In American waters it has been taken as far south on the Pacific coast as Puget Sound (Giesbrecht and Schmeil, 1898), but apparently it does not reach San Diego, not having been found there by Esterly. Willey (1920) records it from south of the Alaska Peninsula, from Bering Sea, and from several localities along the Arctic coasts of Alaska and Canada. On the Atlantic side it occurs in the Labrador current off the Straits of Belle Isle (Herdman, Thompson, and Scott, 1898). The Canadian fisheries expedition found it one of the most plentiful of copepods in the Gulf of St. Lawrence and had it at most of the stations between the Newfoundland and Scotian Banks, as well as along Nova Scotia, though not in such abundance (Willey, 1919). Wright (1907) also describes it as abundant off Canso, Nova Scotia, in July and August; and as I have remarked in several previous communications, Pseudocalanus is one of the most characteristic members of the copepod community of the Gulf of Maine. West and south of this it is much less abundant and more seasonal. In warm summers it probably finds its farthest bound about New York, judging from the fact that it has not been reported at Woods Hole during the warm half of the year, though Fish (1925) found it there in winter, and from our failure to find it at any of the nine southern stations in 1913 (Bigelow, 1915). In the cool August of 1916 it was recognized at three stations on the continental shelf off New York (stations 10363, 10364, and 10365) and may have occurred at others, for only a preliminary examination has been made. In September, 1914, it was taken just outside the continental edge off Marthas Vineyard (station 10260), and in October, 1915, it occurred at all three stations across the continental shelf on this line (stations 10331 to 10333; table, p. 298). It enters Narragansett Bay in January and February (Williams, 1907), and Dr. C. B. Wilson (in a letter) writes that he has "examined specimens taken in winter as far south as the thirty-seventh parallel of latitude, opposite the mouth of Chesapeake Bay," this being the most southerly record of it along the seaboard of eastern North America.

Gulf of Maine.—Pseudocalanus is nearly as universal as *Calanus finmarchicus* in the gulf, indifferently in the coastal zone, in the deep parts of the open basin, and on the off-shore banks. Evidently it is a constant member of the plankton of Gulf of Maine harbors, the *Grampus* having had it in Gloucester, Rockport, and Kittery (Bigelow, 1914, p. 116). Doctor McMurrich took it at St. Andrews, where he lists it for 71 per cent of the 160 tows covering all seasons of the year. Since 1913 it has been recognized in the following proportion of the stations for which the copepods have been listed:[49]

Date	Percentage of stations with Pseudocalanus	Date	Percentage of stations with Pseudocalanus
February, 1920	83	September, 1915	90
March, 1920 and 1921	94	October, 1915	91
April, 1920	90	December, 1920	88
May, 1915 and 1920	77	January, 1921	80
June, 1915	77		
August, 1913, 1914, 1915, and 1922	69	General average	83

[49] The summer of 1912 and winter of 1912–13 are not included in this calculation because there is reason to believe that Pseudocalanus is underestimated in the published lists because of the nets employed (Bigelow, 1914, p. 115; 1914a, p. 409).

We have found it at 77 per cent of the stations on Georges Bank and the shelf off Marthas Vineyard, 72 per cent of the stations in the basin as inclosed by the 100-meter contour, 86 per cent in the coastal zone inside 100 meters from Cape Cod to Grand Manan, 77 per cent in the coastal zone along western Nova Scotia, 86 per cent in the eastern and northern channels, but at only half the stations on Browns Bank and 65 per cent of the stations outside the continental edge.

Thus, on the whole, *Pseudocalanus elongatus* is somewhat more nearly universal close along shore than out at sea in the gulf (fig. 83); but the regional difference is so small inside the continental edge that it may be of no general significance and merely the result of one haul chancing to pick up and another to miss scattered specimens at times and places where the species is scarce. Probably the apparent infrequency of this copepod on Browns Bank is to be explained in this way.

Although *P. elongatus* is so nearly universal, the numbers actually present at any given time have usually averaged larger in the basin, in the entrant channels (northern and eastern), and along the offshore slope than anywhere in the coastal belt of the gulf inside the 100-meter contour. The locations of the stations where the number of specimens per square meter has been larger than the average for the respective month and year afford a graphic illustration of this localization of the rich catches in the deeper parts of the gulf, for 22 out of 36 have been outside and only 14 inside the 100-meter contour (fig. 84). Otherwise expressed, only 20 per cent of the shoal catches have been above average, as contrasted with 40 per cent of the deep hauls.

The "rich" catches in the basin have been distributed indifferently from the west side to the east; but this correlation between the abundance of Pseudocalanus and the topography of the bottom does not apply in the southern part of the area, for rich hauls have been made over the outer part of Georges Bank and on the continental shelf off Marthas Vineyard, while all records of the species so far obtained from farther west and south than this along the coast have been well inside the 100-meter contour.

Vertical distribution.—In the northerly part of its range *P. elongatus* has been found commonly at the surface in other seas as well as at various deeper levels, and its presence is established down to about 900 meters by the use of the closing net (Wolfenden, 1904), but its chief zone of abundance lies above 200 meters. The Canadian fisheries expedition took it as regularly at the surface in the Gulf of St. Lawrence as in deep tows down to 150 meters, and apparently about as abundantly.

The great majority of records for this species in the Gulf of Maine have been based on hauls from depths greater than 50 meters, not so much because of a concentration in deeper water as because the deeper hauls, horizontal or vertical, have been the basis for most of the lists of copepods. During the *Albatross* cruise of 1920 Pseudocalanus was found regularly at the surface as well as at deeper levels from the last week in February until the last week in March (about 90 per cent of the stations), irrespective of locality, but less frequently (only about 42 per cent of the stations) through April and May (table, p. 303). It is probable that this change resulted from a general tendency on its part to desert the uppermost stratum as the season advances. It was detected at only three of the six stations where the surface net yielded enough

copepods to be worth listing in the summer of 1914, but its constant presence in surface tows at St. Andrews the year round (p. 276), with the *Grampus* captures of it at the

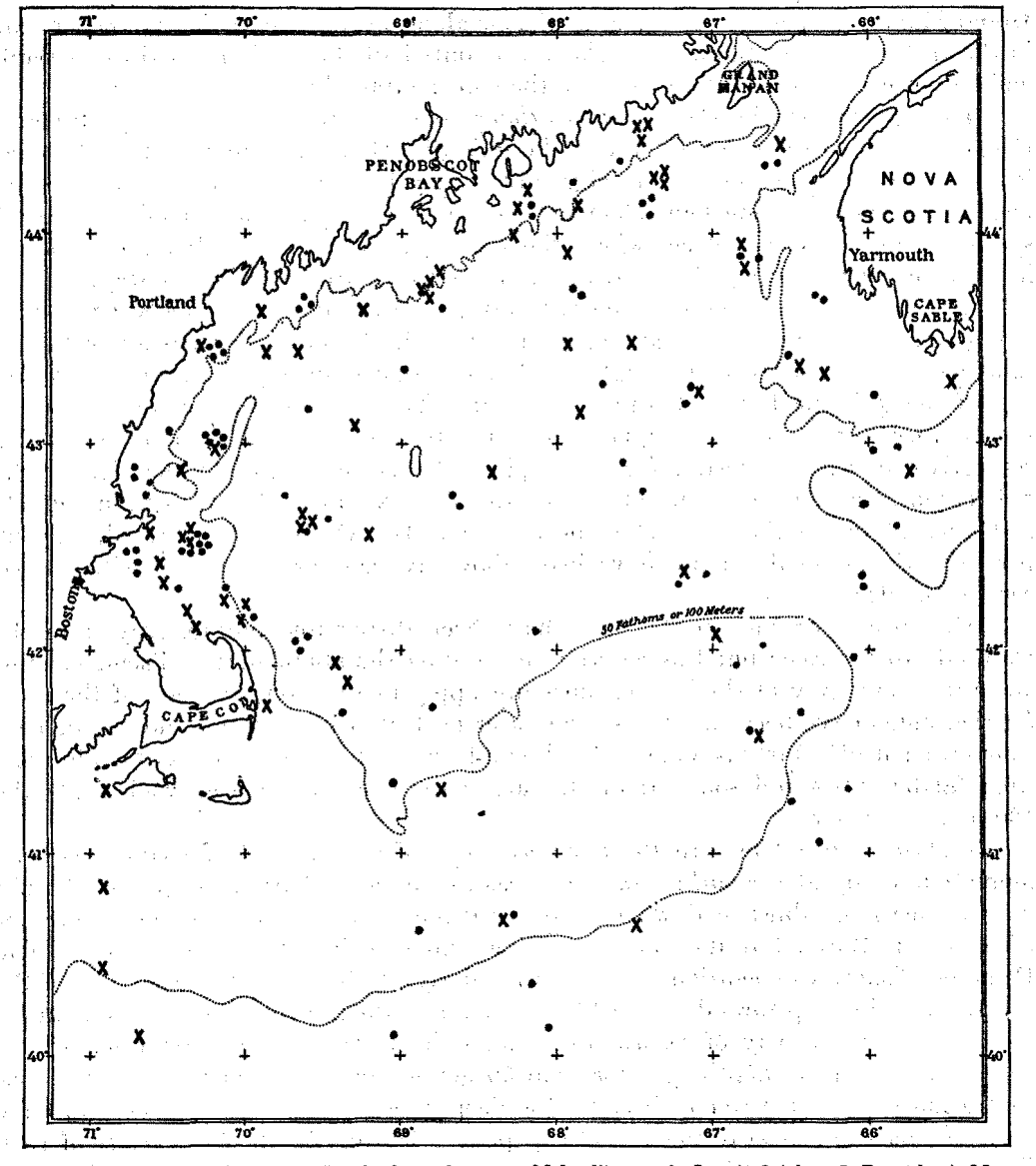

FIG. 83.—Occurrence of the copepod *Pseudocalanus elongatus*. X, locality records, June to October; ●, December to May

surface in other harbors in midsummer, proves that it is always to be expected a few meters down and is brought up by the mixing effect of moderately strong tidal currents.

I have been unable to find evidence of a stratification of this species at any definite depth in the gulf. The concentration of the richer catches of Pseudocalanus

in the deeper parts of the gulf, together with the fact that the average depth of the 36 hauls yielding more than the average number of specimens per square meter for the respective month and year has been 164–0 meters, but only 113–0 meters for the

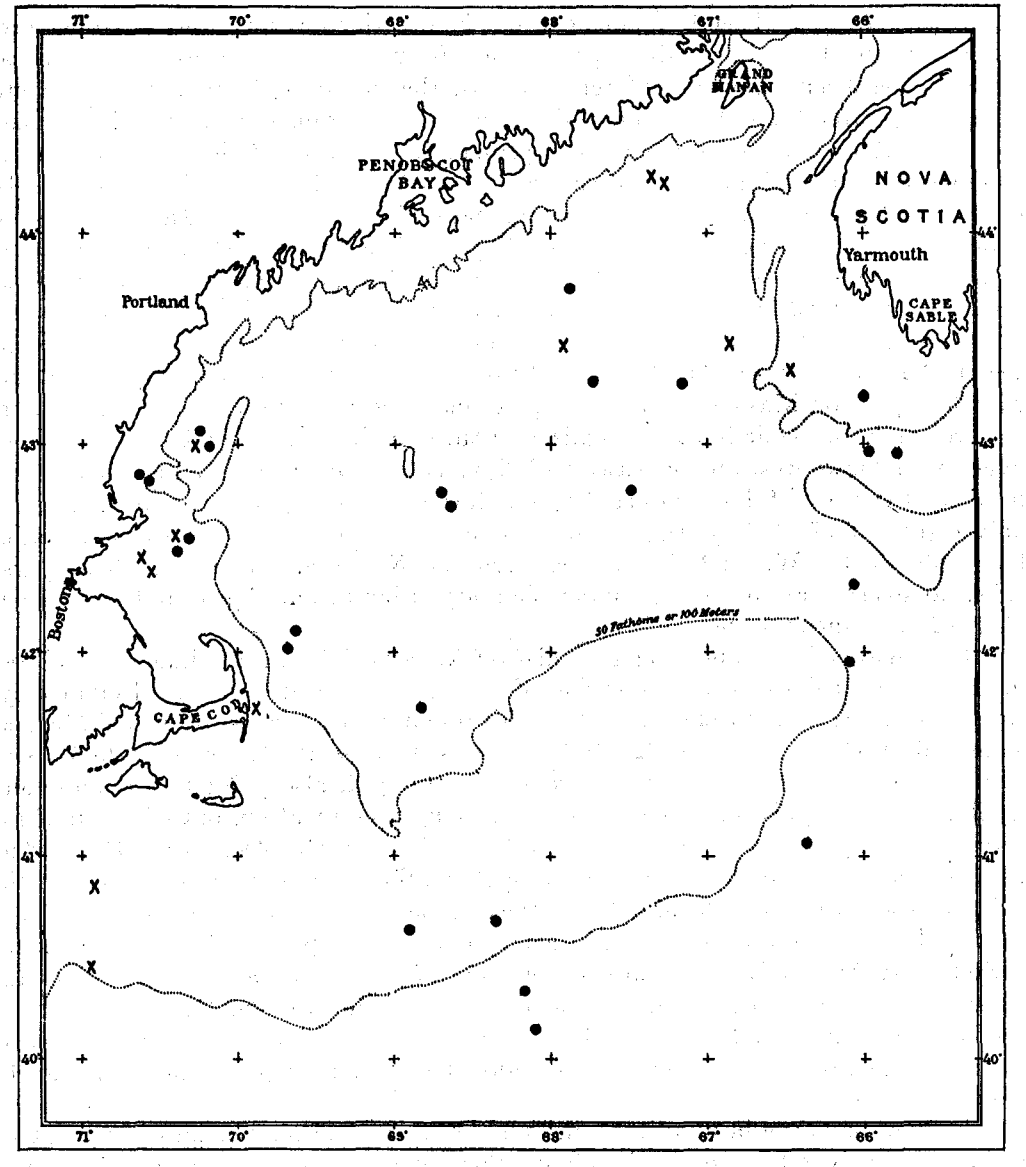

FIG. 84.—Localities where the vertical hauls have yielded more *Pseudocalanus elongatus* per square meter of sea area than the average for the respective month. X, June to October; ●, February to May

80-odd hauls yielding less than the average number of specimens, does not suggest any impoverishment of Pseudocalanus in the deep strata of the gulf, such as is demonstrated for *Calanus finmarchicus* (pp. 203, 205). On the other hand, there is nothing

in the data here offered to indicate any tendency on the part of *P. elongatus* to keep to the deepest levels, nor can I offer any evidence of diurnal vertical migration on its part, though this is so common a phenomenon among copepods that more detailed study of the occurrence of the species is likely to show it in some degree.

Seasonal cycle.—Pseudocalanus can not be described as definitely seasonal anywhere within the gulf. This appears both from the percentages of stations at which it has been taken in different months, the variation from month to month being no greater than the chances of the hauls, and from the distributional chart (fig. 83), which proves Pseudocalanus present in all parts of the gulf both in the summer-autumn and in the winter-spring seasons.[50] However, if the records be considered by locality, the following regional differences appear: In the coastwise zone out to the 100-meter contour, from Cape Cod to Grand Manan, the frequency of occurrence (percentage of stations) has been about the same for one season as for another,[51] and Pseudocalanus was taken with equal regularity (70 to 80 per cent of the stations) over the western half of the basin west of the longitude of Mount Desert Island (long. 68° 30′ W.) in July-August as in October-January, February-March, April, or May-June (the copepods have been listed at 39 stations from that region); but while it was recognized at three of the four December-May stations over the shallows west and southwest of Nova Scotia, out to the 100-meter contour, it failed at two out of five summer-autumn stations there. It appears in the lists for only eight out of 17 July-August stations in the eastern half of the basin, east of longitude 68° 30′ W. (including the Eastern and Northern Channels), where it was taken at every station for September, January, March, and April, and at four out of five May-June stations.

On Georges Bank and over the shelf off Marthas Vineyard it likewise occurred in all the vertical hauls for the spring of 1920 but failed at four out of eight July-August stations in 1913 and 1914, though present at all three stations off Marthas Vineyard on October 21 and 22, 1915 (stations 10331 to 10333; table, p. 298). Our few hauls outside the continental edge abreast the gulf also point to a definite and similar seasonal cycle for Pseudocalanus, it being present at six out of seven of the December-May stations but at only two of the five for May-October. Thus, while Pseudocalanus is uniformly frequent throughout the year in the western half of the gulf, irrespective of depth, and along the northern coast, it occurs somewhat less frequently and regularly in the southeastern and eastern part during the two-month period, July-August, than at any other time of year. Apparently it follows the same seasonal cycle, but with a decidedly greater impoverishment in summer, on the offshore banks and in the more oceanic water outside the continental edge, though more tows are needed in this region before a final pronouncement can be made.

It must be borne in mind that any planktonic animal may or may not be taken most frequently when most abundant (may even be most frequent when least numerous), the relationship between the two measures of occurrence depending on the uniformity of distribution. In the case of *P. elongatus* the data afforded by

[50] In contrast, compare the seasonal fluctuations in the regional distribution of such an immigrant species as *Sagitta serrato-dentata* (p. 320).

[51] Eighty-five per cent for December-May, 90 per cent for June-October; total number of hauls, 51.

the vertical hauls for 1915 and 1920 (tables, pp. 297, 299) point to a greater absolute abundance over the area as a whole in late summer and autumn than in early spring, constantly increasing from March until October, with average numbers per square meter, by months, for the years 1915 and 1920, as follows: February–March, 685; April, 501; May–June, 2,238; August–September, 5,723; and October, 8,456.

If the year 1913 be included in the calculation (Bigelow, 1915, table, p. 286), the August average would mount to 19,834, making this the seasonal maximum; but the possibility of an annual as well as a seasonal fluctuation must always be kept in mind.

The seasonal cycle for 1915 and 1920 in the coastal zone between Cape Cod and Grand Manan paralleled the figures just given for the gulf as a whole, with the average numbers of *P. elongatus* augmenting from about 300 per square meter in March–April, to 2,124 for May–June (or 1,699, if the stations where it failed as well as those where it occurred are counted), 2,819 or 3,947 for August–September, and 7,622 or 8,710 for October, depending on which basis of calculation be employed. The vertical hauls in the deeper parts of the gulf show a similar seasonal augmentation from early spring to September, whether for the basin as a whole or for its eastern half separately, as follows:

Average numbers per square meter, by months, counting only the stations of occurrence

Locality	February–March	April	May–June	August–September	October (only 1 station)
Basin as a whole	1,068	656	2,914	8,963	9,110
Basin east of longitude 68° 30′ W	1,083	811	3,149	6,752	----------

Unfortunately, nothing can be said as to seasonal fluctuations in the abundance of *P. elongatus* as distinguished from its frequency on Georges Bank or outside the continental edge, no vertical hauls being available thence for summer.

Breeding habits.—In the northeastern Atlantic sexually adult specimens of both sexes have been reported repeatedly at various dates between April and September (for a summary see With, 1915), and since Willey (1919) describes females with eggs and attached spermatophores from the Gulf of St. Lawrence for August, the breeding season for Pseudocalanus might be expected to fall in late spring and through the summer in the Gulf of Maine. Dr. C. B. Wilson writes, in a letter:

> In this connection it is of interest to report that although the present collection includes specimens of this species taken in every month of the year except November, not a single specimen was observed with eggs.

However, as he points out, Sars's (1903, p. 21) discovery that the ovisac is so very fragile that it becomes detached at the slightest touch "readily explains Willey's (1919) statement that the ovisacs of all the females were ruptured, and the fact that no females with eggs were found in the present collection."

Next to the actual discovery of egg-bearing females, the constant presence of this species in the gulf, its universal distribution and considerable abundance there, and the unmistakable seasonal cycle in its abundance are the strongest evidence that it is

regularly endemic there and that the maintenance of the local stock is primarily by local reproduction. The seasonal fluctuations in the numerical strength of the stock point to breeding as taking place most actively from June until September and to the entire gulf as its site.

Relation to temperature and salinity.—*P. elongatus* has been taken over a wide range of temperature. Judging from its abundance in polar seas, it thrives in temperatures close to the freezing point; but, on the other hand, notwithstanding its northerly distribution (p. 275), it has been found living in the warm Mediterranean and in upwards of 20° in the Gulf of Suez. However, the species reaches its maximum abundance and frequency in seas and at levels where the water is cooler than about 15°.

In the Gulf of Maine its presence has been definitely established in water as warm as 20° (surface, station 10254, August 22, 1914) and 19.56° (surface, station 10256, August 23, 1914); but its usual scarcity at the surface during the warmest months (pp. 24, 277) and the great preponderance of records (vertical and subsurface horizontal hauls) from temperatures below 12 to 15° would seem to set this as the upper limit for its optimum environment, even though much warmer water is not fatal either to its existence or even to its reproduction—witness its Mediterranean range. If the rising temperature of spring is actually the factor which tends to drive Pseudocalanus down into the deeper and cooler water in summer, this does not take place until the uppermost stratum of water has warmed from its winter minimum to warmer than 7 to 8°, for Pseudocalanus occurred rather more frequently on the surface in May, 1920, when the surface temperature averaged about 7.9° at the *Albatross* stations, than in April at an average temperature of about 3.5°.

Any species living indifferently in the inner Baltic, on the one hand, and in the open Atlantic and Mediterranean, on the other, necessarily exists over a much wider range of salinity than obtains in the Gulf of Maine. Therefore, it is not likely that the details of distribution of Pseudocalanus in the gulf are governed by the local and temporal variations in salinity obtaining there, nor does any parallel between the two appear from what is known so far.

Economic importance.—In the English Channel, Lebour (1919, 1919a, and 1920) found that Pseudocalanus was, on the whole, the copepod chiefly preyed upon by all kinds of larval fishes and young fish fry; and since it may be expected to play the same rôle in the Gulf of Maine (though there are no local observations bearing on this point), probably it ranks next to *Calanus finmarchicus* in its importance in the natural economy of the gulf. Granting Pseudocalanus second rank in this respect, it must still fall far behind Calanus, not only because its individuals are much smaller but because it is seldom as numerous anywhere in the gulf. Thus, Pseudocalanus outnumbered Calanus in only eight out of 139 vertical hauls between the longitudes of Marthas Vineyard and Cape Sable during the years 1913, 1915, and 1920, and equaled it in three others. As a rule there have been from five to ten times as many Calanus as Pseudocalanus at any given station. Taking the vertical hauls together for all years, for all localities west of Cape Sable, and for all seasons, Pseudocalanus has averaged about 11 per cent of the copepods. Assuming the Pseudocalanus to

have been uniformly distributed vertically, the numbers present per cubic meter of water work out as follows for our richest catches of the species:

Station	Date	Number	Station	Date	Number
10092	Aug. 11, 1913	119	10332	Oct. 21, 1915	958
10095	Aug. 12, 1913	666	10333	Oct. 22, 1915	382
10096	do	330	10336	Oct. 26, 1915	287
10097	Aug. 13, 1913	306	10338	Oct. 27, 1915	306

Rhincalanus cornutus Dana

This species has its center of distribution in the Tropic belts of the three great oceans. It has been described from the Sulu Archipelago, from the Philippines (Brady, 1883), and from the western Pacific between latitudes 7° S. and 15° N. (Giesbrecht, 1892). It is common in the Malay Archipelago (Cleve, 1901; A. Scott, 1909). Thompson and Scott (1903) had it at ten stations in the Indian Ocean; A. Scott (1902) reports it from the Red Sea; but up to the present I have found no record of it in the Mediterranean. The German South Polar expedition found it widespread in the South Atlantic (Wolfenden, 1911). To the northward it is reported from the equatorial belt off Africa; from the Gulf of Guinea, where T. Scott (1894) found it one of the most common and widely distributed species; and in the eastern side of the Atlantic at a few stations up to latitude 52° (Thompson, 1903). The only previous report of it on the American side is from one station outside the continental edge off Cape Sable by the Canadian fisheries expedition, July, 1915 (Willey, 1919). So far as eastern North American waters are concerned, the true home of this species lies well outside the continental edge, in almost Tropic temperatures and high salinities.

In the Gulf of Maine this species is an accidental stray, appearing in the lists for nine hauls, including both horizontals and verticals (fig. 72; tables, p. 298–305), the captures within the gulf being in the northeastern part of the basin, off Penobscot Bay, off Cape Elizabeth, off the Merrimac River, and in Massachusetts Bay, a localization along the northern and western shores which parallels the distribution of other immigrants. There are also two station records for it on the continental shelf off Marthas Vineyard.

Two of the records for *R. cornutus* in the inner part of the gulf are for March, two for September, and three for December. Evidently it may enter at any time of year, and is about as apt to do so at one season as another. The records off Marthas Vineyard were for October 21 and 22, 1915 (table, p. 298).

There is no reason to suppose that this copepod is able to breed successfully within the gulf or to establish a permanent foothold there, the records from within the gulf all being for scattering specimens, up to a frequency of about 455 per square meter off Massachusetts Bay, September 29, 1915 (station 10321), at most 2 per cent of the copepods. Off Marthas Vineyard, however, the vertical haul yielded about 2,000 per square meter at one station (10333).

Rhincalanus nasutus Giesbrecht

This is a typically oceanic species, warm temperate in its relationship to temperature, and wide ranging in all three great oceans. It has been recorded widely in the eastern Pacific (Giesbrecht, 1892; Esterly, 1905), in the Malay Archipelago (Andrew Scott, 1909 [52]), at several localities in the northern part of the Indian Ocean (Thompson and Scott, 1903; Wolfenden, 1905), and at the mouth of the Red Sea (A. Scott, 1902). In the Atlantic it is known from latitude 35° 10′ S., in the south (Wolfenden, 1911), to Denmark Strait, the sea south of Iceland, the neighborhood of the Faroes, the Norwegian sea, and the northern part of the North Sea in the north. Farran (1910) and With (1915), who have summarized what is known of its distribution, have both pointed out that in the northeastern part of its area of occurrence its range is coterminous with the ebbings and flowings of the highly saline and comparatively warm waters of the Atlantic current. This applies equally off the Atlantic seaboard of North America, where it has been taken outside the continental edge off Chesapeake Bay, off Delaware Bay, and off New York in the summer of 1913 (stations 10064, 10071, and 10076); off Georges Bank, July, 1914 (stations 10218 and 10220); off Cape Sable; off Sable Island; and off the mouth of the Laurentian Channel between the Nova Scotian and Newfoundland Banks, June–July, 1915 (Willey, 1919, 7 stations); also east of the Grand Banks by the *Michael Sars* (Murray and Hjort, 1912, p. 654).

Within the Gulf of Maine *R. nasutus* has much the same status as its close relative *R. cornutus* (p. 283), there being 10 records, all but one of them in the peripheral belt, around which they are scattered from Browns Bank and off Yarmouth, Nova Scotia, to off the tip of Cape Cod, a distribution quite typical for any planktonic animal reaching the gulf as an immigrant from the Atlantic basin and unable to survive long or to reproduce itself there.

The geographic locations of the stations where *R. nasutus* was taken (fig. 72) are also interesting in pointing to the upper 100 meters or so as the stratum in which it enters, for if it drifted into the gulf in the underlying waters it might be expected to follow the branches of the basin, as do the bathypelagic chætognaths *Eukrohnia hamata* (p. 328) and *Sagitta maxima* (p. 324), instead of circling along and inside the 100-meter contour.

Farran (1910) and With (1915) have described the vertical range of this species as uniform from the surface down to 1,800 meters. Most of the captures listed by Willey (1919) in Canadian waters were in open vertical hauls from depths of 200 to 375 meters; once on the surface. The *Michael Sars* record just mentioned was in a closing net at 950 to 525 meters. The captures within the Gulf of Maine have all been in open nets—horizontal (station 10225) or vertical—from depths of from 48–0 down to 240–0 meters; none from the surface.

The Gulf of Maine records for *R. nasutus* are for the months of March (three), April (two), May (four), and one for July;[53] but with so few records it is questionable whether this seasonal periodocity actually means that *R. nasutus* is more apt to enter

[52] He uses the name *Rhincalanus gigas* Brady for it.

[53] In addition to the stations listed in the tables, (p. 297), *R. nasutus* was taken at station 10225 on July 23, 1914, and at stations 10272 and 10273 on May 10, 1915.

the gulf in spring and early summer than at other seasons, or whether it has been an accidental feature of the towings.

It should be noted that the presence of *R. nasutus* in the Gulf of Maine at any particular temperature or salinity does not necessarily bear any relation to the range of these factors in which it finds its most favorable environment, but simply means that once swept into the eastern side of the gulf by the entrant eddy it has been able to survive long enough to drift to the place where found. The present records prove such survival possible for a time in water as cold as 2 to 3° (stations 20072 and 20095) and in salinities no higher than 29.16 to 31.36 per mille (station 20120), though its usual range in the open North Atlantic is nearly if not wholly limited to salinities higher than 34.9 per mille, and for the most part to regions where the water is warmer than 10° at some level. Geographic distribution suggests that *R. nasutus* finds temperatures and salinities appreciably lower than these figures an effective preventative to successful reproduction.

The records for *R. nasutus* within the gulf have invariably been for small numbers of specimens, in three cases for single individuals noted in the catch of copepods (designated "T" (trace) in the accompanying tables), and only once for as many as 550 per square meter (station 20120). It has invariably been a minor element (5 to 10 per cent) in the copepod community, even along the continental slope, where it occurs more constantly, with a maximum abundance of about 1,000 to 4,000 per square meter (stations 20045 and 20069).

Scolecithricella minor (Brady)

This species has its chief center in the North Atlantic and neighboring Arctic seas. In the northerly part of its range it has been found along the Norwegian coast as far as Lofoten; at many localities, but usually in small numbers, between Spitzbergen and Greenland northward to latitude 80° 17′ N.; and generally distributed about the Faroes and Iceland, in Denmark Strait, off southern Greenland, and northward to latitude 64° 54′ in Davis Strait (see With, 1915, for a summary of the records for this species so far published).

The *Michael Sars* did not find it off the western slope of the Grand Banks, but the Canadian fisheries expedition had it at six stations outside the continental edge at the mouth of the Laurentian Channel between Banquereau and Green Bank, off Sable Island, and off Cape Sable; also twice in the Gulf of St. Lawrence (Willey, 1919), and there are a few records for it in the Gulf of Maine, to be noted below. It has not been reported south of Cape Cod in the western Atlantic. In the eastern Atlantic it is common west of Ireland (Farran, 1905 and 1908), and while not known in the Mediterranean or anywhere in the north-central Atlantic, it was found by T. Scott (1894) in two samples from the Gulf of Guinea, one of them taken so close in to the mouth of the Congo River that the water was visibly brownish. *S. minor* has not been reported either from the South Atlantic, the Pacific, or from the tropical part of the Indian Ocean, but the original specimens of the species were from the subantarctic zone of the latter, west of the Crozet Islands, in latitude 46° 46′ S., longitude 45° 31′ E., in a surface haul.

Gulf of Maine.—This species has not been reported previously from the gulf, nor for that matter from off the American seaboard south of Nova Scotia, but it appeared in one vertical haul off Yarmouth, Nova Scotia, and one off Shelburne, Nova Scotia, in 1915 (stations 10272 and 10313), off Boothbay Harbor on March 4 and again on April 10, 1920 (stations 20058 and 20096), and in one horizontal haul near the mouth of the Merrimac River on the 20th of the following December (station 10492), in each case for odd specimens only (tables, pp. 297 and 299).

This copepod is typically warm oceanic, though tolerance for low temperature is evidenced by its more northerly distribution in the Arctic–Atlantic area. In the Gulf of Maine it occurs only as one of the rarest of strays from outside the continental edge. The localization of the records of capture (fig. 72), in which it agrees with Rhincalanus, points to the upper 100 meters as the stratum in which it most often enters the gulf, where, like other immigrants, it circles first north, then west, then south around the periphery, drifting in the great anticlockwise eddy. If it were swept in with the deeper lying water along the bottom of the eastern channel it would be more apt to be found along the two branches of the basin; and since it has been taken over a wide range of depth elsewhere, from the surface downward, in low latitudes as well as high, and most often from 20 to 400 meters (With, 1915), odd captures of it may be expected in the deepest strata of the gulf. So far it has not been detected in any surface haul in the Gulf of Maine.

The present records, with those of the Canadian fisheries expedition off Nova Scotia and in the Gulf of St. Lawrence (Willey, 1919), cover so many different months that this copepod may be expected in the Gulf of Maine at any season, a fact instructive for its bearing on the question of the periodicity of oceanic circulation in the region.

The biology of this species must be understood better before the relationship of its distribution to temperature and salinity can be stated. The records of capture locate it over a wide range of each—that is, in temperatures as low as $-1.6°$ to $-1.8°$ along East Greenland to upward of 24° in the Gulf of Guinea, while in the Greenland Sea the *Belgica* (Damas and Koefoed, 1907) found it nearly universal in salinities ranging from about 32 per mille on the Greenland side to nearly 35 per mille about Spitzbergen.

So far as temperatures and salinities *per se* are concerned, the Gulf of Maine is thus wide open to it, and its presence there in any particular temperature and salinity is simply the result of the particular drift which the specimens in question have taken and of its ability to survive wide fluctuations, something which is true of most copepods.

Scolecithricella is never sufficiently numerous in the Gulf of Maine to figure in the natural economy of the local plankton, but its immigrant nature being beyond dispute, with the Atlantic Basin as the source, it is among the most instructive of natural floats when it appears there, as showing the course followed by the indraft.

Temora longicornis Müller

This copepod is neritic in the sense that its areas of abundance are confined to the continental shelves of the continents or large islands and to their close vicinity. The vast majority of the records obtained for it have been from one or other side of the North Atlantic,[54] none from either the South Atlantic or from any part of the Pacific. It enters the Mediterranean to some extent (Thompson and Scott, 1903) and has been recorded from the Indian Ocean (van Breemen, 1908). Off the coasts of Europe its range as now known is confined between the latitudes of about 35° and 74° N., and it reaches its maximum development in the English and Irish Channels, in the North Sea region generally, whence it extends far up into the Baltic, and along the whole southern and western coasts of Norway. Except for a few records between northern Europe and Spitzbergen (Farran, 1910), its range seems hardly to encroach on the Arctic Seas. It has not been found in the Greenland Sea, but Sars (1903) reports it from Iceland.

On the American side the most southernly station for it is off Chesapeake Bay (Bigelow, 1922, p. 146). It is an important member of the coastwise plankton from New York eastward, including the Gulf of Maine, the continental shelf all along Nova Scotia, along the southerly aspect of the Newfoundland Banks, and in the Gulf of St. Lawrence, where the Canadian fisheries expedition collected it at about 70 per cent of the tow-net stations in 1915, locally in abundance (Willey, 1919). It has also been found in the Labrador current off the Straits of Belle Isle and thence eastward to latitude 55° 24′, longitude 41° 10′, south of Greenland (Herdman, Thompson, and Scott, 1898), which is the most northerly station known for it in the western side of the North Atlantic.

Gulf of Maine.—As the chart (fig. 85) shows, *T. longicornis* is widespread in the shoaler parts of the gulf, not only from land out to 10 to 12 miles outside the 100-meter contour, from Cape Cod to Cape Sable, but on Browns and Georges Banks as well, and across the whole breadth of the continental shelf off Marthas Vineyard and Nantucket. It is a creature both of the open sea and of harbors, common in winter right up to the dock at Woods Hole (Wheeler, 1901, p. 175), in Portland Harbor (Bigelow 1914), and at St. Andrews (from Doctor McMurrich's unpublished plankton lists), but recorded at only 10 to 12 per cent of the stations farther out in the deep basin of the gulf. Within this neritic area, as bounded above, and between longitudes 65° and 71° W., it has been recognized at about 41 per cent of all the tow-net stations for which the copepods have been determined, irrespective of year, season, or precise locality. Its independence of the distance from land, within the bounds of the continental shelf, may be further illustrated by the fact that Dr. W. C. Kendall, in his field notes (p. 12), mentions "small brown copepods," which from the context were almost certainly Temora, as plentiful in haul after haul on the northwestern part of Georges Bank and over the shelf out from Nantucket in August and September, 1896.

The neritic nature of Temora is further brought out by its quantitative distribution, for only three of the 20-odd stations where we have taken a greater number of specimens per square meter than the average for the respective month and year

[54] Sars (1903) and Farran (1910) have summarized its distribution; the reader is referred to them for more detailed information.

have been as far as 16 miles out from the 100-meter contour, and the only two swarms of this species which we have encountered (p. 290) have been well inside the 100-meter line. Among all the records of it in American waters west of the longitude of Sable

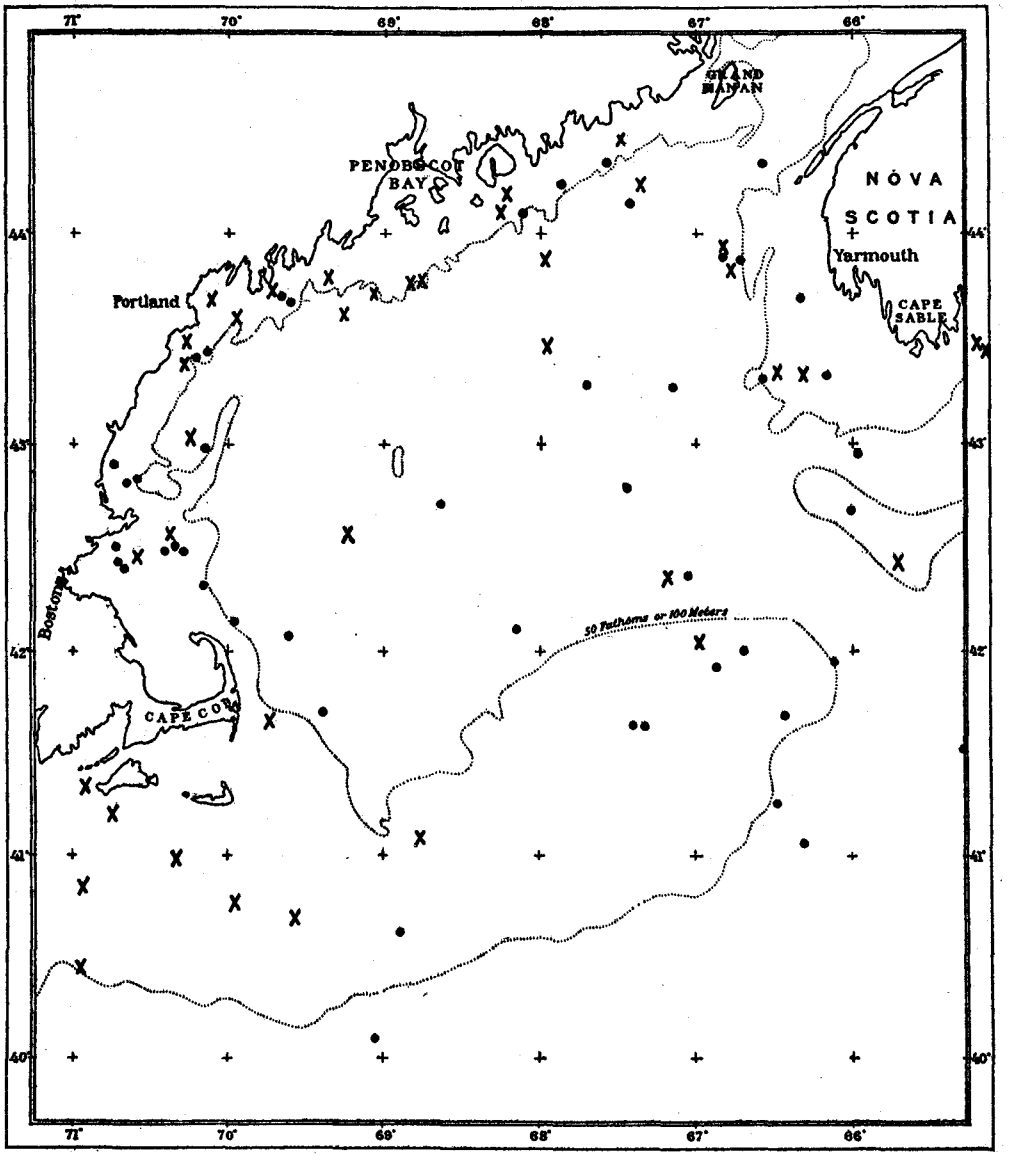

FIG. 85.—Occurrence of the copepod *Temora longicornis*. X, locality records, June to November; ●, December to May

Island, which have now been gathered by the cruises of the *Grampus*, *Albatross*, and *Halcyon* and by the Canadian fisheries expedition, not one has been from outside the continental edge as outlined by the general contour line for 400 meters; but it drifts out to the Laurentian channel between Nova Scotia and Newfoundland

and over the deep trough within the Gulf of St. Lawrence (Willey, 1919), and its range extends far out into the ocean off Labrador, as just noted (p. 287).

Seasonal distribution.—McMurrich (1917) has remarked that Temora occurred at intervals at St. Andrews during the autumn of 1914 and up until January 27, 1915 (on which date it was the dominant component of the plankton), but not at all from February to mid-May. His unpublished plankton lists for November, 1915, to October, 1916, carry the observations a step farther, showing Temora constantly present at St. Andrews, and in considerable numbers, from mid-September through January, but only at intervals, and represented by odd individuals, during the other months. Wheeler (1901) and Fish (1925) have likewise found it much more plentiful at Woods Hole in winter than in summer.[55]

Temora longicornis has been recorded in the open waters of the Gulf of Maine in every month in the year except November and February, when few tows have been studied for their copepods. In the coastwise belt the frequency of occurrence has been highest during the period September to January, and again from March to April, as indicated by the percentage of stations at which it occurred (about 50 per cent in each case), and lowest during the June–August quarter, when it was recorded at only 22 per cent of the stations in this region. However, this may reflect an annual and not a seasonal fluctuation, because Temora occurred in a much larger percentage of our hauls in July and August of 1913 (about 50 per cent in the gulf, on Georges Bank, and off Nantucket) than in those months in 1912. It was again scarce in the summer of 1914 (14 per cent of the stations on Georges Bank and in the gulf; not at any of the stations off Marthas Vineyard); but the year 1915, when Temora occurred at about 42 per cent of the stations right through the season from May to October, apparently saw the local stock increase once more. The percentage of occurrence has been about the same (33 to 38 per cent of the stations) for July–August as for February–May on the offshore banks and over the shelf off Nantucket and Marthas Vineyard.

In short, such analysis as I have been able to make does not prove a definite periodicity in the frequency of this species in the open gulf beyond suggesting the possibility that there is a minimum in midsummer.

The evidence of the vertical hauls (tables, pp. 297 and 299) is that Temora is seldom if ever dominant anywhere in the open gulf at any time, for at the maximum it has constituted only 20 per cent of the catch of copepods (station 20062);[56] and in only six of the many vertical hauls anywhere between the longitudes of Marthas Vineyard and Cape Sable has it constituted as much as 10 per cent of the copepods, the average for all being only about 3 to 4 per cent of Temora, even if the calculation be limited to those stations where this copepod was plentiful enough to be picked up by the vertical net. If the stations where it was missed be included, its average percentage drops below 2 per cent. The absolute numbers of individuals per square meter have been correspondingly insignificant, compared to those of *Calanus finmarchicus*, at the maximum being only about 18,000 within the gulf, 18,760 off Shelburne, Nova Scotia (station 10313, September 6, 1915), and about 33,000 near Marthas

[55] Williams (1907) reported it as abundant throughout the year in Narragansett Bay.

[56] 28 per cent off Shelburne, Nova Scotia, Sept. 6, 1915, Station 10313.

Vineyard on October 21, 1915 (station 10331). But perhaps less reliance can be placed on quantitative calculations based on vertical tows for this species than for any of the other copepods of frequent occurrence in the gulf, because, as Farran (1910, p. 72) has remarked (which our own experience corroborates), it "has the habit, more marked than in most copepoda, of forming swarms of great density but of limited extent." For this reason conclusions as to its abundance in any region may be entirely misleading unless a great number of hauls are made close together, both in time and in location.

On two occasions we have encountered such swarms (fig. 20) within the geographic limits covered by this report—first over Nantucket shoals on July 9, 1913 (station 10060), when Temora dominated the tow at 40 meters (Bigelow, 1915, p. 287),[57] and second on the surface off Gloucester on October 31, 1916 (station 10399), as recorded elsewhere (Bigelow, 1922, p. 135). Had a vertical net chanced to pass through either of these swarms, we would have obtained very much larger numbers per square meter than have ever resulted from the vertical hauls actually made. But were Temora as abundant in the Gulf of Maine (relative to other copepods) as Brady (1878–1880) describes it about the British Isles, along the Norwegian coast, at the mouth of the Baltic, or in the Gulf of St. Lawrence (where Willey (1919) found it locally constituting up to 62 and 70 per cent of the copepod catches of the surface nets), surely our many towings would more often have yielded it in comparative abundance instead of with monotonous scarcity.

Because the distribution of Temora is so often streaky and its frequency of occurrence varies so much in the gulf from year to year, numerical calculations based on vertical hauls scattered through different years, and often too far apart in miles, can not be depended upon to reflect its seasonal cycle correctly. But whereas the frequency of occurrence has been as high for March and April as for summer or autumn, the numbers of specimens actually taken per station have ranged smaller, averaging only about 200 per square meter for March and 300 for April at the stations where it was taken, with maxima of 1,075 (station 20068) and 1,300 (station 20105), respectively; and if the stations where the species failed were included in the calculation the averages would fall below 100 per square meter for both these months.

In summer Temora has usually been much more plentiful than this, if taken at all, the August catches for 1913 ranging from 600 to 18,000 per square meter (average 5,362), with 800 to 3,300 (average 1,484) for September, 1915.[58] In October, 1915, there were from 980 to 5,700 per square meter at the stations within the gulf (average 2,755), with 32,760 and 8,160 at two stations off Marthas Vineyard. No vertical hauls were made in November, December, or January, but the small percentages of Temora in the uniformly scanty catches of copepods in the horizontal hauls for December, 1920, and January, 1921 (table, p. 304), and our failure to take it at all off Gloucester during the winter of 1912–13 (Bigelow, 1914a, table, p. 409), point to this as a season of local scarcity.

Thus, there is some evidence, if not entirely conclusive, that while Temora is widespread in the open gulf in early spring it is usually very sparsely represented

[57] In the published account this and the preceding station are confused.

[58] Also 18,760 per square meter off Shelburne, Nova Scotia, station 10313.

anywhere at that season; but that as the existing stock, which has carried over the winter, dies out entirely in some localities between April and August, active multiplication takes place locally, which under exceptionally favorable circumstances may build up the shoals previously alluded to (p. 290) and which in any case raises the general average of abundance to several times its early spring level. It is not possible to set a definite date when this multiplication begins. In 1915 catches as large as 1,100 to 8,200 per square meter were made in the eastern side of the gulf by May 6 to 10 (stations 10270 and 10272; table, p. 297), but we found only 140 to 420 Temora per square meter at stations in the western side from the 4th to the 17th of the month in 1920. Probably the schedule varies over a period of several weeks from year to year, as do most periodic changes in northern seas, but it agrees essentially with the seasonal periodicity of the species in the Irish Sea, where it is most plentiful in summer,[59] and in the Baltic generally, where it is scarce in February, most common in August and November, and scarce or common in May, depending on the locality (Farran, 1910).

Comparison of the data just outlined for the open Gulf of Maine with Doctor McMurrich's plankton lists brings out the interesting difference that Temora commences to multiply three months or more earlier in the season out at sea than in the inclosed waters at St. Andrews, a difference which may be correlated with temperature.

Vertical distribution.—Obviously a species having its center of distribution within the 100-meter contour must be most plentiful above that level, and Temora has been found most numerous close to the surface. For example, the swarm off Nantucket of July 9, 1913 (station 10060), was so closely confined to the uppermost stratum that while the surface haul with a small net yielded thousands the haul from 40 meters with a large net caught only 25 specimens (Bigelow, 1915, p. 294). The Massachusetts Bay swarm of October 31, 1916, was likewise on the surface, with Calanus, not Temora, dominating the catch from 60 meters. Doctor McMurrich's St. Andrews records were all from within 7 meters of the surface, and many of them were immediately at the surface irrespective of season. Dr. W. C. Kendall also took it repeatedly in surface tows on Georges Bank in August and September, 1896. In the spring of 1920 the surface tows (table, p. 303) yielded it with about as great frequency and in about as great numbers as the vertical hauls, and as an extralimital instance of the same sort in neighboring American waters *Temora longicornis* dominated the surface tow between Block Island and Marthas Vineyard on November 10, 1916 (station 10405). It is plentiful in very shoal water at Woods Hole, and Willey (1919) found it regularly on the surface in the Gulf of St. Lawrence and about as often in surface as in vertical hauls on the Nova Scotian shelf. Herdman, Thompson, and Scott's (1898) records in the North Atlantic were all from within a couple of fathoms of the surface, and this copepod has repeatedly been taken in abundance at the surface in north European waters.

No direct evidence is available as to how deep Temora descends in the Gulf of Maine, but apparently the zone of greatest abundance for it hardly extends below about 50 meters. No attention has been paid to possible stratification of Temora

[59] This appears in the counts of copepods given by Herdman (1908 and 1919).

in the gulf within this depth zone, but at one of Doctor Kendall's stations off Nantucket shoals (September 2, 1896), when there was a difference of less than one degree of temperature between the surface (14.2°) and the 20-meter level (13.6°), the catch of "small brown copepods" in 5-minute tows at 10 meters, 20 meters, and 30 meters was roughly proportionate to the depth—that is, to the length of the column of water fished through—indicating that Temora was comparatively uniformly distributed down to that depth.

Temperature and salinity.—The distribution of *T. longicornis* in other seas proves it tolerant of a wide range in its physical surroundings from salinities as low as 6.54 per mille in the inner Baltic to upward of 35 per mille in the open Atlantic, in temperatures as low as about 2° and upwards of 20°. Its tendency to congregate near the surface makes it subject to a wide seasonal variation in temperature in many seas. Thus, at St. Andrews it survives temperatures as low as −1° to 0° in midwinter; at Woods Hole also. At the other extreme, one of our largest catches of Temora (station 10260, surface) was from water of 16°.

The highest temperature at which it has been definitely recorded in North American waters is 20.5° on the surface at a July station off New York (station 10066; Bigelow, 1915, p. 294), where sinking to a depth of only 30 meters would have lowered the temperature by 10°. But there is some reason to believe that it finds somewhere between 15° and 20° the upper limit of favorable temperature, for it was fairly well represented in the hauls from 25 and 10 meters, at another station off New York on August 1, 1916 (station 10362), levels at which the temperature was, respectively, about 12° and 16°, but was wanting at the surface in 21.1°. Within the Gulf of Maine any planktonic animal can always reach water cooler than 15° by sinking down less than 20 meters even at the warmest season and in the warmest region, but there is no direct evidence that Temora tends to sink below the warmest zone. The fact that Doctor Kendall, in his notes for August and September, 1896, records "small brown copepods" (in all probability *T. longicornis*) in several surface tows off the northwestern slope of Georges Bank and in the neighboring parts of the basin at temperatures of 17.5° to 20°, as well as repeatedly in 13° to 15° on the bank itself, makes it more likely that temperatures as high as 18° to 20° do not hinder its existence or growth.

It is not likely that differences in salinity within the limits prevailing in the Gulf of Maine affect the distribution of this copepod, but the high salinities of the oceanic basin, *per se*, or in conjunction with high temperature, may be the effective barrier which confines it to the banks water inside the inner edge of the Gulf Stream off the North American coast.

Why Temora (and this applies to many other neritic members of the plankton) should be so closely confined to comparatively shoal regions, irrespective of the physical state of the water within wide limits, when it has no connection with the bottom at any stage in its existence but is pelagic throughout its life, is a question to which no answer can yet be given.

Breeding.—No direct observations have been made on the breeding of Temora in the Gulf of Maine nor have its larval stages been detected there, but its distribution, regional and seasonal, is such as to leave no doubt that it is regularly endemic. Its

seasonal periodicity, both in the gulf and in the seas of northern Europe (p. 291), points to a wave of reproduction in the rising temperature of late spring or early summer, very little production taking place during the coldest months of the year; but with Temora occupying so broad a range in latitude and living under physical conditions so various, it is not likely that the precise temperature governs its periods of reproduction. Even in an area as confined as the Gulf of Maine there may be regional differences in this respect, for the comparatively large catches made at two stations in the eastern side of the gulf on May 6 to 10, 1915 (stations 10270 and 10272), at temperatures of 3° to 4°, point to reproduction in even colder water shortly previous, whereas Doctor McMurrich did not begin to find Temora a constant element in the tow at St. Andrews until the temperature of the water was near its annual maximum of 12° to 13° in September. It is questionable, however, whether it breeds successfully in temperatures higher than 15° to 16°.

Economic importance.—Wherever Temora abounds in northern seas it is one of the most important articles in the diet of herring (it is described by Willey (1921, p. 187) as "herring food *par excellence*"), of mackerel, and probably of other plankton-eating fishes. Lebour (1920) found it one of the copepods most commonly eaten by young fishes at Plymouth, England. Except for Willey's (1921) suggestion that fluctuations in the abundance of this and of other copepods may possibly be correlated with the weir catches of young herring ("sardines") in the Bay of Fundy, I know of nothing published on Temora as food for fishes in the Gulf of Maine. Certainly it can not rival *Calanus finmarchicus* in that respect in the open gulf, but on the occasions when it swarms any schooling fish in the vicinity would no doubt gorge on it, and large mackerel opened by Doctor W. C. Kendall off the northwest slope of Georges Bank on August 23, 1896, were full of these "small brown copepods" and of red feed (Calanus).

The frequency and comparative abundance of Temora at St. Andrews from September on suggests greater economic importance for it there than in other parts of the gulf.

Temora turbinata (Dana)

This form is very closely allied to *T. longicornis* but is recognizable by a uniform and well-defined difference in the size and structure of the fifth legs of both male and female, a difference which Dr. C. B. Wilson writes he has been able to substantiate on a very large number of specimens from Chesapeake Bay. There are differences, also, in the relative length of the last two segments of the abdomen and in the structure of the two terminal setae of the furca, as described by Giesbrecht (1892).

T. turbinata is a more southern copepod than *T. longicornis*, previously published records for it including the tropical Pacific, Sulu Sea, China Sea, New Zealand, Malay Archipelago, and Gulf of Guinea. It has not been reported from the North Atlantic, but Dr. C. B. Wilson contributes the note that it "is present in great abundance in the plankton of Chesapeake Bay and vicinity," and he detected a scattering of *T. turbinata* at three Gulf of Maine stations in the spring of 1920—viz, off the continental slope of Georges Bank on February 22 and April 16 (stations 20045 and 20109) and in Massachusetts Bay near Boston Harbor on April 9 (station 20089). In the Gulf of Maine it is evidently a very rare stray from the south.

Tortanus discaudatus (Thompson and Scott)

This species has so far been found only off the Pacific and Atlantic coasts of North America, either close to land or in partially inclosed waters. On the west coast it is reported from Puget Sound (Thompson and Scott, 1898) and from Bering Sea and Alaska (Willey, 1920). The Atlantic records are from the Gulf of St. Lawrence, whence it was first described (Thompson and Scott, 1898) and where it has since been found widespread and in abundance in the shoaler parts (T. Scott, 1905; Willey, 1919), and recently at Woods Hole (Fish, 1925). The Canadian fisheries expedition had it outside Cabot Strait and at two stations close to the outer coast of Nova Scotia (Willey, 1919). Wright (1907) records it from Canso, Nova Scotia, Willey (1921) has stated that it is plentiful at St. Andrews, and there are other Gulf of Maine records, as below. It has been found in considerable numbers at Woods Hole in July and occasionally in December and May (Wheeler, 1901; Sharpe, 1911; Sumner, Osburne, and Cole, 1913a), but it has not been found further south.

Gulf of Maine.—At St. Andrews this is one of the most frequent and abundant copepods. It appeared in about half the hauls from mid-May through June in Doctor McMurrich's plankton lists for 1915 and 1916, rising to its maximum during July, August, and September, for which quarter it is listed in almost every haul. In October and November it was much less constant (only about 50 per cent of the hauls), and when taken it was less abundant. In December Tortanus occurred in only about 25 per cent of the hauls, in January only once, and not at all in February, March, or April. During the late autumn and winter of 1916–17, Tortanus formed 46 per cent of the copepods in a gathering at St. Andrews on November 2, 9 per cent on December 8, 4 per cent on February 23, and was not detected at all on April 7, May 1, or May 17 (Willey, 1921). It is likewise plentiful in summer at Canso, Nova Scotia (Wright, 1907), and in the Gulf of St. Lawrence, Willey (1920, p. 22) describing it as composing "50 to 75 per cent of the summer copepod plankton off Souris, Prince Edward Island." On the whole, therefore, it may be classed as a summer species along the northeastern coast of America. A periodicity of this sort indicates one breeding period yearly, probably extending from early summer until early autumn, with little or no reproduction taking place in late autumn, winter, or early spring.

The abundance and frequency of Tortanus at St. Andrews, with its presence in Portland Harbor in July (Bigelow, 1914) and at Woods Hole, as just noted, suggest that it occurs in estuarine and inclosed waters all around the coast line of the gulf; but it is so closely confined to such situations that we have taken it only four times in the open gulf in all our towing—twice in Massachusetts Bay during the winter season of 1912–1913 (station 10048, November 20, and station 10053, February 12), once on German Bank (April 15, 1920, station 20103), and once in the northeastern corner of the basin off the mouth of the Bay of Fundy (January 5, 1921, station 10502). Not only is Tortanus extremely infrequent outside the outer headlands in the Gulf of Maine, but it is among the scarcest of copepods there, in numbers, the first three of the records just listed being based on one or two specimens each.

In the last instance there were 7 per cent of this species in a very scanty catch of copepods made with the open net towing horizontally at 150–0 meters.

It will be noted that the dates of these offshore captures do not correspond with the seasonal periodicity of the species at St. Andrews, but with a species as rare as this is out at sea it is largely a matter of luck whether any given haul chances to pick it up, and if the catch of other copepods be large, it is equally a matter of luck whether the particular sample of the tow examined chances to contain it.

Tortanus discaudatus is thus so strictly neritic in the gulf (decidedly more so than in the Gulf of St. Lawrence, where it is widespread over the shoal southern part) that it is hardly a factor at all in the offshore plankton, but probably it enters regularly into the diet of the small herring and other young fishes among the islands and in the harbors of the gulf, judging from its abundance at St. Andrews.

Undeuchæta major Giesbrecht

This species is probably worldwide in temperate and tropic latitudes in the oceanic basins. It has been recorded off the west coast of Ireland in the north and from several stations below the Equator down to 40° S., 35° E., off South Africa in the south. It was originally described from the central Pacific and has since been taken off southern California (Giesbrecht, 1895) and at San Diego (Esterly, 1905) in that ocean. *U. major* has not yet been found in the Mediterranean but has been reported from the Indian Ocean (van Breemen, 1908) and among the Malay Archipelago (A. Scott, 1909).

Previous records for this species off the Atlantic coast of North America are one station outside the continental edge off New Jersey, in July, 1913 (Bigelow, 1915, p. 287, station 10071), and three Canadian fisheries stations in July, 1915—one outside the continental edge off La Have Bank, one at the same relative location somewhat farther east off Banquereau Bank, and the third in the oceanic basin off the mouth of the Laurentian channel between Sable Island Bank and the Newfoundland Banks (Willey, 1919). To these Dr. C. B. Wilson's table (p. 299) adds two vertical hauls in the Gulf of Maine—one of them on Browns Bank (March 13, 1920, station 20072) and the other on German Bank (April 15 of that year, station 20103). In each instance there were about 10 specimens in the catch, being at the rate of about 50 per square meter.

In the Gulf of Maine this copepod is one of the rarest of strays from the oceanic basin offshore, locally interesting when it occurs as an indicator of the prevailing indraught. Not having been taken farther in than German Bank, it may be assumed to be shorter-lived in the gulf than the species of Eucheirella, Pleuromamma, or Rhincalanus, which are similarly exotic and immigrant in the gulf.

Undeuchæta minor Giesbrecht

The distribution of this species parallels that of *U. major* and it is equally oceanic. In the North Atlantic it has been reported as far north as the Faroe–Shetland channel (lat. 61° 20′ N.) and west of Ireland; as far south as latitude 35° (Wolfenden, 1911; With, 1915); it is known from the central Pacific and from off

southern California (Giesbrecht, 1892); also at San Diego, Calif. (Esterly, 1905), from the Indian Ocean (Thompson and Scott, 1903), and among the Malay Archipelago (A. Scott, 1909). Previous records for this species off the east coast of North America are one station off New York (July 11, 1913, station 10064) and four by the Canadian fisheries expedition—two of them off La Have Bank, one off Banquereau Bank, and one in the deep between the latter and the Newfoundland Banks (Willey, 1919). All these American records were from outside the continental edge.

U. minor was not detected in the Gulf of Maine until 1920, when Dr. C. B. Wilson found occasional specimens in the vertical hauls on Browns Bank on March 13 and on German Bank, April 15 (stations 20072 and 20103), these being the same two hauls that yielded *U. major* (p. 295).

Judging from the numbers of specimens taken, *minor* is, if anything, even scarcer than *major* in the gulf. In the Canadian hauls the reverse was true. So seldom entering the gulf, its chief local interest is as flotsam from the Atlantic offshore.

Zaus abbreviatus G. O. Sars

This harpacticoid, described by Sars (1903–1911) as not rare off the west coast of Norway, appears in Doctor McMurrich's lists of plankton at St. Andrews, New Brunswick, in about 20 per cent of the gatherings between November 23 and January 26, occasionally in April and June, and not at all during the later summer or early autumn. Sars (1903–1911, p. 59) speaks of it as restricted to the red algæ, where it often occurs in considerable numbers. There is no reason to suppose that its presence in the plankton is anything but accidental, and it has not been found in any of the tow nettings in the open Gulf of Maine.

Zaus spinatus Goodsir

This species is widespread on North Atlantic and Arctic coasts, Sars (1903–1911) enumerating the polar islands north of Grinnell Land, Nova Zembla, and Franz Josef Land in the Arctic, all along the Norwegian coast, the British Isles, Helgoland, and the coast of France. It has not been recorded previously from American waters. According to Brady (1878–1880) it lives among seaweeds from tide mark down to 10 to 12 fathoms. Under normal circumstances it is strictly littoral, living close to shore, but in regions of active vertical circulation it, like other littoral harpactoids, may be swept up to the surface. At St. Andrews, for example, Doctor McMurrich found it on one occasion (March 17, 1916), in a haul at 7 meters. It has not been detected in any of the tow nettings in the open Gulf of Maine nor in its other harbors.

Percentages of the several species of copepods in vertical hauls, May to October, 1915, identified and tabulated by Dr. C. B. Wilson

[In this and similar tables, T. = occasional specimen or trace; A. = abundant; C. = common; F. = few.]

Station number	10266	10267	10269	10270	10271	10272	10278	10279
Month	May							
Day of month	4	5	6	6	7	10	14	26
Depth in meters	125-0	260-0	115-0	175-0	70-0	90-0	150-0	65-0
VERTICAL NET								
Acartia clausi	5	10	10	5	14	1	2	2
Aetidius armatus					T.			
Anomalocera pattersoni							T.	
Calanus finmarchicus	90	85	80	80	70	84	70	78
Calanus hyperboreus		1	5	5	1	5	3	3
Candacia armata				T.				
Centropages hamatus				1				
Centropages typicus				1				
Eucalanus elongatus				T.				
Euchæta norvegica		1						
Euchirella rostrata							T.	
Metis ignæa					T.			
Metridia longa				2			2	5
Metridia lucens		1		1		3	15	
Paracalanus parvus	5	2	5	1	14	2	3	4
Pseudocalanus elongatus				2	1	3	5	5
Scolecithricella minor						T.		
Temora longicornis				2		2		3
Development stages	A.	C.	C.	A.	F.		F.	
Total number of copepods per square meter [1]	511,000	50,000	48,000	411,500	11,000	55,000	175,000	189,000

Station number	10282	10283	10284	10286	10287	10288	10290	10291	10293	10294	10296	10299
Month	June											
Day of month	10	10	11	14	14	19	19	23	23	23	24	26
Depth in meters	180-0	180-0	80-0	80-0	70-0	200-0	60-0	70-0	75-0	170-0	60-0	200-0
VERTICAL NET												
Acartia clausi	15	10	2	4	25	3	50	45	5	2	2	3
Acartia longiremis												1
Calanus finmarchicus	75	50	70	80	60	80	25	20	50	58	78	40
Calanus hyperboreus	1	10	1	6	5	6	3	10	5	5	10	15
Centropages bradyi						T.						
Dwightia gracilis								T.				
Eucalanus attenuatus	T.											
Euchæta media			T.									
Euchæta norvegica	1					3					3	
Halithalestris croni	1											
Metis ignæa				T.								
Metridia longa		10	15			3	15	10	15	25		20
Metridia lucens		5								3		15
Paracalanus parvus	3	10	6	4	5	2	7	5	10	5	5	3
Pseudocalanus elongatus	4	5	6	6	5	3			5			3
Temora longicornis								10	10	2	2	T.
Development stages	A.	F.	F.	S.								
Total number of copepods per square meter [1]	10,000	21,000	2,500	11,500	35,000	55,500	21,500	15,500	20,000	65,500	9,500	43,000

[1] From Bigelow, 1917, p. 319.

Percentages of the several species of copepods in vertical hauls, May to October, 1915, identified and tabulated by Dr. C. B. Wilson—Continued

Station number	10303	10304	10306	10307	10309	10310	10311	10313	10315	10316	10318	10319	10320	10321
Months	August				September									
Day of month	4	6	31	31	1	2	2	6	7	11	16	20	29	29
Depth in meters	70-0	200-0	140-0	230-0	200-0	190-0	60-0	70-0	80-0	60-0	70-0	30-0	70-0	40-0
VERTICAL NET														
Acartia clausi	30	1	1	10	6	10	40	6	------	40	50	30	15	8
Acartia longiremis	6	------	------	5	2	------	5	2	------	40	4	5	5	4
Aetidius armatus	------	------	------	T.	------	------	------	------	------	------	------	------	------	------
Calanus finmarchicus	30	65	60	30	80	80	30	30	45	10	30	20	45	15
Calanus hyperboreus	------	1	3	1	------	------	5	2	------	------	------	------	------	------
Candacia armata	------	------	------	------	------	------	------	------	------	------	------	5	------	------
Centropages bradyi	------	------	------	------	------	------	------	------	------	------	------	T.	------	------
Centropages hamatus	------	------	1	1	1	------	------	2	1	------	6	5	------	15
Centropages typicus	------	------	1	1	1	------	------	5	2	------	------	5	10	40
Eucalanus attenuatus	------	------	------	------	------	------	------	------	------	------	------	------	------	T.
Eucalanus elongatus	------	------	------	------	------	------	------	------	------	------	------	------	T.	T.
Euchæta norvegica	------	2	------	1	1	------	------	------	------	------	------	------	------	------
Eurytemora herdmani	------	------	------	1	1	------	------	------	------	------	------	------	------	------
Halithalestris croni	------	1	------	------	1	------	------	------	------	------	T.	------	------	------
Mecynocera clausi	------	------	------	------	------	------	------	------	------	------	------	T.	1	T.
Metridia longa	------	10	20	20	2	------	3	------	15	------	6	5	------	3
Metridia lucens	------	10	------	------	1	------	2	------	5	------	4	5	5	4
Paracalanus parvus	30	10	5	15	3	3	4	10	15	------	------	10	2	8
Pseudocalanus elongatus	------	------	10	15	3	7	4	15	15	10	------	5	15	2
Rhincalanus cornutus	------	------	------	------	------	------	------	------	------	------	------	------	T.	1
Scolecithricella minor	------	------	------	------	------	------	------	T.	------	------	------	------	------	------
Temora longicornis	4	------	------	------	------	------	2	28	2	------	------	5	2	------
Development stages	------	C.	C.	C.	A.	A.	A.	C.	C.	F.	------	------	------	------
Total number of copepods per square meter [1]	------	234, 500	51, 500	104, 000	173, 000	114, 500	41, 000	67, 000	47, 000	39, 700	14, 700	66, 500	42, 500	45, 500

Station number	10323	10324	10325	10326	10327	10328	10329	10331	10332	10333	10336	10337	10338	10339
Month	October													
Day of month	1	1	4	4	9	9	9	21	21	22	26	26	27	27
Depth in meters	80-0	150-0	175-0	145-0	60-0	60-0	60-0	30-0	50-0	80-0	50-0	60-0	80-0	70-0
VERTICAL NET														
Acartia clausi	10	15	6	15	30	10	15	5	15	6	15	10	------	------
Acartia longiremis	10	2	9	5	------	2	8	------	5	2	------	------	------	------
Aetidius armatus	------	------	------	------	------	------	T.	------	------	------	------	------	------	------
Anomalocera pattersoni	------	------	------	------	------	------	T.	------	------	------	------	------	------	------
Calanus finmarchicus	30	30	70	55	25	25	30	15	15	25	50	50	50	50
Calanus gracilis	------	------	------	------	------	------	------	1	T.	------	------	T.	------	------
Calanus hyperboreus	------	------	------	------	4	------	------	------	------	------	------	------	------	------
Candacia armata	------	------	------	------	------	------	------	------	------	------	T.	------	------	------
Centropages hamatus	10	------	------	------	------	------	------	25	5	6	7	6	10	8
Centropages typicus	10	------	------	------	2	3	------	25	5	6	6	6	10	10
Dwightia gracilis	------	------	------	T.	T.	------	------	------	------	------	------	------	------	------
Eucalanus attenuatus	T.	------	------	------	------	------	------	------	------	------	------	------	------	------
Euchæta media	------	------	------	------	------	------	------	------	------	------	------	T.	------	------
Eurytemora herdmani	------	------	T.	------	------	------	------	------	------	------	------	------	------	------
Metis ignea	T.	------	------	------	------	------	------	------	------	------	T.	------	------	------
Metridia longa	10	30	6	7	7	10	8	4	------	2	------	4	5	8
Metridia lucens	10	15	4	4	25	30	25	5	------	8	------	4	5	8
Paracalanus parvus	------	3	2	7	7	5	8	3	40	25	15	10	10	8
Pseudocalanus elongatus	10	5	6	7	------	5	4	3	15	15	7	10	10	8
Rhincalanus cornutus	------	------	------	------	------	------	------	------	T.	1	------	------	------	------
Temora longicornis	------	------	1	------	------	10	2	14	T.	4	------	------	------	------
Total number of copepods per square meter [1]	77, 000	112, 500	158, 500	86, 000	30, 700	57, 000	49, 000	234, 000	319, 500	204, 000	205, 000	------	244, 500	50, 500

[1] From Bigelow, 1917, p. 319.

Percentages of the several species of copepods in vertical hauls, February to May, 1920, identified and tabulated by Dr. C. B. Wilson

Station number	20044	20045	20046	20047	20048	20049	20050	20052	20053	20054	20055	20056	20057
Month	February						March						
Day of month	22	22	22	23	23	23	1	2	3	3	3	3	4
Depth in meters	150-0	150-0	50-0	50-0	150-0	200 0	150-0	200-0	225-0	250-0	225-0	100-0	120-0
VERTICAL NET													
Acartia clausi									4				
Acartia longiremis									1				
Calanus finmarchicus	5	6	10	2	75	90	80	35	64	66	90	70	75
Calanus hyperboreus	5	14	5	2	3	3	2	5	5	1	2	2	5
Candacia armata									1				
Centropages typicus				18		7							
Eucalanus elongatus	5	10											
Euchæta norvegica		20						10	2		4		
Halithalestris croni									1			2	
Metridia longa			10						10		1		
Metridia lucens			30	60	2			25	3	1	1	6	
Paracalanus parvus	50	30	30	3	10		4			15		10	15
Pleuromamma gracilis												T	
Pleuromamma xiphias					T								
Pseudocalanus elongatus	30	10	15	15	10		14	25	8	15	2	10	5
Rhincalanus nasutus	5	10											
Temora longicornis									1	2			
Temora turbinata			T										
Development stages	A	C	A	A	A	C	A	C	C	F			
Number of adult copepods per square meter of sea surface (approximate)	10,000	10,000	3,750	1,250	8,750	37,500	10,750	5,000	15,000	12,500	15,000	150	500

Station number	20058	20059	20060	20061	20062	20063	20064	20065	20066	20067	20068	20069	20071
Month	March—Continued												
Day of month	4	4	4	5	5	10	11	11	11	12	12	12	13
Depth in meters	45-0	60-0	90-0	175-0	50-0	190-0	340-0	80-0	70-0	90-0	150-0	1000-0	150-0
VERTICAL NET													
Acartia clausi		30	5		30	10	5	20	5	1			
Acartia longiremis		5	8		5	30	1	5	2	1			
Calanus finmarchicus	60	25	75	70	6	40	80	40	60	70	96	60	75
Calanus hyperboreus	1	1	1				1	1	2			2	
Dwightia gracilis						3							
Eucalanus elongatus												5	
Euchæta norvegica							4	3			1	10	
Heterorhabdus spinifrons												4	
Lucicutia grandis													T
Metridia longa	20		2	10	1	1	4	25	25	20		10	10
Metridia lucens	10		1	10	3	1		3	3	4	1	4	5
Paracalanus parvus	3	24											
Pseudocalanus elongatus	6	15	8	10	35	10	5	3	3	3	1		10
Rhincalanus nasutus												5	
Scolecithricella minor	T												
Temora longicornis					20	5				1	1		
Development stages	F	F					C						
Number of adult copepods per square meter of sea surface (approximate)	1,250		1,000	2,500	50	130	2,000	1,000	370	5,000	107,500	77,500	10,000

Percentages of the several species of copepods in vertical hauls, February to May, 1920, identified and tabulated by Dr. C. B. Wilson—Continued

Station number	20072	20073	20074	20075	20076	20077	20078	20079	20080	20081	20083	20085	20086	20087	20088
Month	March—Continued														
Day of month	13	17	19	19	19	19	20	22	22	22	23	23	23	24	24
Depth in meters	75–0	70–0	150–0	90–0	200–0	800–0	110–0	210–0	60–0	200–0	65–0	60–0	170–0	250–0	75–0
VERTICAL NET															
Acartia clausi	10	------	2	------	------	15	------	------	5	------	------	40	------	------	2
Acartia longiremis	5	------	10	------	------	5	------	------	------	------	------	8	------	------	2
Aetidius armatus	------	------	------	------	------	------	------	------	------	------	------	1	------	------	------
Anomalocera pattersoni	------	------	------	------	------	------	------	------	------	------	------	1	------	------	------
Calanus finmarchicus	32	30	30	55	50	30	55	50	45	75	50	50	75	25	50
Calanus hyperboreus	------	------	30	5	10	10	15	10	5	5	------	------	2	15	10
Candacia armata	------	------	------	------	------	1	------	------	------	------	------	------	------	------	------
Centropages bradyi	------	------	------	------	------	------	------	------	------	------	------	------	------	------	1
Centropages hamatus	------	------	------	------	------	------	------	------	------	------	------	------	------	2	------
Euchæta media	------	------	------	------	------	------	------	------	------	------	------	------	------	T	------
Euchæta norvegica	------	------	5	------	10	4	------	5	5	5	------	------	------	10	10
Eurytemora herdmani	------	------	------	------	------	------	------	------	------	------	------	------	------	2	------
Galdius tenuispinis	------	------	------	------	------	1	------	------	------	------	------	------	------	------	------
Labidocera æstiva	------	------	------	------	------	------	------	------	------	------	------	------	------	1	------
Metridia longa	7	10	6	15	20	20	10	5	5	------	15	------	7	15	20
Metridia lucens	25	35	6	15	10	10	10	15	10	5	20	------	10	20	5
Paracalanus parvus	5	------	6	------	------	4	------	------	------	------	------	------	------	------	------
Pleuromamma xiphias	4	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Pseudocalanus elongatus	6	15	5	10	------	------	10	10	20	10	15	------	6	10	------
Rhincalanus cornutus	------	------	------	------	------	------	------	------	------	T	------	------	------	------	------
Rhincalanus nasutus	T	------	------	------	------	------	------	------	------	T	------	------	------	------	------
Temora longicornis	------	10	------	------	------	------	------	------	------	------	------	------	------	------	------
Temora turbinata	------	------	------	------	------	------	------	5	5	------	------	------	------	------	------
Undeuchæta major	4	------	------	------	------	------	------	------	------	T	------	------	------	------	------
Undeuchæta minor	2	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Number of adult copepods per square meter of sea surface (approximate)	1,250	100	5,000	1,000	2,300	------	25,000	1,250	375	5,000	250	500	8,750	27,750	4,750

Percentages of the several species of copepods in vertical hauls, February to May, 1920, identified and tabulated by Dr. C. B. Wilson—Continued

Station number	20089	20090	20091	20092	20093	20094	20095	20096	20097	20098	20099	20100	20101	20102	20103
Month	April														
Day of month	6	9	9	9	9	10	10	10	10	10	12	12	12	13	15
Depth in meters	60–0	120–0	30–0	80–0	160–0	90–0	90–0	35	80–0	90–0	70–0	225–0	115–0	60–0	90–0
VERTICAL NET															
Acartia clausi			15				10	10	15	2	1	10	1	45	20
Acartia longiremis										2	14	1	1	5	5
Aetidius armatus											1				
Anomalocera pattersoni													1		
Calanus finmarchicus	50	45	65	75	25	80	75	80	80	80	80	75	34	30	35
Calanus hyperboreus		45	4	10	20	17	5	3	2	2	2	2	1	5	5
Candacia armata															1
Centropages hamatus															2
Centropages typicus									1						
Dwightia gracilis				T											T
Eucalanus attenuatus	2														2
Eucalanus elongatus													1		
Euchæta media										T					2
Euchæta norvegica		1								2		2			
Euchirella rostrata													1		
Gaidius tenuispinis									1						
Halithalestris croni		1													
Labidocera æstiva									1						
Metis ignea	1														
Metridia longa	10	4	12		20	1	5	4				2	35	1	5
Metridia lucens	15	2	4		20	1	3	2				1	20	1	5
Paracalanus parvus	T									1					2
Phyllopus bidentatus									T						
Pleuromamma abdominalis													1		
Pleuromamma gracilis															1
Pleuromamma robusta	2									1					
Pleuromamma xiphias														1	
Pseudocalanus elongatus	15	2		10	12	1	2			10	1	5	4	10	10
Rhincalanus cornutus	2														
Rhincalanus nasutus							T								
Scolecithricella minor								1							
Temora longicornis	2			5	3		1				1	1	1	1	2
Temora turbinata	1														
Tortanus discaudatus															1
Undeuchæta major															2
Undeuchæta minor															T
Development stages						F	C	C	A	C	A	A	A	A	C
Number of adult copepods per square meter of sea surface (approximate)	2,500	7,500	7,500	12,500	7,500	5,000	10,600	7,800	3,250	1,250	2,000	4,750	2,750	900	2,650

Percentages of the several species of copepods in vertical hauls, February to May, 1920, identified and tabulated by Dr. C. B. Wilson—Continued

Station number	20104	20105	20106	20107	10108	20109	20110	20111	20112	20113	20114	20115	20116	20117	20119
Month	April—Continued														
Day of month	15	15	15	16	16	16	16	17	17	17	17	18	18	18	20
Depth in meters	45-0	125-0	40-0	240-0	135-0	155-0	80-0	65-0	290-0	230-0	175-0	295-0	200-0	85-0	90-0
VERTICAL NET															
Acartia clausi	1	2	50	2	45	2	6	25	2	1		4	20	20	15
Acartia longiremis		1	4				10		10	1		4	10	5	
Aetidius armatus			1			1									
Calanus finmarchicus	25	60	20	60	35	60	60	60	50	54	75	50	55	65	75
Calanus hyperboreus	1	7	20	5	5	10			2	1		4	5	1	5
Centropages typicus	1												1		
Dwightia gracilis							5								
Eucalanus elongatus				1											
Euchæta norvegica									2	1		4	2		
Eurytemora herdmani						1									
Halithalestris croni	1									T		1			
Metis ignæa											1		1		
Metridia longa	10	20	2	2	5	10	3	5	25	20	3	20	1	1	1
Metridia lucens	16	6	1	20	5	10	3	5	3	15	15	1	2	2	2
Paracalanus parvus					2		7					8		1	
Pleuromamma gracilis											1				
Pleuromamma xiphias														1	
Pseudocalanus elongatus	45	3	1	10	2	5	5	5	5	7	4	1	2	2	2
Rhincalanus nasutus														1	
Temora longicornis		1	1		1		1		1		1		1	1	
Temora turbinata						1									
Development stages	C	F										F	C	C	A
Number of adult copepods per square meter of sea surface (approximate)	2,600	130,000	6,000	4,800	47,250	1,000	2,800	9,000	8,600	5,600	20,000	20,000	28,000	17,500	5,000

Station number	20120	20121	20122	20123	20124	20125	20126	20127	20128	20129
Month	May									
Day of month	4	4	7	16	16	16	17	17	17	17
Depth in meters	48-0	55-0	95-0	55-0	90-0	140-0	155-0	145-0	70-0	160-0
VERTICAL NET										
Acartia clausi	10	15	15	8	10	7	5	5	5	1
Acartia longiremis	5	2	5	8	1	1	5	5		2
Aetidius armatus										T
Anomalocera pattersoni	1									
Calanus finmarchicus	40	60	60	80	75	80	80	80	80	80
Calanus hyperboreus			5	2		3	3	5	1	1
Candacia armata										2
Centropages bradyi		1								
Centropages typicus										1
Eucalanus attenuatus		1								
Euchæta media						1				
Euchæta norvegica	1									1
Halithalestris croni			1		1					1
Heterorhabdus spinifrons	1									
Metridia longa	10	2	3	1	2	3	3	2	2	2
Metridia lucens	30	2	3	1	2		1		2	2
Paracalanus parvus		1	2			1	1	2		2
Pseudocalanus elongatus	1	15	5		8	4	1	1	10	2
Rhincalanus nasutus	1									1
Temora longicornis		1	1		1		1			2
Development stages	A	A	C	C	F					
Number of adult copepods per square meter of sea surface (approximate)	55,000	12,600	27,750		14,000	77,000	21,750	28,750	28,500	21,250

Percentages of the several species of copepods in samples from the surface hauls, February to May, 1920, identified and tabulated by Dr. C. B. Wilson

Station number	20044	20045	20046	20047	20048	20049	20053	20056	20058	20059	20060	20061	20063	20064
Month	February						March							
Day of month	22	22	22	23	23	23	1	3	4	4	4	5	11	11
SURFACE NET														
Arcartia clausi											25	T.	20	
Acartia longiremis											T.	10	4	
Asterocheres boecki										T.				
Calanus finmarchicus	66	50	80	75	34	90	60	70	66	95	50	60	10	45
Calanus hyperboreus											T.		T.	10
Halithalestris croni							10	4		5	T.	4	T.	
Metridia lucens		20		25	33	5					15	6		
Monstrilla serricornis								T.						
Pseudocalanus elongatus	34	30	20		33	5	30	22	17		10	20	66	45
Temora longicornis								3	17					
Development stages			A.	A.	A.	C.	A.	C.	F.					C.

Station number	20065	20067	20070	20071	20072	20073	20075	20077	20079	20081	20083	20084	20087	20088
Month	March—Continued													
Day of month	11	12	13	13	13	17	19	19	22	22	23	23	24	24
SURFACE NET														
Acartia clausi		25	10	60	T.		30	5	T.	10	15	25	15	10
Acartia longiremis		5	5		T.		3	5	T.	6	65	25	5	5
Calanus finmarchicus	80	30	75		66	50	30	65	50	60	8	5	60	75
Calanus hyperboreus						5	T.	5	25		2			1
Euchæta norvegica								6	25					
Halithalestris croni										1	2		5	1
Metridia longa	5	10				10		5		15	2			
Metridia lucens	8	5		20	1	5		3		6	6	25		
Monstrilla serricornis			T.											
Paracalanus parvus								5		2		10		
Pseudocalanus elongatus	5	25	10	20	33	30	33	1	T.				15	8
Temora longicornis	2	T.					4					10		
Development stages										C.	C.	A.	A.	C.

Station number	20089	20090	20091	20092	20093	20094	20096	20099	20100	20101	20104	20105	20106	20107	20108
Month	April														
Day of month	6	6	9	9	9	10	10	12	12	12	15	15	16	16	16
SURFACE NET															
Acartia clausi	15		1			1	40			12	65	20	1	70	45
Acartia longiremis	5		1			1	5			6	10	3	1	5	40
Calanus finmarchicus	70	98	97	50	55	95	45	98	100	50	10	50	65	5	10
Calanus hyperboreus			1	1	1	1	2	2				7	30		3
Halithalestris croni										1					
Metridia longa				25	16	1	6			20		15	1		
Metridia lucens	10			12	14	1	2			10	10	5	1		
Monstrilla serricornis										T.			T.		
Pseudocalanus elongatus				10	12					1	5		1	20	
Temora longicornis		2		2	2										2

Percentages of the several species of copepods in samples from the surface hauls, February to May, 1920, identified and tabulated by Dr. C. B. Wilson—Continued

Station number	20109	20110	20111	20112	20113	20114	20115	20119	20120	20122	20124	20125	20127	20128	20129
Month	April—Continued								May						
Day of month	16	16	17	17	17	17	18	20	4	8	16	16	17	17	17
SURFACE NET															
Acartia clausi	45	16	17					8	35	6	6	10	6	30	7
Acartia longiremis	40	16	17					2	5	3			1	4	2
Calanus finmarchicus	10	60	33	100	100	98	80	87	60	90	90	75	65	60	90
Calanus hyperboreus	5	6				T.	5		T.	1	1	2		2	
Halithalestris croni		2				T.									
Metridia longa						2	5					3	20	1	
Metridia lucens													4	1	
Paracalanus parvus			20				10	1							
Pseudocalanus elongatus			10					2			3	10	4	1	
Temora longicornis			3											1	1
Development stages							F.	C.	C.	C.	A.	A.	C.		

Percentages of the several species of copepods in samples from the horizontal hauls, December, 1920, and January and March, 1921, identified and tabulated by Dr. C. B. Wilson

Station number	10488	10489	10490	10491	10492	10493	10494	210495
Month	December							
Day of month	29	29	29	30	30	30	30	31
Depth, in meters, of major part of haul	15	75	240	125	20	75	60	60
HORIZONTAL NET, OPEN								
Acartia clausi	5	3	1	3	1	10	3	5
Acartia longiremis	6	15		2	1	10	5	5
Anomalocera pattersoni	T.							
Calanus finmarchicus	65	30	90	55	55	55	75	25
Calanus hyperboreus			5					
Centropages hamatus	8							5
Centropages typicus	5	2				1		5
Dwightia gracilis					T.			
Euchæta norvegica			2					
Eurytemora herdmani	1							
Metis ignea	1							
Metridia longa	1	20		25	10	15	5	3
Metridia lucens	1	20		5	10	2	3	1
Paracalanus parvus			2		2	2	2	
Pseudocalanus elongatus	5	10		10	15	5	5	50
Rhincalanus cornutus					1		1	
Scolecithricella minor					T.			
Temora longicornis	2				5		1	1

Percentages of the several species of copepods in samples from the horizontal hauls, December, 1920, and January and March, 1921, identified and tabulated by Dr. C. B. Wilson—Continued

Station number	10496	10497	10499	10500	10502	10505	10506	10507	10508	10509	10510	10511
Month	January					March						
Day of month	1	1	4	4	5	4	4	4	4	5	5	5
Depth, in meters, of major part of haul	100	50	150	60	150	20	10	60	40	150	175	100
HORIZONTAL NET, OPEN												
Acartia clausi	------	5	2	------	10	5	5	3	15	5	10	5
Acartia longiremis	------	2	1	------	------	------	------	------	T.	------	2	2
Calanus finmarchicus	65	35	75	35	10	45	45	50	50	70	30	70
Calanus hyperboreus	2	2	5	------	------	------	------	------	------	------	2	------
Centropages bradyi	------	------	------	T.	------	------	------	------	------	------	------	------
Centropages hamatus	3	16	------	2	5	------	------	------	------	------	------	------
Centropages typicus	5	8	------	3	3	------	------	------	------	------	1	1
Eucalanus attenuatus	T.	------	------	------	------	------	------	------	------	------	------	------
Euchæta norvegica	2	------	2	------	T.	------	------	------	------	------	30	------
Gaidius tenuispinis	1	------	------	------	------	------	------	------	------	------	------	------
Halithalestris croni	------	------	------	------	5	------	------	------	------	1	------	1
Labidocera æstiva	1	------	------	------	------	------	------	------	------	------	------	------
Metis ignea	------	------	------	------	------	T.	------	------	------	------	------	------
Metridia longa	10	8	10	30	25	5	------	20	10	15	15	10
Metridia lucens	5	8	------	30	5	------	------	2	T.	5	------	5
Paracalanus parvus	------	2	------	------	10	------	5	------	------	------	------	1
Pseudocalanus elongatus	5	14	5	------	10	45	45	25	25	3	10	5
Rhincalanus cornutus	1	------	------	------	------	------	------	------	------	------	------	------
Temora longicornis	------	------	------	------	10	------	------	------	------	1	------	------
Tortanus discaudatus	------	------	------	------	7	------	------	------	------	------	------	------
Development stages	------	C.	C.	C.	A.	C.	A.	C.	F.	------	------	------

Supplementary note on the copepods[60]

Since the preceding account of the copepods was written, Dr. C. B. Wilson has made a further examination of the tow nettings of 1920 and 1921 and communicates the following notes on additional species detected. Most of these appear only in very small numbers. One, however—*Oithona similis*—is plentiful enough to suggest that it will prove widespread in the gulf.

Aegisthus mucronatus.—A single female was obtained from a vertical haul at station 20069, March 12, 1920, southeast of Georges Bank.

Alteutha depressa.—About a dozen of these peculiar harpactids, which look very much like sowbugs, were taken in a vertical net at station 20117 on April 17, 1920, close to the eastern shore of Cape Cod.

Amallophora magna.—Three females taken in a vertical net just off the southern edge of Georges Bank, February 22, 1920, station 20044.

Calanus minor.—Ten of these tiny calanids were taken at the surface between the eastern end of Georges Bank and Nova Scotia, April 16, 1920, station 20106.

Calanus tonsus.—Six females were taken in a vertical net off the eastern end of Georges Bank, April 16, 1920, station 20107.

Candacia norvegica.—Three females were captured at the surface off the southern edge of Georges Bank, May 17, 1920, station 20129.

Chiridius armatus.—Eight specimens, including both sexes, were taken in a vertical net southeast of Nova Scotia, March 19, 1920, station 20077.

[60] Communicated by Dr. C. B. Wilson.

Chiridius obtusifrons.—Three females were captured in a vertical net southeast of Cape Sable, March 19, 1920, station 20075.

Chirundina streetsii.—Two females were found in a vertical haul just south of Georges Bank, February 22, 1920, station 20045.

Clytemnestra rostrata.—A single female was taken in a vertical haul south of Georges Bank, February 22, 1920, station 20044.

Cornucalanus magnus.—A single female of this large calanid was found in a vertical haul southeast of Nova Scotia, September 6, 1915, station 10313.

Corycæus carinatus.—Eight specimens, including both sexes, were taken in a vertical net just north of Georges Bank, February 23, 1920, station 20048.

Corycæus elongatus.—Ten specimens, including both sexes, were found in the same haul with the preceding species, station 20048.

Corycæus ovalis.—Two females were taken with the preceding species.

Corycæus speciosus.—Two females were captured in a closing net north of Georges Bank, March 1, 1920, station 20053.

Dwighia gracilis.—Ten specimens, including both sexes, were taken in a vertical net just north of Georges Bank, February 23, 1920, station 20048 (see also p. 226).

Dwightia oculata.—Six females and three males of this beautifully colored species were taken in a vertical haul southeast of Nova Scotia, March 19, 1920, station 20076.

Euchæta marina.—A single male of this species was taken in a vertical haul northeast of Cape Cod, August 31, 1915, station 10307.

Euchirella curticauda.—Six specimens, including both sexes, were taken in a vertical net southeast of Nova Scotia, September 6, 1915, station 10313.

Euchirella pulchra.—Three females were captured in a vertical haul south of Georges Bank, February 22, 1920, station 20044.

Gætanus miles.—A single female was taken in a vertical net in deep water southeast of Nova Scotia, March 12, 1920, station 20069.

Gaidius brevispinus.—Three females were taken in a bottom net at a depth of 150 meters south of Georges Bank, February 22, 1920, station 20045.

Heterorhabdus norvegicus.—Six specimens, including both sexes, were captured in a vertical haul south of Georges Bank, February 22, 1920, station 20044.

Metridia brevicauda.—Fifteen specimens, including both sexes, were taken at the surface northeast of Cape Cod, April 18, 1920, station 20115.

Metridia princeps.—A single female was taken in a vertical haul off the southern edge of Georges Bank, February 22, 1920, station 20044.

Microthalestris forficula.—About 50 specimens of both sexes of this tiny harpactid were obtained at the surface north of Georges Bank, station 20114.

Oithona atlantica.—Thirty males and females were taken at the surface southeast of Nova Scotia, March 19, 1920, station 20075.

Oithona plumifera.—Three females were captured at the surface at station 10511, March 5, 1921.

Oithona similis.—Several hundred specimens of both sexes were obtained at various stations in vertical nets and at the surface.

Oncæa conifera.—Twelve specimens, including both sexes, were taken at the surface in the Eastern Channel, April 16, 1920, station 20107.

Oncæa minuta.—Fifteen males and females were captured in a vertical haul in deep water southeast of Georges Bank, March 12, 1920, station 20069.

Oncæa venusta.—Twenty-five males and females were found in a vertical haul south of Georges Bank, February 22, 1920, station 20044.

Scolecithricella obtusifrons.—Three females were captured in a vertical net in deep water southeast of Nova Scotia, March 19, 1920, station 20077.

Scolecithricella ovata.—Twenty females were taken in a vertical net south of Georges Bank, February 22, 1920, station 20044.

Temora stylifera.—A single female was captured in a vertical net southeast of Nova Scotia, September 6, 1915, station 10313.

Tisbe furcata.—A single female was taken at the surface just outside Boston Harbor, April 6, 1920, station 20089.

Daphnids (Cladocera)

These little crustaceans are often extremely plentiful in the coastwise waters of boreal seas, especially of the North Sea region. It is probable that they are an important element in the plankton of estuarine situations all around the coast line of the Gulf of Maine, for McMurrich found the genera Podon and Evadne regularly at St. Andrews during the summer months, often in abundance, while to the south of our area Fish (1925) reports both Evadne and Podon in abundance at Woods Hole and in Long Island Sound. The group as a whole, however, is so strictly neritic that it hardly figures in the planktonic communities of the open gulf more than a few miles out from land, except at rare intervals for brief periods, and is only accidental outside the 100-meter contour.

Only one cladoceran genus—Evadne—has yet been noted in our catches, and because of its slight importance in the natural economy of the offshore waters of the Gulf of Maine no attempt was made to list the occurrence in the towings of 1912 to 1914. A preliminary survey of the surface towings for 1915 located it at stations 10287, 10302, 10303, 10313, 10317, 10318, and 10319 and in Shelburne Harbor, Nova Scotia. In 1916 Evadne was recorded at only one Gulf of Maine station—10398. All these localities, as I have already stated (p. 35), lie within 15 miles of land. It did not appear in the samples of the catch at the other summer stations, which were passed under the microscope, but as examination of larger amounts of the plankton might have disclosed occasional specimens of Evadne, the most that can be said is that it was certainly scarce if not actually absent at the stations where it was not recorded (also on Georges Bank, August 13, 1926).

Evadne was not found at all in the spring towings of 1920 or during the winter and early spring of 1920–1921, but in August, 1922, it appeared at several stations in Massachusetts Bay (10636, 10637, 10638, 10640, 10641, 10643, and 10644). Up to that time we had found it in large numbers on only two occasions, namely, near Cape Elizabeth, September 20, 1915 (station 10319), and Cape Cod Bay, August 24, 1922 (station 10644), most of the other records being based on only a scattering. On August 18, 1924, however, after this report was ready for the press, surface tows

yielded a great abundance of Evadne off Gloucester, 1 to 10 miles out in Massachusetts Bay. It was less abundant 16 miles out and scarce or absent over the northern end of Stellwagen Bank. A tow made that same day close to the extremity of Cape Ann yielded only a fraction as many Evadne as off the mouth of Gloucester Harbor, and only a scattering was taken two days later in Provincetown Harbor, though young herring seined there were full of Podon and Evadne.

In the North Sea region Evadne is definitely seasonal in its occurrence. The two species whose occurrence there has been plotted—*spinifera* and *nordmani*—are both most plentiful in August. The entire stock of the former produces resting spores in autumn; then dies off. This is likewise the fate of most of the *nordmani*, though some few of these survive and continue to reproduce parthogenetically during the winter. The spores of the two species winter on the bottom, hatch in May, and by rapid asexual multiplication the stocks are again built up to their summer plurimum.[61]

Specific identification of the Evadne of the Gulf of Maine has not been attempted as yet, but our few records of the genus as a whole, with McMurrich's data for Podon and Evadne at St. Andrews, show a corresponding seasonal periodicity in the Gulf of Maine, all falling within the period June 8 to September 20, with the largest offshore catches in August and September. At Woods Hole, Fish (1925) found *Evadne nordmani* most plentiful in November, least so in spring, but *E. tergestina* at its maximum during the summer and early autumn.

Cladocera are one of the most important items in the diet of many species of larval and post-larval fishes in British waters (Lebour 1919 and 1920). Judging from the general similarity between the planktonic communities in general, probably this applies also to the inshore waters of the Gulf of Maine. The various young fishes that are in shoal water there in summer will probably be found to consume Evadne and Podon regularly—herring, for instance, as just noted.

WORMS

Glass worms (chætognaths)[62]

Four species of chætognaths are known from the Gulf of Maine, one of which—*Sagitta elegans*—is a regular member of the local endemic plankton while the others enter its limits as immigrants only.

Sagitta elegans

If I were asked to name three animals as most characteristic of the plankton of the offshore waters of the Gulf of Maine I should unhesitatingly select the copepods *Calanus finmarchicus* and *Pseudocalanus elongatus* and the chætognath *Sagitta elegans*.[63] Throughout the year and in every part of the Gulf of Maine, as well as over the offshore banks which inclose it on the south, this large, active, and voracious worm is so nearly universal that it has been taken at practically every station and in the great majority of our hauls. To the east and north of our limits,

[61] See Apstein (1910) for an account of the seasonal cycle.

[62] Identifications follow von Ritter-Záhony (1911) and Huntsman (1919).

[63] I follow Huntsman (1919) in treating as a unit the several "subspecies" of *S. elegans*, a species comparable to the herring, among fishes, in its tendency to develop local races in different physical environments.

too, it is a regular inhabitant of the whole continental shelf off Nova Scotia (Bigelow, 1917, and Huntsman, 1919), likewise over the Grand Banks of Newfoundland and in the Gulf of St. Lawrence, where the Canadian fisheries expedition found it at many localities and in large numbers (Huntsman, 1919). Generally speaking, the Gulf of Maine is the most southerly important center of regular reproduction and constant abundance for *S. elegans*, as it is for various other boreal planktonic animals. West and south of Cape Cod this chætognath is less plentiful, less regular in its occurrence, and more or less seasonal, ranging southward as far as Chesapeake Bay in cold summers (e. g., 1916) but rare beyond Nantucket in warm (e. g., the year 1913), as I have elsewhere remarked (Bigelow, 1922, p 152). At Woods Hole it is fairly plentiful from December to June, but decidedly rare or lacking entirely in summer (Fish, 1925, fig. 34). Probably it occurs farthest to the southward in winter, but the limit to its distribution in that direction is not yet known for the western Atlantic.

It has been well established, both by our own records and by those of the Canadian fisheries expedition of 1915 (Huntsman, 1919), that *S. elegans* (though not dependent on the bottom at any stage of development) is a creature of coast and not ocean waters. This, indeed, its occurrence in other seas would suggest. Broadly speaking, the outer edge of the continental shelf is its offshore boundary west of Cape Sable at all seasons, a fact illustrated by its rarity at our deep stations over the continental slope[64] both in the cold months and in the warm. East of this, however, Huntsman has shown that its outer limit fluctuates with the seasons, spreading out to the eastward to cover the great oceanic triangle between the Nova Scotian and Newfoundland Banks in spring, to contract again to the general contour of the continental edge as far as the tail of the Grand Banks (including the Laurentian Channel, however) in midsummer. The high temperature, or high temperature combined with high salinity, of the inner edge of the so-called Gulf Stream is an impassable offshore barrier to it along the North American coast.

Only a preliminary survey has yet been made of the collections of this species gathered during the Gulf of Maine cruises; enough, however, to show that its range covers the offshore parts of the gulf. We have seldom found it in any abundance over the deep basin, however, as appears clearly from the accompanying chart (fig. 86) showing the numbers of *S. elegans* per square meter of sea area as calculated from the catches of the vertical nets for the summer seasons of 1913, 1914, 1915, and 1916. Out of a total of about 80 such hauls, only seven have yielded more than 50 *S. elegans* per square meter anywhere in the gulf outside the general 100-meter contour, and these seven stations were all located close to that contour line. With these few exceptions, all our rich hauls of *S. elegans* have been in shallow water, either in the coastal zone (in July, 1912, we found *S. elegans* in some numbers in Casco Bay) or on the offshore banks. But the localization of the rich and poor catches show that not all parts of the peripheral zone of the gulf offer an equally favorable habitat for *S. elegans*,

[64] None were taken at station 10220 in 1914, station 10352 in 1916, stations 20044 and 20129 in 1920, nor at any of the deep stations on the slope west and south of Cape Cod either in 1913 or in 1916, but a few were detected in the vertical haul from 500 meters off Georges Bank, July, 1914 (station 10218).

the "rich" hauls (50+ and especially 400+ per square meter) being definitely concentrated in three chief centers of abundance—viz., in the Massachusetts Bay region and the waters immediately to the north and south of it on Georges Bank, which would

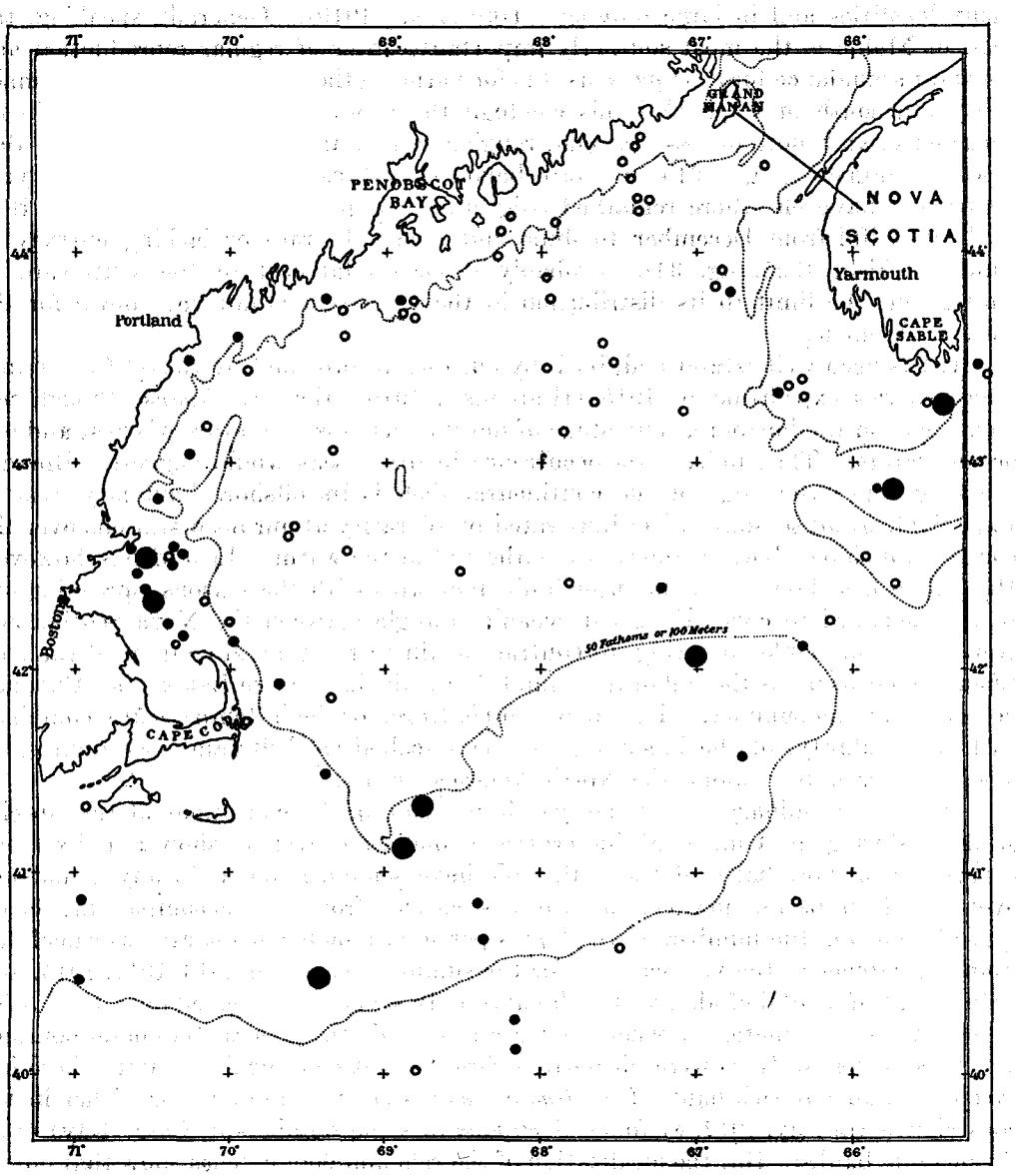

FIG. 86.—Numbers of the glass worm *Sagitta elegans* per square meter of sea area, June to September, as calculated from the vertical hauls. ○, less than 50, including stations where it was so scarce that none were taken in the verticals; •, 50 to 1,000; ●, 1,000+

probably apply equally to Nantucket Shoals, and in the neighborhood of Cape Sable in the eastern side of the gulf. It is only in these regions that we have made catches of 1,000 and more to the square meter.

The most abundant congregation of *S. elegans* so far encountered in the gulf was approximately 5,000 per square meter (young stages) over the outer part of the shelf off Nantucket on July 25, 1916 (Station 10354). *S. elegans* is far less abundant along the coast of Maine east of Cape Elizabeth, and off western Nova Scotia it is often so rare that the vertical nets failed to take it, though it might occur in the horizontal hauls. It is frequently as numerous as 50 per square meter in the Bay of Fundy, however, as Huntsman and Reid (1921) have pointed out.

Approximate numbers of individuals of Sagitta elegans per square meter of sea surface, based on the catches of the vertical nets

Station	Date	Number	Station	Date	Number
10213	July 19, 1914	10	10329	Oct. 9, 1915	230
10214	do	10	10336	Oct. 26, 1915	10
10215	July 20, 1914	1,380	10337	do	0
10216	do	860	10338	Oct. 27, 1915	100
10219	July 21, 1914	20	10339	do	385
10223	July 23, 1914	170	10341	July 19, 1916	2,500
10224	do	2,000	10342	do	1,750
10225	do	260	10344	July 22, 1916	60
10226	July 24, 1914	260	10345	do	810
10227	do	50	10346	do	445
10229	July 25, 1914	1,340	10347	July 23, 1916	2,500
10230	do	2,140	10349	July 24, 1916	470
10243	Aug. 11, 1914	70	10354	July 25, 1916	5,000
10244	Aug. 12, 1914	40	20048	Feb. 23, 1920	65
10245	do	10	20049	do	50
10246	do	20	20050	Mar. 1, 1920	30
10247	do	0	20053	Mar. 3, 1920	25
10248	Aug. 13, 1914	0	20054	do	15
10249	do	10	20055	do	50
10250	Aug. 14, 1914	10	20058	Mar. 4, 1920	5
10253	Aug. 22, 1914	50	20060	do	5
10255	Aug. 23, 1914	30	20061	Mar. 5, 1920	15
10266	May 4, 1915	10	20062	do	0
10267	May 5, 1915	0	20064	Mar. 11, 1920	204
10269	May 6, 1915	10	20065	do	5
10270	do	15	20066	do	50
10271	May 7, 1915	40	20067	Mar. 12, 1920	150
10272	May 10, 1915	25	20068	do	0
10278	May 14, 1915	5	20069	do	0
10279	May 26, 1915	0	20074	Mar. 19, 1920	180
10282	June 10, 1915	0	20075	do	50
10283	do	5	20079	Mar. 22, 1920	150
10284	June 11, 1915	0	20080	do	60
10286	June 14, 1915	10	20082	Mar. 23, 1920	10
10287	do	0	20086	do	5
10288	June 19, 1915	20	20087	Mar. 24, 1920	0
10290	do	20	20089	Apr. 6, 1920	10
10291	June 23, 1915	585	20090	Apr. 9, 1920	40
10296	June 24, 1915	0	20094	Apr. 10, 1920	0
10298	June 25, 1915	5	20095	do	65
10299	June 26, 1915	0	20100	Apr. 12, 1920	50
10303	July 7, 1915	70	20102	Apr. 13, 1920	5
10304	Aug. 7, 1915	25	20105	Apr. 15, 1920	50
10306	Aug. 31, 1915	15	20107	Apr. 16, 1920	20
10307	do	10	20108	do	10
10309	Sept. 1, 1915	25	20109	do	10
10310	Sept. 2, 1915	0	20110	do	490
10311	do	20	20111	Apr. 17, 1920	85
10313	Sept. 6, 1915	15	20112	do	10
10315	Sept. 7, 1915	410	20113	do	5
10316	Sept. 11, 1915	10	20115	Apr. 18, 1920	20
10318	Sept. 16, 1915	15	20116	do	15
10319	Sept. 20, 1915	455	20118	Apr. 20, 1920	90
10320	Sept. 29, 1915	130	20120	May 4, 1920	0
10321	do	145	20121	do	0
10323	Oct. 1, 1915	45	20122	May 8, 1920	20
10324	do	130	20123	May 16, 1920	100
10325	Oct. 4, 1915	115	20124	do	95
10326	do	5	20125	do	5
10327	Oct. 9, 1915	5	20128	May 17, 1920	1,000
10328	do	25	20129	do	100

We have encountered one or more centers of abundance for *S. elegans* on every cruise, and on such occasions the numbers actually present in the water may be very great (for so large an animal), as illustrated by the following examples:

Date	Station	Approximate number of S. elegans per square meter	Date	Station	Approximate number of S. elegans per square meter
July 19, 1916	10341, Massachusetts Bay	2,500	July 25, 1916	10354, off Nantucket	5,000
Do	10342, Massachusetts Bay	1,750	July 23, 1914	10224, Georges Bank	2,000
July 23, 1916	10347, Georges Bank	2,500	July 25, 1914	10330, near Cape Sable	2,140

In every case, however, we have found these swarms limited to areas so small that the neighboring stations have yielded only a fraction as many Sagittæ. Thus, in July, 1913, hauls off northern Cape Cod and on the western end of Georges Bank each yielded upwards of 1,000 large *S. elegans*, but an intermediate station of about the same temperature and salinity yielded only 28, while a month later the Sagitta stock at the first of these localities had dwindled nearly to the vanishing point (Bigelow, 1915, p. 298). Variations in the local abundance of this species were no less striking on August 15 of the same year, when we found it abundant off Cape Elizabeth and near the Isles of Shoals but extremely rare at a station halfway between those two localities. Again, on July 23, 1914, we found the waters over the northeast edge of Georges Bank (station 10224) alive with *S. elegans*, though there were very few at a neighboring station (10223) on the bank to the south or over the deep a few miles to the north. Similarly, *S. elegans* swarmed a couple of days later near Cape Sable and in the Northern Channel (stations 10229 and 10230), but was so rare over Browns Bank (station 10228) that our tow nettings yielded only one or two examples; and in July, 1916, we found *S. elegans* in multitudes in Massachusetts Bay on the 19th (station 10342) but much less common off Cape Cod only a few miles away (station 10344).

The data gathered on the spring cruises of 1913 and 1920 show that *S. elegans*, like most other large planktonic animals, becomes very scarce in most parts of the Gulf in early spring shortly after the water has cooled to its winter minimum, and falls to its lowest numerical ebb during the vernal flowering period of the diatoms. Thus in Massachusetts Bay in 1913 *S. elegans* dominated the tow in mid-February, with a catch of about 125 cubic centimeters in the horizontal haul on the 13th (Bigelow, 1914a, p. 405); but it had become so scarce by March 4 that the total catch in the large net (half hour's haul) was only 12 individuals, and no Sagittæ at all were taken on April 3, when diatoms were swarming. In 1920 *S. elegans* persisted in some numbers in the bay until the diatom flowerings were well advanced, vertical hauls on April 6 and 9 (stations 20089 and 20090) still yielding Sagittæ at the rates of 10 and 40 specimens, respectively, per square meter; but shortly thereafter they became so scarce in that general region that none were taken in the vertical haul and only occasional specimens in the horizontals on May 4 (station 20120). In this respect

Passamaquoddy Bay closely parallels Massachusetts Bay, for Saggittæ do not appear at all in Doctor McMurrich's plankton lists for St. Andrews between the first week in April and the first week in June. Our spring cruises in 1915 and 1920 suggest

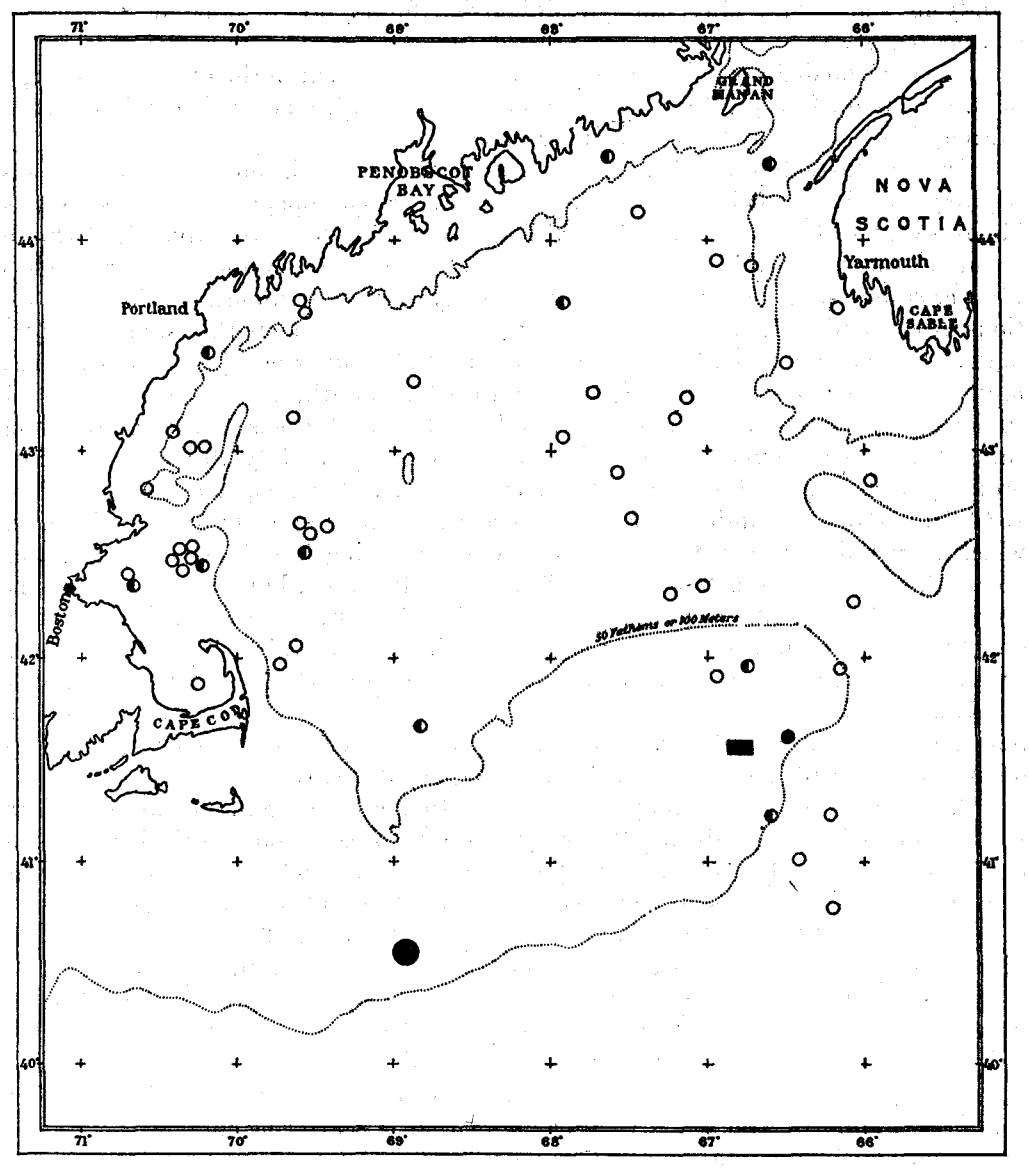

FIG. 87.—Numbers of *Sagitta elegans* per square meter of sea area in March, April, and May, as calculated from the vertical hauls. ○, less than 50, including stations where none were taken in the verticals; ◐, 50 to 400; •, 400 to 1,000; ●, 1,000+; ▬, stations where the horizontal haul yielded a swarm, but where no vertical haul was made

that the stock of *S. elegans* is at its lowest ebb over the inner parts of the gulf as a whole at about the same season (that is, end of April and beginning of May) as it is in Massachusetts and Passamaquoddy Bays (fig. 87) but does not fall to so low an

ebb offshore, having proved sufficiently plentiful in April and May for the vertical net to pick up at least a few specimens at almost every station. Similarly, Huntsman and Reid (1921) record considerable numbers of Sagittæ in the open Bay of Fundy in March and May, though McMurrich found few or none at St. Andrews at that season.

We have no definite evidence of vernal impoverishment in the numerical strength of *S. elegans* on Georges Bank, having, on the contrary, made rich catches there in March, April, and May [65] as well as in midsummer.

In the Massachusetts Bay region *S. elegans* increases in numbers after the first few days of May coincident with the multiplication of copepods, which is so notable an event in the planktonic cycle (p. 41), and may do so rapidly. In 1920, for example, the *S. elegans* population had risen to the respectable number of about 100 per square meter at two stations in the bay and at its mouth on the 16th (stations 20123 and 20124). Unfortunately we have no data on this subject for this part of the gulf for June, but it is probable that *S. elegans* usually reaches its maximum abundance there during the last half of that month, because in the very cold summer of 1916, when the seasonal cycle lagged several weeks behind more normal summers, vertical hauls at two stations within the bay on July 19 yielded an extraordinary abundance of this Sagitta—2,500 and 1,750 per square meter (stations 10341 and 10342)—numbers far in excess of its usual summer frequency there, and which may reflect the status of this chætognath during late June of warmer summers. This tremendous Sagitta population had dwindled, however, to perhaps not more than 50 individuals per square meter by the 29th of the month following; [66] and this may be an annual event, for although we have taken *S. elegans* in every subsurface haul which we have made in the Massachusetts Bay region in summer, it has usually been only a minor element in the local plankton in July or August, as reflected in catches of only 10, 50, and 15 individuals per square meter, respectively, on August 9, 1913, August 22, 1914, and August 31, 1915.

Apparently *S. elegans* may be expected to increase again in numbers in the western side of the gulf during the early autumn, because our vertical net yielded it at the rates of 130 and 145 per square meter in Massachusetts Bay on September 29, 1915 (stations 10320 and 10321), and of 100 and 385 per square meter at neighboring localities on October 27 (stations 10338 and 10339). By the evidence of horizontal hauls it was perhaps as abundant as this near the Isles of Shoals on November 1, 1916 (station 10400), and formed about one-fifth to one-fourth of the volume of the catch in Massachusetts Bay, off Gloucester, on December 4, 1912 (Bigelow, 1914a, p. 404). But *S. elegans* proved scarce throughout the northern half of the gulf generally on the December to January cruise of the *Halcyon* in 1920–1921, none of the hauls yielding more than a scattering among the copepod plankton, and at one station (10493) we missed it altogether—an unusual event. Our data on the status of *S. elegans* during the later winter are confined to the

[65] On the eastern part of the bank *S. elegans* dominated the horizontal catch on March 11, 1920 (station 20066), though the vertical haul indicated only about 50 per square meter, which illustrates the unreliability of the latter method when dealing with animals so large and so active. There were 490 per square meter at a neighboring location on April 16 (station 20110), and on the southwest part of the bank 1,000 per square meter on May 17 (station 20128).

[66] Judging from the scanty yield of the horizontal haul at station 10298. No vertical haul was made.

Massachusetts Bay region. Here we found it constituting from one-fourth to one-half of the rather scanty tow in January, 1913, and it dominated the planktonic community off Gloucester on February 13.

Sagitta elegans certainly is endemic in the Gulf of Maine. Huntsman and Reid (1921, p. 104), to whom we owe the only local record of its eggs (this for the Bay of Fundy), found from examination of ovarian eggs that in the Bay of Fundy the "spawning season is a long one, extending from the end of March or the beginning of April to September at least. September 4 would seem to be near the end of the season." Corresponding to this, they found eggs (identified by comparison with large series of eggs and young Sagittæ from the southern part of the Gulf of St. Lawrence, an important breeding ground) in the Bay of Fundy plankton from April to October, numerous or rare locally according to the abundance of the adult Sagittæ. Huntsman and Reid further point out that the proportional abundance of eggs at different stages in development proves that they do not develop properly in the Bay of Fundy until September, the warmest month of the season, nor did they find the young Sagittæ in any numbers in the plankton until that time. However, the young proved to be even more widely distributed than their parents, occurring not only in the open bay but also up the estuaries, where the adults are not to be found; and in general the younger stages were most plentiful at locations where the water was stratified vertically as to its temperature and density, and least so where vertical circulation was most active.

Huntsman and Reid concluded (and I believe justly) that the Bay of Fundy is such an unfavorable environment for the reproduction of *S. elegans* that the stock raised there locally is small and that the Sagitta population is kept up by immigration from the Gulf of Maine.

Sagitta eggs have not been detected (perhaps because not especially sought) in our plankton hauls in the open gulf, nor has the probable spawning season, as revealed by the state of the ovarian eggs, yet been established except for the Bay of Fundy, a region so peculiar in its hydrography as to be a law unto itself. Statistical study of the relative sizes of the Sagittæ captured in our hauls, from which much information about the seasons and localities of reproduction may be hoped, is likewise a task for the future. However, I may point out that catches of *S. elegans* made prior to mid-May during the springs of 1915 and 1920 consisted chiefly of very large individuals, such as might be expected toward the end of a period of growth. In 1915 it was not until June 14 that Sagittæ less than 10 millimeters in length were recognized among the plankton of the gulf. In 1920, however, equally young *S. elegans* (8 millimeters long) were taken in Massachusetts Bay as early as May 16 (station 20123), with still smaller stages (5 to 12 millimeters long) on the western part of Georges Bank on the 17th (station 20128), and from June on through the summer, until the last of October, specimens smaller than 10 millimeters have been detected at a considerable proportion of our stations.[68]

On the whole, then, it is safe to say that *S. elegans* is a late spring and summer breeder in the Gulf of Maine, in so far as any considerable production is concerned, but probably it reproduces more or less throughout the entire year. Fish's (1925)

[68] Oct. 31, 1916, is our latest date for specimens of 10 millimeters or shorter (station 10399).

records suggest that its most active breeding season commences earlier to the westward of Cape Cod, for he found them with ripe eggs at Woods Hole as early as March, and many eggs in the plankton during the latter part of April. He first observed the young on May 2 and found them in abundance throughout May and June. Thus the season of active reproduction falls later and later from southwest to northeast along the coast, as it does for many other animals.

It is likely that with sufficient search the young would be found to be as widely distributed as the adults over the open gulf, just as is the case in the Bay of Fundy, but definite records of them from outside the 100-meter contour are still so few (as a rule based on few individuals and invariably greatly outnumbered by larger sizes) that the importance of coastwise and shoal banks waters as the breeding ground of this species appears very clearly on the chart (fig. 88). Georges Bank in particular serves as a nursery for Sagittæ, witness the notable concentration of young Sagittæ, accompanied by a few larger (15 to 20 millimeters) specimens, over its western end on May 17, 1920 (station 20128). Specimens ranging in size from 4 millimeters upwards abounded over a considerable area at about the same general locality in mid-July, 1916 (stations 10347, 10348, and 10354). Slightly older specimens, 5 to 15 millimeters long, were also plentiful a few miles farther east on the 20th of the same month in 1914 (about 430 per square meter at station 10216) and occurred sparingly among the hosts of adults on the eastern part of the bank three days later (station 10224). Other notable catches of young *S. elegans* were made near Cape Sable among a swarm of adults on July 25, 1914 (station 10230), and off Shelburne, Nova Scotia, June 23, 1915 (about 200 small ones of 6 to 10 millimeters in a total of about 600 Sagittæ of all sizes per square meter at station 10291). I may also mention the presence of young *S. elegans* in Casco Bay in July, 1912, as an example of its propagation close in to the land. Probably it is simply because the adults are more abundant, not because physical conditions are more favorable to reproduction, that more young Sagittæ are produced within the 100-meter contour than over deeper water. At any rate we can regard it as established that *S. elegans* is not only endemic in the Gulf of Maine but breeds there in sufficient numbers to maintain the abundant stock by local production, quite apart from any additions this may receive by immigration from other rich centers of reproduction.

The general relationship of *S. elegans* to temperature and salinity, and its bathymetric status, is well established by Huntsman's (1919) exhaustive analysis, which our Gulf of Maine data generally confirm. Broadly speaking, it is a creature of low temperatures and comparatively low salinities, and wherever its range spreads out from the coastal banks over parts of the oceanic basin high salinities act as a barrier to its downward migrations. It is not likely, however, that this applies to any part of the Gulf of Maine, unless it be to the deepest stratum of water in the extreme southeastern corner. On the other hand, judging from the occurrence of *S. elegans* in the Baltic, no part of the gulf, not even the larger estuaries, is too fresh for some local variety of it to survive. Consequently, its local presence or absence in the Gulf and its concentration at one or other level there can not be ascribed to the precise salinity of the water, but its bathymetric distribution as it varies from season to season is just what might be expected of any planktonic animal preferring

low temperature and tending to shun strong light. Thus in late February and March of 1920, while the water was still near its annual minimum in temperature, with the surface nowhere warmer than 3.6° in the inner parts of the gulf or 4° to

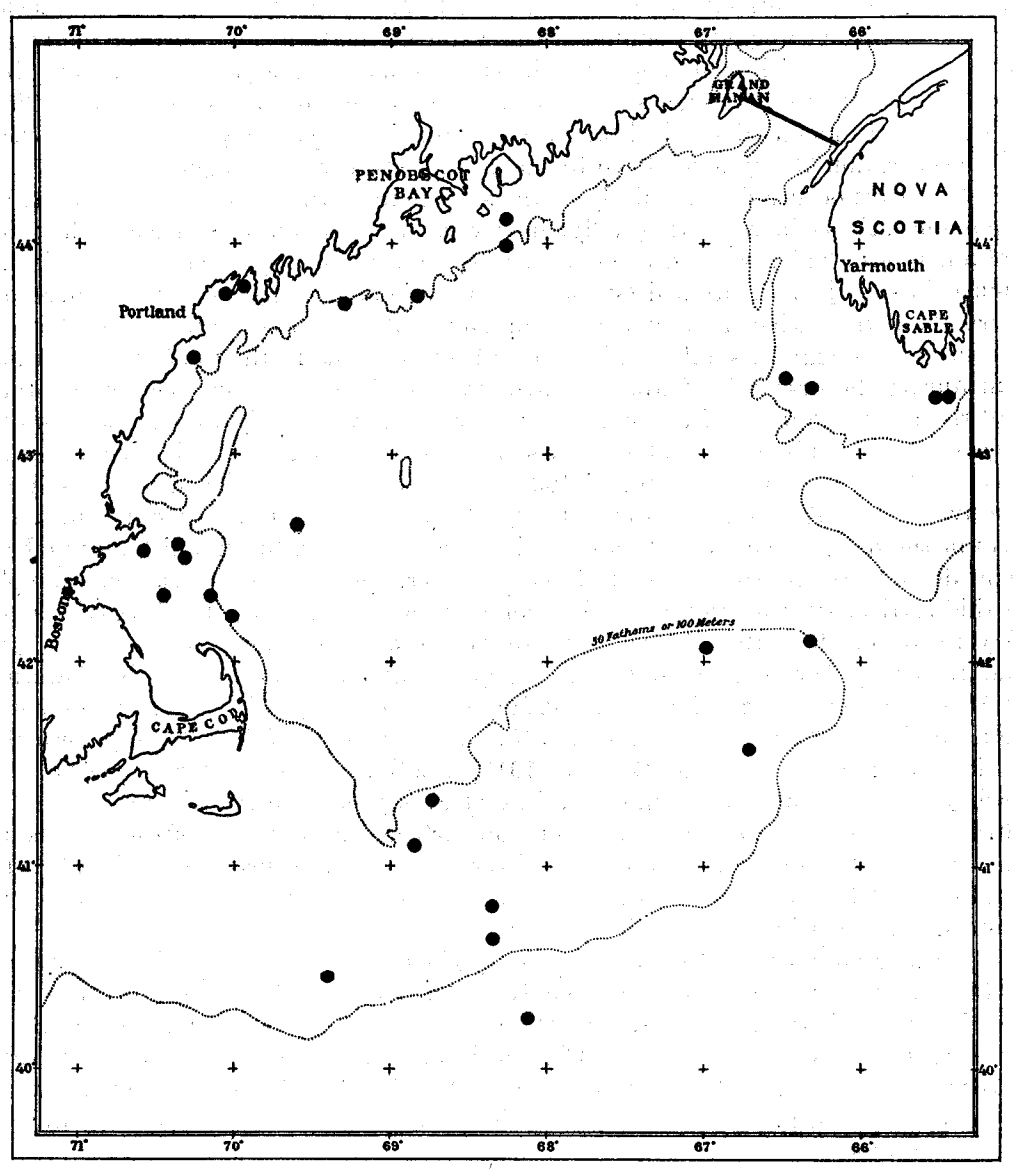

FIG. 88.—Locality records for young *Sagitta elegans* less than 10 millimeters long, June to October, 1912 to 1916

5° over the seaward slope of Georges Bank, and with the vertical range of temperature less than 4° at most of the stations, we found large *S. elegans* indifferently at all the depths at which we towed and almost as regularly at the surface as at any other

level,[69] but the numbers caught at the surface were usually small compared to the deep hauls. The two stations at which moderately rich surface catches were made were both occupied after dark; at one of them (20049) there were nearly as many *S. elegans* on the surface as in the 240–0 meter haul, while at the other (20066) swarms of this chætognath dominated the water at the time, but the deep haul captured upwards of a liter of them and the surface net but about half as many. On the whole, these stations suggest that the sagitta population was sparser above than below, say, 10 meters depth in March, but below that depth they afford no evidence of concentration at any level down to the deepest stratum of the gulf.

S. elegans occurred as regularly at the surface in April, 1920 (18 stations out of a possible 22), as in March; usually, however, in small numbers, except that the notable swarm which we had encountered on the eastern part of Georges Bank the month before, just mentioned (station 20066), still dominated the water there on April 16, at the surface as well as at 50 meters depth. *S. elegans* was also taken on the surface, though in small numbers, at all our stations in the western side of the gulf during the first half of May in 1920, by which time the surface temperature had risen to 6° to 9.7°. In summer, however, we have usually found few or no *S. elegans* at the surface, even at localities where it has been plentiful at some lower level, and the zone between 40 and 100 meters has generally proved the most productive of the large adult *S. elegans*, though they have been taken in sufficient numbers in the deeper hauls to establish their presence, though in diminishing number, right down to the bottom of the deep basins. Perhaps the most instructive example of this vertical stratification which has come to our notice was in the Massachusetts Bay region on July 19, 1916, when there were few or no *S. elegans* at the surface and relatively few (compared to the copepods) at 30 to 40 meters, but swarms at 80 to 90 meters. Similarly, the surface haul took no Sagittæ and the 30-meter haul but few off Cape Cod on July 8, 1913, although the net from 60 meters brought back an abundance of them (Bigelow, 1915, p. 267). In the eastern corner of the basin of the gulf, off the mouth of the Bay of Fundy (station 10246), on August 12, 1914, only one *S. elegans* was taken on the surface, many in the 50–0-meter haul, and few at 150–0 meters. No *S. elegans* were taken on the surface on July 23, 1914 (station 10224), on the eastern part of Georges Bank, where it was plentiful at 40 meters, and other instances of this same sort might be mentioned.

Although our surface tows usually have yielded no *S. elegans* or only a scattering of them in summer, we have occasionally taken it in abundance right on the surface in July and August. This, for instance, was the case near Mount Desert Rock on August 16, 1912 (station 10032), south of Nantucket Shoals, July 9, 1913 (station 10060), and in the Northern Channel, July 25, 1914 (station 10229), while Huntsman (1919, p. 464) records it at the surface at one station in the Bay of Fundy in mid-September.

The large-sized individuals of *S. elegans* were relatively as scarce at the surface in the western half of the gulf at the end of October and during the first days of November in 1916,[70] when the surface temperature had fallen to 8.3° to 10.2°, as they

[69] *S. elegans* taken in 20 surface tows out of a possible 27.

[70] No large ones taken in the surface hauls, stations 10399 to 10404.

are in summer, though moderately plentiful at deeper levels in temperatures of 4 to 7°; but the small sizes were taken in all the surface hauls on that cruise, once in some numbers (station 10399). With the continued cooling of the water the adults must spread through the superficial stratum of water at some time during the late autumn and winter to attain the distribution just described for March (p. 317), but the horizontal hauls at our winter stations have not been adapted to show just when this takes place.

The data just outlined for the Gulf of Maine are directly in line with Huntsman's (1919, p. 465) observations based on the collections made by the Canadian fisheries expedition, that off Nova Scotia the large *S. elegans* rise to the surface by night during May and June while the surface temperature is still low, sinking again during the hours of bright daylight, but are virtually absent from the surface during July and August, night as well as day.

The primary cause for this seasonal variation in the vertical distribution of *S. elegans* is to be found in the temperature of the water, which, being uniformly low during the early spring, then imposes no barrier to upward dispersal; but when the vernal warming of the surface has proceeded to a certain degree, which may tentatively be set at 10 to 12°, most of the Sagittæ remain below the warm superficial layer. The diurnal migration described by Huntsman (1919), together with the fact that when *S. elegans* rises to the surface in the Gulf of Maine in July or August this usually takes place at night, makes it probable that bright light as well as high temperature to some extent limits its dispersal upwards. But, judging from its vertical distribution in March and April, when it is at the surface day and night indifferently, this is not the case until the sun attains a comparatively high declination, the inference being that while *S. elegans* is negatively tropic to light of more than a certain intensity, its movements are little influenced by a paler illumination. This warrants the following working hypothesis. In winter and early spring all levels in the Gulf are sufficiently cool for *S. elegans*, and the illumination by the sun is not so bright but what a certain number may regularly be found at the surface by day as well as by night; but in late spring and early summer it is daily driven downward for some meters by the sun, and by July and August the high temperature renders the uppermost stratum of water unsuitable for its permanent presence, an unfavorable condition from which it can and does escape by sinking. Occasionally it rises to the surface in summer, irrespective of temperature or of illumination. We found an abundance of medium-sized specimens south of Nantucket Shoals, July 9, 1913 (station 10060), at 6 p. m., in a surface temperature of 16.1°, but it is not likely that such upward incursions endure for more than a brief period, perhaps only for a few hours.

Huntsman and Reid (1921) have pointed out for the Bay of Fundy (and our own observations corroborate them) that the young *S. elegans* tend to congregate nearer to the surface than the adults.

In the deeper strata of the gulf, below 20 meters or so, where the physical state of the water is apparently favorable for the existence of *S. elegans*, the local variations in its abundance at different depths may be governed by quite a different

factor—that is, the supply of available food—for this chætognath is both extremely voracious and an active swimmer and hence would tend to gather at the levels, and probably to some extent to congregate in the regions where the copepods on which it chiefly preys are most abundant. Furthermore, it would naturally grow fastest and breed most actively where food was most plentiful, tending to produce and maintain an abundant local stock.

It seems more probable that it is the dependence of *S. elegans* on the calanoid copepod plankton which, as remarked above (p. 30), is most plentiful in the mid-levels, which accounts for the comparatively sparse sagitta population of the deepest levels in the Gulf of Maine and not the comparatively high salinity at these depths, for it thrives in still higher salinities in the North Sea region (Apstein, 1910).

Temperature not only governs the distribution of *S. elegans* but also the size to which it grows, a fact that has long been recognized. Indeed, three varieties or subspecies of this species, one of them a large northern (*"arctica"*), another a smaller boreal-temperate (*"elegans"*), have been recognized by von Ritter-Záhony (1911); but Huntsman (1919) points out that these are not distinct, being connected by intermediates. In fact, the Gulf of Maine collections suggest that the difference in size between them probably is not hereditary at all, but the result of a direct physiological influence of the environment on the individual, for the adults average decidedly larger (up to 35 millimeters long) in March and April, when the temperature is near its lowest for the year, than in summer. This is not the maximum size for the Gulf of Maine, however, Huntsman (1919, p. 446) having recorded specimens of this length with ovaries still immature, and he describes *S. elegans* up to 52 millimeters long from the still colder waters of parts of the Gulf of St. Lawrence. He has also pointed out that it matures sexually at a smaller size in high temperatures than in low, as is the case with sundry other boreal planktonic animals—for example *Aglantha digitale*.[71]

Sagitta serratodentata Krohn

The fact that *S. serratodentata* is an annual immigrant to the Gulf of Maine and not endemic there has been brought out in an earlier chapter (p. 58), and its tropical origin and lines of dispersal have been discussed. It is safe to say there are no *S. serratodentata* in the inner parts of the gulf in late winter or early spring, the visitors of the previous summer all having perished, because our February and April cruises of 1920 did not yield it anywhere within the continental edge except for a single specimen in the southeastern part of the basin on March 11 (station 20064). It is probably to be found in the warmer water along the slope abreast of the gulf, however, throughout the year, for odd specimens were detected at our outer stations off the southwest face of Georges Bank on February 22 (station 20044), and off Cape Sable on March 19 (station 20077).

In the year 1915 *S. serratodentata* had penetrated the eastern side of the gulf as far as the neighborhood of Lurcher Shoal and the northeastern part of the basin by May 10 (stations 10272 and 10273; Bigelow, 1917, p. 296), and by the last of that month and first days of June the Canadian fisheries expedition found it at two

[71] For a discussion of other differences between the races of *S. elegans* living in high temperatures and in low see Huntsman (1919).

stations on the outer part of the shelf off Halifax and generally distributed over the deep oceanic triangle into which the Laurentian Channel debouches, but not

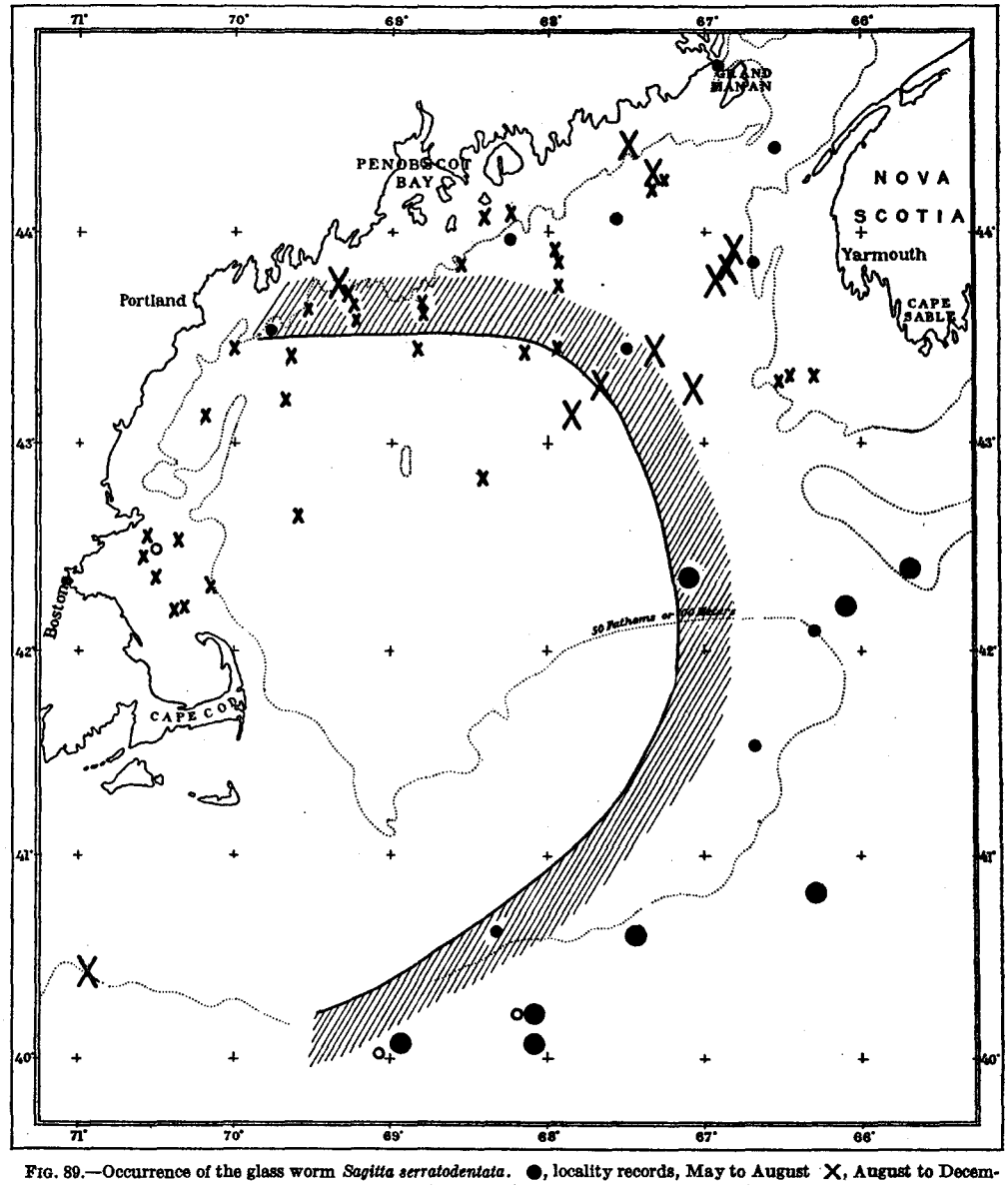

FIG. 89.—Occurrence of the glass worm *Sagitta serratodentata*. ●, locality records, May to August ✕, August to December; ○, December to May. The large symbols mark the stations where this species has predominated notably over *S. elegans*. The hatched curve is the approximate limit to its area of occurrence up to August

nearer shore in Scotian waters (Huntsman, 1919, p. 442, fig. 5). During June of that year *S. serratodentata* spread generally over the eastern side of the gulf with locality records on Browns Bank, in the Fundy Deep, in the Grand Manan Channel,

off Mount Desert Island, and in the eastern basin, as well as on the outer edge of the continental shelf and over the slope off Shelburne, Nova Scotia (stations 10281, 10282, 10286, 10294, 10295, and 10296). By the 1st of August it may be expected anywhere over the southern and eastern parts of Georges Bank, in the eastern channel, on Browns Bank, in the eastern side of the gulf generally, and as far westward along the coast as outlined on the accompanying chart [72] (fig. 89). As the summer advances *S. serratodentata* continues to spread westward, until by August we have found it very generally distributed over all parts of the gulf where we have towed during that month, right across from Massachusetts to the Nova Scotian Bank, though still with a decided preponderance of locality records for the eastern side (p. 58), reminiscent of the fact that it enters the gulf chiefly between the eastern part of Georges Bank and Cape Sable, perhaps not in the western side at all. The Canadian fisheries expedition likewise found it plentiful on the banks off southern Nova Scotia late in July; also at most of the stations along and outside the continental edge and in the trough of the Laurentian Channel, marking a considerable expansion in its range in this general region since May, but not at all on the banks off Cape Breton or on the Newfoundland Banks.

Judging from captures in 1915, it continues as widespread in the gulf during September and probably throughout October, also, when we found it at localities as widely separated as off Machias, Me., off Mount Desert Island, Massachusetts Bay (two stations), and the continental edge off Marthas Vineyard.

S. serratodentata reaches its maximum expansion and greatest abundance in the gulf during the late summer and early autumn, the precise date no doubt varying from year to year. Later in the autumn it disappears. In some years it seems that this happens as early as the first week in November, for we did not find it at any of the stations in the western side of the gulf from October 31 to November 8 in 1916 (stations 10399 to 10404); but in 1912 there were a few in Massachusetts Bay on November 20 (station 10047; Bigelow 1914a, p. 403). Although *S. serratodentata* was not detected anywhere in the inner part of the gulf during the December to January, 1920–1921, cruise of the *Halcyon*, the fact that odd specimens were towed off Gloucester on December 14, 1912 (station 10048), and January 16, 1913 (station 10050), and none on December 23 (station 10049) suggests that a scattering may continue to exist in Massachusetts Bay for a month or two after they have vanished from other parts of the gulf.

No attempt has been made to estimate the numerical strength of *S. serratodentata* in the gulf, but, as I have previously remarked (Bigelow, 1917, p. 297), we have always found it subordinate to *S. elegans* early in the season—that is, until August—and in the western part of the gulf at all seasons. In fact, most of the Gulf of Maine records from west of Penobscot Bay and north of the continental edge have been for odd individuals or at most for a few dozens per haul; but during August and September we have found it predominant over *S. elegans* at the several stations in the eastern side of the gulf marked on the chart (fig. 89), and once swarming (station 10032, August 16, 1912). In July and August, 1914, "*Sagitta serrato-*

[72] For station records for 1912 to 1915, on which this statement is based, see Bigelow, 1914, p. 121; 1914a, p. 403; 1915, p. 297; and 1917, p. 294.

dentata was much the more numerous of the two in the deep hauls in the eastern and southeastern parts of the gulf (stations 10225, 10245, 10246, 10249), in the eastern channel (station 10227)" (Bigelow, 1917, p. 295), and on the southern edge of Georges Bank.

Along the continental edge abreast of the gulf, *S. serratodentata* has usually predominated over *S. elegans* at most of our stations irrespective of the season of the year, or at least equaled the latter in numbers (stations 10218, 10219, 10220, 10233, 10260, 10261, 10295, 10349, 10351, 20044, 20077, and 20129).

From New York southward *S. serratodentata* is the prevalent chætognath right in to the shore during warm summers such as that of 1913 (Bigelow, 1915), but in cooler years, such as 1916, *S. elegans* is the dominant member of the pair over the inner part of the shelf as far south as Delaware Bay and perhaps still farther, but with *S. serratodentata* outnumbering it farther offshore and along the continental edge generally, as I have pointed out in a previous report (Bigelow, 1922, p. 152).

The strong probability that *S. serratodentata* is not able to reproduce successfully in boreal water, though it not only grows to a larger size there than in higher temperatures but attains sexual maturity, as evidenced by the large size of the reproductive organs (Huntsman, 1919, p. 482), lends interest to the wide range of temperature in which it occurs both in the Gulf of Maine and off southern Nova Scotia. In the gulf its presence is definitely established in water as cold as 3.9° (station 10272, May 10, 1915) and 4.4° to 7.5° (stations 10281, 10282, and 10286, June 4, 10, and 14, 1915), and the Canadian fisheries expedition likewise had it in 4° to 5°; but most of the Gulf of Maine records (also the Canadian) have certainly been from temperatures upwards of 7° to 8°, though there is no positive evidence of its presence in the gulf in water warmer than 13.9° (station 10032, August 16, 1912; Bigelow, 1914, p. 122), most of the captures having been in subsurface hauls, or if at the surface in regions of low surface temperature (stations 10030, 10229, and 10247). However the occurrence of *S. serratodentata* elsewhere forbids the assumption that high temperatures are *per se* unfavorable to it, for it has been taken in great abundance off the continental edge in Gulf Stream temperatures (station 10070, surface 23.33°; a few at stations 10071, 10073, and 10074 in temperatures of 24.44° and 23.9°), as well as off southern Nova Scotia in 19.7° (Huntsman, 1919, *Acadia* station 44, surface).

Uncertainty as to the depth of the captures makes it impossible to establish the precise salinity for the Gulf of Maine records of *S. serratodentata* except in the following instances:

	Salinity, per mille
Station 10025, closing net, 30 fathoms	32. 9
Station 10027, closing net, 30 fathoms	33. 3
Station 10030, surface	32. 7
Station 10032, surface	32. 5
Station 10229, surface	32. 01
Station 10247, surface	32. 52

It is not likely that it would be altogether barred from the surface by salinities considerably lower than this, for Huntsman (1919) found it repeatedly in eastern

Canadian waters on the surface in 31 to 32 per mille when a few fathoms sinking would have carried it into much more saline water.

From the data just outlined it would appear that the whole column of water in the offshore parts of the Gulf of Maine offers an environment favorable for the existence if not for the reproduction of *S. serratodentata* during the season (July to September) when it is most widespread there, but probably it could not long survive water much less saline than about 31 per mille or colder than 6° to 8°, and Huntsman (1919) has suggested that low salinity may be the factor that bars it from the Gulf of St. Lawrence.

Neither temperature nor salinity offers an explanation for the disappearance of *S. serratodentata* from the gulf in autumn, for the water is considerably warmer in November than when it first enters the gulf in spring, and the salinity is not very different from that of late summer. Neither does its immigration into the gulf in spring parallel the vernal warming of the water, but is not at its height until long after the gulf is warm enough for its support. It is therefore likely that the increase in its numbers with the summer chiefly mirrors an accumulation of the stock within the gulf, where it finds good feeding ground and conditions favorable for growth and prolonged existence. Apparently no more enter after early autumn, a phenomenon probably connected with the seasonal reproductive cycle of the species, and as the visitors of summer die off during the autumn from one cause or another or are devoured by other animals without leaving progeny to take their places, *S. serratodentata* disappears from the gulf, not to reappear there until with the earliest immigration of the succeeding spring.

Our data do not allow a statement as to the vertical distribution of *S. serrato dentata* in the Gulf of Maine more definite than that it has seldom been detected there at the surface, though most often in hauls from shoaler than 100 meters. If it is actually as uncommon right at the top of the water in the gulf as now appears to be the case, the food supply may be as effective a factor as any of the physical features of its surroundings in holding so rapacious an animal at lower levels.

There is no evidence that this chætognath ever succeeds in reproducing itself in the gulf.

Sagitta maxima Conant

In a previous chapter (p. 64) I have discussed the geographical distribution of this species and of the next within the gulf from the standpoint of their routes of entrance and dispersal. What demands chief emphasis here is that both *S. maxima* and *S. lyra* are distinctly seasonal in the inner parts of the gulf, like *S. serratodentata*. During all our cruises we have found only a single specimen of *S. maxima* within the offshore banks during the summer or early autumn months (eastern basin, September 2, 1915, station 10310), our failure to find it there in July and August, 1914, being specially significant because it occurred then off the seaward slope of Georges Bank (station 10220). Neither have we any early winter records for it in the gulf; this, however, may be an accident, for we have tried only two tows in the deep trough in December or January, which may simply have missed the *S. maxima*. However, this large chætognath was detected at 12 stations within the gulf as well as over the deeper parts of the continental shelf off southern Nova Scotia during March, April,

and early May of 1920, and at all four of the stations on the continental slope. The localities for the gulf proper (fig. 90) are all from the deepest trough, as is the one autumn record for the eastern basin just mentioned, and most of the captures have been in hauls from considerable depths, as follows:

Station	Depth in meters	Number of specimens	Station	Depth in meters	Number of specimens
20044	250–0	1	20081	40–0	1
	750–0	13	20086	150–0	2
20055	180–140	1	20087	200–0	2
20066	60–0	1	20107	140–0	2
20069	1,000–0	9	20112	100–0	1
20074	125–0	5		200–0	3
20076	200–0	15	20013	130–0	2
20077	800–0	20	20015	200–0	3
20079	180–0	1	20129	100–0	

The single September specimen was from a tow at 130–0 meters, while the June specimens off southern Nova Scotia (station 10295) were from 500–0 meters. The reader will note that there are only two records (a total of two specimens) from tows shoaler than 100 meters, one of which was taken over much deeper water and may have been brought up from its normal habitat by some local upwelling; the other was on Georges Bank.

Associated with the considerable depth of the records, we have usually found *S. maxima* in water of the relatively high salinity of 33.5 to 34 per mille, or more, though on the rare occasions when it is swirled up toward the surface it may stray into less saline strata of water (32.36 per mille at station 20081; 32.6 per mille on Georges Bank). Its general distribution farther north, and especially its failure to colonize the Gulf of St. Lawrence (Huntsman, 1919), suggests that it is unable to survive in water of low salinity, irrespective of temperature.

S. maxima is at home only in comparatively low temperatures. We have never found it in temperatures warmer than about 6.5° within the gulf, but, on the other hand, it usually lies below the coldest level in waters of 3.5 to 5°, the only records from temperatures lower than 3° being its sporadic appearances in the upper levels, in about 1.63° at station 20081 and about 2.6° at station 20066. The captures of *S. maxima* along the continental slope have been in temperatures of 3 to 6° and salinities of 34 to 34.9 per mille. It occurred under about these same conditions over the continental shelf abreast of Shelburne in March, 1920 (stations 20074 and 20076). Occasionally, however (whether or not as a result of upwelling is not clear), we have taken it in decidedly warmer water at our outermost stations; for example, in 7 to 8° temperature at station 20129 and one specimen in 9° or warmer at station 20044.

In north European seas *S. maxima* is equally characteristic of cold but highly saline water layers (Apstein, 1911), and probably it is this rather precise relationship to the physical state of the water which bars it from the Gulf of Maine in summer but allows it access there in winter; for while the trough of the gulf is sufficiently salt for it throughout the year and cold enough—say, 5° to 6° below 100 meters—in winter and early spring, the bottom water may well be too warm for it in some summers if not in all. At such times any *maxima* that drift inward through the eastern channel