, from Cape Ann to Platts Bank) decreases along the coast to the eastward (fig. 49). Observations taken in the summers of 1914, 1915, and subsequently have not afforded a single exception to the rule (stated in Bigelow, 1917, p. 168) that the surface temperature is progressively lower and lower in summer, the bottom temperature (depth for depth) progressively higher and higher, around the margin of the gulf from Cape Cod to the Bay of Fundy, with the average vertical range of temperature decreasing from about 12° off Cape Ann to virtually nil in the Grand Manan Channel.

Thus, the difference of temperature between the surface and the 50-meter level (never less than about 10° at the mouth of Massachusetts Bay in summer) was only about 5° to 8° off Casco Bay (stations 10019 and 10103), 4° to 5° near Monhegan Island on August 4, 1915 (station 10303), and about 4° at the west entrance to Penobscot Bay on August 22, 1912 (station 10039). Near Mount Desert Island the vertical range for the corresponding column of water was only 2° on August 18, 1915 (station 10305), about 4° on August 13, 1912 (station 10099),[25] about 4.5° on the 5th of the month in the very cold year 1923, or an average of 3° to 4°. The water is kept even more nearly homogeneous in temperature among the islands of the Mount Desert region by strong tides, so that the surface was only 1.5° to 0.1° warmer than the bottom a couple of miles off Little Duck Island on August 8 to 11, 1925, in depths of 25 to 30 meters.

This also applies off the open coast farther east. Off Machias, for example, the surface reading was only about 1° higher than the bottom reading on August 16, 1912 (station 10033), 1.2° higher on August 13, 1913 (station 10098), 1.5° higher on August 12, 1914 (station 10247), 1.7° higher on July 15, 1915 (station 10301), and 0.33° higher on September 11 (station 10316) in 60 to 70 meters (fig. 50).

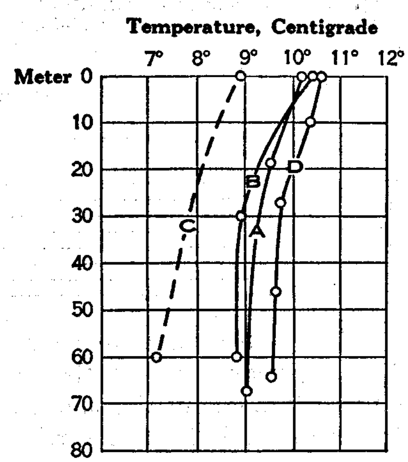

FIG. 50.—Typical summer temperatures off Machias, Me. A, August 13, 1913 (station 10098); B, August 12, 1914 (station 10247); C, July 15, 1915 (station 10301); D, August 16, 1912 (station 10033)

We found the surface at the two ends of the Grand Manan Channel, through which the tidal currents run with great velocity, only fractionally warmer (10° to 10.6°) than the bottom (9.6° to 9.7°) in 80 to 100 meters on August 17 and 19, 1912 (stations 10034 and 10035). Vertical stirring is thus complete at this locality.

The temperature gradient that develops within the Bay of Fundy by the end of the summer differs regionally, depending on local variations in the tidal circulation. At the mouth, between Grand Manan and Brier Island, where tidal disturbances are proverbially strong, Mavor (1923, p. 6, Sec. IV) records a maximum difference of only 0.7° to 1.3° between the surface and 50 meters for August 27, 1919; but his Section I shows a slightly greater average range (2.2°) for the corresponding stratum at three stations halfway up the bay. This thermal difference, which develops between the Bay of Fundy and the western side of the gulf during the summer, is summarized in the following tabulation:

[25] Forty meters was the deepest reading taken at this station.

Locality	Approximate temperature		
	Surface	50 meters	100 meters
	°C.	°C.	°C.
Bay of Fundy	10–12	7.5–9	7–8
Off Massachusetts Bay	16–20	5.5–8	4.5–6

The fact that the deep water is warmer in the Bay of Fundy, and for that matter in the northeastern part of the gulf generally, than in the southwestern, while the surface is so much colder, deserves special emphasis because of its bearing on the circulation of the two regions (p. 924).

In St. Marys Bay the relative difference between surface and bottom temperature increases from the mouth, inward, in July, as follows, if the total depth of water be taken into consideration.

Surface and bottom temperatures at successive localities from the mouth of St. Marys Bay toward its head, July, 1915. (From Craigie and Chase, 1918.)

Station	Depth, meters	Surface temperature	Bottom temperature
		°C.	°C.
21	43	9.28	8.06
15	34	10.12	8.44
11	32	11.96	9.29
8	33	12.98	9.03
6	21	13.52	10.36
4	28	13.95	11.37
2	13	13.78	11.82
1	7	14.8	13.40

The water is likewise kept comparatively homogeneous in temperature out to the 100-meter contour over the coastal banks off western Nova Scotia by active tidal stirring throughout the summer. Dawson (1905, p. 15) has already called attention to the thermal effect of vertical circulation in this region, where the topography of the bottom causes "a long trail or wake of colder water to extend from islands or shoals along the line of the current; as, for example, north and south from Lurcher Shoal." He also points out that "when the islands and shoals are numerous, the general effect of these strong currents is to chill the water in the vicinity of the coast by mixing the surface water with the colder water from below." As the result of local disturbances of this sort, the vertical range of temperature is much narrower along the 100-meter contour off Lurcher Shoal in August than at corresponding locations over the western slope of the gulf. The temperature on German Bank has proved almost perfectly homogeneous from surface to bottom in August and September, as follows:

German Bank approximate temperatures

Depth, meters	Aug. 14, 1912, station 10029	Aug. 12, 1913, station 10095	Aug. 12, 1914, station 10244	Sept. 2, 1915, station 10311
	°C.	°C.	°C.	°C.
0	10.33	8.89	10.00	9.44
20	9.83	8.67	9.85	10.30
40	9.67	8.61	9.64	10.20
60	9.61	8.56	9.65	10.10