The salinities of the open waters of the Gulf of Maine lie so far inside the limits within which *C. typicus* has been found abundantly in other seas that this is probably not an important factor in its local distribution horizontally or vertically. Certainly no part of the gulf can ever be too salt for an animal occurring regularly in salinities of upwards of 35 per mille in European seas. Toward the other extreme, *C. typicus* is common in salinities of 31 to 32 per mille at Woods Hole, and one of our largest catches was in water of about 31.5 per mille (on the surface off New York, July 12, 1913, station 10066); but the fact that this species is apparently absent from the Baltic makes it probable that it is more susceptible to low salinity than its relative, *C. hamatus*, which is generally distributed there, and thus suggests that the very lowest salinities of the surface along shore in the gulf (below 30 per mille) at the time of the spring freshets may be unfavorable for it.

Dactylopusia thisboides (Claus)

The known distribution of this harpacticoid [24] includes Franz Josef Land, Bear Island (south of Spitzbergen), the north and west coasts of Norway, the British and French coasts, Mediterranean, Red Sea, and Woods Hole, Mass., where Sharpe (1911) collected it among algæ on sandy bottom in about 2 fathoms of water in July, the latter being the only previous American record. It is also reported from Kerguelen in the southern Indian Ocean, from the collections of the German South Polar Expedition (Brady, 1910), but until these southern specimens are described it remains doubtful whether they are actually identical with the northern form. Brady (1878–1880) dredged this species in all kinds of situations, from brackish water, on the one hand, out to depths of 40 fathoms, on the other, among weeds on bottom; but it has been found only close to land and is not usually planktonic.

At St. Andrews, where the stirring of the water by violent tides is probably responsible for bringing it up to the top, Doctor McMurrich lists a few specimens on one occasion only—a tow at 7 fathoms on April 5. This record is interesting as extending its known range to the littoral zone of the Gulf of Maine, but it is hardly to be expected in the plankton of the open sea there.

Dwightia [25] gracilis (Dana)

This species is widespread in the warmer parts of all three great oceans. In the Atlantic it has been taken at various localities from latitude 36° 44′ S. to latitude 52°27′ N. (west of Ireland) in the east, and northward to the Gulf of Maine in the west, most frequently in the tropical zone between latitudes 10° S. and 30° N. It also occurs far and wide in the Mediterranean (Thompson and Scott, 1903). In the Red Sea, Arabian Sea, Indian Ocean down to the latitude of the Cape of Good Hope, and among the Malay Archipelago it has been reported from so large a proportion of tow nettings that it can be described as universal (Thompson and Scott, 1903; Cleve, 1901, 1903; and A. Scott, 1902, 1909); and the German South Polar Expedition had it at Kerguelen and even farther south (Brady, 1910; Wolfenden, 1911).

[24] This has been summarized, with quotation of authorities, by Sars (1903–1911) and Sharpe (1911).

[25] C. B. Wilson (1924), finding that the generic name Setella, by which this species has long been known, was preoccupied by Schrank in 1902 for a genus of Lepidoptera, has proposed Dwightia in its place.

In the Pacific it has been described from north of Papua, the Philippines, Straits of Sunda, the China Sea, north of the Hawaiian Islands, and other localities between latitudes 32° S. and 30° 22′ N. (see Giesbrecht, 1892, and Brady, 1883, for lists of Pacific records), but it does not appear in Esterly's (1905 and 1911) lists of the copepods of the San Diego region.

The geographic distribution of this species is thus tropical and warm temperate. The only previous records of *Dwightia gracilis* off the North American coast are from the "Gulf Stream," 70 miles south of Marthas Vineyard, where many were taken on July 25, 1899 (Wheeler, 1901, p. 188), and Woods Hole (Fish, 1925). Dr. C. B. Wilson's lists add seven records for the Gulf of Maine (table, p. 297) and one near Shelburne, Nova Scotia (station 10291). In the gulf, *D. gracilis* is to be regarded as an immigrant of southern-oceanic affinity, and, correspondingly, most of the locality records for it, like those for the two species of Rhincalanus and for Scolecithricella, are in the peripheral belt near the eastern, northern, and western shores. Being for the months of March, April, June, October, and December, they show that it is to be expected in the gulf at any time of the year; but since all five of the records from within the gulf have been based on odd specimens (three at station 20063 were the most specimens noted in any one haul inside of Georges Bank), either the immigrations into the gulf are in very small numbers and at rare intervals or such as do enter survive only for a brief period in the low temperatures to which they are subjected there. A somewhat larger catch (about 140 per square meter) was made on the southeastern part of Georges Bank on March 12, 1920 (station 20063). It may be taken as certain that this copepod appears in the gulf only as an immigrant, never breeding there.

In tropical seas this species has been taken repeatedly on or close to the surface, and the Gulf Stream specimens described by Wheeler (1901) were also, presumably, from the surface; but it has not been found in any surface haul in the Gulf of Maine, all the records there being from open-net hauls, vertical and horizontal, from depths ranging from 30–0 to 190–0 meters. Apparently it is more apt to enter the gulf at least some few meters down and to remain there as long as it survives in its journeyings in the gulf. But for it, as for Scolecithricella (p. 285) and for the two species of Rhincalanus (p. 283), the preponderance of captures near the coast of the gulf points to the upper 50 to 100 meters, where the counterclockwise Gulf of Maine eddy is most active, as the stratum in which it chiefly drifts. The chart for Rhincalanus, Scolecithricella, and Dwightia (fig. 72) is a graphic illustration of the tendency of natural flotsam of any kind, entering the eastern side of the gulf from the oceanic basin offshore, above, say, 100 meters, and keeping at or above that level, to circle its periphery, leaving its central basin bare.

Ectinosoma neglectum G. O. Sars

This harpacticoid is described by Sars (1903–1911) as abundant along the southern and western coasts of Norway, usually in 10 to 20 fathoms on muddy bottom. He also records it from polar islands north of Grinnell Land, and Willey (1920) mentions it from the Arctic coast of Canada. Apparently it is strictly a boreal–Arctic species. I find no previous record of it on the east coast of North America, but

Doctor McMurrich (in his plankton lists, see p. 12) lists a few at St. Andrews on January 23 and again on January 26, 1916. Probably it becomes pelagic only by accident in tide-swept situations.

Eucalanus attenuatus Dana

This species is widely distributed in the warmer parts of the Atlantic, Pacific, and Indian Oceans, and in the Mediterranean. In the northeastern Atlantic it has been taken as far north as the Faroe Channel. Wheeler (1901) records one specimen from the Gulf Stream off Woods Hole; our outermost station (10218) off the continental edge south of Georges Bank yielded a few in hauls from 60–0 and 300–0 meters on July 21, 1914; and Willey (1919) records it in equally small numbers from about the same position, relative to the continental slope, off Cape Sable on July 22, 1915.

In the Gulf of Maine it occurs very rarely, only as a stray from the oceanic waters of the Atlantic Basin. Its name does not appear at all in the summer lists for the years 1912 to 1914, or during the months of February and March, 1920, or May, 1915; but there is record of it in small numbers (1 to 2 per cent of the copepods) in Massachusetts Bay on April 6 (station 20089) and on May 4 (station 20121), and on German Bank on April 15 (station 20103), all in 1920. In 1915 odd specimens appeared in the vertical hauls in the Fundy Deep on June 10 (station 10282), in and off Massachusetts on September 29 and October 1 (stations 10321 and 10323), and finally off Penobscot Bay on January 1, 1921 (station 10496). When these locality records are plotted in connection with those of its genus mate, *E. elongatus* (fig. 71), they point to immigration into the eastern side of the gulf and around its northern shore to the Massachusetts Bay region, which is the route followed by most of the planktonic immigrants. It is evident from the dates just given that *E. attenuatus* may stray into the gulf at any time of the year, but it is not likely that it is ever able to establish more than a temporary footing there.

Eucalanus elongatus Dana

This species, described by Farran (1911, p. 93) as "characteristic of the warm seas of the open ocean," has been recorded from sundry widely separated localities in the tropical parts of the Pacific and Indian Oceans, in the Mediterranean, and in the south and north Atlantic. According to Farran (1911) it occurs the year round in the Atlantic as far north as the coasts of Ireland, while Wolfenden (1904) describes it as abundant in the Faroe Channel and not uncommon in the fjords of Shetland, and the plankton lists of the International Committee for the Exploration of the Sea show that it is frequently carried round the north of Scotland into the North Sea and even to the Skager-Rak. Not being known from the Norwegian sea farther north, its northern limit, as Wolfenden remarks, is well defined. Wheeler (1901) did not find it in the Gulf Stream gatherings taken off Marthas Vineyard, but more recently we have taken it at three stations over and seaward from the southwestern part of Georges Bank (July 21, 1914, station 10218, and February 23, 1920, stations 20044 and 20045); also off the southeast face of the same bank on March 12 (Station 20069) and in the eastern channel on April 16 (station 20107),

proving it to be of general occurrence in the oceanic water outside the continental edge abreast of the gulf in winter as well as in summer. It was in sufficient numbers at the three spring stations (approximately 500, 1,000, and 3,800 per square meter) to show that it may locally attain a fair degree of abundance at that season. Willey (1919) also reports it in small numbers from one station outside the continental edge off Cape Sable on July 22, 1915.

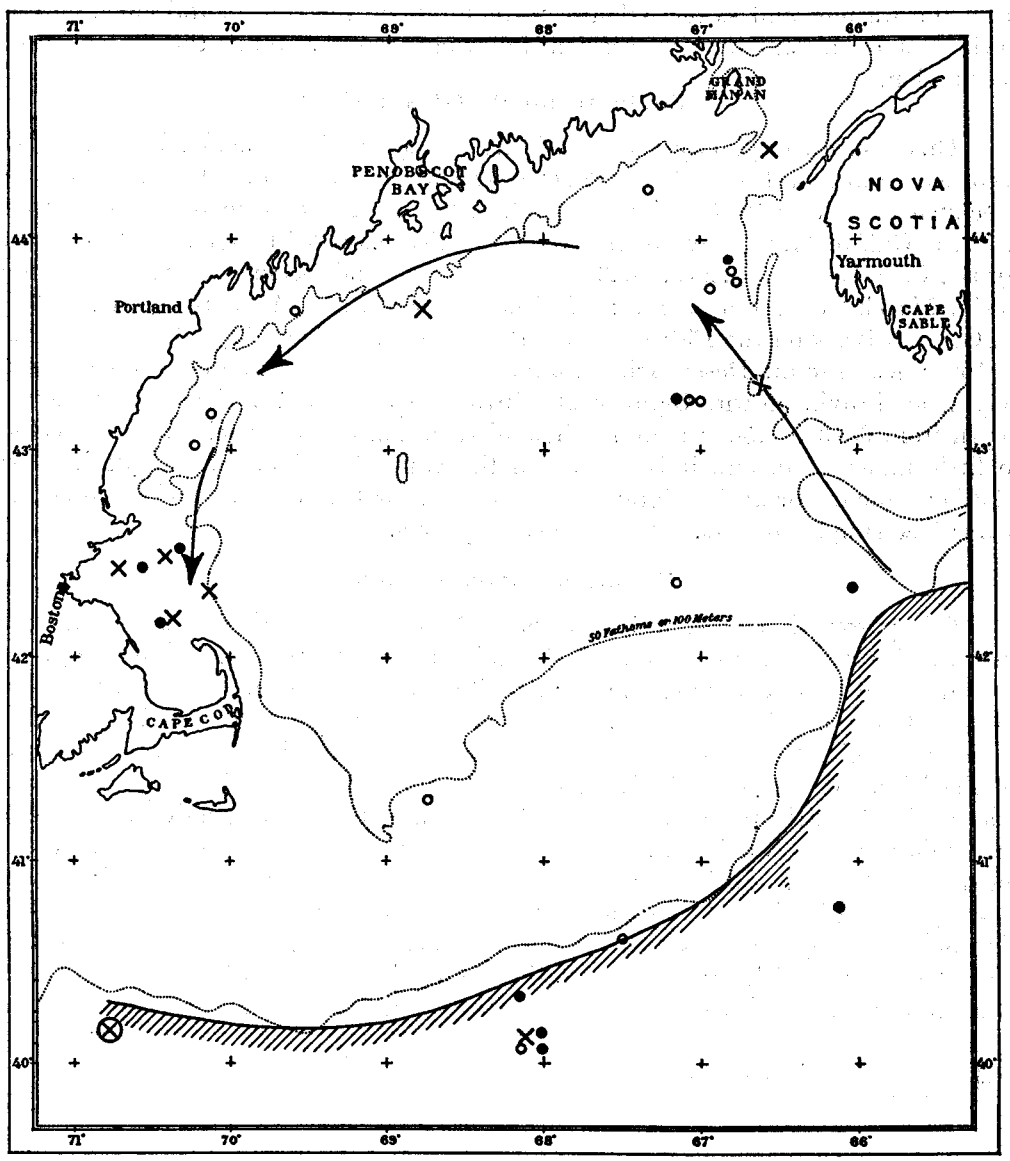

FIG. 71.—Occurrence of the copepods *Eucheirella rostrata, Eucalanus attenuatus,* and *E. elongatus.* ○, locality records for *Eucheirella rostrata:* ×, locality records for *Eucalanus attenuatus* (⊕, approximate location of Wheeler's record); ●, locality record for *E. elongatus.* The arrows mark the chief route of immigration into and around the Gulf; the hatched curve, the inshore boundary to the area of regular occurrence for all three of these copepods.

Only five captures of this species are recorded from the inner parts of the gulf (fig. 71), as follows: Massachusetts Bay region, August 22, 1914 (station 10253), and September 29, 1915 (stations 10320 and 10321); eastern basin, May 6, 1915 (station 10270); and off Lurcher Shoal, April 12, 1920 (station 20101). In each case the record is based on occasional specimens only. [26]

Eucalanus elongatus, like *E. attenuatus*, is only a rare stray in the Gulf of Maine from the warmer and salter Atlantic waters outside the continental edge, entering in the eastern side and on rare occasions following around as far as the Massachusetts Bay region.

Euchæta media Giesbrecht

This species, originally described from the tropical Pacific, has since been recorded from San Diego, Calif. (Esterly, 1905), and from off Delaware Bay (one specimen at station 10072, Bigelow, 1915, p. 287). There is no previous record of it in the Gulf of Maine, but the lists of the vertical hauls of 1915 and 1920, prepared by Dr. C. B. Wilson (pp. 297 and 299), include occasional specimens of it in the western basin, March 24 (station 20087); off Mount Desert Rock, April 10 (station 20098); on German Bank on the 15th (station 20103); off Cape Cod, May 16 (station 20125) in 1920; near Mount Desert Island, June 11 (station 10284); and in Massachusetts Bay near Provincetown, October 26, 1915 (station 10337). The hauls vary in depth from 60–0 to 250–0 meters. The distribution of this species in the oceans is so little understood, and it is so rare in the Gulf of Maine, that its status there, whether endemic or an immigrant, is a question for the future. For the present it will suffice simply to report the few local captures.

Euchæta norvegica Bœck

This powerful species, which, as Sars (1903) has remarked, reaches the truly gigantic size, for a free copepod, of 10 millimeters or more in length of body, with the furca and its setæ adding another 10 millimeters, is known only from the North Atlantic Ocean and from polar seas. It is one of the most characteristic inhabitants of the Norwegian Sea below 400 meters and occurs in quantities at 200 to 400 meters north of Iceland (Paulsen, 1906). Its known range extends southward in the eastern side of the Atlantic to latitude about 50° N., and to the Skager-Rak, but hardly encroaches on the North Sea. It is not known in the Baltic. It is abundant in the Faroe Channel and is recorded from many localities around Iceland; between Norway, Greenland, and Spitzbergen; in Barents Sea; and in the polar basin.[27] No doubt its range extends right across the North Atlantic, for it is reported from West Greenland. The Ingolf Expedition found it in the southern part of Davis Strait to latitude 65° N., and Murray and Hjort (1912) reported it between the Grand

[26] At station 20101 Doctor Wilson lists it as 1 per cent of the copepods (table, p. 301), but with only about 550 copepods of all kinds caught in the net there were but 6 of this species.

[27] For further details and references see Farran (1911), Sars (1900, 1903), Damas and Koefoed (1907), With (1915), and Willey (1920).

Banks of Newfoundland and Flemish Cap.[28] *E. norvegica* is widespread in the Gulf of St. Lawrence, in the deep oceanic triangle between the Scotian and New-

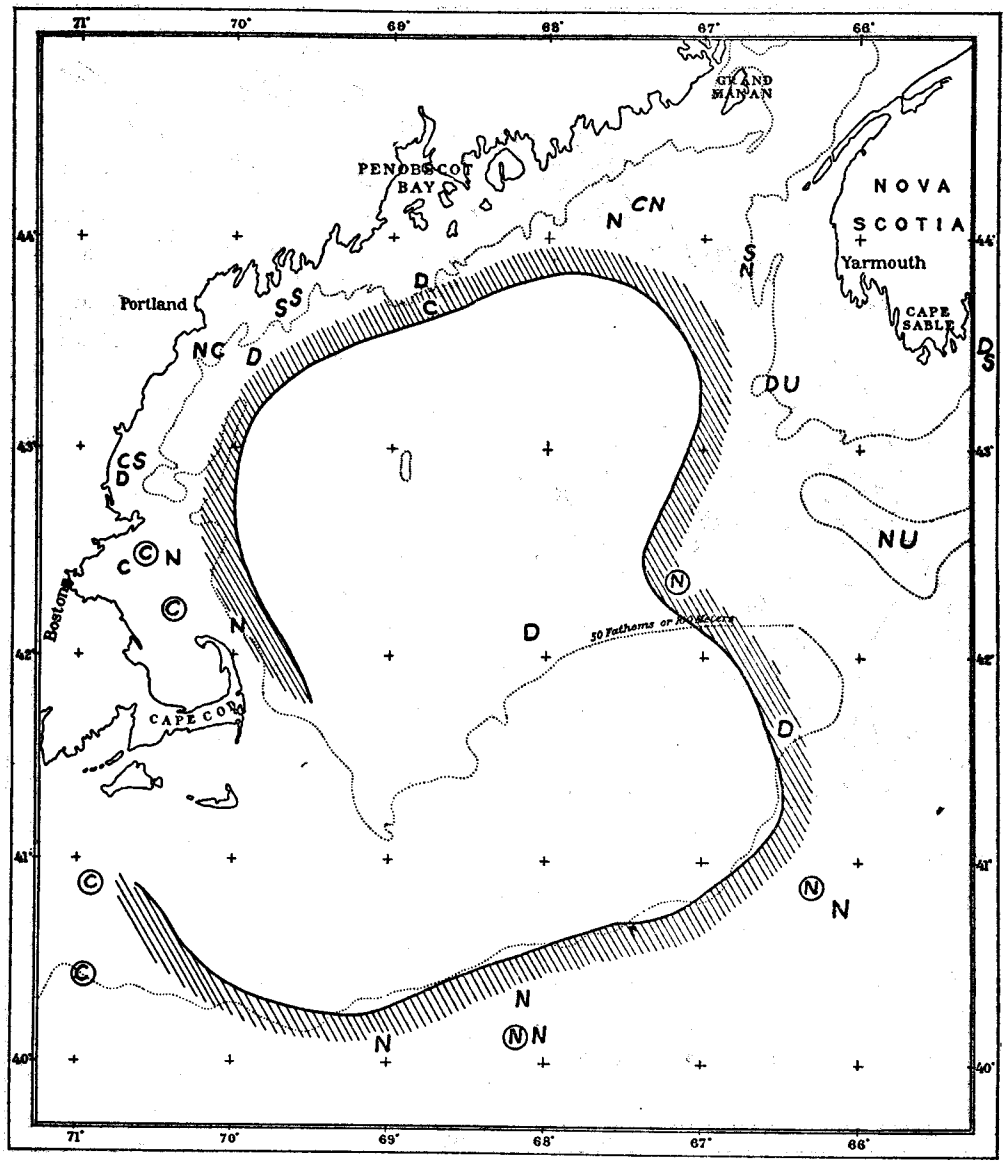

FIG. 72.—Occurrence of the copepods *Rhincalanus cornutus; Rh. nasutus; Scolecithricella minor; Dwightia gracilis: Undeuchæta major*, and *U. minor*. C, locality records for *Rhincalanus cornutus:* D, for Dwightia; N, for *Rhincalanus nasutus:* S, for Scolecithricella; U, for Undeuchæta. The hatched curve incloses the area where these oceanic species have been taken most frequently

foundland Banks, and over the deeper parts of the continental shelf along Nova Scotia (Willey, 1919, tables; Bigelow, 1917, fig. 88). It is one of the most charac-

[28] Listed simply as Euchæta, but probably this species.

teristic planktonic animals in the deeper strata of the Gulf of Maine and abreast its mouth along the continental slope. The most southerly record of it off the American

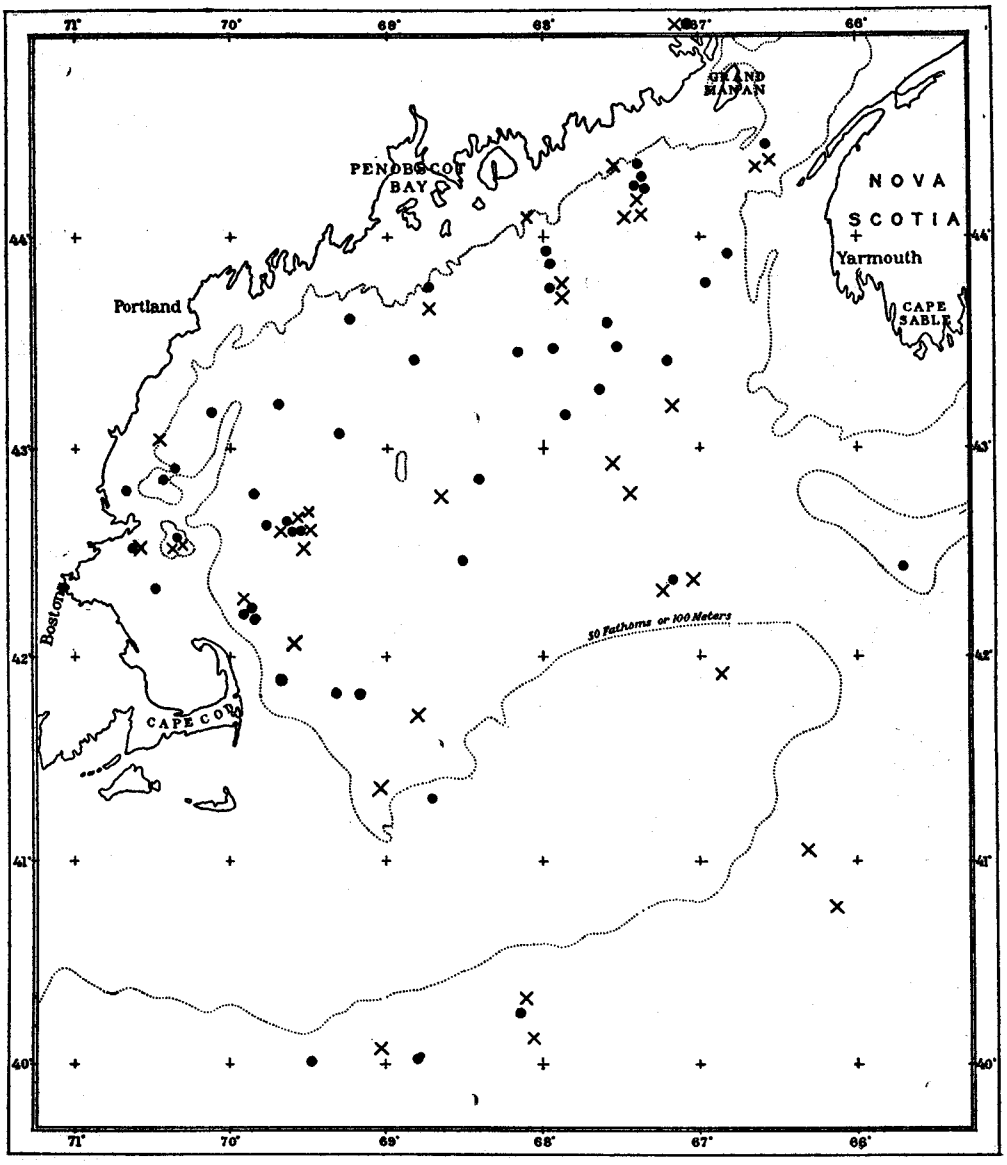

FIG. 73.—Occurrence of the copepod *Euchæta norvegica*. X, locality records, December to May; ●, June to November

coast is in latitude 37° 46′ N. (Bigelow, 1922, p. 148; station 10384, August 12, 1916) in a haul from 500–0 meters.

The locality records for *E. norvegica* prove it generally distributed over the basin of the Gulf of Maine at all times of the year (fig. 73), and so nearly universal there that it has been taken in about 80 per cent of all the horizontal hauls below 100

meters, irrespective of the season. In August, 1913, for example, every such haul captured it, and in the spring of 1920, 80 per cent of the deep hauls took it. In fact, we have learned to expect it in every deep haul (it is made very conspicuous in the catch by its large size and by the brilliant blue egg clusters borne by the adult females) and to regard it as almost as typical of the bottom waters of the gulf below, say, 150 meters as *Calanus finmarchicus* is of the upper 100 meters. The plotted positions (fig. 73) do not suggest that its area of regular occurrence in the gulf undergoes any expansion or contraction with the change of the seasons.

Although so nearly universal in appropriate depths, *E. norvegica* "is never abundant in the Gulf of Maine in the sense that Calanus or any of the other small copepods can be so described" (Bigelow, 1915, p. 292), the richest horizontal hauls yielding a few thousands at most, as is described in detail below. Since the passage of even the deeper vertical hauls through the stratum regularly inhabited by Euchæta is necessarily brief everywhere in the gulf,[20] the result has been that the vertical hauls have often missed it at stations where it has been taken in the horizontals, and consequently do not give a true picture of its distribution. For example, it does not appear in the list of copepods for the vertical haul in the eastern basin on June 10, 1915 (station 10283), though considerable numbers were taken in the horizontal haul as they had been a month previous also (station 10273).

Contrasted with its universal distribution in the basin of the gulf and its constant occurrence there, we have few records of this species inside the general 100-meter contour, whether in the coastwise zone or over the offshore banks—Georges and Browns. Records of it in Massachusetts Bay (fig. 73)—apparent exceptions—are all located in the deep sinks off Gloucester where Euchæta is apparently a permanent inhabitant of the deepest water below, say, 60 to 70 meters.

Present knowledge suggests that *E. norvegica* regularly ranges closer in to the land—and in shoaler water—off the Eastport-St. Andrews region, just within the entrance to the Bay of Fundy, than elsewhere in the gulf, Willey (1921) having reported 7 per cent of this species in a 10-fathom tow off Eastport on August 2, 1916, and having found a quantity of Euchæta in the stomachs of pollock caught about Campobello Island, New Brunswick. *E. norvegica* also entered the mouth of the St. Croix River to abreast of St. Andrews on February 23, 1917 (Willey, 1921), this being the only record of its presence in any estuarine situation tributary to the Gulf of Maine. Our failure to take this species at any of the stations in the deep eastern and northern channels is instructive in connection with the possibility of its immigration into the gulf.

Although the geographic range of *E. norvegica* follows the continental edge as far as the longitude of Delaware Bay (p. 232), it has been found at only about 50 per cent of our deep stations abreast the mouth of the Gulf of Maine, and only once (the station noted, p. 232) beyond the longitude of Nantucket in this direction, although a number of hauls were made along the slope southward to the latitude of Chesapeake Bay in the summers of 1913 and 1916. Longitude 70° may therefore be set as about the western boundary to its regular presence along the North American coast.

[20] In explanation I may point out that only the deepest half of a vertical haul from 200 meters is likely to take Euchæta.

Records of *E. norvegica* along the slope westward and southward from the eastern channel have all been from deeper than 100 meters, and this southward extension of its range is probably only a narrow zone above the 500-meter level—perhaps not more than 20 to 30 miles wide—sandwiched in between the continental slope on the one side and the high temperatures offshore on the other. The recent discovery of this copepod living at 1,000 to 1,250 meters at two *Michael Sars* stations in the Sargasso Sea west of the Azores, however, between the fortieth and fiftieth meridians of longitude (Murray and Hjort, 1912, p. 657), makes it probable that it will be found widely distributed over the whole Atlantic basin in the deeps, like the chætognath *Eukrohnia hamata*, with which it is often taken.

The presence of *E. norvegica* at six out of our seven deep stations off the slopes of Georges Bank and off Shelburne, Nova Scotia, during the spring of 1920 (not found at station 20109), but at only three of our five summer stations outside the continental edge abreast the gulf, and at none of our July, August, or October stations off Marthas Vineyard, indicates a distinct seasonal periodicity in this part of its range, with its maximum abundance in the cold months; but one of these spring stations (20069, March 12, 1920) yielded it in greater numbers per square meter (about 7,750) than any vertical haul yet made within the Gulf of Maine.

Actual numbers.—Although *E. norvegica* often gives character to the catches of the deepest horizontal hauls because of the scarcity of other copepods, it has averaged only about 930 per square meter for all seasons and at all the stations where it figures in the lists for the vertical hauls, with maxima of 4,690 in the eastern basin on August 6, 1915 (station 10304), and 7,750 off the southeast slope of Georges Bank on March 12, 1920, as just noted (station 20069). The average for June to September within the gulf (about 1,200 per square meter) has been slightly above the annual average, and that for February to May slightly below it (about 800), but so small a difference can not safely be interpreted as evidence of any notable seasonal fluctuation in the numerical strength of the species.

The density of aggregation, as measured by number per cubic meter, is likewise invariably small. Assuming that all the specimens taken in hauls deeper than 100 meters came from below that level, as most of them certainly did, the maximum per cubic meter would be less than 50 and the average something like 10; but this is probably an overstatement, because some few Euchæta were shoaler—that is, scattered through a longer column of water.

In terms of percentage *E. norvegica* has invariably ranked low in the vertical hauls, its maximum being 20 per cent off the southwest slope of Georges Bank, February 22, 1920 (station 20044), and 10 per cent on several occasions within the gulf (tables, p. 297), where its average for all the verticals has been about 4 per cent. But it occasionally dominates the catch in the deepest horizontal hauls at or below 150 meters (e.g., closing-net haul at 85 to 60 fathoms, August 29, 1912, station 10043), and on several occasions it has amounted to 30 to 50 per cent of the copepods taken. At times, however, we have found only 2 per cent or less of Euchæta in hauls as deep as 175 to 250 meters (table, p. 304).

Vertical distribution.—Perhaps the most interesting phase of the status of *E. norvegica* in the gulf is its vertical distribution, for, unlike most of the other common

local copepods, it is most characteristic of the deepest water there. As just pointed out, it has been taken in the great majority of the horizontal hauls below 100 meters, and as a general rule it may be stated that the deeper the haul the more certain it is to yield Euchæta, and in the greatest numbers, both absolutely and relative to other copepods. During the July and August cruises of 1913, for example, it was taken more abundantly at "90–0 fathoms at station 10100, 80–0 fathoms at stations 10088 and 10097, 75–0 fathoms at station 10090, 70–0 fathoms at station 10061" (Bigelow, 1915, p. 292) than in any of the shoaler tows. The use of closing nets is requisite for more definite information on this point, because the open tow nets often pick up such large amounts of Calanus and other copepods in their journeys up and down that it is impossible to estimate the relative abundance of Euchæta and Calanus at the towing level.

In contrast with the frequency with which *E. norvegica* occurs in the deepest Gulf of Maine hauls, it is usually wanting in tows shoaler than 100 meters, which establishes that level as roughly the upper limit to its regular range. Among the several hundred hauls at lesser depths with various nets it has been detected in only 20 of the horizontals[30] and 7 verticals (tables, pp. 297 and 299) and only twice shoaler than 40 meters; and the fact that on at least two of these occasions it was about equally abundant at 60 meters and in considerably deeper hauls is evidence that *E. norvegica* reaches the upper strata of water as the result of temporary dispersals and not by a general ascent on the part of the whole local stock. On six occasions it has been taken on the surface in various parts of the gulf, as follows: (1) 12 miles off Mount Desert Rock, August 16, 1912, at 3 a. m. (station 10032); (2) in the northeastern part of the basin off the mouth of the Bay of Fundy, August 13, 1913, 2 a. m. (station 10097); (3) near the same locality, August 12, 1914, 10 p. m. (station 10247); (4) western basin, August 22, 1914, 8 p. m. (station 10254); (5) in the southwestern part of the basin, the following night, 11 p. m. (station 10256); and (6) Fundy Deep, March 22, 1920, 2 p. m. (station 20079). It will be noted that these localities extend right across the gulf from northeast to southwest—that is, they do not suggest that Euchæta comes more often to the surface in the northeastern corner of the gulf, where vertical mixing by tidal currents is most active, than in the more stagnant and stratified and vertically stable waters off Massachusetts Bay and Cape Cod. More extensive data may prove that a local difference of this sort does actually obtain; indeed, it is to be expected. Neither does the evidence available suggest that Euchæta rises to the surface more frequently during the winter or spring than in summer, for it appeared in only one of the 55 surface tows for February–May, 1920 (table, p. 303). The times of day for the several surface captures of *E. norvegica*, if corroborated, would indicate that in summer it makes its rare visits to the surface only at night, but that in early spring (probably also in winter) it may do so at any hour.

Damas and Koefoed's (1907) characterization of *E. norvegica* as a form living mostly in midwater but occasionally appearing at the surface applies as well to it in the Gulf of Maine as in the Greenland seas. *E. norvegica* has been found in small numbers at the surface in most other regions where it occurs regularly. This, for

[30] Willey (1921) also reports Euchæta at about 20 meters off Eastport and near the surface at St. Andrews.

instance, is the case in the fjords and along the coast of Norway (Sars, 1903; Farran, 1910), between Iceland and the Faroes (Wolfenden, 1904), in the Faroe channel, in the Gulf of St. Lawrence, and along the outer coast of Nova Scotia (Willey, 1919). In the northeastern Atlantic reports of it at the surface have usually been based on immature specimens; but this rule does not apply to the Gulf of Maine, Willey (1922) having found it in the breeding state close to the surface near St. Andrews. Euchæta necessarily inhabits a somewhat shoaler zone in the gulf (with its lower limit set at about 300 meters by the topography of the bottom) than in the Norwegian sea and between Iceland and the Faroes, where it occurs chiefly below 200 to 300 meters, and down to 1,000 meters.

Breeding.—Our failure to find *E. norvegica* at any time in the eastern or northern channels (we have one record of it on Browns Bank, June 24, 1915, station 10296) and the fact that its seasonal fluctuations in abundance along the continental shelf are not reflected within the gulf are evidence that the maintenance of the Gulf of Maine stock depends more on local reproduction than on immigration. Were the opposite true, we would expect to find it in the two channels, these being the entrances for visitors from the mid-depths offshore, or from the east and north, and most plentiful within the gulf at the season when it is most plentiful outside. Adult females with egg clusters attached are familiar objects in the deeper Gulf of Maine tows, while Willey (1921) has found adult males with spermatophores as well as egg-bearing females and immatures of both sexes at St. Andrews.

Willey's specimens were taken in February, and since females with egg sacs were noted in the *Albatross* tows on March 3, 1920 (station 20055), and outside the continental edge off Shelburne, Nova Scotia, on the 19th (Station 20077), while most of the summer catches of the species have contained them, *E. norvegica* evidently spawns throughout the year in the Gulf of Maine. The vertical distribution of the species proves that reproduction takes place almost entirely below 100 meters, though occasional individuals in breeding condition may occur at the surface.

Relationship to temperature and salinity.—The tendency of this species to keep to deep water makes it easy to establish the physical conditions under which it lives in the gulf.

The great majority of the captures have been in comparatively high salinities (33 to 34 per mille) and from temperatures lower than 10°, the quantitative occurrence of the species pointing to the higher salinity and to a temperature lower than 8° as its optimum. Such of the Gulf of Maine stock as lives below 150 meters inhabits a zone in which the yearly range of temperature is narrow—for the most part between 6 and 4°. However, its presence at the surface proves that it can survive a brief visit in water as warm as 19 to 20° (stations 10254 and 10256, western basin, August 22 and 23, 1914). On the other hand, the wide Arctic distribution of *E. norvegica* makes it unlikely that the temperature is ever unfavorably low for it in the Gulf of Maine, which is corroborated by its presence near the surface at St. Andrews during the coldest season (Willey, 1921). The failure of this species to work farther inward toward the Baltic [31] than the Skager-Rak makes it probable that salinities lower than

[31] One record from the Kattegat is mentioned by Farran (1910).

32 to 33 per mille are an effective bar to its wanderings, and its distribution in the Gulf of Maine is consistent with this.

Economic importance.—*E. norvegica* has been considered as of comparatively little economic importance in the northeastern Atlantic because of the considerable depth of its habitat. But it occurs regularly within reach of at least one of the important plankton-eating fishes in the Gulf of Maine, for Willey (1921) found the stomach of an American pollock (*Pollachius virens*) densely packed with a mass of Euchæta and euphausiid remnants in about equal amounts, the percentages of different copepods which he tabulates—84 per cent Euchæta, 3 per cent *Calanus finmarchicus*, 2 per cent *C. hyperboreus*, and 1 per cent *Metridia longa*—suggesting that the fish had voluntarily selected the Euchætæ in preference to the smaller *C. finmarchicus*, which was probably far the more plentiful of the two. Another pollock opened by him had also eaten Euchæta. To what extent mackerel and the several species of herring feed upon it in the gulf is not known, but it is likely to be an important article in their diet when it rises toward the surface.

Euchæta spinosa Giesbrecht

This species, known from localities in the North Atlantic, Mediterranean, Indian Ocean, and Pacific (Giesbrecht, 1892; van Breemen, 1908; Thompson and Scott, 1903; Esterly, 1905), has been reported from surface collections off Nausett Beach, Cape Cod, and off the northern extremity of the cape by Sharpe (1911, p. 410), but it has not appeared in any of the more recent towings in the gulf or in Canadian Atlantic waters.

Eucheirella rostrata (Claus)

This is an oceanic species, widespread in the temperate Atlantic (Cleve, 1900; T. Scott, 1911) and common on the Pacific coast of the United States at San Diego, Calif. (Esterly, 1905 and 1911). It has been recorded at several stations along and outside of the continental edge off Chesapeake and Delaware Bays and off New York (Bigelow, 1915, p. 296; 1922, p. 147), abreast of Georges Bank (stations 10218 and 10219), and thence eastward and northward along the slope of the Nova Scotian shelf and in the Laurentian channel (Willey, 1919, p. 189, fig. 9). Although this copepod is not typically tropical, it enters the Gulf of Maine as a visitor from the mid-depths along the inner edge of the "Gulf Stream," and its locality records, like those for other planktonic organisms of that category, are localized in the eastern side of the gulf and around its periphery (fig. 71). The station records number 13, all but 4 of them being for July and August—2 for May, 1 for June, and 1 for September. Evidently the species is most apt to enter the gulf during the warm months, and apparently it does not do so at all in the low temperatures of late autumn, winter, and early spring.

All records of the species off the east coast of America have been from depths of 50 meters or deeper, and the Gulf of Maine records are all based on occasional specimens.

Eurytemora herdmani Thompson and Scott

This species is known only from the coasts of North America. It was originally described from the lower reaches of the St. Lawrence River below Quebec (Thompson and Scott, 1898), and has since been found in the Gulf of St. Lawrence (T. Scott, 1905; Willey, 1919), on the Bering Sea shore of Alaska and Arctic shores of Canada (Willey, 1920), in the Gulf of Maine, at Woods Hole (Sharpe, 1911; Fish, 1925), and in Narragansett Bay (Williams, 1906 and 1907).

In the Gulf of Maine it probably occurs in all harbors, having been taken at Gloucester, Rockport, Kittery (Esterly, in Bigelow, 1914, p. 116), and at St. Andrews, where Doctor McMurrich [32] found it regularly throughout June, July, August, September, and October, occasionally in February, April, and May, but not at all in November, December, or March. Willey (1919 and 1921) also records it from one station in Passamaquoddy Bay in September, 1915, and again on November 2, 1916. Altogether we have eight records of this species in the open Gulf—off Boston Harbor and off Boothbay Harbor on July 13 and 26, 1912 (stations 10006 and 10016); in the western and eastern basins on August 31 and September 1, 1915 (stations 10307 and 10309); off the Isles of Shoals on October 4, 1915 (station 10325); western basin and southeast slope of Georges Bank on March 24 and April 16, 1920 (stations 20087 and 20109); and off Boston Harbor on December 29, 1920 (station 10488). Never more than a few specimens have been taken at any offshore station.

Judging from these records, it seems that *Eurytemora herdmani* is characteristic of estuarine situations and perhaps also of brackish water all around the coast line of the gulf, but that such specimens as drift offshore are equally able to survive in the open sea, and so are as apt to be met with in one part of the gulf as another and even out to the continental edge. But being so scarce everywhere in the gulf away from the close vicinity of the coast, it is not likely that this species breeds successfully there outside the outer headlands. McMurrich's observations point to the summer and early autumn as its season of maximum abundance, and winter and early spring as its minimum abundance in Gulf of Maine harbors and river mouths, but at Woods Hole Fish (1925) found it regularly in winter as well as summer.

Gaidius tenuispinis Sars

This is an Arctic and North Atlantic species recorded from many stations in the polar basin (under the ice, Sars, 1900), from the seas between northern Norway and Jan Mayen, Spitzbergen and Greenland; around Iceland; along east and west Greenland and in Davis Strait; [33] and Esterly (1911) had one specimen in a vertical tow from 325 fathoms at San Diego, Calif. In the eastern side of the Atlantic it occurs southward regularly to the Iceland–Faroe and Faroe–Shetland channels. There are a few records from the Norwegian sea, from north and east of Scotland, and from deep water southwest of Ireland (Murray and Hjort, 1912, p. 655). In the polar sea it has been taken at the surface in latitude 85° N. (Sars, 1900). All other records of it have been from considerable depths, varying from 100 to 1,000 meters.

[32] In his unpublished plankton lists.

[33] For more detailed statements of its occurrence in northern seas see Sars (1900), Mrázek (1902), Damas and Koefoed (1907), Farran (1910), and especially With (1915).

On the American side Willey (1919) lists it at one station in the Gulf of St. Lawrence and one just outside the continental edge of Le Have Bank off Nova Scotia, and the *Michael Sars* had it near Flemish Cap, east of the Grand Banks. Wolfenden (1911) has described as this species a Gaidius from the Antarctic and off the Cape of Good Hope, but differences which he mentions, though slight, may prove sufficient to differentiate the northern from the southern form when larger series are compared; hence the bi-polarity of the species can not be accepted yet as definitely established (With, 1915). *G. tenuispinis* has not been found in the Pacific, where a closely allied form, *G. pungens* (Giesbrecht), occurs in lower latitudes.

There are no previous records of *G. tenuispinis* in the Gulf of Maine or farther south in the western Atlantic, but odd specimens were taken in the vertical hauls off Penobscot Bay on April 10, 1920 (station 20097), and again on January 1, 1921 (station 10496)—about 6 specimens on the first occasion and 15 on the second. It also figures (1 per cent) in the list of copepods taken at the outermost station outside the continental edge off Shelburne, Nova Scotia, on March 19, 1920 (station 20077, table, p. 300). Evidently *G. tenuispinis* reaches the gulf, which is its extreme southern limit on the American coast, only as an accidental stray from the north, and is more apt to do so during the cold half of the year than in summer.

Halithalestris croni (Krøyer)

This is one of the largest of harpacticoid copepods and one of the few representatives of the group recognized in the plankton of the open Gulf of Maine by Doctor Esterly (in Bigelow, 1914, p. 115; 1915, p. 287; 1917, p. 290) or by Dr. C. B. Wilson (tables, p. 207), and at Woods Hole by Fish (1925, p. 146). It is widely distributed in the North Atlantic, being known on the European side from the Bay of Biscay northward to the Faroe Channel, Iceland, Spitzbergen, and north of Norway, including the English Channel and the northern part of the North Sea. On the American side it has been reported at several stations in the Gulf of St. Lawrence (Herdman, Thompson, and Scott, 1898; Willey, 1919), in the Straits of Belle Isle (Herdman, Thompson, and Scott, 1898), in the Gulf of Maine, and at Woods Hole, but as yet not farther south.

Gulf of Maine.—Previous records for the Gulf are two hauls in the central basin in July, 1894;[34] St. Andrews, September, 1915 (Willey, 1919); and occasional specimens mentioned for that locality during the months of November, January, and April in Doctor McMurrich's lists of the local plankton (p. 12). *H. croni* was not detected in the numerous horizontal hauls for the years 1912 to 1914, reported on by Doctor Esterly, probably because entirely overshadowed by the masses of Calanus and other calanoids; but the vertical and surface hauls for 1915, 1920, and 1921 (tables, pp. 297, 299 and 304) extend its range over the Gulf of Maine generally, including the coastal zone and the basin indifferently, to the eastern part of Georges Bank and to the continental slope off its southwestern face (fig. 74). It has not yet been found on the western part of the bank or off Nantucket, but judging from its widespread distribution in the gulf it is to be expected there. The records cover the months of March, April, May, June, August, September, and January, proving that it is present in the gulf the year

[34] Listed by Sharpe (1911) from latitude 42° 55′, longitude 68° 49′, and latitude 42° 07′, longitude 70° 08′, and collected by the *Grampus*.

round, with 12 station records for March, 7 for April, 3 for May, and only 1 or 2 for each of the remaining months. On its face this seasonal distribution of the records would suggest that *H. croni* is most widespread during the spring, and so scarce during

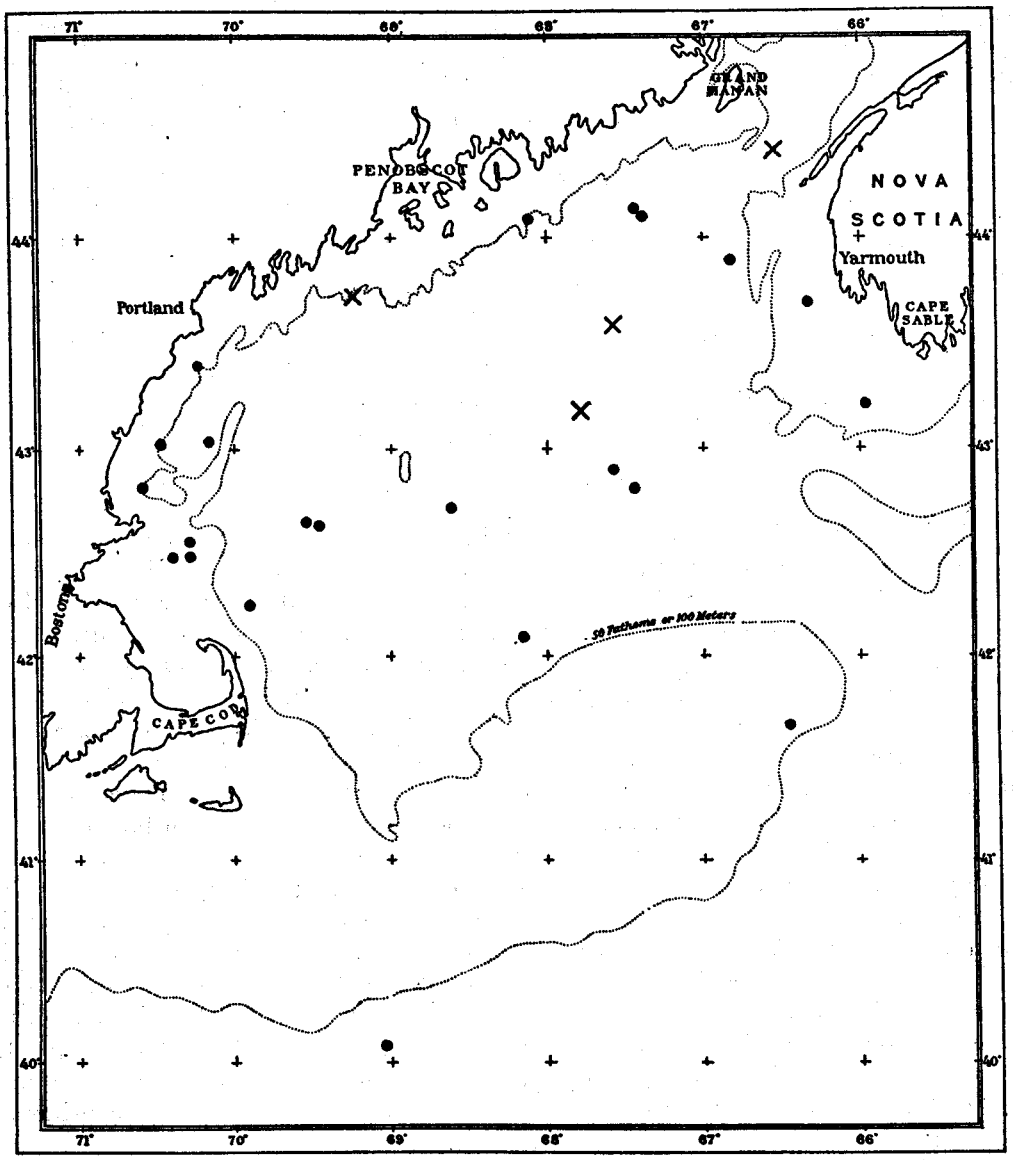

FIG. 74.—Occurrence of the copepod *Halithalestris croni*. ●, locality records, December to May; ×, June to November

October that all the hauls missed it; but this conclusion may need modification when a greater number of surface hauls for the autumn have been examined. We have taken it in greatest abundance locally in August.

No seasonal localization of the species in one region or another is demonstrated within the gulf. In other seas *H. croni* has usually been taken at or near the surface, and the *Grampus* specimens of 1894, just mentioned, were likewise from hauls at or near the surface. Similarly, this copepod occurred in about 25 per cent of the surface hauls during the spring of 1920, but only in about 12 per cent of the verticals. Evidently it lives chiefly close to the top of water, but the fact that seven verticals took it at April and May stations when the surface net missed it, although the latter filtered much the larger volume of water, is evidence that its vertical range extends down at least for some few meters and possibly to a considerable depth. No information is available as to its presence or absence on the surface in the gulf during the remainder of the year.

H. croni has never been more than a very minor factor in the copepod fauna of the gulf, as revealed by the tow net. At the stations where it has been recognized it has averaged only about 1 per cent of the copepods; at the most 5 per cent. The numbers per square meter at the stations of record for the species have varied from a mere trace to a maximum of about 2,300 (station 10304, August 6, 1915). Although *H. croni* was taken at more stations during the spring months than in summer, the numbers per haul were less (average less than 150 per square meter for March, April, and May; maximum about 277) than in August, when there were 1,700 and 2,300 per square meter at the two stations (stations 10304 and 10309; table, p. 298); but it is not safe to draw conclusions as to the numerical fluctuations of the species from so few hauls.

Dr. C. B. Wilson, in a letter, speaks of the egg sacs of the females; therefore it is to be presumed that this copepod is endemic in the gulf, but no observations have yet been made on its season of reproduction there.

Harpacticus littoralis G. O. Sars

This is a littoral species, known from the south and west coasts of Norway, where it is usually found in very shallow water, especially at the heads of flat, sandy creeks, and about Great Britain.[35] *H. littoralis* has not been reported previously from the American coast under its own name, but it is possible that it was included among the *H. chelifer* recorded by Sharpe (1911) from Woods Hole and from the vicinity of New York.

At St. Andrews Doctor McMurrich lists *H. littoralis* occasionally between December 12 and March 28, rather more frequently but always in small numbers during April and May (about 45 per cent of the stations), and not at all during the other months.

Judging from its littoral nature on the other side of the Atlantic there is no reason to suppose that it ever becomes planktonic outside the outer islands in the Gulf of Maine; but probably tow nets would take it in most of the harbors north of Cape Cod at some stage of the tide.

[35] See Sars (1903–1911) for the history of this species, previously confused with *H. chelifer* Müller.

Harpacticus uniremis Krøyer

This harpacticoid becomes planktonic only occasionally or accidentally but normally lives on the bottom—according to Sars (1903–1911) on muddy bottom in 20 to 100 fathoms. The localities of capture which he quotes from various earlier authorities include the Scottish coast, Norwegian coast, Spitzbergen, Bear Island, polar sea north of Grinnell Land, and Bering Sea. Williams (1907) has also recorded it from Narragansett Bay and from the brackish Charlestown Pond in Rhode Island, Fish (1925) at Woods Hole, and the Canadian Arctic expedition collected it in surface tows at two localities off southern Alaska (Willey, 1920).

Doctor McMurrich, in his plankton lists, records this species occasionally at St. Andrews in December (one haul); in five hauls between March 28 and May 19; twice in June; not at all during the later summer or autumn; and Willey (1923) reports it from the stomachs of winter flounders (Pseudopleuronectes) caught there. In this region of violent tidal circulation it is perhaps swept up from the bottom by the active stirring of the water. It has not been taken in the open Gulf and is hardly to be expected there in the plankton.

Heterorhabdus spinifrons (Claus)

Dr. C. B. Wilson contributes the following note on this species, which "is easily recognized by the asymmetry of the caudal rami and by the excessive length of one of the apical setæ attached to the left ramus. In the plankton taken continuously across the Atlantic by Herdman this species was found sparingly between mid-ocean and the Canadian shore, and hence is found considerably north of the Gulf of Maine. During the *Challenger* expedition it was taken at several widely separated stations in the North Atlantic, and at one place in the South Atlantic from a depth of 2,650 fathoms (Brady, 1883). Thompson and Scott (1903) have reported it in the Mediterranean, in the Indian Ocean, and near Ceylon. Esterly (1905) obtained only a single female of this species from the plankton at San Diego on the Pacific coast, and incidentally one or two specimens of three other species of the genus. In the Gulf of Maine it was obtained in only two vertical hauls—one in the open ocean southeast of Georges Bank and the other outside of Boston Harbor. The first haul was made on March 12, 1920, and this species had a percentage of four in the catch. The second haul was made on May 4, 1920, and *spinifrons* formed only 1 per cent of the catch. In none of the reports here enumerated was it found in any numbers, and the four per cent mentioned [indicating an absolute abundance of about 3,100 per square meter] is about its maximum anywhere."

In the Gulf of Maine it may be classed as an accidental visitor from warmer and more oceanic waters offshore.

Idya furcata (Baird)

Sharpe (1911, p. 417) describes this as "perhaps the commonest and most widely distributed of all the Harpactoida." Probably it will eventually prove cosmopolitan in suitable situations, being recorded from widely separated localities in the Arctic Ocean, including the Alaskan shore of Bering Strait and the Arctic

coast of Canada (Willey, 1920), and from north European coasts generally inward to the mouth of the Baltic. Brady (1878–1880) calls it ubiquitous around Great Britain, and Sars (1903–1911) names it the commonest of Norwegian harpactoids. It occurs in the Mediterranean and Red Seas and about New Zealand and the Chatham Islands in the Pacific.[36] Like most of its group it chiefly inhabits the littoral zone, among seaweed, often in tide pools, and only occasionally, perhaps accidentally, it becomes pelagic out at sea.

In northeastern American waters it has previously been reported from Narragansett Bay, Rhode Island (Williams, 1907), and from Woods Hole, where Sharpe (1911) collected it in summer, both among floating algæ and eel grass (Zostera) in water about 10 fathoms deep and in the so-called "eel pond," an inclosed tidal pool.

At St. Andrews, Idya, like other Harpactoida, is perhaps swept up into the upper waters by the violent tides. Doctor McMurrich lists it three times between January 26 and March 28; in nearly 50 per cent of the hauls from March 28 to May 19; and in 25 per cent of the hauls from May 20 to July 6; but not at all during the later summer, autumn, or early winter. It has not been detected in the plankton of the open gulf and is hardly to be expected there except perhaps as a stray from the littoral zone with the masses of eel grass (Zostera) and rock weed (Fucus) so often seen drifting on the surface.

In estuarine situations, where this little copepod is plentiful, it may be an important article of diet for fishes, Willey (1920, p. 35) having found it in abundance in the stomach of the winter flounder (Pseudopleuronectes) at St. Andrews.

Labidocera æstiva Wheeler

This species was described by Wheeler (1901) from Woods Hole, where he found it very common in the tow during June and September, and where Parker (1902, p. 103) speaks of it as "one of the commonest species." Williams (1906 and 1907) did not find it in Narragansett Bay nor Fowler (1912) off New Jersey, but Dr. C. B. Wilson writes me that it is "in considerable numbers along the Atlantic coast south of New England," and in August, 1916, it was taken at three stations off the mouth of Chesapeake Bay (Bigelow, 1922, p. 146). Fish (1925) had it at Woods Hole from June through November. Up to the present time it is known only from the American side of the North Atlantic.

The only previous records of it from east or north of Cape Cod are T. Scott's (1905) mention of it in the Gulf of St. Lawrence and Willey's (1919) two citations of it in Northumberland Strait and between Prince Edward Island and Cape Breton Island in the Gulf of St. Lawrence, but the towings of 1920 and 1921 extend its range into the Gulf of Maine.

There are only three records for it in the Gulf of Maine—that is, western basin, March 24, 1920 (station 20087); off Penobscot Bay, April 10, 1920 (station 20097); and again on January 1, 1921 (station 10496)—always in minimal amounts. Thus it is evidently very rare in the gulf, and probably only a straggler there from its center of abundance in the Woods Hole region. This species, having no constant place in the local plankton, is chiefly interesting here as the subject of Parker's (1902)

[36] Sars (1903–1911) and Sharpe (1911) summarize its distribution as known.

experiments on the vertical migrations of copepods, which lead to the conclusion that while it is at all times negatively geotropic—that is, tends to swim upward against gravity—the phototropism of the females, whether positive or negative, depends upon the intensity of the light, weak attracting and strong repelling them, whereas the males show a weak negative phototropism under all conditions. Thus, he concludes, the females may be expected to rise with the setting sun, as the light weakens, and to descend again after sunrise, when they become positively phototropic enough to counteract their negative geotropism. The males, he believed, follow the females because chemically attracted to them. What little is known of the vertical movements of Labidocera at liberty in the sea conforms to this schedule, for Parker found them at the surface from sunset to sunrise.

This species is an important article of diet for copepod-eating fishes farther south, writes Dr. C. B. Wilson, but probably it is never sufficiently plentiful for this in the Gulf of Maine.

Lucicutia grandis Giesbrecht [37]

This species was founded on a single male specimen obtained off the west coast of South America just north of the Equator. The two Gulf of Maine specimens are interesting because there has been no subsequent report of it except one female from the North Atlantic doubtfully referred to it by Wolfenden (1904). The Gulf of Maine collections contain two males from a vertical haul from 1,000–0 meters off the southeast slope of Georges Bank, March 12, 1920 (station 20069), indentified by Dr. C. B. Wilson (table, p. 299).

Metis ignea Philippi

This small, brilliant, blood-red harpacticoid, originally described from the Mediterranean, has since been redescribed as "*Ilyopsyllus coriaceus*" from the Irish coast by Brady (1883) and by Brady and Robertson (1873); Sars (1903–1911) also found it at several localities on the coast of Norway. *M. ignea* has not been reported definitely from American waters, but Williams's (1907) "*Ilyopsyllus natans*" from Narragansett Bay is a very closely allied form, if not identical, as Sars (1903–1911, p. 346) suggests. So, also, is the "*I. sarsi*" described by Sharpe (1911) from Woods Hole. Brady and Robertson described *M. ignea* as living among black peaty mud and roots of seaweed near high-tide mark; Sars also found it in moderate depths on a muddy bottom amid decaying algæ, and Sharpe (1911) took his *sarsi* among floating algæ at Woods Hole. Another species of the genus *M. holothuriæ* [38] was taken from a holothurian. On the other hand, Williams (1907) described his *natans* as swimming at the surface in Narragansett Bay, so that the genus is both bottom dwelling and planktonic.

The Gulf of Maine records of *M. ignea*, nine in number, are for the months of December, March, April, May, June, and October, proving it present the year round with no definite seasonal maximum, and always in numbers so small that no haul yielded more than a few specimens. At the most it was 1 per cent of the copepods, meaning about 20 to 28 specimens per square meter, and usually only one or two were detected per haul.

[37] Originally described by Giesbrecht (1895) as *Leuckartia grandis*, but this generic name being preoccupied he later (Giesbrecht and Schmeil, 1898) replaced it by Lucicutia.

[38] Described by Edwards (1891) as *Abacola holothuriæ*.

All but two of the records are inshore from the general 100-meter contour—that is, off Boston Harbor (stations 20089, 10488, and 10505, April 5 and December 29, 1920, and March 5, 1921); outer part of Massachusetts Bay (station 10323, October 1, 1915); near Chatham, Cape Cod (station 10336, October 26, 1915); near Mount Desert Island (station 10286, June 14, 1915), and on German Bank (station 10271, May 6, 1915)—but one of the stations of record lies in the central part of the basin (station 20114, April 17, 1920) and another outside the 100-meter contour off Cape Cod (station 20116, April 17, 1920). The locations of the several locality records are not such as to suggest that the specimens in question had been swept up from the bottom by some current, for most of them are in regions where vertical currents are comparatively weak; and it is significant that *M. ignea* was not taken at any of the stations where the surface tows contained sand brought up by active stirring of the whole column of water. It may therefore be concluded that in the Gulf of Maine this copepod is regularly planktonic in small numbers; but judging from its habitat in other seas it is also to be expected on the bottom in shoal water, and probably in greater abundance.

The data of capture point to the upper 100 meters as the habitat of this species where it is planktonic, probably because this covers the normal depth zone of the stock living on the bottom, some of which take to a pelagic life. It will be noted, however, that none of the surface hauls made during the spring of 1920 took it, this negative evidence suggesting that it is more apt to be at some little depth than close to the top of the water. No observations have been made on the breeding of this species.

Mecynocera clausi J. C. Thompson

Dr. C. B. Wilson contributes the following note on the general geographic range of this species:

> The original specimens were obtained near the Canary Islands and at Malta, to which localities Giesbrecht (1892) has added Naples and the tropical Pacific from the surface to a depth of 1,000 meters. Thompson and Scott (1903) reported the species from the Red Sea and throughout the Indian Ocean, Wolfenden (1905) among the Maldive Islands, and A. Scott (1909) in the Malay Archipelago. Wheeler (1901) obtained a single specimen from the Gulf Stream 70 miles south of Marthas Vineyard, and Esterly (1905) found the species at San Diego on the Pacific Coast. Esterly's specimens were taken on December 30, while Wheeler's were captured July 25. It is thus very widely distributed but does not seem to occur anywhere in any but small numbers. This, coupled with its small size, makes it of practically no economic importance.

Except for Wheeler's specimen just mentioned, this species had not been taken anywhere along the Atlantic coast of North America, hence its presence at three stations in the Gulf of Maine in September, 1915—one near Cape Elizabeth on the 20th (station 10319) and two in Massachusetts Bay on the 29th (stations 10320 and 10321)—is interesting as extending its known range.

Metridia longa (Lubbock)

This brilliantly phosphorescent copepod is a true Arctic species, though its distribution in the Gulf of Maine suggests that Farran's (1910, p. 70) characterization of it as "probably the most typically arctic copepod of whose distribution there is any accurate knowledge" needs some modification. Except for one record from the

Indian Ocean (van Breemen, 1908), it is known only from the North Atlantic and polar oceans. It is commonly distributed over the parts of the polar basin crossed by the *Fram* on her famous drift (Sars, 1900); in the Kara Sea; between Norway, Spitzbergen, Greenland, and Iceland; and southward regularly to the Greenland–Faroe and Faroe–Shetland channels. It is widespread in the Norwegian sea, numerous in the deeps of the Norwegian fjords, and occurs southward to the Skager-Rak, where it is usually present in fair numbers. There are isolated records of it in the central part of the North Sea, and it has been taken to latitude 55° 23′ N., longitude 11° 6′ W., west of Ireland (Wolfenden, 1904), this being the most southerly record of it off Europe.

On the American side it is recorded from Baffin Bay and from the Arctic coasts of Alaska and western Canada (Willey, 1920), hence is no doubt circumpolar. On the east coast of North America the Canadian fisheries expedition found it widespread in the Gulf of St. Lawrence, over the continental shelf along Nova Scotia, and outside the neighboring continental slope, but, curiously enough, not at all in the Green Bank–St. Pierre Bank region off Newfoundland. It also occurs with some regularity in the Gulf of Maine and over the shelf south of Marthas Vineyard, which so far as known is its most southerly outpost along the eastern seaboard of America.

Distribution in the Gulf of Maine.—*M. longa* was not recognized at any of our stations in the gulf during the summer of 1912 or the following winter, nor can it have been other than very rare during that period, if actually present at all, for Dr. C. O. Esterly examined many samples of the copepods. In July and August, 1913, however, he detected it in small numbers at four stations east and north of Cape Cod (20 per cent of the stations). In the summer of 1914, as in 1912, not one was detected in the gulf, or for that matter along the outer coast of Nova Scotia, although special watch was kept for it; and if not actually altogether absent from the gulf then, it must at least have been extremely rare, for it is so easily distinguishable in general body form from its relative *M. lucens* that it could not have been overlooked had it occurred in such numbers as we have subsequently found in the gulf. The year of local abundance for it was 1915, when it was detected in vertical hauls at about 65 per cent of the stations right through the season from May to October. It again dropped wholly out of sight in the gulf in the summer and early autumn of 1916, when it was not found in the preliminary examination of any of the hauls (Bigelow, 1922, p. 147), although this was a very cold season, which is evidence that the low temperatures of that summer were reminiscent simply of extreme winter chilling and of tardy vernal warming resulting from local climatic conditions, and not due to any unusual flood of cold northern water. A few *M. longa* must, however, have existed in the gulf during the autumn of 1916, for Willey (1921) reports it as occasional at St. Andrews on November 2 and December 8 of that year, with a scattering of it in the tow on February 23, 1917.

Owing to the interruption of all oceanographic research in the open gulf by the war, no information is available as to the local status of *M. longa* during the remainder of 1917, 1918, or 1919, but it occurred in 81 per cent of the vertical hauls during the spring (March to May) of 1920 and at 90 per cent of the stations during December of that year and in January and March of 1921 (tables, pp. 299, 304). Thus it

is evident that *M. longa* fluctuates widely in the gulf from year to year, being extremely rare, if not altogether absent, in some years but widespread in others. The years 1912 and 1914 and the summer of 1916 were periods of scarcity, while 1915, the winter of 1916–17, and 1920 were times of plenty. The relationship of temperature to these annual differences is discussed below (p. 252).

Seasonal distribution.—During the years 1915, 1920, and 1921, which may be taken as representative of the periods when *M. longa* is at a maximum in the gulf, it was taken at the following percentages of the stations:

Months	Percentage of stations	Months	Percentage of stations
January	100	June	60
February	17	August	75
March	74	September	60
April	87	October	86
May	72	December	87

This suggests that on the whole *M. longa* is apt to be found most widespread in the gulf during the late autumn, winter, and early spring, and least so during the summer and early autumn. The low percentage of stations at which it was recognized in February, 1920 (only station 20046), would upset this rule were it a regular annual phenomenon; but it is more likely that that month marked the beginning of a period of abundance which endured throughout 1920, and that still fewer stations, if any, would have yielded it during the preceding January or December. In fact, a February station was most prolific of this species at St. Andrews during the winter of 1916–17, as noted above (Willey, 1921).

Seasonal fluctuations in the actual abundance of *M. longa*, as reflected in the numbers of specimens per square meter, did not parallel the seasonal rise and fall in the percentage of stations at which it occurred, it being much more plentiful in the vertical hauls in August and October than from March to June or in September of the years 1915 and 1920, as shown in the following table:

Date	Average number per square meter at stations where it occurred	Average number per square meter, all stations included	Date	Average number per square meter at stations where it occurred	Average number per square meter, all stations included
March, 1920	990	692	August, 1915	14,850	13,637
April, 1920	1,650	1,429	September, 1915	2,453	1,533
May (1915 and 1920 combined)	2,504	1,808	October, 1915	8,601	7,280
June, 1915	3,193	1,552			

It is unfortunate that only four vertical hauls were made during August, 1915, when the species averaged so much more plentiful than we have ever found it before or since in the gulf. It may have been only a chance that the net hit local swarms, and more vertical hauls might have proved barren of *M. longa*, thus reducing the month's average. However, the fact that this northern species should have been so plentiful (from 10,300 to 23,400 per square meter) at three late summer stations

when the temperature was near the maximum for the year, and at localities as widely separated as the eastern basin (station 10304), the mouth of Massachusetts Bay (station 10306), and the western basin (station 10307), is an interesting and an unexpected find, for we have seldom found more than two or three thousand per square meter even during its years of abundance.

The numbers per square meter can not be stated for December, 1920, and January, 1921, when *M. longa* was nearly universal in the northern parts of the gulf, for want of vertical hauls; but although the percentages of *M. longa* among copepods as a whole averaged larger then than in any other month except August (table, p. 304), the total catches of copepods were so scanty that the number of specimens concerned was small. Even during its periods of maximum abundance *M. longa* has never been more than a minor element in the total copepod population of the gulf, the average percentages in the vertical hauls for 1915 and 1920 combined being as follows at the stations at which it occurred:

Months	Average percentage	Months	Average percentage
February	10	June	9
March	10	August	17
April	9	September	4
May	3	October	9

If the stations at which it was not taken be counted in, the February percentage is thereby reduced to 2 per cent, August to 12 per cent, and percentages for all the other months by 1 to 3 per cent. The table suggests that in its years of abundance in the gulf *M. longa* is relatively least important in the plankton at seasons when the Calani are most plentiful, irrespective of fluctuations in its own numerical strength and in the generality of its distribution over the gulf.

Vertical distribution.—In the polar basin north of Europe and Asia *M. longa* seems indifferently distributed from the surface downward to 300 meters (Sars, 1900), and Nordenskiöld (1882) has given an interesting account of its occurrence in great abundance along the tide line in water-soaked snow in Spitzbergen.

Passing southward in the eastern Atlantic, European observers have described this species as tending to keep deeper and deeper. Thus, it occurs chiefly between 50 and 200 meters in the seas between Spitzbergen and Greenland, though to some extent at the surface (Damas and Koefoed, 1907); in the Norwegian seas (Damas and Koefoed, 1907) and fjords (Sars, 1903) it has been taken in greatest number below 200 meters, rarely at the surface; chiefly below 300 meters between the Faroes and Iceland (Damas and Koefoed, 1907); and its most southerly record—west of Ireland—was from 540 to 720 meters (Wolfenden, 1904).

It likewise occurs more regularly in the deeper levels than at the surface off the American coast, figuring in only 30 per cent of the surface hauls in the Gulf of Maine for the spring of 1920, contrasted with its presence in 46 per cent of the verticals during that same period; but it is worth noting that at two stations it was taken in the surface but not in the vertical hauls (stations 20081 and 20092),

on the second occasion with 100 specimens in a total of only 400 copepods of all kinds. Willey (1919) also records it much more often from vertical than from surface hauls in the Gulf of St. Lawrence and off Nova Scotia.

I can offer no data on its presence or absence at the surface in the Gulf of Maine during the summer months; but Willey's (1919) tables, which show that a larger proportion of the records of it obtained by the Canadian Arctic expedition were from the surface in May and June than in July and August, suggest that it tends to sink down into cooler strata as the seasonal warming of the top of the water progresses.

The vertical distribution of this species in other seas makes it probable that it ranges right down to the deepest levels in the Gulf of Maine, but the data are not sufficient to show whether it tends to gather at any particular level or is more evenly and indifferently distributed vertically.

When the locality records for *M. longa* are plotted (fig. 75) it is evident that in the years when it is most plentiful in the gulf it becomes generally distributed over the entire area of the latter, indifferently in the peripheral zone, in the central basin, and over the offshore banks as far west as Marthas Vineyard. It should be noted that the absence of summer and autumn records on Georges and Brown's Banks, and in the southeastern part of the gulf generally, is actually not a contradiction, because there were no, or at least very few, *M. longa* in the gulf during 1914, the year when we made our chief midsummer cruise in this region. The apparent predominance of records in the western side of the gulf is equally deceptive, due simply to the fact that we have worked more there than elsewhere.

Immigration and breeding.—The periodic appearances and disappearances of *M. longa* in the Gulf of Maine, coupled with its Arctic nature in general, identify it as primarily an immigrant to the gulf from the north, depending on frequent accessions from more prolific centers to maintain the local stock. But the fact that, unlike most of the immigrant species, it is not localized in the eastern side and around the peripheral belt of the gulf is evidence either that the visiting specimens come in such abundance and live so long that they spread universally over the entire extent of the latter before they perish, or that they succeed in breeding within the gulf to an extent sufficient for the dispersal of the resulting generations to hide the routes of entrance of their parents. In this connection it is instructive to find the distribution of *M. longa* paralleling the spring status of *Calanus hyperboreus*, a species similarly of northern affinities but for which a certain amount of local reproduction within the gulf seems sufficiently demonstrated.

The locations of the stations (fig. 76) where more *M. longa* have been taken than the average numbers per square meter for their respective months (in which respect *M. longa* closely parallels *Calanus hyperboreus*) are further evidence of this. In spring and early summer (the season when the influx of northern water is at its height, and when consequently the greatest invasions of *M. longa* are to be expected) two distinct lines of immigration are suggested by the rich catches—the one inward into the eastern side of the gulf via the northern and eastern channels, and the other westward along the continental edge of Georges Bank. The rich spring catches made in the western side of the gulf in 1920 might have been the result either of local

propagation or of invasion (probably of the latter, judging from the scarcity of the species in the preceding February, as shown in the table on p. 299); but the rich gatherings of *M. longa* made there during August, September, and October, 1915,

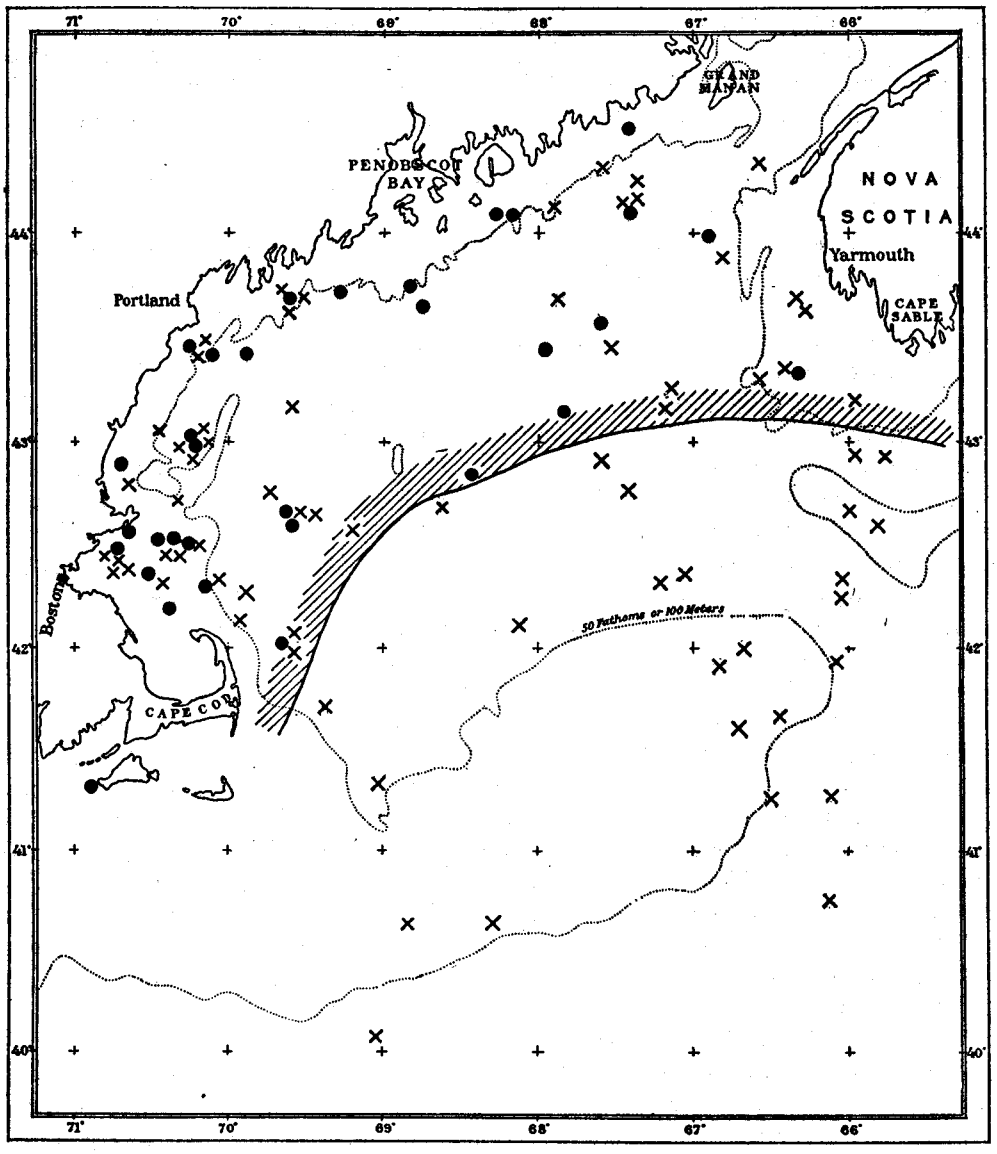

FIG. 75.—Occurrence of the copepod *Metridia longa*. ●, locality records, August to January; X, February to June. The hatched curve incloses the area where it has been found in summer and autumn

are the clearest evidence, short of the actual discovery of breeding adults and of young stages, that active reproduction had been taking place locally, because there was nothing in the plankton in general, in the salinity, or in the temperatures of that

year to suggest that any unusual influx of northern water or immigration of Arctic animals had entered the gulf during that summer. The large catch of *M. longa* on October 21, 1915, near Marthas Vineyard (station 10331, about 9,000 per square

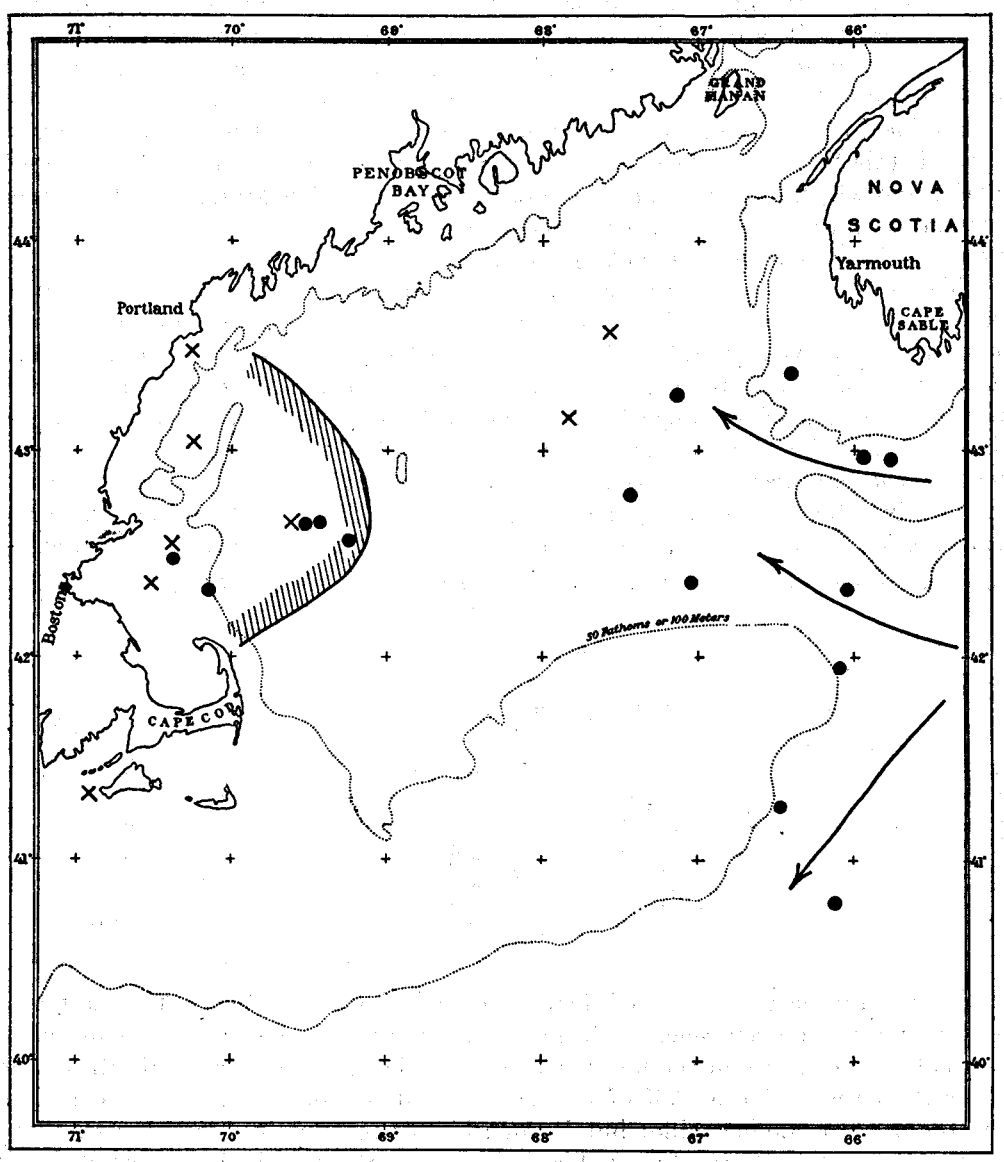

FIG. 76.—Localities where the vertical hauls have yielded more *Metridia longa* per square meter of sea area than the average for the respective month. ●, March to June; X, August to October. The arrows indicate the chief migration routes; the hatched curve incloses the area where reproduction probably takes place within the Gulf

meter), at a location much farther west and south than the species had ever been taken before, is especially instructive in this connection, for in this case there is no possibility that any direct influx had taken place from Nova Scotian waters for

several months previous. Probably the specimens in question had drifted thither around Cape Cod from the center of abundance in the southwestern part of the gulf.

Granting that *M. longa* is able to breed in the gulf to some extent, its periodic disappearances are sufficient evidence that it does so only sporadically and temporarily. Perhaps it is only able to carry on through one or two generations in the high temperatures in which it must exist there, and failing accessions of new stock dies out until there is a fresh invasion from the north. Evidently such fluctuations in local reproduction and migrations mirror the physical features of the water in which this little crustacean lives, but it is not yet possible to state the precise relationship which its temporary appearances in the Gulf of Maine bear to temperature and salinity there or in the waters to the east and north, or to the seasonal or annual variations in the flow of the currents.

There is every reason to class it a cold-water species in the gulf, and it has actually been taken there in water a fraction cooler than zero (at St. Andrews, February, 1917; Willey, 1921); but having been found widespread in the summer and autumn of 1915 in temperatures as high as 8 to 10°, it can survive and perhaps even breed over a wider range than has generally been supposed in European seas, where 6.75° is the highest temperature of record for it (Farran, 1910), and where most of the captures have been from water of 2.25 to 3.25°. *M. longa* was in comparative abundance and apparently in good condition off Marthas Vineyard at 14.5° (station 10331), but it is hardly conceivable that it could have lived long there.

Minimum temperatures at any depth at stations where Metridia longa is recorded for August, September, or October, 1915

Station	Date	Minimum temperature in degrees C.	Station	Date	Minimum temperature in degrees C
10304	Aug. 6	4.78	10325	Oct. 4	5.28
10306	Aug. 31	5.78	10326	do	5.39
10307	do	5.1	10327	Oct. 9	9.4
10309	Sept. 1	5.72	10328	do	9.4
10311	Sept. 2	9.4	10329	do	8.95
10315	Sept. 7	10	10331	Oct. 21	14.5
10318	Sept. 16	8.61	10333	Oct. 22	11.89
10319	Sept. 20	8.5	10337	Oct. 26	10.39
10321	Sept. 29	11.22	10338	Oct. 27	9.4
10323	Oct. 1	6	10339	do	7.28
10324	do	6.78			

More information is needed before the relationship between the salinity of the water and the occurrence of *M. longa* in the gulf can be traced. Most of the records for this species in the northeastern Atlantic have been from salinities rather higher than those of the Gulf of Maine, where it has been taken most commonly in water of 32 to 33.5 per mille; but Nordenskiöld's account (p. 248) suggests that in the very low temperatures of the polar sea it may be able to exist in water but slightly saline, and we took it in salinities of 31 to 32 per mille on several occasions during the spring of 1920 and once in 29.94 per mille (station 20096, surface haul). Probably *M. longa* is never plentiful enough to be of much importance in the natural economy of the Gulf of Maine, but no doubt it serves to some extent as fish food, having been

found in the stomach of the Arctic cod (*Boreogadus saida*) in the Greenland Sea (Damas and Koefoed, 1907, p. 566).

Metridia lucens Bœck

This species has a more southern range than *M. longa*, being widely distributed over the temperate and boreal parts of the North Atlantic but hardly entering the Arctic zone. On the European side it occurs regularly west of France, at the mouth of the English Channel, south and west of Ireland, between the Faroes and Iceland, in the northern part of the North Sea to the Skager-Rak, and northward along the west coast of Norway to the Lofoten Islands. There are a few records of it north of the Murman coast and in the Greenland Sea[39]. To the southward it occurs in the Mediterranean, and it has also been recorded from the Gulf of Suez (van Breemen, 1908). Presumably *M. lucens* ranges right across the North Atlantic, though Herdman did not find it on his passages between England and the Gulf of St. Lawrence (Herdman, Thompson, and Scott, 1898), for the Canadian fisheries expedition had it generally in and off the mouth of the Laurentian channel, along Nova Scotia, and occasionally in the Gulf of St. Lawrence (Willey, 1919, p. 202, fig. 27).

M. lucens is a common species in the Gulf of Maine. Wheeler (1901) reports it from Woods Hole (as "*M. hibernica* Brady and Robertson") and Fish (1925) found it there in winter. During the summers of 1913, 1914, and 1916 the *Grampus* towed it at about a dozen stations on the outer part of the shelf and outside the continental edge southward from off Cape Cod to abreast of Chesapeake Bay (Bigelow, 1915, p. 295; 1917, p. 290; 1922, p. 147), as well as at two localities near land—off Long Island (station 10083, August 1, 1913) and off Delaware Bay (station 10375, August 4, 1916). West of Cape Cod it seems to keep offshore, for Williams (1906 and 1907) does not list it from Narragansett Bay nor does Fowler (1912) from New Jersey. The latitude of Chesapeake Bay, in the one direction, and the deep water between the Scotian and Newfoundland Banks and the Gulf of St. Lawrence, in the other, are, respectively, the southern and northern limits to its known range along eastern North America.

M. lucens is also known from the Pacific, being described by Esterly (1905) as one of the most abundant copepods in the plankton at San Diego, Calif., both in summer and winter.

As van Breemen (1908) has pointed out, this is one of the few copepods which is luminescent, and as it is chiefly responsible for the phosphorescence on the Irish coast in spring (Farran, 1903, p. 12), no doubt it is partly responsible for the brilliant phosphorescence so often seen in the Gulf of Maine.

Distribution in the Gulf of Maine.—Next to *Calanus finmarchicus* and *Pseudocalanus elongatus*, *M. lucens* has appeared most frequently in the towings in the gulf, but with considerable fluctuation in the regularity of its distribution and in the numerical strength of the local stock from year to year. In the summer of 1912 it was recognized at 26 per cent of the offshore stations and at 30 per cent during the ensuing winter; but this was the poorest period for it in our experience, for Doctor Esterly

[39] For a summary of what is known of its distribution see Sars (1903) and Farran (1910).

found it at 76 per cent of all the stations east and north of Nantucket in the summer of 1913 and at 60 per cent of the July-August stations of 1914. The year 1915 yielded *M. lucens* in the vertical hauls at 58 per cent of the stations right through the season, irrespective of locality in the gulf (table, p. 297), and 1920 and 1921 were the best years, with *M. lucens* occurring at 84 to 85 per cent of the stations, both for the spring months and for December and January. In addition to the captures of this species on the recent cruises of the *Grampus*, *Albatross*, and *Halcyon*, Wheeler (1901, p. 176, as "*M. hibernica*") describes it as very common in Plymouth Harbor, Mass., in August, 1899, while Dr. A. G. Huntsman (Willey, 1919) and Dr. J. P. McMurrich [40] have taken it frequently in the neighborhood of St. Andrews.

Plotting the stations at which *M. lucens* has and has not been taken (fig. 77) shows that it occurs over the whole extent of the Gulf of Maine, on the offshore banks as well as inshore, across the whole breadth of the shelf off Marthas Vineyard, and along the continental slope; and although we failed to find it in the harbors of Gloucester, Rockport, Kittery, or Portland during July and August, 1912, its presence in Plymouth Harbor and at St. Andrews proves that it inhabits estuarine and inclosed waters as well as the open sea. The rather confused picture presented by the chart of distribution is simplified if the records be classed as summer-autumn and winter-spring, for all the years combined, and if the gulf be divided as follows:

1. Coastal zone out to 150 meters, Cape Cod to Grand Manan. Summer-autumn, present at 53 per cent of the stations; winter-spring, present at 70 per cent of the stations. (In the Massachusetts Bay region it was present at 77 per cent of the summer-autumn stations.)

2. Off Lurcher Shoal. Occurred at all the stations, both summer-autumn and winter-spring.

3. Coastal banks west of Nova Scotia, out to German Bank. Occurred at all the stations, both summer-autumn and winter-spring.

4. The basin in general, west of longitude 68° 30′. Summer-autumn, at 56 per cent of the stations; winter-spring, at 73 per cent.

5. Basin in general, east of longitude 68° 31′ W, including the Fundy Deep. Summer-autumn, 75 per cent of the stations; winter-spring, 75 per cent.

6. Northern channel. Occurred at all the three stations for which the copepods have been listed, spring and summer.

7. Browns Bank. Occurred at one of two stations in summer, and at the two spring stations for which the copepods have been listed.

8. Eastern channel. Occurred at all the stations, four in number, for which copepods have been listed, summer as well as spring.

9. Eastern half of Georges Bank, east of longitude 68° W. Present at one and absent at one summer station; present at all five spring stations.

10. Georges Bank west of longitude 68° W, and continental shelf off Marthas Vineyard and Nantucket. Present at three of eight summer-autumn stations for which the copepods have been listed and at one station in July, 1916; present at all three winter-spring stations.

[40] In his unpublished lists of the plankton for St. Andrews.

11. Outside the continental edge abreast of the gulf, off Cape Sable, and off Marthas Vineyard. Present at two out of seven summer-autumn stations and three out of four winter-spring stations.

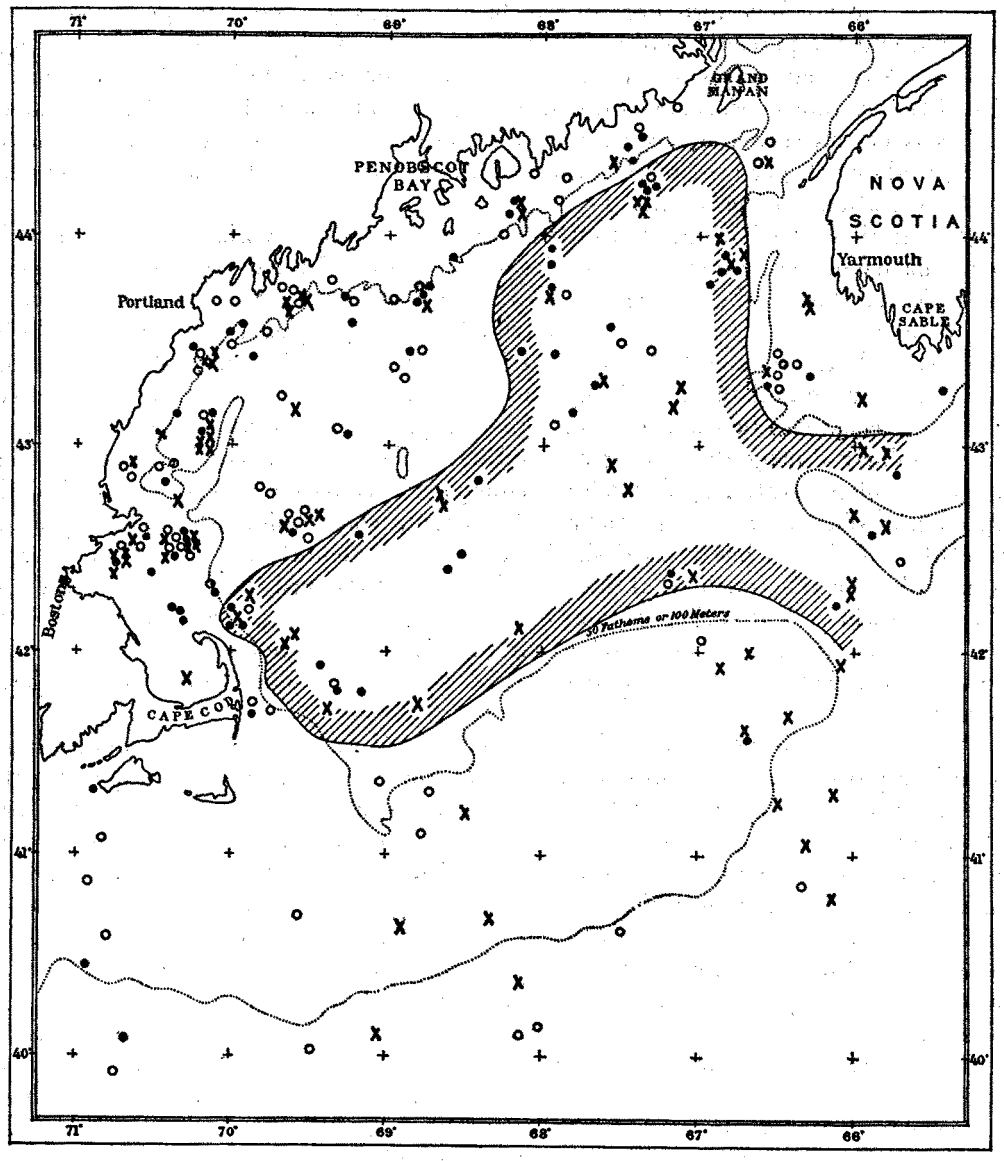

FIG. 77.—Occurrence of the copepod *Metridia lucens*. ●, locality records, June to November; X, December to May; ○, stations where it was not found. The hatched curve incloses the area where it has been taken at 75 per cent of the stations, irrespective of the year or season

Irrespective of the time of year *M. lucens* has appeared more regularly in the towings made in the two deep entrances to the gulf (eastern and northern channels) and along the eastern slope of the basin, where every station in every year has yielded

it, than anywhere else in the gulf. Its occurrence has been nearly as universal over the whole eastern half of the basin and in the southern part right across to Cape Cod (recorded at 75 to 80 per cent of all the stations), but it has been decidedly less regular in the northwestern part of the basin generally (about 63 per cent of the stations), and the percentage of occurrences has been much lower in the deep trough off Cape Ann than anywhere else. The trough between Jeffreys Ledge and the Isles of Shoals, however, seems a definite center of abundance for it. On the whole, *M. lucens* occurs rather less regularly over the coastwise belt out to the 100-meter contour (about 59 per cent of the stations) than in deeper water (about 72 per cent of all the stations in the basin).

In the richer region outlined on this chart no seasonal variation is apparent in the regularity of occurrence of the species for the periods June to October and December to May, the number of occurrences being the same (28) and the number of stations at which *M. lucens* was not detected as nearly equal (6 and 3) as could be expected with the constant possibility that one net will pick up and another miss any particular animal unless it is present in abundance and uniformly distributed.

In the coastwise belt and the northwestern part of the basin it occurs somewhat more regularly during the winter and spring, when it has been detected at about 66 per cent of the stations for which the copepods have been listed by Doctor Esterly and Doctor Wilson, than in summer and autumn, when it figured in only about 45 per cent. *M. lucens* has proved similarly but more definitely seasonal on Georges Bank and over the continental shelf off Marthas Vineyard, having been taken at all the late winter and spring stations of 1920 but at only 30 per cent of the summer and autumn stations; as pointed out in the foregoing regional analysis, this also applies to the waters outside the continental shelf as far offshore as our lines have extended.

When the stations where *M. lucens* was more plentiful than the average for the month are plotted (fig. 78), a definite regional separation can be drawn between the northeastern part of the gulf, where it has been found in relatively large numbers on several occasions in August, September, and October but never in the spring, and the southeastern and southern parts of the area generally, including Georges Bank and its offshore slope and the eastern and northern channels, where rich catches of Metridia have been made in February, March, and April but never from May to October. In the coastwise belt in the western side of the gulf there are "rich" stations both for spring and for summer–autumn.

Seasonal variations in the actual numerical strength of the stock of *M. lucens* in the gulf can only be stated in a tentative way until more extensive data have been gathered, because the annual fluctuations in its abundance introduce a source of error of unknown magnitude into calculations based on a combination of the data for different years; and unfortunately the only year when vertical hauls were taken at frequent intervals from spring until autumn (1915) was one in which this copepod occurred less regularly than it sometimes does. Furthermore, *M. lucens*, like most other copepods, has proved decidedly "streaky" in its distribution. This phenomenon was illustrated off Gloucester on May 4, 1920, when, with the *Albatross* lying at anchor, a vertical haul at 3 p. m. (station 20120) yielded this species at the

rate of 16,500 per square meter (an unusually rich catch for it in the gulf), but a second vertical haul with the same net, hauled up at the same rate of speed and from a

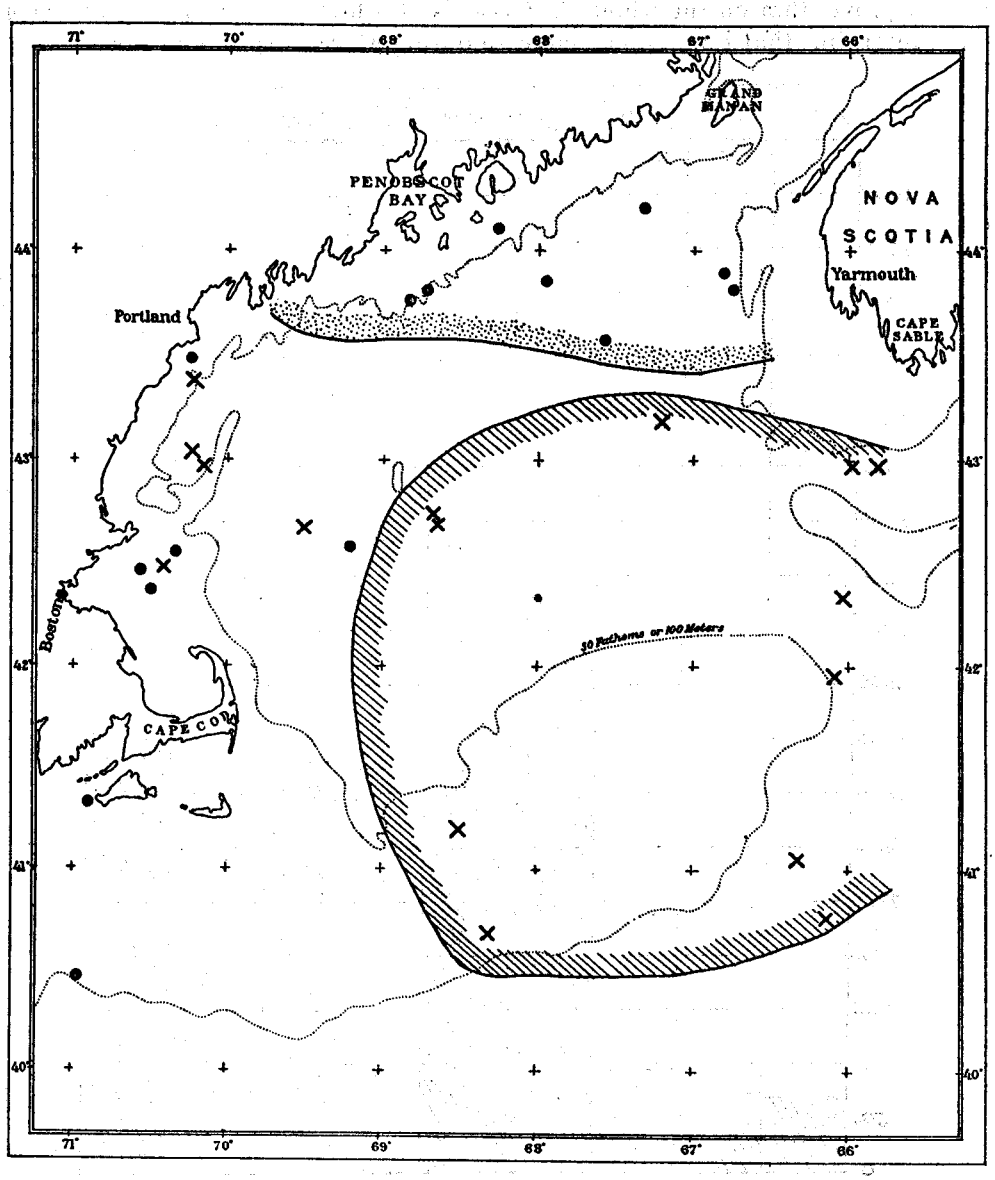

FIG. 78.—Localities where the vertical hauls have yielded a larger number of *Metridia lucens* per square meter than the average for the respective month. ●, June to October; X, February to May. The hatched curve incloses the area where it has been found notably abundant only in late winter and spring; the stippled curve where it has been found abundant only in summer and autumn

slightly greater depth (55 meters) at 10 p. m., gave a frequency of only 252 per square meter. Evidently the shoal encountered by the first haul had drifted past with the tide during the 7-hour interval before the second haul was made. Never-

theless, the average numbers per square meter, calculated by months, for the seasons of 1913, 1915, and 1920 combined (fig. 79), are consistent enough to suggest, though hardly to prove, that on the whole *M. lucens* is at a low ebb numerically at the end of the winter, but that its numbers increase during March, April, and May.

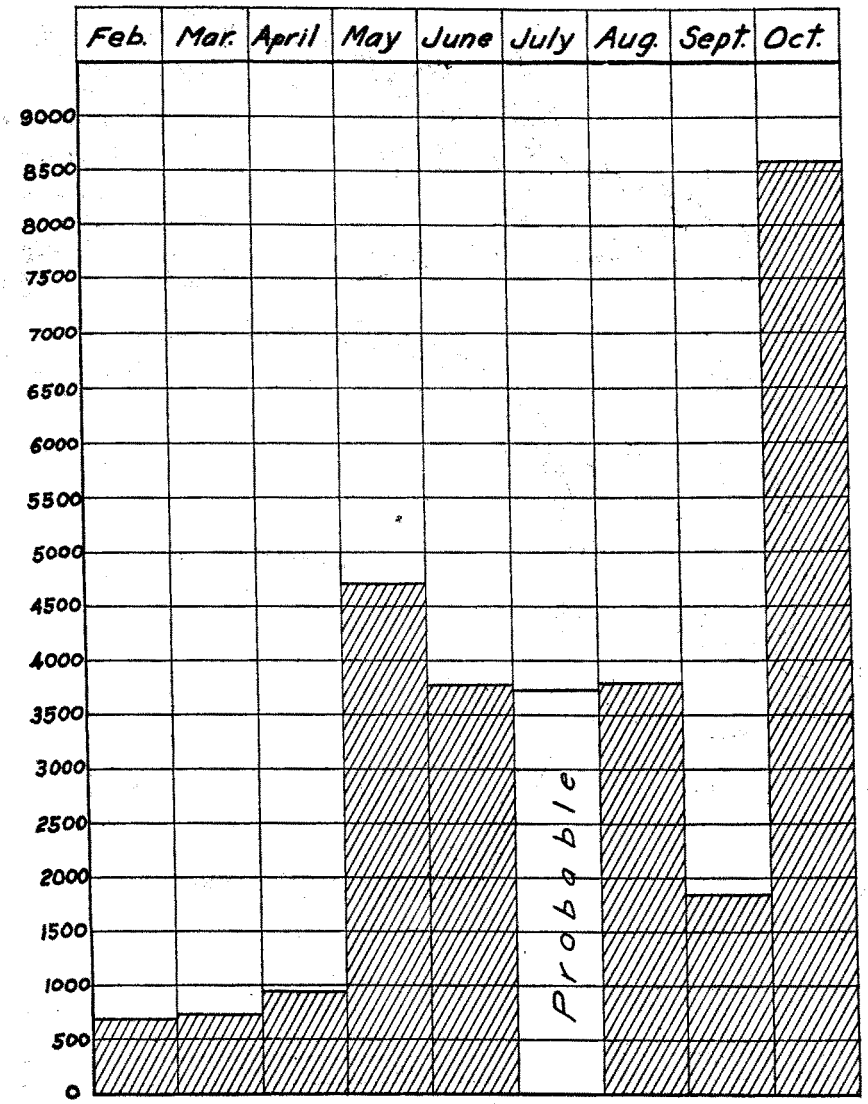

FIG. 79.—*Metridia lucens*. Average numbers per square meter of sea area taken in the vertical hauls, by months, for all the years and stations combined

Off Gloucester the number rose from nothing on March 1, 1920 (station 20050), to 150 per square meter on April 9 (station 20098) and to 16,500 in one haul on May 4, but only 252 in another, as just noted. Off the Isles of Shoals the increase was from none on March 5 (station 20061) to 1,500 per square meter on April 9 (station 20093).

In the western basin the number per square meter rose from none on February 23 (station 20049) to 5,550 on March 24 (station 20087), and then declined again to only 200 per square meter on April 18 (station 20015). It is probable, however, that this decline was local, one haul hitting and the other missing a shoal, for a few miles to the eastward. The interval from March 2 (station 20052) to April 17 (station 20114) saw the number of *M. lucens* increase from 1,250 per square meter to 3,000. Increases were likewise registered in the southeastern part of the basin, in the eastern and northern channels, and over the eastern part of Georges Bank from March to April. In the year 1915 the average number of *M. lucens* at 4 stations in the inner part of the gulf was about 8,000 in May, but one very rich catch, at the rate of about 26,000 per square meter off the Isles of Shoals (station 10278), was chiefly responsible for this large figure.

In 1920 the vernal augmentation of *M. lucens* was apparent earliest in the season over a belt extending west-east across the gulf from the Massachusetts Bay-Cape Elizabeth region to the southeastern part of the basin; but no general change of this sort can have taken place in the northeastern part of the gulf generally until a month or more later, because all the early spring catches were decidedly scanty there (at the most 550 per square meter), and in most instances the March figure was somewhat larger than the April count. Neither did the numbers of *M. lucens* taken in the southwestern part of the basin and over the western end of Georges Bank in that year show any change sufficient to be classed as seasonal, some of the later catches being the larger, some the smaller. Off the southeastern slope of Georges Bank there was an apparent falling off in the numbers of *M. lucens* from March 12 (stations 20067 to 20069) to April 16 (station 20109), but a high frequency (2,360 per square meter) on the east slope of the bank on the 16th (station 20108) makes it likely that the apparent seasonal drop actually reflected nothing more significant than a streakiness in the distribution of the species. However this may be, our failure to find *M. lucens* at the stations outside the slope of Georges Bank in July, 1914 (stations 10218, 10220), argues against the idea that this region is the site of a vernal augmentation such as takes place in the inner part of the gulf.

An average of about 3,300 per square meter at 14 stations in the inner part of the gulf for August, 1913, ranging from 600 to 9,000 at the individual stations (Bigelow, 1915, p. 286), does not indicate any notable alteration in the numerical strength of the stock of this species during the summer. One August station for 1915 (10304, eastern side of basin) was unusually productive of *M. lucens*, the vertical haul taking it at the rate of about 23,000 per square meter, but probably the net chanced to pass through a local shoal of these little crustaceans on this occasion.

In 1915, which may or may not have been a typical year, some multiplication of *M. lucens* seems to have taken place from August to October, for though the differences between the numbers taken are not large they are consistent. Thus none at all were taken in a vertical tow off Gloucester or in the basin off Cape Ann on August 31 (stations 10306 and 10307), but the stations in the coastal zone between Cape Cod and Cape Elizabeth (stations 10319, 10320, and 10321) gave an average of about 2,400 per square meter on September 20 to 29. On October 1 to 4 three stations along the same zone (stations 10323, 10324, and 10325) gave an average of

nearly 6,000, and *M. lucens* averaged about 8,000 per square meter at two stations at the mouth of Massachusetts Bay on October 27 (stations 10338 and 10339).

The count off Penobscott Bay rose similarly from 590 per square meter on September 16 (station 10318) to 12,250 per square meter on October 9 (station 10329), and from none at all off Machias, Me., on September 11 (station 10316) to 7,687 per square meter on October 9 (station 10327). In no case did we find the numbers of *M. lucens* decrease from September to October at any given locality. Though the evidence just detailed is not precise, with each example being explicable as the result of chance, when all are taken together they point to a more or less definite autumnal maximum for *M. lucens* within the Gulf of Maine.

The scarcity of *M. lucens* in the Woods Hole region in summer, deducible from the fact that the only specimen which Wheeler (1901) saw there was taken in December, contrasted with large catches of 11,700 and 16,300 per square meter made close in to Marthas Vineyard and offshore on this line on October 21, 1915 (stations 10331 and 10333), suggests a similar autumnal augmentation for the species as far west and south as it regularly inhabits the shoal waters over the inner part of the continental shelf.

Unfortunately no vertical hauls were made, and consequently the numbers per square meter can not be stated for the later autumn or until February in any year; but it is probable that the numbers existing over the Gulf of Maine as a whole suffer a sharp drop in November because the catches of copepods in the horizontal hauls during the midwinter of 1920–21 were uniformly very scanty, *M. lucens* averaging only about 8 per cent of them.

Vertical distribution.—In other seas *M. lucens* has been found from the surface down to 2,000 meters. In the North Atlantic it is, on the whole, most abundant between 50 and 100 meters, with a decided tendency to swim up to the surface at night and to sink again by day (Farran, 1910); but in the San Diego region on the Pacific coast of the United States, where Esterly (1912, p. 301) describes it as "overwhelmingly more abundant and frequent on the surface between 10 p. m. and 2 a. m." and "practically absent from the surface between 8 a. m. and 8 p. m.," its daytime plurimum is much deeper—200 to 300 fathoms.

In the gulf of Maine it is decidedly more numerous at some little depth than at the surface, and the frequency of its presence at the top of the water is apparently a factor of the time of year, to some extent, as well as of the time of day. Thus, during the spring of 1920 it was recognized in 24 surface hauls (table, p. 303), widespread over the gulf, and in 62 verticals. It has been listed only five times at the surface in July and August—twice in 1912 (Bigelow, 1914, table, p. 115), three times in 1914 (Bigelow, 1917, table, p. 290), and not at all in 1913, although this was a summer when it was nearly universal east and north of Cape Cod. No data are available for 1915. As regards the time of day, sixteen of the spring records for it at the surface were from between 6 p. m. and 8 a. m., and eight between 8 a. m. and 6 p. m. All but one of the summer records were between sunset and sunrise, the single exception (station 10245, August 12, 1914) being for 10.30 a. m., but at a locality near Lurcher Shoal where considerable vertical stirring of the water by tidal currents is to be looked for. Thus, in the Gulf of Maine *M. lucens* is more apt to come to the surface

in spring than in summer, and its excursions upward to the top of the water are not so closely confined to the hours of darkness in spring as they are during July and August.

The vertical hauls shoaler than 100 meters yield further evidence of a diurnal migration of *M. lucens*, for the catches have averaged decidedly larger between 6 p. m. and 8 a. m. (average 4,246 per square meter for 26 stations) than between 8 a. m. and 6 p. m. (average 896 per square meter for 21 stations); and if further separated into two groups by months—February to May and September to October—the same holds good, as follows:

	6 p. m. to 8 a. m.	8 a. m. to 6 p. m.
Average number per square meter, February to May	1,601	287
Average number per square meter, September to October	7,854	4,553

To compensate for this, smaller averages might be expected by night and larger by day in the deeper hauls as the Metridia swim up and sink back. Interpretation of these and comparison of the deeper hauls with the shoaler is complicated by the fact that we have one unusually rich catch of almost 23,000 per square meter in a vertical haul from 200 to 0 meters (station 10304, August 6, 1915) by night, but it is obvious that if the specimens in question were concentrated near the surface, as is perfectly possible, a shoal haul would have caught nearly or quite as many. This applies to any individual haul, but when deep hauls consistently average more productive than shoal, with a greater difference than can be accounted for by the longer column of water fished through, it is safe to say that the animals are concentrated in the lower levels.

The greater the number of hauls, the greater the dependence which can be placed on the average results. In the present case the number of hauls is not large enough to warrant definite conclusions. If the one very rich deep haul just mentioned be omitted, we have 1,190 as the average number per square meter in vertical hauls from deeper than 200 meters from 8 a. m. to 6 p. m. and 1,200 from 6 p. m. to 8 a. m. This does not suggest any diurnal migration as deep as 200 meters.

It is obvious that the contour of the bottom of the gulf largely determines the depth range of this copepod or of any other animal, for such of the stock as inhabit the coastal zone are necessarily confined to a very shoal stratum. No copepod can sink as deep in the Gulf of Maine, where the greatest depth is only about 330 meters, as it can off San Diego. Apart from this limitation by topography, however, the level of plurimum abundance of this species is about the same in the gulf as in the eastern North Atlantic—namely 50 to 150 meters. Thus all but one [41] of the vertical hauls which have yielded 5,000 or more per square meter have been from depths of 200 meters or less, more than half of them shoaler than 100 meters, irrespective of the time of day or part of the gulf in which the stations were located. The depths of the five richest catches of all (those yielding *M. lucens* at the rate of more than 15,000 per square meter) have likewise varied from shallow to deep.

[41] The exception is station 20087, Mar. 24, 1920, from 250 meters.

Station	Date	Number of Metridia lucens per square meter	Depth in meters	Station	Date	Number of Metridia lucens per square meter	Depth in meters
10278	May 14, 1915	26,250	150–0	10333	Oct. 22, 1915	16,300	80–0
10304	Aug. 6, 1915	23,450	200–0	20120	May 4, 1920	16,500	48–0
10328	Oct. 9, 1915	17,100	60–0				

These average numbers of this copepod per square meter, calculated from the vertical hauls, do not suggest that the strata of water below 150 to 200 meters added appreciably to the catches, although not enough deep hauls were made for a positive assertion.

Depth of vertical hauls	Average number per square meter
Between 30 and 100 meters	2,750
Between 101 and 199 meters	3,136
Deeper than 200 meters	2,562

Local breeding and immigration.—No direct observations have been made on whether or to what extent *M. lucens* spawns in the Gulf of Maine. Consequently, its geographic and seasonal distribution is the only basis on which to judge whether the local stock is chiefly the result of local reproduction or depends upon immigration from richer centers of propagation for its maintenance. The regularity of occurrence and comparative abundance of the species within the gulf is a strong argument that it is regularly native there. Its regularly increasing numbers during the spring and the pronounced augmentation in its numerical strength in September and October likewise point to vernal and autumnal waves of propagation. However, no definite areas of abundance which might be looked upon as local centers of reproduction have yet been demonstrated for this species in the gulf, notwithstanding the large numbers of locality records and counts of actual abundance which the *Grampus*, *Albatross*, and *Halcyon* cruises have afforded. The fact that it has been found most regularly in the eastern and southern parts of the gulf points to a certain amount of immigration via the two channels and across Browns Bank from the continental shelf off Nova Scotia, where the Canadian fisheries expedition found it widespread (Willey, 1919).

Until its status is better understood in the gulf the latter may be looked on as a regular and important breeding center for it, but with the local stock augmented by immigration.

Relationship to physical conditions.—In other seas *M. lucens* has been found over a wide range of temperatures from 4.83 to 20.5°, usually upwards of 5.5°; and in salinities ranging from 28.1 to 35.4 per mille, most commonly in 33.3 to 35.3 per mille (Farran, 1910; Esterly, 1912). The Gulf of Maine records bring the lower limit of temperature down to 0.33 to 0.78° (station 20062, March 5, 1920); and its presence on the surface in the coastal waters of the gulf in late winter and early

spring (e. g., stations 20056, 20058, 20060, 20061, 20077, 20081, and 20083, March, 1920) makes it unlikely that any temperature that may be experienced in the open gulf is fatally cold for this species, though it may not be able to survive the subzero temperatures of ice-laden seas. On the other hand, one of the records of it on the surface of the western basin (station 10256, August 23, 1914) was from nearly as high a temperature (19.56°) as it has ever been found in, although it could have reached decidedly cooler water by sinking a few meters. Most of the records of this copepod in the gulf have been from temperatures between 4 and 15°, but, like Esterly (1912), I have found it impossible to correlate its regional and seasonal variations in abundance with changing temperature. Nor is it likely that its distribution within the gulf is governed by local differences in salinity, the whole of that body of water being well within the limits within which *M. lucens* occurs commonly elsewhere.

Economic importance.—While no definite observations seem to have been made on the extent to which *M. lucens* is eaten by plankton-feeding fishes, it is generally assumed to be an important article in the diet of the mackerel in Irish waters. No doubt mackerel, all the herring tribe, and the other copepod eaters consume it to some extent in the Gulf of Maine, but it averages such a small numerical percentage of the catch of copepods compared with the dominating swarms of *Calanus finmarchicus*, which its adults about equal in size, that it can vie with the latter in economic importance only when local shoals gather.

Average percentage of Metridia lucens, by months, in the total catches of copepods

Hauls	Percentage	Hauls	Percentage
March, 1920, verticals	8	September, 1915	4
April, 1920, verticals	7	October, 1915	12
May, 1915 and 1920, verticals	5	December, 1920, horizontals	6
June, 1915, verticals	9	January, 1921, horizontals	12
August, 1913 and 1915	5		

On three occasions in October, 1915 (stations 10327, 10328, and 10329), *M. lucens*, forming 25 to 30 per cent of a moderately abundant copepod community (table, p. 298) and about equaling Calanus, would have offered an attractive pasture for the schooling fishes. This was also the case off Gloucester on May 4, 1920 (*M. lucens* constituted 30 per cent at station 20120). In every other instance, however, when we have found it forming 25 per cent or more of the copepods the total catch of all kinds has been extremely scanty.

Monstrilla serricornis Sars

G. O. Sars described this species in 1921 from two male specimens taken off the west coast of Norway. Occasional specimens from four surface hauls in the Gulf of Maine in March and April, 1920 (table, p. 303), are the second record of its occurrence; but these four, including Browns Bank, the northeastern part of Georges Bank, the neighborhood of Lurcher Shoal, and Mount Desert Island, indicate that it is to be expected anywhere in the gulf. It is the only representative of its family yet reported there.

Oithona similis Claus

This species has variously been described as "world-wide" (Farran, 1910) and as Arctic, with southern extension (Willey, 1920). The first would seem to fit it best, for it has been taken from Barents Sea, Spitzbergen, and from the Arctic coasts of Alaska and Canada (Willey, 1920) in the north, right down the whole extent of the North and South Atlantic to latitude 35° S., and beyond that to latitude 60 to 65° S. in the Antartic south of Kerguelen Island. It is likewise widespread in the Red Sea and in the Indian Ocean and about Ceylon; it is also reported from the Pacific and New Zealand, occurs in the Mediterranean, has been taken at the Canaries, is plentiful about the British Isles, enters the Baltic, and is abundant along the whole coast of Norway, in the Norwegian sea, and in Barents Sea.[42] It occurred in practically every one of Herdman's gatherings right across the North Atlantic and through the Gulf of St. Lawrence from Liverpool to Quebec (Herdman, Thompson, and Scott, 1898). T. Scott (1905) also lists it from the Gulf of St. Lawrence, but the only other published records for it on the eastern coast of North America are for Woods Hole (Wheeler, 1901; Fish, 1925) and Rhode Island (Williams, 1907).

This species appears in Doctor McMurrich's plankton lists for St. Andrews during December and January in about two-thirds of the hauls; less frequently during February and March (about 50 per cent of the hauls). During the late spring, summer, and early autumn until mid-October, it was found in about 11 per cent of the hauls. This indicates a winter plurimum for the species, but at no season was it as abundant as the larger calanoids, being almost always recorded in the lowest of the four classes of abundance (1 to 4) used by Doctor McMurrich.

Oithona similis was not found in any of the earlier towings in the open gulf, but being so frequent at St. Andrews and so widely distributed over the high seas elsewhere, probably this slender little copepod has usually slipped through the comparatively large-meshed nets used for the vertical hauls and for the horizontals for which the copepods have been listed. This seems the more likely because the Canadian fisheries expedition did not take it at all in many hauls in the Gulf of St. Lawrence, where Herdman found it in almost every gathering. This is corroborated by Doctor Wilson's report of it at several stations in 1920 and 1921, as noted below in his supplementary note on the copepods (p. 306).

Perhaps no marine planktonic copepod exists over a wider range of temperature and of salinity than does this little cyclopid. Equally at home in the tropic Indian Ocean, in polar seas close to the freezing point, in the brackish Baltic (it has been found there in salinity as low as 7 per mille), and in the very salty surface water of the Gulf of Suez and Red Sea (salinity upwards of 38 per mille), it is not likely that either of these factors determines its seasonal periodicity or regional distribution in the Gulf of Maine.

Paracalanus parvus (Claus)

This species is probably cosmopolitan in temperate and tropical seas, the localities from which it has already been reported being almost "world wide" (Farran, 1910, p. 61) except for the Arctic and Antarctic. These include the northeastern Atlantic

[42] For further details see Giesbrecht (1892); Sars (1918); Farran (1910); Thompson and Scott (1903); Wolfenden (1911); Willey (1920); van Breeman (1908).

up to Denmark Strait and to the north of Iceland (With, 1915); the Faroes; the west and south coasts of Norway; the English Channel; southern part of the North

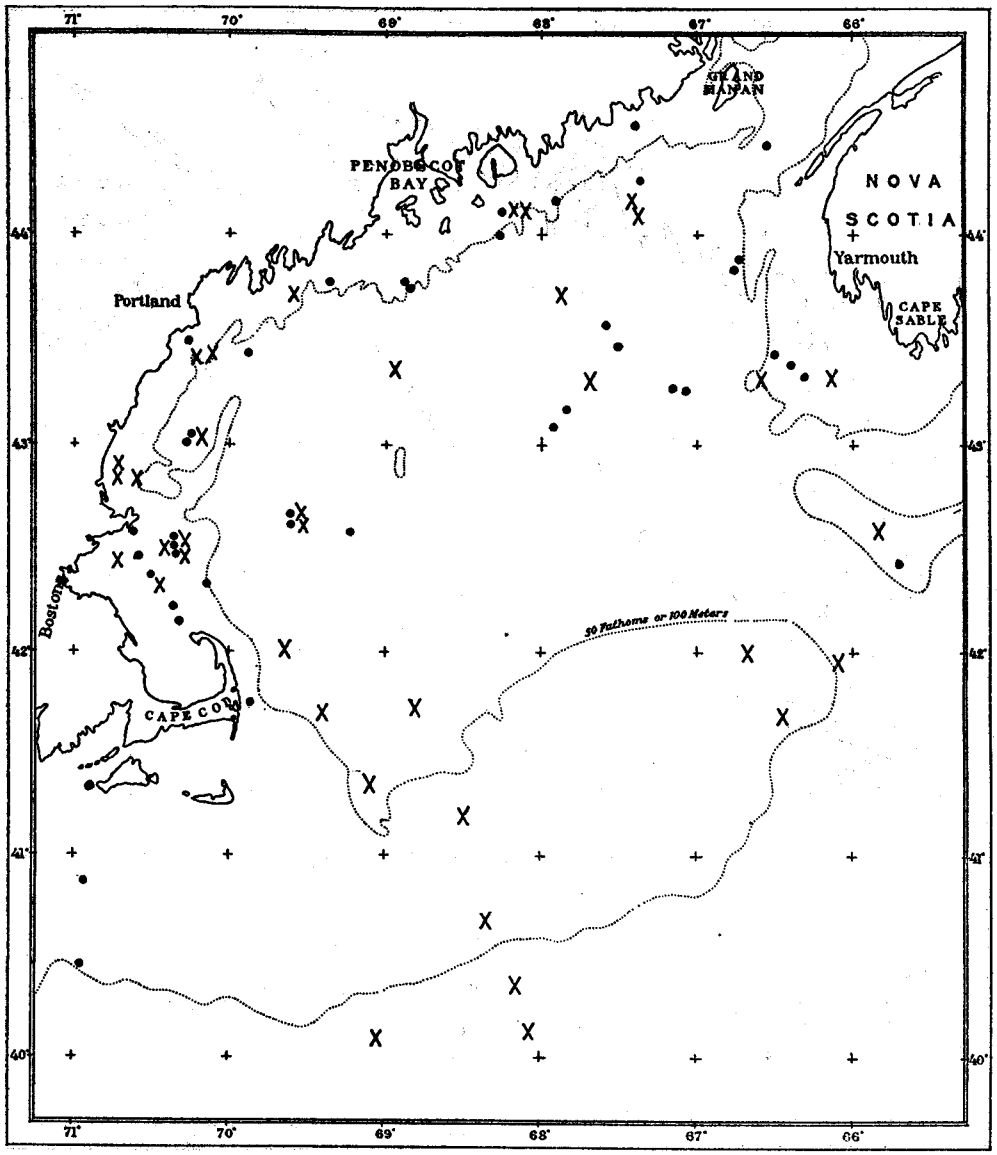

FIG. 80.—Occurrence of the copepod *Paracalanus parvus*. ●, locality records, June to October; X, December to May

Sea, Skager-Rak, and west Baltic; the Mediterranean and Black Seas; the Gulf of Guinea (T. Scott, 1894[43]); the south Atlantic off the Cape of Good Hope; the Red and Arabian Seas and the Indian Ocean (A. Scott, 1902 and 1909; Cleve, 1901); the Malay

[43] Wolfenden (1911) questions whether these specimens of Scott's were correctly identified.

Archipelago; New Zealand (Brady, 1901); and from various other localities in the Pacific between latitudes 61° N. and 55° S.[44]

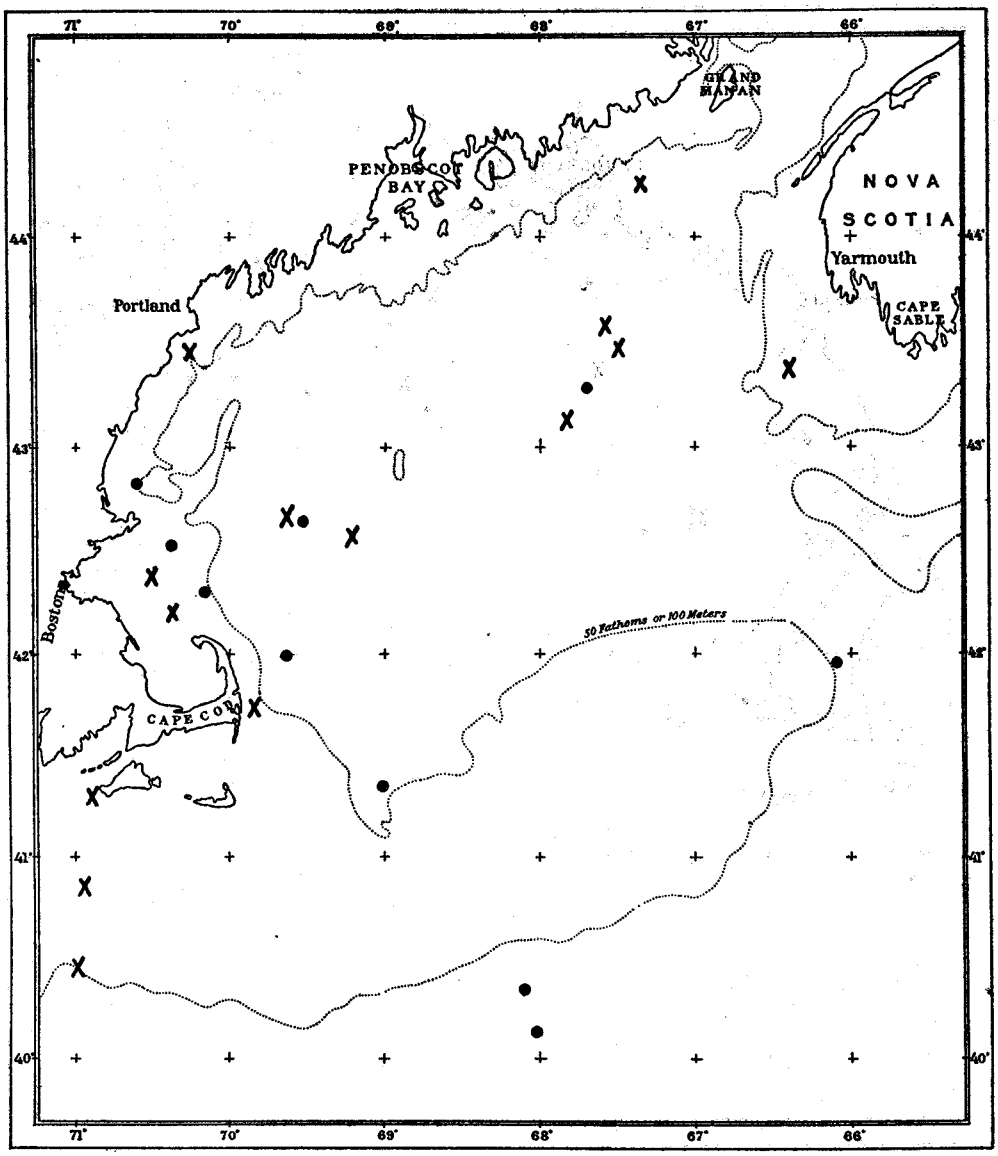

FIG. 81.—Stations where the vertical hauls have yielded more *Paracalanus parvus* per square meter than the average for the respective month. X, June to October; ●, February to May

There are only three previous records for it on the east coast of North America—that is, Gulf Stream off Woods Hole (Wheeler, 1901), Woods Hole (Fish, 1925), and

[44] For a more complete account of the distribution of this species as at present understood see Thompson and Scott (1903), Farran (1910), and With (1915).

Gloucester Harbor (Esterly, in Bigelow, 1914, p. 116). Farran (1910) has classed it as a tropical and temperate form, which is corroborated by Willey's (1919) failure to find it in the collections of the Canadian fisheries expedition off Nova Scotia and Newfoundland or in the Gulf of St. Lawrence, where it has never been reported, and by its absence from the plankton collections made by Herdman off the Straits of Belle Isle (Herdman, Thompson, and Scott, 1898); but it ranges eastward along Nova Scotia for some distance past Cape Sable, for the *Grampus* took it at three stations across the continental shelf off Shelburne, Nova Scotia, on June 23, 1915 (stations 10291, 10293, and 10294), and the *Albatross* found it again near Roseway Bank (station 20074) and outside the continental edge on this line (station 20077) on March 19, 1920.

Paracalanus parvus may have been overlooked in the earlier towings in the Gulf of Maine because it is so tiny (it is the smallest of calanoids), but the collections of 1915, 1920, and 1921 prove it present in the gulf in every month in the year except July and November, when no hauls were made—that is, a year-round resident. In spite of its brief history in our towings its records extend widespread over the gulf, indifferently outside the continental edge, over the offshore banks, in both sides of the deep basin, and all around the coastal belt (fig. 80). There are also records over the continental shelf off Marthas Vineyard (stations 10331 to 10333; table, p. 298).

In spite of the seasonal fluctuations outlined below, the regional distribution is as general in the cold half of the year as in the warm half, and Paracalanus occurs in all parts of the gulf and about as regularly in one region as another. The plotted records might suggest a concentration in the inner parts of the gulf, but in reality this merely reflects the greater number of hauls which have been made there, and more especially the fact that no towing was done in the southern or eastern parts of the basin or on Georges Bank during the summer of 1915. In short, this copepod is to be expected anywhere in the region at any time of year. I have not been able to subdivide the gulf into regions "rich" or "poor" for this species, whether for the year as a whole or for the individual months, the stations where catches were larger than the monthly average being widely distributed (fig. 81) (having reference to the regional distribution of the hauls in different years and seasons) both for the winter-spring and for summer-autumn; but we have taken it in much larger numbers off Marthas Vineyard (station 10332 and 10333) than anywhere east or north of Nantucket, suggesting that the waters over the continental shelf south of southern New England are a center of abundance for it.

Seasonal fluctuations.—*P. parvus* has been taken at the following percentages of the stations for 1915, 1920, and 1921 (tables, p. 298):

Date	Percentage of stations	Date	Percentage of stations
March, 1920 and 1921	29	September, 1915	75
April, 1920	23	October, 1915	93
May, 1915 and 1920	80	December, 1920	50
June, 1915	100	January, 1921	40
August, 1915	100		

Cautioning the reader that the difference may be partly explicable as evidence of "rich" and "poor" years for the species, the percentages indicate that it is practically universal in the inner half of the gulf throughout the summer and early autumn but less plentiful during winter and spring. The average number per square meter likewise shows it to be most abundant in the inner part of the gulf during the warm months.

The average numbers of *P. parvus* per square meter in vertical hauls, counting only the stations where it occurred, are as follows:

Date	Average number	Date	Average number
March, 1920	455	August, 1915	14,042
April, 1920	600	September, 1915	4,065
May, 1915 and 1920	3,656	October, 1915	9,045
June, 1915	1,015		

If the table were made to include the stations where it was absent, or at least so rare that the vertical net failed to take it, the discrepancy between March and April and the other months would be still greater. The hauls for February, 1920 (stations 20044 to 20048), are omitted from this table because the high average resulting from them (about 2,000 per square meter) is due to catches of 5,000 and 3,000 per square meter at the two stations outside the continental edge (stations 20044 and 20045), which would undoubtedly be several times too high for the inner waters of the gulf at this season.

In the western side of the basin Paracalanus increased in number in 1915 from about 1,000 per square meter on May 5 (station 10267) and 1,300 on June 26 (station 10299) to 16,100 on August 31 (station 10307).

In the eastern side of the basin where there were only about 1,100 Paracalanus on June 19 (station 10288) the vertical haul took 23,450 per square meter on August 6 (station 10304). On September 29 there were 850 per square meter at a station in Massachusetts Bay (10320), and the number had risen to about 14,000 by October 27 (mean of stations 10338 and 10339). A change of the opposite order at a neighboring location near Gloucester, where the number per square meter declined from more than 25,000 on May 4 (station 10266) to about 2,500 on August 31 (station 10306) and about 3,000 on October 1 (station 10324), shows how the formation and dispersal of local shoals may more than offset the general seasonal augmentation of the species at any particular locality.

Off the Isles of Shoals a slight decrease took place from 5,250 per square meter on May 14 (station 10278) to 3,170 on October 4 (station 10325); on German Bank the figure remained about stationary from May 7 (1,500 per square meter at station 10271) to June 19 (1,500 at station 10290) and September 2 (1,600 at station 10311).

Notwithstanding these irregularities, not one of the October stations yielded less than 2,000 *P. parvus* per square meter, and the maxima within the gulf were much greater in October (30,750 off Cape Cod, station 10336, and 24,450 in Massachusetts Bay, station 10338) than in September (6,650 per square meter, station 10319). Thus it seems that there are actually more *P. parvus* in the gulf in mid-autumn than

a month earlier in the season; probably more than in summer, though perhaps no more than in May. This parallels its seasonal periodicity off northern Europe, for it is usually most plentiful in the English Channel in autumn (Farran, 1910), with its plurimum falling in late summer and early autumn in the northeastern Atlantic up to Iceland (With, 1915).

Another fact clearly brought out is that this species, like most other copepods, may be decidedly streaky in its distribution at times. For instance, when we made one of our richest catches of it (24,450 per square meter at station 10338) on October 27, 1915, there were hardly one-sixth as many a few miles inshore (station 10339; about 4,040 per square meter). As a less striking example, there were respectively 3,600 and 3,400 at two stations (10321 and 10324) at the mouth of Massachusetts Bay on September 29, but only 850 per square meter at a third station (10320). This makes it impossible to draw any but the most general conclusions from the numbers of specimens taken until a much larger body of information has been accumulated.

I have purposely refrained from discussing seasonal periodicty for *P. parvus* on the offshore banks for want of sufficient data. Until something is known of its status there during the summer and autumn all that can be said is that it was slightly more plentiful on Browns Bank on June 29, 1915 (470 per square meter, station 10296) than on March 13, 1920 (60 per square meter, station 20072), but both catches were so scanty and the difference between them so small that it is not significant. On the eastern part of Georges Bank it was not taken at all at two stations on March 11, 1920 (stations 20065 and 20066), but was comparatively plentiful on April 16 and 17 (3,400 per square meter at station 10310; 1,640 at station 10311). Off the southwestern slope of the bank, on the contrary, it was much more numerous on February 22 (5,000 and 3,000 per square meter, respectively, at stations 20044 and 20045) than on May 17 (only 400 per square meter at station 20129), contradictory observations from which no conclusions can be drawn.

Vertical distribution.—With (1915) has described the species as usually near the surface in the northeastern Atlantic, and the majority of records of it in other seas have been from shoal towings. In the Gulf of Maine, however, it showed no tendency to congregate in the uppermost strata during the spring of 1920, for it was detected in a smaller percentage (10 per cent) of the surface hauls than of the vertical hauls, and only in small numbers at these few (table, p. 303). Little can be said of its vertical distribution in other months of the year because the copepods have not yet been listed from any of the surface hauls for 1915 or subsequently, and a record from a vertical haul merely locates the specimen somewhere between the top and the bottom of the water. It is probable, however, that most of the specimens collected by the *Halcyon* in 1920–1921 (table, p. 304) came from the general level at which the nets were working horizontally—that is, from depths varying from 20 to 240 meters.

The average depth of all the vertical hauls which had more than the average number of *P. parvus* is 127 meters, and the four richest catches of all—that is, those with more than 20,000 *P. parvus* per square meter (stations 10332, 10333, 10336, and 10338)—were, respectively, from 50–0, 80–0, 50–0, and 80–0 meters, locating the zone of chief abundance for the species as shoaler than 100 to 125 meters.

Relationship to temperature and salinity.—The geographic distribution of *P. parvus* in the ocean in general points to moderately high temperatures as most favorable for it, justifying Farran's (1910) characterization of it as a tropical and temperate species. The many records of it in the Red Sea, around Ceylon, and in the Malay Archipelago, often from hauls no deeper than the intake pipe of a steamer's pump (A. Scott, 1902), make it probable that no temperature ever prevailing in the open sea is fatally high or even unfavorably so for it. Toward the other extreme, the presence of *P. parvus* at so many localities in the Gulf of Maine in February and March (table, p. 299) proves it able to survive cooling down to 3 to 5°. In fact, the actual localities and depths of capture locate it in water fractionally cooler than 2° at three different stations;[45] but most of these February-March records are from localities where the temperature was above 3° at some level between the surface and the bottom (stations 20044, 20045, 20046, 20048, 20054, and 20081). Specimens drifting into colder regions or levels of the gulf in early spring may perish, as any animal finding its optimum environment in high temperature probably would.

Thus, the zone close to the coast may well be a death trap for this copepod during the coldest season, but the stock living in the basin can avoid winter chilling by sinking to the deeper levels, where it would not experience a temperature lower than 4 to 5° in most years. Therefore, it would not be surprising if more extensive study proves its zone of maximum abundance in the gulf to lie at a greater depth during the coldest season than during summer and autumn. Tending to corroborate this prediction is the fact that the richest catches for March and April (stations 20054 and 20115) were in vertical hauls from 250 and 295 meters, respectively, where the temperature below 150 meters was 5° or higher; and that the vertical nets fished through zones of water warmer than 10° (below 100 meters) at the localities of the "rich" catches off the southwest slope of Georges Bank for February (stations 20044 and 20045).

Previous records locate *P. parvus* in salinities higher than 40 per mille in the Arabian Gulf and as low as 19.33 per mille in the Kattegat. In addition it appears indifferently oceanic or neritic, occurring from the open sea, on the one hand, to tide pools, on the other (*fide* Dr. C. B. Wilson). Therefore, it is not likely that the variations in salinity which obtain in the Gulf of Maine are an important factor in influencing its distribution there. Perhaps no member of the crustacean plankton of the open sea can accommodate itself to greater fluctuations in the salinity of the water than this little copepod.

Endemicity and immigration.—The spawning of *P. parvus* has not actually been recorded in the Gulf of Maine, but the fact that the species occurs there throughout the year and is about equally widespread from month to month, though with a definite periodic cycle in its abundance and in the regularity of its distribution, is strong evidence that *P. parvus* does reproduce successfully in the gulf, and that enough of the stock survives the winter to multiply to the frequencies recorded for summer and autumn. The monthly averages for the percentages of stations at which the species has been taken and for the numbers of specimens per square meter both point to May as the commencement of the breeding season in the gulf;

[45] Station 20056, whole column cooler than 1.19°; station 20058, whole column 1.39 to 1.43°; station 20081, surface 1.95°.

but it is not clear how continuously reproduction proceeds throughout the summer and autumn or whether the definite wave of propagation from September to October, which the catches for those months suggest, actually takes place.

Economic importance.—Numerically, *P. parvus* usually forms only a small fraction of the catches of copepods in the Gulf of Maine, the maximum percentage recorded for any station east and north of Nantucket being only 30 per cent in one instance (station 10303). The averages for the area thus limited have been about 11 per cent for March, 3 to 5 per cent for April to June, 15 per cent for August, and 6 to 8 per cent for September and October. Therefore, owing to its small size, it can never be of much importance as fish food within the gulf; but the shoals which we have encountered in the shallows off Marthas Vineyard (station 10332) may serve as a large item in the diet of the smaller and young fishes there. This may also apply at times outside the continental edge off Georges Bank, where *P. parvus* constituted 30 to 50 per cent of the copepods at two stations on February 22, 1920 (stations 20044 and 20045).

Parathalestris jacksoni (Scott)

The localities where this species has been taken (assembled by Sars, 1903–1911) are mostly Arctic and exclusively coastwise, including the polar islands north of Grinnell Land, Franz Josef Land, and the north coasts of Norway and Finland. He found it occasionally on the west and south coasts of Norway, the latter being the most southerly station for it previously reported.

Doctor McMurrich lists *Parathalestris jacksoni* occasionally between December 28 and January 20 at St. Andrews, New Brunswick; more frequently (about 44 per cent of the hauls) from January 20 until mid-May, but not at all during the summer or autumn. The greatest frequency—late winter and spring—falls during the coldest season, which corresponds to its Arctic nature.

Probably *P. jacksoni* will be found all around the coast line of the Gulf of Maine in similar situations and in the littoral zone generally to Cape Cod, but not farther south except as a stray.

It was never sufficiently numerous at St. Andrews to suggest that it has any great importance in the economy of the estuarine waters of the gulf, much less in the offshore parts of the latter, where it has not yet been found.

Phyllopus bidentatus Brady

This species, first described (Brady, 1883) from a single specimen from the south Atlantic off the mouth of the Rio de la Plata in a haul from 2,650 fathoms, has since been recorded by Giesbrecht (1892) from the eastern equatorial Pacific, from the Gulf of Guinea at a depth of 5 fathoms at night and 360 by day by T. Scott (1894); at San Diego, Calif., by Esterly (1905); in the Malay Archipelago by A. Scott (1909); and off the west coast of Ireland by Thompson (1903), Wolfenden (1904), and Farran (1905); but in subsequent publications (Farran, 1908; Wolfenden, 1911) the last two authors have referred their Irish specimens to two new species since described by Farran (1908) from that same region under the names *belgæ* and *impar*.

So far as I can learn, the genus Phyllopus has not previously been reported anywhere along the eastern seaboard of North America, hence two female specimens recognized by Dr. C. B. Wilson in a vertical haul from 80 meters off Penobscot Bay, April 10, 1920 (station 20097), are of interest.

Genus Pleuromamma

Four species of this genus have been taken occasionally in the Gulf of Maine—*P. abdominalis* (Lubbock), *P. gracilis* (Claus), *P. robusta* (Dahl), and *P. xiphias* (Giesbrecht). These are all true oceanic forms, widespread on the high seas in tropical and temperate oceans, and as they are only strays in the Gulf of Maine a brief outline of their geographic distribution will suffice.

P. abdominalis has been taken at many localities in the eastern side of the Atlantic from the Cape of Good Hope (Wolfenden, 1911) to the west of Ireland (Farran, 1908), in the North Atlantic between England and longitude 46°, and in the Gulf of St. Lawrence (Herdman, Thompson, and Scott, 1898). There are many records for it in the Mediterranean; it has been taken repeatedly in the Red Sea and right across the northern part of the Indian Ocean (Thompson and Scott, 1903; Wolfenden, 1905); commonly in the Malay Archipelago (Cleve., 1901; A. Scott, 1909); and at stations widely distributed over the Pacific, both south and north of the Equator, including San Diego, Calif., where Esterly (1905) describes it as common.

P. gracilis has been found over much the same geographic range in the eastern Atlantic (Ireland to the Cape of Good Hope), in the Mediterranean, Red Sea, Indian Ocean, and Pacific, but has not been recorded so often.

P. xiphias is so far known from the Atlantic between the latitudes of Ireland and the Cape of Good Hope, the Indian Ocean, Malay Archipelago, and Pacific, where it has been reported at San Diego (Esterly, 1905) and in the tropical belt between 3° S. and 20° N., 99° W. and 160° E. (Giesbrecht, 1892).

Up to the present time *P. robusta* is known only from the Atlantic between the tropical belt on the south (Dahl, 1893) and the latitudes of the Faroe Channel and the coast of Norway on the north (Sars, 1903), from the Mediterranean, and from the Red Sea. It is, it seems, the most northerly of the four species of the genus here mentioned and the only one which has occurred often enough at the stations of the International Committee for the Exploration of the Sea in the northeastern Atlantic province to be treated by T. Scott (1911) in his résumé.[46]

Previous records for the four species of Pleuromamma off the Atlantic seaboard of North America, outside the Gulf of Maine, are as follows:

P. abdominalis, near Sambro Bank and outside the continental edge off Nova Scotia, June and July, 1915 (Willey, 1919, three stations); also Gulf of St. Lawrence, as just mentioned.

P. gracilis, two stations on a line across the continental shelf off Marthas Vineyard, August, 1914, and one off the continental edge southeast of Georges Bank, July 22 of that same year (stations 10220, 10258, 10260, and 10261; also one record east of the Grand Banks (Murray and Hjort, 1912, p. 654).

[46] The more important locality records for the genus have been collected by Giesbrecht (1892), Thompson and Scott (1903), A. Scott (1909), Wolfenden (1911), Farran (1908), T. Scott (1911), Sars (1903), and van Breemen (1908).

P. robusta, two stations outside the continental edge between the latitudes of Delaware Bay and New York, July, 1913 (stations 10064 and 10071); one station outside the edge off Shelburne, Nova Scotia, July 28, 1914 (station 10233); one Canadian fisheries expedition station outside the continental edge and three over the outer part of the shelf off Nova Scotia, July, 1915 (Willey, 1919); and one *Michael Sars* station east of the Grand Banks (Murray and Hjort, 1912, p. 654).

P. xiphias, one station outside the continental edge off Delaware Bay, July 20, 1913 (station 10071). The Canadian fisheries expedition of 1915 had it at one June station in deep water off the mouth of the Laurentian channel, one July station near Sambro Bank and one outside the continental edge off Cape Sable (Willey, 1919); it was also listed by Sars from the same *Michael Sars* station east of the Grand Banks which yielded *gracilis* and *robusta* (Murray and Hjort, 1912, p. 654).

It is probable that when the ranges of these four Pleuromammas are better understood it will be found that all of them are universal away from land over the temperate and tropic latitudes of all oceans. Off the eastern coast of America, the continental edge and the outer part of the continental shelf would seem their normal inshore boundary, along which all of them may be expected in the warm, highly saline waters of the inner edge of the so-called "Gulf Stream" as far north as the Grand Banks; but the presence of *abdominalis* in the Gulf of St. Lawrence and the Gulf of Maine records to be mentioned next show that on occasion they may drift into distinctly neritic situations.

One other species of the genus, *P. boreale*, is to be expected in the Gulf of Maine, having been found by the Canadian Fisheries Expedition of 1915 at five stations off Nova Scotia (Willey, 1919) side by side with the others; but as yet it has not been detected in the Gulf of Maine towings.

The several Pleuromammas, like other planktonic animals which are purely immigrants, and uncommon ones, in the Gulf, have most often been found in the eastern side—that is, nearest their path of entrance (fig. 82)—and in the southwest part, which they may fairly be assumed to have reached via the anticlockwise eddy which dominates the circulation of the gulf.

If the data so far obtained are fairly representative, *abdominalis* (only one record) is the least common of the four species in the Gulf of Maine, whereas it is the only Pleuromamma yet reported from the Gulf of St. Lawrence and the most common at San Diego (Esterly, 1905). Pleuromamma has been represented by scattering specimens in the Gulf of Maine tows, its numbers per square meter working out as follows for the spring stations of 1920:

Species and station	Number per square meter	Species and station	Number per square meter
P. gracilis:		P. xiphias:	
20056	10	20048	10
20103	26	20072	50
20114	200	20102	9
P. robusta:		20117	175
20089	50		
20098	12		

The summer records inside the gulf and over the shelf off Marthas Vineyard have likewise been for odd specimens, but on August 26, 1914 (station 10261), *P.*

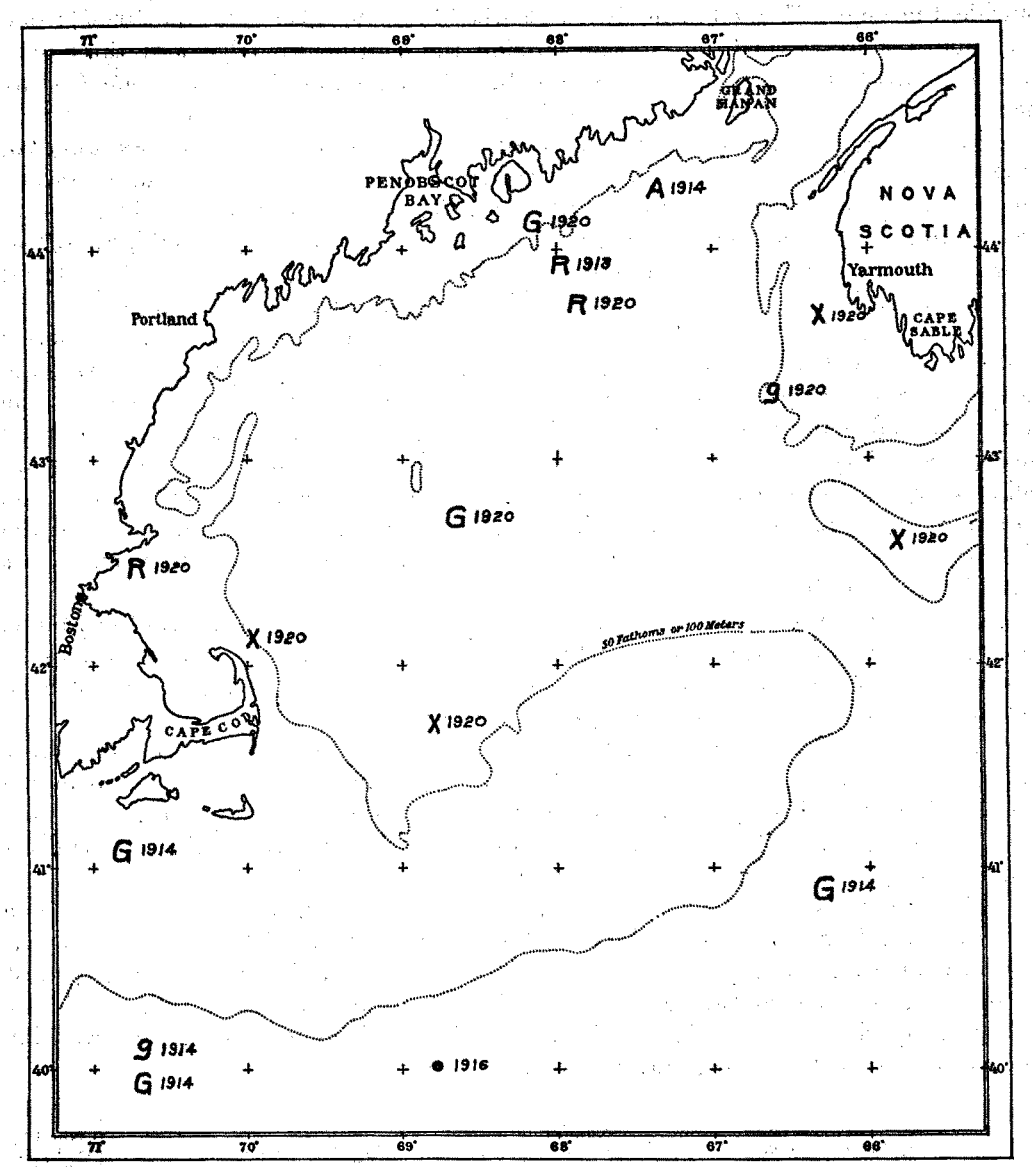

FIG. 82.—Occurrence of the genus Pleuromamma in the Gulf of Maine. A, locality records for *P. abdominalis:* G, locality records for *P. gracilis:* R, locality records for *P. robusta:* X, locality records for *P. ziphias:* ●, locality records for Pleuromamma species (?). The dates are the years of record

gracilis was the dominant copepod outside the continental edge off Marthas Vineyard, as *P. robusta* was at the same relative position off New York on July 11, 1913 (station 10064: Bigelow, 1915, p. 287).

It is interesting that 80 per cent of the 10 records of occurrence within the offshore banks of a genus whose source is undoubtedly the oceanic basin outside the continental edge should be for March and April, when the temperature is lowest, and only two for the summer-autumn season (*P. robusta*, station 10100, August 13, 1913; *P. abdominalis*, station 10246, August 12, 1914), whereas our summer stations alone have yielded this genus outside the banks.[47] However, with the possibility that a rare species may be overlooked among the masses of Calanus and other of the more plentiful copepods taken in the horizontal hauls, the few records do not show at what season the genus as a whole (or any one of its several species) is most likely to enter the Gulf of Maine.

It is not likely that Pleuromamma succeeds in breeding in the gulf; but the geographic distribution of the records indicates that individual specimens may be long-lived there. No relation is apparent between the occurrences of Pleuromamma in the gulf and high temperature, for its presence has been established there in readings as low as 0.49 to 1.95° (station 20056), and the two midsummer records *may* have been from water as cold as 4.22° and 7.58°, though, equally, the few specimens involved may have been picked up by the open net near the surface in a much higher temperature.

Pleuromamma has not been taken on the surface in the Gulf of Maine, but none of the hauls producing it have been from deeper than 175 meters and all but three of them were as shoal as 100 meters, or shoaler, pointing to the strata above the latter level as the region which it usually inhabits in the gulf. At San Diego Esterly (1912) found both *P. abdominalis* and *P. gracilis* coming nearly or quite to the surface during the night and sinking to considerable depths by day, chiefly to deeper than 150 meters. Similar diurnal migrations, though not so deep, are to be expected of the few specimens unfortunate enough to stray into the Gulf of Maine.

Pseudocalanus elongatus Bœck[48]

This is a northern species and one of the most widespread and abundant copepods in the North Atlantic region and in the Arctic, where it is circumpolar. The records of its distribution have recently been summarized by Farran (1910) and by With (1915). On the European side its southern boundary seems to be the Black Sea (Sars, 1903, p. 154), the Mediterranean, and the Gulf of Suez (Thompson and Scott, 1903), which it would seem to have reached via the Suez Canal, not being known from farther down the Red Sea or from the Indian Ocean. It is widespread, probably universal, northward from Gibraltar to the North Sea, along the entire length of the coast of Norway, and far up into the Baltic. It is recorded near the New Siberian Islands, repeatedly and at many localities in the White Sea, about Spitzbergen, off Jan Mayen, in the Norwegian and Greenland seas, about the Faroes, Iceland, northward to Disko along West Greenland, from East Greenland, and right across the North Atlantic from England to the Gulf of St. Lawrence.

[47] None at stations 20044, 20045, 20068, 20069, 20077, 20109, February-April, 1920.

[48] According to With (1915) the *P. minutus* of Krøyer was based on immatures of this species, which should therefore bear the name *minutus;* but until the change is generally accepted by students of the group (Willey's (1920, 1921) recent communications still use *elongatus*) it is as well to follow the more general usage in a paper not concerned with systematics.