probably perish shortly, whereas during the cold months they survive long enough to spread generally along the trough of the gulf. There is no reason to suppose that *S. maxima* ever breeds successfully in the Gulf of Maine.

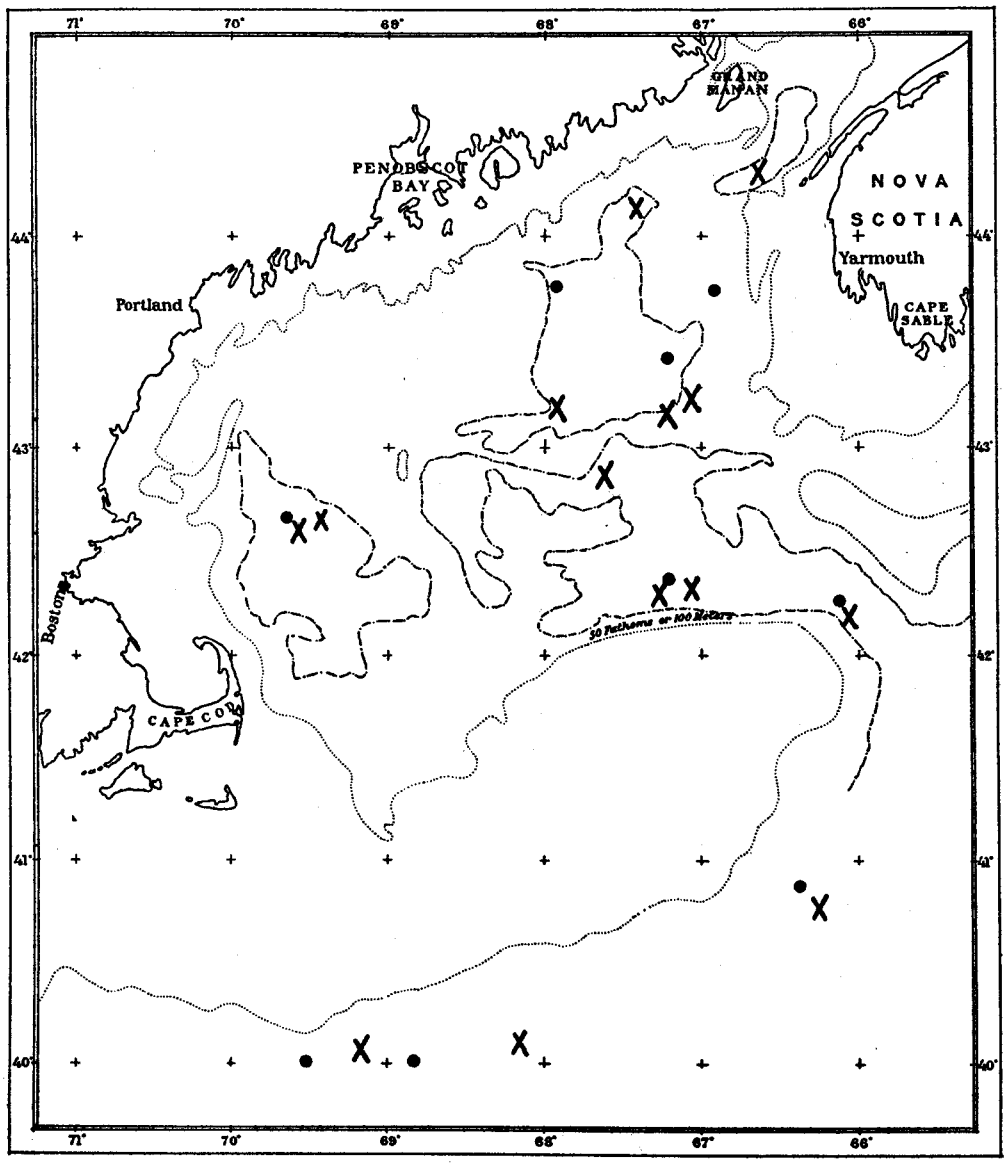

FIG. 90.—Occurrence of the glass worms *Sagitta lyra* and *S. maxima*. ●, locality records for S. lyra; X, locality records for *S. maxima*. Contours for 100 and 200 meters.

Sagitta maxima is as cosmopolitan on the high seas as Eukrohnia (von Ritter-Záhony, 1911) but reaches its maximum abundance at a rather deeper level. Only in high latitudes does it normally rise near the surface, then usually in the persons of young specimens, and it is on such that most of our Gulf of Maine records are based.

Inasmuch as the planktonic communities of the deeper levels of the Atlantic never penetrate the gulf *in toto* (p. 67), it can hardly be questioned that such examples of *S. maxima* as appear there come via the northeastern route in the band of cold mixed water along the edge of the continent, not from the much greater depths which they inhabit off the slope. Very likely the chief source of supply for this species in the Gulf of Maine is the deep oceanic triangle between the Nova Scotian and Newfoundland Banks, where the Canadian fisheries expedition found *S. maxima* in great abundance in a haul from 200 meters on the 1st of June, 1915 (Huntsman, 1919, p. 429). In short, it is as a distinctively northern visitor and as such alone that *S. maxima* reaches the Gulf of Maine, but our experience so far has been that but few individuals find their way in through the eastern channel, which is the only line of ingress sufficiently deep to be normally open to it.

S. maxima is an extraordinarily voracious animal and as such must occupy an important position in the natural economy of the plankton of the deepest waters of the gulf if it ever enters the latter in any abundance.

Sagitta lyra Krohn

This chætognath is as distinctly a summer visitor as is its larger relative, *S. maxima*, a winter one to the inner parts of the Gulf of Maine, where it has been detected on six occasions in three distinct years—all in July and August. These records are as strictly confined to the deep trough as are those of *S. maxima* (p. 325), and whether within or without the gulf the depths of capture are about the same as for that species.

Station	Depth in meters	Specimens	Station	Depth in meters	Specimens
10031	100–0	2	10227	180–0	1
10093	155–0	2	10246	150–0	2
10225	225–0	2	10254	225–0	1

S. lyra occurs side by side with *S. maxima* over the continental slope in late winter and early spring as well as in summer.

Station	Date	Depth in meters	Specimens of S. lyre
20129	May 17, 1920	50–0	2
10295	June 24, 1915	750–0	10
10220	July 22, 1914	400–0	5
10061	July 10, 1913	73–0	1

Being a summer visitor to the gulf, *S. lyra* occurs there in rather higher temperatures than does *S. maxima*. About 6° is the lowest in which our records establish its presence, and the upper temperature limit for the captures so far made within the gulf is at least as warm as 8.17° (station 10031). Our records for it over

the continental slope have been in temperatures ranging from about 6 to 10.8° (station 10061).[73]

The salinities have been even higher for *S. lyra* than for *S. maxima*, ranging from 34.3 per mille to about 35 per mille within the gulf and about the same along the slope outside. Thus, on the whole, our observations corroborate Huntsman's (1919, p. 432) conclusion that *S. lyra* is associated with rather higher temperatures than is *S. maxima*, though equally cosmopolitan in the mid-depths of the high seas.

Sagitta hexaptera D'Orbigny

The claim of *S. hexaptera* to mention here rests on a single specimen, since lost, taken near Lurcher Shoal on August 12, 1914, in a tow from 100 meters (Bigelow, 1917, p. 297). Outside the gulf it is a regular inhabitant of the intermediate strata of the oceanic basin, occurring at all the outermost Canadian stations (Huntsman, 1919, p. 423) and at one of our own (station 20044). We likewise found it over the slope abreast of Delaware and Chesapeake Bays in July, 1913 (Bigelow, 1915, p. 297). Huntsman (1919, p. 424) has described its faunistic status, saying that it belongs to the Gulf Stream coming up from the south off the northeastern American coast, not to the cold boreal water coming down from the north. In the former it is characteristic of the intermediate depths from 100 to 200 meters, and it occurs so regularly 50 to 60 miles out beyond the continental edge that careful watch should be kept for it within the Gulf of Maine as an indicator of tropical water.

Eukrohnia hamata Möbius

The general status of this glass worm has been discussed in an earlier chapter (p. 63) as an immigrant in the Gulf of Maine. Only a few notes need be added here on the actual record of its local occurrences. Eukrohnia being, beyond question, a creature of the deeper strata of water in these latitudes, the precise depths of the captures are of interest. So far as I can learn it has only once been found on the surface within the limits of the gulf—viz, a single specimen recorded by Huntsman (1919, p. 476) from Friar Roads in the Bay of Fundy. No doubt, as he suggests, vertical currents were responsible for bringing this lone Eukrohnia up to the surface there from its normal habitat deeper down, the local tides being "of such magnitude that the water forms whirlpools and the boiling up of the deep water to the surface can be seen constantly." At this locality three Eukrohnia were also taken at 20 meters on the same occasion. For the open gulf our shoalest records for it are from 40 meters (stations 10095 on German Bank, 10099 close to Mount Desert Island, and 10102 off Penobscot Bay, one or two examples at each, all in August, 1913, and several taken near the eastern Maine coast on March 22, 1920, station 20080), 50 meters (one specimen, station 10497, near Mount Desert Rock, January 1, 1921, and odd specimens from Browns Bank, June 24, 1915, station 10296), and 60 meters (off Cape Elizabeth, December 30, 1920, station 10494; near Lurcher Shoal; and over the deep trough to the northeast on August 12 and 13, 1913, at stations 10096 and 10097).

[73] At station 10295 the specimens may have come from water as cold as 4.9°, but equally from the warmer strata penetrated by the net on its journey down and up.

That Eukrohnia should so seldom have been captured in the many tows that have been made between the surface and 60 meters in different years and seasons and in various parts of the gulf is sufficient evidence that it is only an accidental visitor to the upper strata of water there; so much so, indeed, that we have learned not to expect it shoaler than 75 meters except on rare occasions.

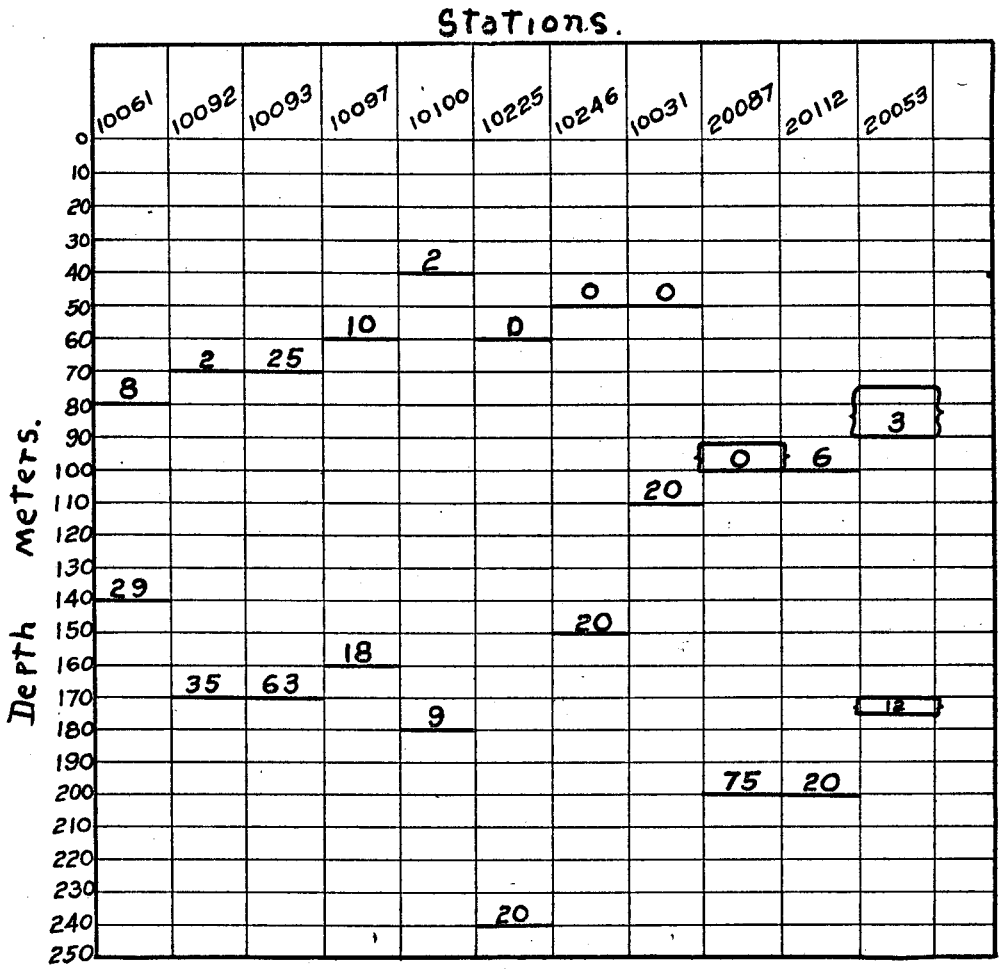

FIG. 91.—Numbers of specimens of *Eukrohnia hamata* taken in hauls from different depths at selected stations. In the case of closing-net hauls the depth zone is bracketed

Its scarcity at 60 to 100 meters, contrasted with its comparative abundance in deeper water, illustrated by the accompanying diagram of the catches of Eukrohnia at representative stations where two deep horizontal tows were made at different levels (fig. 91) points to the 100-meter level or thereabouts as about the upper limit to its common and regular occurrence. Below 100 meters, however, it has been de-

tected in something like 50 per cent of our horizontal tows,[74] irrespective of season or general situation in the gulf. The average depth of the trough of the gulf being about 250 meters, it follows that the bulk of its Eukrohnia population is confined to a

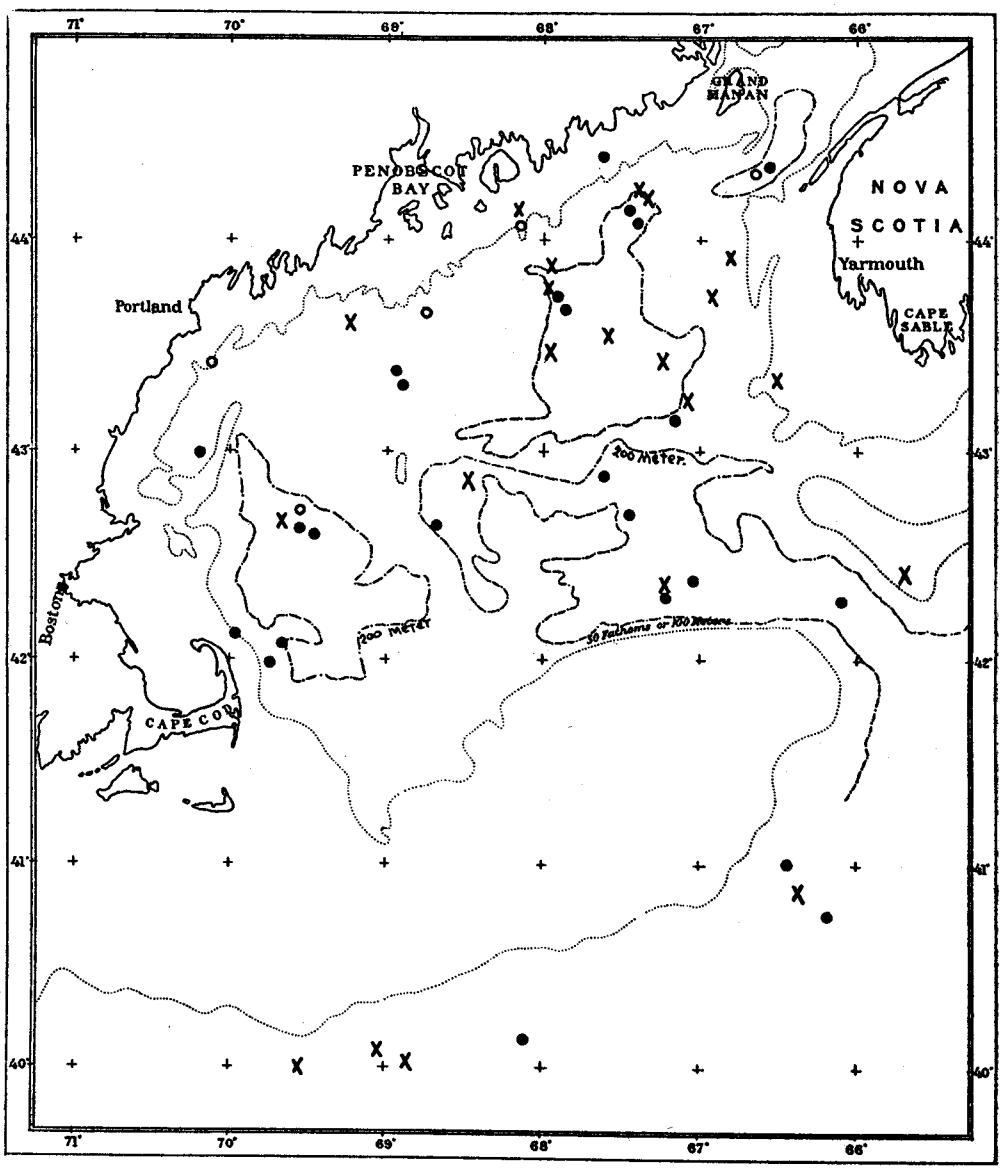

FIG. 92.—Occurrence of *Eukrohnia hamata* in the Gulf of Maine. X, locality records, June to September; ○, December to January; ●, February to May. Contour for 100 and 200 meters

stratum hardly more than 150 meters in thickness; but whether it is usually concentrated in the deepest water within this stratum is still to be learned, for up to the

[74] Eukrohnia usually occurs in numbers so small that its presence or absence in vertical tows is not significant, with nets as small as we have employed for that purpose. Contours for 100 and 200 meters.

present time we have made only 9 horizontal tows at depths of 200 meters or more within the gulf, in six of which Eukrohnia occurred.

It follows from the bathymetric status of Eukrohnia, as just outlined that this worm is practically confined to the offshore parts of the gulf (fig. 92), occurring only very rarely between the 100-meter contour and the coast; and while it may be expected anywhere in tows of appropriate depth, the actual localities of capture have been concentrated along the eastern, northern, and western margins of the deep

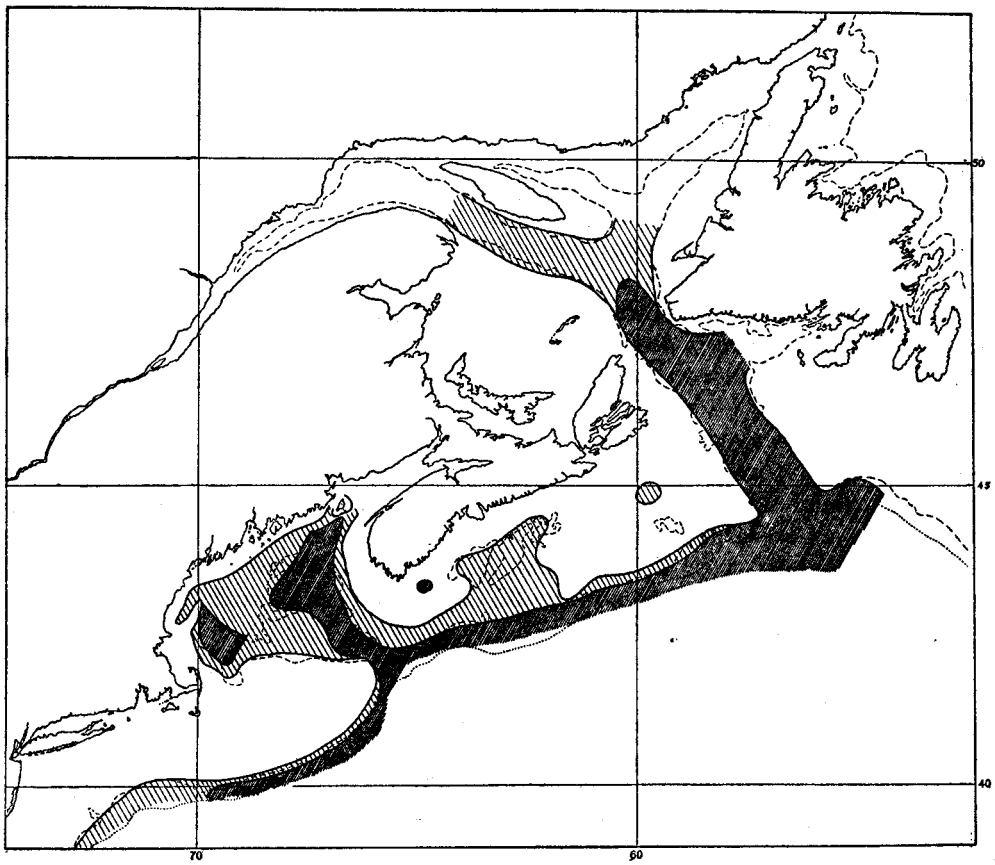

FIG. 93.—General distribution of the glass worm *Eukrohnia hamata* off the coasts of the northeastern United States and of eastern Canada. A half hour's tow with a net 1 meter in diameter, at the appropriate depth, may be expected to yield up to 20 specimens in the lightly hatched areas, and more than 20 in the heavily hatched area. The chart east of longitude 63° is based on the published records of the Canadian fisheries expedition (Huntsman, 1919)

basin, a reflection of its immigrant origin and of the anticlockwise eddy current with which it drifts once it is within the gulf. It has usually proved far more numerous along the eastern side of the basin from the Eastern Channel right up to the entrance of the Bay of Fundy on the one side of the gulf, and in the northern half of the western trough on the other, than in the intervening deep waters. In these two rich areas half an hour's tow with a meter net at any level deeper than 100 meters will usually yield at least 20 Eukrohnia if it occurs at all (fig. 93); elsewhere it is usually

represented in the tow by occasional examples only, even though the water be well over 100 meters deep. Its apparent rarity in the southeastern deep of the gulf—I say apparent because we have made few tows there—is interesting in connection with the probable route which it follows in its journeyings (p. 64). Eukrohnia occasionally reaches the trough between the Isles of Shoals and Jeffreys Ledge, where we have found it at one station (20093, April 9, 1920); but apparently it never finds its way into the sink at the mouth of Massachusetts Bay, or at least so rarely that we have never taken it there, though we have towed repeatedly at various seasons of the year [75].

The largest catch of Eukrohnia actually counted so far from any one of our tow-net hauls has been 63 specimens (station 10093, haul from 85–0 fathoms, August 12, 1913). Possibly other hauls may have yielded more, but, if so, very rarely. We have no reason to suppose that it ever occurs anywhere in the gulf in numbers to compare with *S. elegans* or even with *S. serratodentata.*

A catch of 20 to 50 individuals in half an hour's towing (which may be stated as a fair average of the more prolific horizontal hauls, whether made with the 1-meter open net or with the slightly smaller closing net) means a very sparse population, indeed, when translated into terms of actual density of aggregation in the water—say one Eukrohnia to every 30 to 70 cubic meters of sea water. To make this more graphic let us say not more than one Eukrohnia in a space the size of an ordinary room.

There is no direct evidence that Eukrohnia breeds within the gulf at any time of year, sexually mature specimens never having been found there. Hence the local stock is maintained chiefly if not entirely by immigration from centers of production elsewhere, but a few large Eukrohnia (up to about 45 millimeters in length) with well-developed ovaries were taken among the more numerous immature specimens in the deep haul over the slope abreast of Cape Sable on March 19, 1920 (station 20077).

Eukrohnia is never absent from the gulf at any time of year, but our records, if they can be taken at face value, point to the late spring and early summer as a period of decided scarcity, for only one specimen was taken at our May stations in 1920 (station 20125), and none at all during May or June in 1915.

The stock of Eukrohnia present in the Gulf of Maine fluctuates unmistakably and widely from year to year. The summer of 1913, when it occurred in all but one of the horizontal hauls deeper than 100 meters and at a total of 10 stations in July and August, was the best summer for it in our experience, while the summers of 1912 [76] and 1915 stand at the other extreme. In March and April, 1920, Eukrohnia was detected in 60 per cent of all the horizontal hauls deeper than 100 meters, and at 21 stations scattered far and wide over the gulf; likewise in the deep water along the continental slope.

[75] For records of Eukrohnia, 1912 to 1916, see Bigelow, 1914, p. 123; 1915, p. 294; 1917, p. 298; and 1922 pp. 138 and 155. During the spring of 1920 it was recognized at stations 20044, 20053, 20055, 20057 ,20064 ,20068 ,20069 ,20074 ,20075, 20077, 20079, 20080, 20081 20086, 20087, 20088, 20093 20097, 20098, 20107, 20112, 20113, 20114, 20116, and 20125, and during the winter of 1920–1921 at stations 10490, 10494, 10496, 10497, and 10499.

[76] Found only once in 1912 (Bigelow, 1914, p. 123), three times within the gulf, in July and August, 1915, once on Browns Bank and once over the continental slope abreast of Shelburne, Nova Scotia (Bigelow, 1917, p. 298).

Thanks to the confinement of Eukrohnia to considerable depths, where seasonal variations in the physical state of the water are slight, it is easy to establish the temperatures and salinities in which it most often occurs in the gulf, the former ranging from 1.3° to upward of 9°, the latter upward of 32.16 per mille, with most of the Eukrohnia living in water more saline than 32.5 per mille. Assuming Eukrohnia to occur close to the bottom, the maximum salinity in the gulf would be about 34.8 per mille.

Our largest summer catches of this worm have been made in water of about 6 to 8° temperature and of 33 to 34 per mille salinity, with an extreme range from about 5.9° to about 9.3° temperature and from about 32.6 per mille to about 35 per mille salinity. In spring we have taken it in 1.3 to 6.7°. The seasonal data thus show that Eukrohnia can survive in the gulf through a considerable range of temperature, from the coldest up to 9° or so, or even slightly warmer, and in water varying in salinity from slightly more than 32 to 35 per mille; that is, in all but the warmest and least saline locations. This is interesting, for with both the salinity and the temperature of the surface waters within these limits over most of the gulf in winter and spring, and with the water as cool and as saline as this only a few meters down even in midsummer, neither temperature nor salinity but probably light is the factor that bars Eukrohnia from the upper layers of water at all seasons.

With Eukrohnia occurring in the gulf only as an immigrant and not as a permanent and endemic inhabitant, a few words as to its distribution in the waters to which the gulf is tributary will be germane. Originally supposed to be an Arctic animal, this glass worm is now known to be cosmopolitan in the high seas from Arctic to Antarctic; but except in high latitudes it is confined to waters so deep that it probably never reaches the Gulf of Maine from the oceanic basin abreast of it. Hence, as Huntsman (1919, p. 476) points out, the Eukrohnia living in the upper 500 meters or so (and this includes practically all the representatives of the species collected either by the Gulf of Maine or by the Canadian fisheries expeditions) may be considered as distinctly northern. It is known to be common in the cool, heavy, mixed water all along the continental slope from the Grand Banks of Newfoundland on the north to the latitude of Chesapeake Bay to the south (fig. 93) in depths of 300 to 500 meters. For records of it east of Cape Sable see Huntsman (1919). How universal it is along this zone abreast the mouth of the Gulf of Maine and thence westward and southward in considerable depths will appear from the fact that it has been detected in the towings from 250 to 1,000 meters at 9 out of 12 *Grampus* and *Albatross* stations from 1913 to 1920, irrespective of the time of year (stations 10076, 10220, 10233, 10352, 10368, 10384, 10393, 20044, and 20077).

Outside the Gulf of Maine it is probably more numerous below 400 meters than above, for on February 22, 1920 (station 20044), none were found at 250–0 meters when a number were taken in a haul from 750–0 meters. Again, on the slope abreast of Cape Sable more Eukrohnia were taken in the haul from 800–0 meters on March 19, 1920 (station 20077), than from 500–0; and on July 21, 1914, none were taken in a horizontal haul at 300 meters off the slope of Georges Bank at station 10218, but several were had at 400–0 meters at a neighboring station (10220) at about

the same relative position on the slope. Farther offshore, where the warm surface stratum is thicker, Eukrohnia probably tends to keep still deeper.

From this main area of distribution it works into the Gulf of St. Lawrence via the Laurentian Channel, and into the Gulf of Maine via the eastern channel. It likewise reaches the deep sinks between the Nova Scotian fishing banks, as Huntsman (1919) showed, recent examples of which are its occurrence at two stations off Shelburne (20074 and 20075) in March, 1920. Generally speaking, the farther in from the continental slope, the less plentiful is Eukrohnia.

Other chætognaths

The species just mentioned completes the list of glass worms so far recorded from the inner parts of the Gulf of Maine, nor are any others to be expected there unless as rare and accidental stragglers; but it would be no surprise to find any of the chætognaths known from any part of the North Atlantic at one level or another in the oceanic basin abreast of the gulf. In fact, *Sagitta enflata*, a tropical species common in waters of southern origin off the east coast of North America "appeared, with other tropical organisms, in the tows over the continental slope in 1914 [stations 10218 and 10220]; off Marthas Vineyard in 1915 [station 10333, one specimen]" (Bigelow, 1917, p. 298). *Pterosagitta draco*, similarly tropical in origin, was represented by about 50 specimens in the 60-meter haul off the slope of Georges Bank on July 21, 1914 (station 10218). Previous to that time we had taken it over the slope abreast of Delaware Bay and Chesapeake Bay in July, 1913 (Bigelow, 1915, p. 299), and Huntsman (1919) has since recorded it at the outer stations of the Canadian fisheries expedition off Cape Sable and off the mouth of the Laurentian Channel in July and August, 1915. Along the American littoral and off the Grand Banks region these two species are among the most reliable of tropical indicators. Watch should therefore be kept for them in the Gulf of Maine, where it is not likely that they could long survive the low temperature.

TOMOPTERIDS

Tomopteris catharina (Gosse)[77]

The curious pelagic worm, Tomopteris, not uncommonly appears in the plankton of the Gulf of Maine, though never forming an important constituent of it, quantitatively speaking. So far the well-known *T. catharina* is the only species of the genus which has been detected regularly within the southern rim of the gulf.

In the western Atlantic this species is Arctic-boreal, having been recorded in abundance on the Newfoundland Banks (Apstein, 1900) and in the Laurentian Channel (Huntsman, 1921); southward, also, over the continental shelf about to latitude 39° 30′ (station 10069, July 19, 1913; Bigelow, 1915, p. 301); but it does not occur in the Gulf of St. Lawrence, except as carried thither in the inflowing current around the northern side of Cabot Strait or via the Strait of Belle Isle.

[77] This Tomopteris has usually been called *T. helgolandica* (e. g., by Apstein, 1900; by Reibisch, 1905; and by Southern, 1911), but Rosa (1908) and Southern (1911) have shown that the common Tomopteris of the North Sea region was first described under the specific name *catharina*, which consequently was adopted by Huntsman (1921). For accounts of Tomopteris and diagnoses o its several species see Apstein (1900), Reibisch (1905), and Huntsman (1921).

In the eastern Atlantic it is widely distributed in the North Sea (not, however, in the Baltic, from which it is probably barred by low salinity), around Ireland, and in the English Channel. It is also recorded from the Sargasso Sea and from off the mouth of the Amazon (Apstein, 1900); but, as Huntsman (1921) points out, it seems so unlikely that *T. catharina* should normally occur at these tropical stations that the records call for confirmation.

Slight differences have been described between the American and European races of this worm (Huntsman, 1921), interesting because of a possible physiological difference in their relation to the salinity of the water.

T. catharina has been taken here and there in the Gulf of Maine in every month of the year, including midsummer (the warmest season), on the one hand, and late winter and early spring (the coldest), on the other. As the chart (fig. 94) shows, it is very generally distributed north of a line from Cape Cod to Cape Sable. For example, it appeared at about 60 per cent of our stations in August, 1913; at about 50 per cent of the stations in the waters thus limited during February to May, 1920; at 5 stations (out of a possible 13) in the northern half of the gulf during December and January, 1920–1921; and occasionally off Gloucester during the winter of 1912–13.[78]

Thus, it is constantly present in the gulf throughout the year, with no definite fluctuations in abundance from season to season except an apparent scarcity in late autumn and early winter, evidence for which is our failure to find it at any of our stations in the western part of the gulf in October and November, 1916, or in Massachusetts Bay during November and December of 1912. We have also found it occupying the same geographic range in the cold season as in the warm, which is also the case around Ireland (Southern, 1911).

Although Tomopteris is so large and conspicuous that one is not apt to overlook it in the catch, it occurs so sparsely (usually from one to half a dozen individuals per haul) that it may well have been missed by the net at other stations, though actually present in the immediate neighborhood.

As appears from the chart, *T. catharina* has been taken with about equal frequency in the coastwise belt and over the deeper basin of the gulf. It is also recorded (once only) from St. Andrews in Doctor McMurrich's plankton lists (p. 12) and in the Bay of Fundy by Huntsman (1921), but we did not find it in Casco Bay in July, 1912, when it was taken at several stations along the coast from Massachusetts Bay to Mount Desert (Bigelow, 1914, p. 121). As we have never taken it in any harbor (e. g., Gloucester, Portland, Southwest, or Eastport, etc.) it is to be looked upon as occurring chiefly outside the outer islands and headlands and rarely in the estuarine waters tributary to the gulf. On the other hand, we have never taken *T. catharina* anywhere on Georges Bank or Browns Bank at any season, nor at any of our deep stations along the continental slope. Thus, while not

[78] For records of *T. catharina* (as "*T. helgolandica*") 1912 to 1913, see Bigelow, 1914 p. 121; 1914a, pp. 403–405; 1915, p. 301. Since then it has been detected at the following stations: In 1914 at 10213, 10214, 10225, 10245, 10246, 10247, 10248, 10249, 10250, and 10255; at stations 10267, 10270, 10290, and 10317 in 1915; 10398 in 1916; at stations 20048, 20050, 20052, 20055, 20056, 20057, 20059, 20060, 20062, 20079, 20080, 20081, 20084, 20085, 20087, 20092, 20093, 20096, 20097, 20098, 20100, 20107, 20113, 20114, 20115, 20116, 20119, 20125, 20126, and 20127 in the spring of 1920; and at stations 10489, 10490, 10494, 10495, 10499, 10510, and 10511 in the winter and early spring of 1920 and 1921.

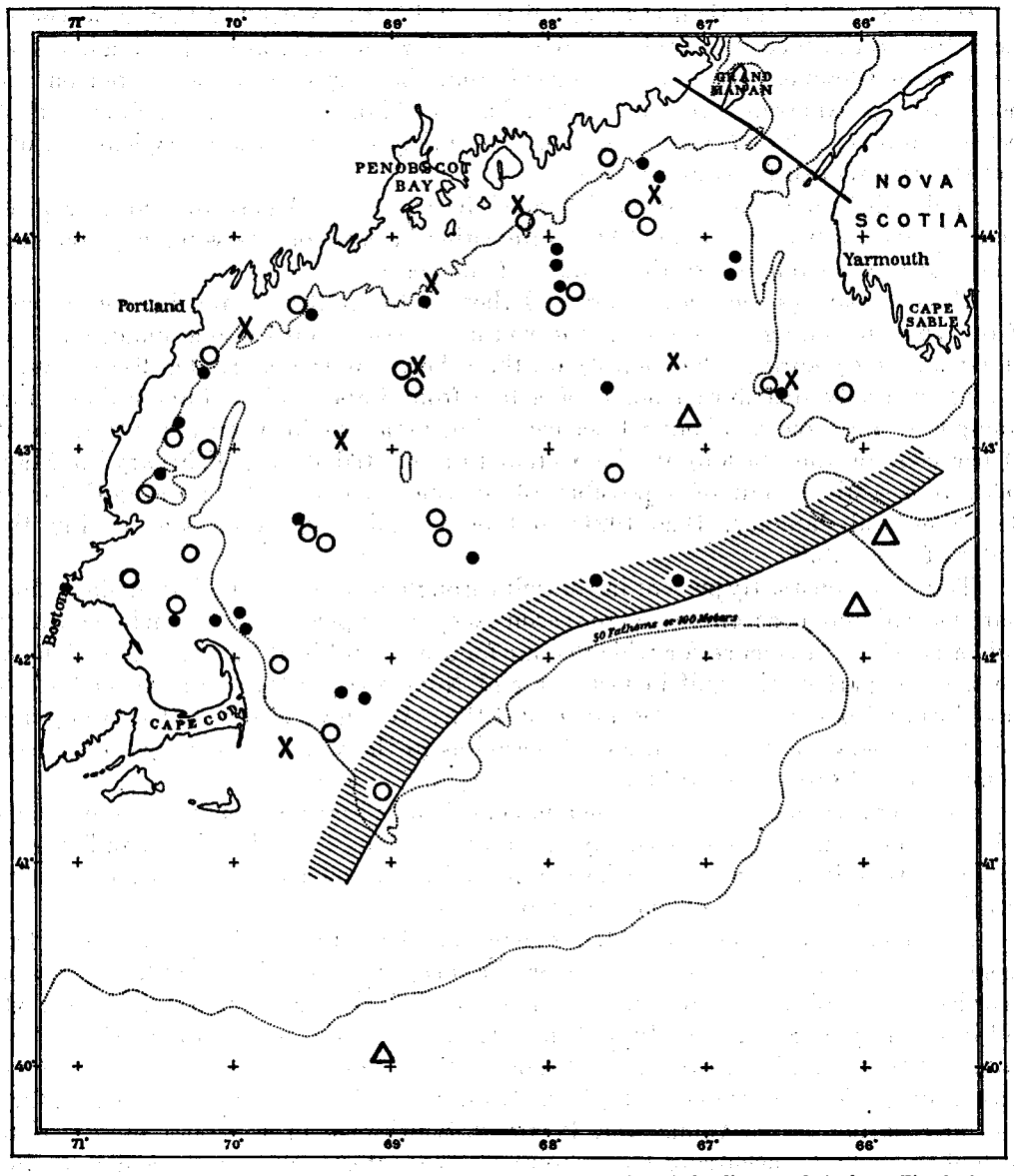

FIG. 94.—Occurrence of the worms *Tomopteris catharina* and *T. septentrionalis*. ●, locality records for large *T. catharina*, July and August; X for young *T. catharina*, July and August; ○, for large *T. catharina*, March to May; △, for *T. septentrionalis*, March to May. The hatched curve includes the parts of the Gulf of Maine where *T. catharina* has been taken in summer

actually neritic (witness its rarity or absence under estuarine conditions), *T. catharina* is clearly a creature of the coastwise waters, as it occurs within the limits of the Gulf of Maine.

The bathymetric range of *T. catharina* in the gulf is considerable. We have taken it on the surface at four stations in August, two in March, and three in April.[79] In connection with the relationship of Tomopteris to temperature, discussed below, it is interesting that the surface captures in summer have all been in the northeast part of the gulf—that is, on German Bank, near Lurcher Shoal, and off the eastern coast of Maine—whereas the localities where we have taken it on the surface in early spring include Massachusetts Bay and the general neighborhood of the Isles of Shoals in the western side as well as German Bank in the eastern.

At the other extreme *T. catharina* certainly occurs as deep as 180 meters (closing-net haul at station 20079, March 22, 1920), and probably down to 200 meters, if not still deeper, though the majority of captures have been in open-net hauls from 40 to 150 meters depth. When the actual depths of the individual hauls yielding Tomopteris are classified by months, its bathymetric distribution appears decidedly uniform from season to season, as illustrated by the following partial list of the captures for midsummer as compared with early spring:

Partial list of the captures of Tomopteris for midsummer, as compared with early spring

MIDSUMMER

Station	Date	Depth in meters	Station	Date	Depth in meters
10011	July 17, 1912	110–0	10103	Aug. 14, 1913	55–0
10014	July 24, 1912	40–0	10213	July 19, 1914	70–0
10030	Aug. 14, 1912	(1)	10214	do	100–0
10032	Aug. 16, 1912	(1)	10225	July 23, 1914	240–0
10057	July 8, 1913	55–0	10245	do	(1)
10058	do	73–0	10246	Aug. 12, 1914	50–0
10088	Aug. 9, 1913	146–0	10247	do	(1)
10091	Aug. 11, 1913	37–0	10248	Aug. 13, 1914	50–0
10095	Aug. 12, 1913	36–0	10249	do	175–0
10097	Aug. 13, 1913	146–0	10250	Aug. 14, 1914	120–0
10099	do	36–0	10255	Aug. 23, 1914	150–0
10100	do	165–0			

EARLY SPRING

20050	Mar. 1, 1920	75–0	20086	Mar. 23, 1920	150–0
20052	Mar. 2, 1920	100–0	20087	Mar. 24, 1920	200–0
20055	Mar. 3, 1920	[2] 180–140	20092	Apr. 9, 1920	(1)
20056	do	75–0	20093	do	(1)
20057	Mar. 4, 1920	75–0	20096	Apr. 10, 1920	35–0
20059	do	60–0	20097	Apr. 11, 1920	80–0
20060	do	(1)	20098	do	90–0
20062	Mar. 5, 1920	30–0	20100	Apr. 12, 1920	100–0
20072	Mar. 13, 1920	75–0	20107	Apr. 16, 1920	140–0
20079	Mar. 22, 1920	[2] 180–0	20113	Apr. 17, 1920	130–0
20080	do	40–0	20114	do	110–0
20081	Mar. 23, 1920	140–0	20115	Apr. 18, 1920	200–0
20084	do	30–0	20116	do	100–0
20085	do	60–0	20119	Apr. 20, 1920	(1)

[1] Surface net. [2] Closing net.

Although *T. catharina* has not yet been detected in the bottom water of the deepest trough of the gulf, it is to be expected there, for off Ireland it occurs indifferently from the surface down to more than 1,000 meters depth (Southern, 1911). Our surface catches, like Huntsman's (1921, p. 87) were with one exception between 6 p. m.

[79] The surface records are as follows: Stations 10030 and 10032, Aug. 14 and 16, 1912; stations 10245 and 10247, Aug. 12 and 13, 1914; stations 20060 and 20085, Mar. 4 and 23, 1920; stations 20092, 20093, and 20119, Apr. 9 and 20, 1920.

and 6 a. m., corroborating his view that *T. catharina* comes to the surface most often by night.

As a rule, Tomopteris has been represented in our hauls by large adults or medium-sized specimens 15 to 40 millimeters long, with from 15 to 21 parapods, and Doctor Huntsman informs me that he has invariably found this to be the case in the Bay of Fundy. But during our August cruise of 1913 we took a considerable number of its young in the northern and western parts of the gulf, including specimens as small as 4 to 8 millimeters in length, with only 6 to 8 parapods (but identifiable as this species by the tail, already visible, and by the number and location of the rosette organs), at about the stage figured by Apstein (1900, pl. 10, fig. 2), as follows:

Locality	Station	Number of specimens	Stage of development
German Bank	10095	(1)	6 millimeters upward, 8 to 12 parapods.
Northeast corner off Grand Manan	10097	1	6 millimeters, 12 parapods.
North of Cashes Ledge	10089	2	8 and 11 parapods.
Near Mount Desert Island	10099	2	10 millimeters, 12and 14 parapods.
Off Penobscot Bay	10101	2	Do.
Eastern basin	10093	1	5.5 millimeters, 13 parapods.
Off Penobscot Bay	10091	1	7 millimeters, 11 parapods.
Off Cape Elizabeth	10103	(1)	4 millimeters upward, 6 parapods and upward.
15 to 18 miles southeast from Chatham, Cape Cod		(1)	6 millimeters upward, 8 to 14 parapods.

[1] Several.

Judging from the early stage in development represented by these specimens, it appears that *T. catharina* reproduced itself in some numbers in the Gulf of Maine during the summer in question, proving that it is actually endemic there and not restricted as a breeder to more northern seas. Although young specimens have not been detected in our tow nettings before or since at any season (evidence that it would be quite exceptional for Tomopteris to breed in any abundance within the gulf), what little reproduction does take place there may be enough to maintain the rather sparse stock of this worm.

Of course, this does not negative the possibility that more or less immigration takes place into the gulf from the north (p. 339); but the distribution of *T. catharina* in eastern Canadian waters, as outlined by Huntsman (1921), suggests rather that the Gulf of Maine colony is to some extent isolated and separated from the more abundant stock of this worm in Newfoundland waters and in the region of the Laurentian Channel by a considerable gap, for it was taken at only one station inside the continental edge along Nova Scotia by the Canadian fisheries expedition of 1915. Our scanty data point to an early summer breeding season, which agrees with Southern's (1911) discovery—based on the occurrence of females with eggs as well as of young—that it breeds from May until August in Irish waters.

Relation to temperature and salinity.—The highest temperature in which we have positively established the presence of *T. catharina* in the Gulf of Maine is 14.44° (surface haul, Station 10245, August 12, 1914), and the great majority of captures have been from water colder than 8°. At the other extreme it has been taken in

temperatures between 0 and 1° at several stations along the coasts of Maine and Massachusetts in March (e. g., stations 20056, 20059, and 20062), frequently in water of 2 to 4°, and the specimens taken by the Canadian fisheries expedition over the Newfoundland Banks and in the Laurentian Channel in May, 1915, were probably in water colder than 0° (see Huntsman, 1921, p. 86, for these records) and very likely fractionally colder than −1°. Thus this worm finds its optimum in comparatively low temperatures. Perhaps 15° might be stated as its absolute upper limit in the Gulf of Maine, and, in fact, it is doubtful whether it could long survive water warmer than 10 to 12°.

On three occasions we have taken *T. catharina* in salinities as low as 31 to 32 per mille,[80] but the great majority of captures have been in water of 32 to 33 per mille. The highest salinity in which our records positively establish its occurrence in the Gulf of Maine (closing-net hauls at stations 20052 and 20055) is 33.7 to 33.8 per mille, and although we took Tomopteris at one station (10225) where the net worked for a time in water as saline as 35 per mille, it is more likely that the odd specimens that it brought back were picked up on its journey up or down through the lower salinities of the superficial strata of water.

Thus, these additional records obtained during 1920 and 1921 corroborate Huntsman's (1921, p. 90) conclusion that a salinity of approximately 33 to 34 per mille is the upper limit for *T. catharina* off North America. On the other hand, it seems well established that it never occurs in water much less saline than 32 per mille except when it makes brief excursions to the surface, and our records thus support Huntsman's (1921, p. 90) suggestion that low salinity is the factor that prevents it from colonizing estuarine situations. In north European waters, as he remarks, the relationship which *T. catharina* bears to salinity is quite different, for around Ireland Southern (1911) found it only in water more saline than 34 per mille. Of course, it is possible that this is a physiological difference between the American and European races of this species; but the question also naturally occurs whether high salinity, *per se*, acts anywhere as a bar to its dispersal, and whether it is not high temperature, quite independent of salinity, which lays down a definite offshore bound for *T. catharina* just outside the American continental edge as far northward as the Nova Scotian banks. The rarity of *T. catharina* over the continental shelf along Nova Scotia (Huntsman, 1921) is especially interesting in this connection, because the temperatures and salinities there both fall within the limits in which it exists either to the south or to the north.

The most reasonable explanation for its peculiar distribution is that *T. catharina* occurs chiefly in the immediate neighborhood of its centers of production, of which there are but two in the seas under discussion—a major on the Grand Banks and a minor in the Gulf of Maine. It does not breed in the intervening stretch of waters because it requires a closer balance in its physical environment for successful breeding than for vegetative existence. This, we may assume, it does not find in the Gulf of St. Lawrence.

It is therefore likely that when the geographic limits within which *T. catharina* breeds successfully are better known, specimens taken elsewhere will prove to be

[80] Station 20092, surface, 31.01 per mille; station 20093, surface, 31.92 per mille; station 20119, surface, 31.43 per mille.

among the most reliable of indicators of ocean currents. Huntsman (1921, p. 89) has remarked that failure to find it more frequently along Nova Scotia "indicates the smallness of the contribution given by the water covering the Newfoundland Bank to the mass of water passing southwestward over the Breton and Scotian Banks." In fact, the evidence so far at hand suggests that it is exceptional for Tomopteris of Newfoundland Bank origin to stray southwestward much beyond 60° longitude, much more so for it to reach the Gulf of Maine by this route.

What rôle *T. catharina* plays in the economy of the planktonic community is still to be learned.

Tomopteris septentrionalis Apstein

Tomopteris catharina is the only species of the genus which so far has been recognized anywhere in the inner parts of the Gulf of Maine at any season, but during March, 1920, a second and much smaller tailless Tomopteris, provisionally identified as *T. septentrionalis*,[81] was taken over the outer edge of the continental shelf off Cape Sable (stations 20076 and 20077), on Brown's Bank (station 20072), and in the southeastern part of the Gulf basin (station 20086); also in the Eastern Channel (station 20107) in April and off the southwest slope of Georges Bank in May (station 20129), one or two specimens on each occasion (fig. 94).

These records are interesting as extending the known range of this species southward along America to the Gulf of Maine. It was found off Halifax and at the mouth of the Laurentian Channel by the Canadian fisheries expedition of 1915 (Huntsman, 1921); has been taken at many localities in the Labrador current from the Grand Banks northward; along the west coast of Greenland; right across the North Atlantic to the Hebrides (Apstein, 1900); off Ireland, where Southern (1911) described it as common; and as far south as the region of the Canaries and as the Mediterranean near Gibraltar (Malaquin and Carin, 1911). It is likewise recorded from the South Pacific off Chile (Rosa, 1908).

Unlike *T. catharina*, *T. septentrionalis*, is characteristically oceanic, but its status in regard to temperature is not yet understood.

PELAGIC CŒLENTERATES

The Gulf of Maine supports many species of cœlenterates, which live pelagic for at least part of their lives. Most of them, however (medusa stages of hydroids), are strictly neritic animals, which find their most favorable environment in the sheltered bays and among the islands and on the offshore banks, and which so seldom stray more than a few miles away during the brief period during which they are afloat that they are of practically no importance in the plankton of the gulf basin. Animals belonging to this category need not concern us here, since they have seldom if ever dominated in our offshore catches. Most of the local species have been described and beautifully illustrated by Alexander Agassiz (1865), to whom I refer

[81] The distinguishing characters of this species are its lack of tail, of rosette organs, or of first cirri; the development of sex organs only in the dorsal branches of the parapodia; and the presence of one glandular organ in each ventral branch of the latter. There is no danger of confusing *septentrionalis*, with the much larger *catharina*, specimens of the former, sufficiently adult to bear 21 parapods, being only 12 millimeters long, according to Reibisch (1905). Our largest with 17 parapods was 7.5 millimeters. The separation from *T. planktonis*, which depends on the parapodial glands, requires specimens in good condition.

any reader who may desire knowledge of them.[82] The few species of hydroid medusæ which do drift out more or less frequently into the open basin are among the most valuable indicators of coast water. Two of the local species of scyphomedusæ, which are of similarly neritic habit, are of still greater interest in this connection because of their large size (p. 33). In the following pages the reader will find notes on the occurrence of most of the species which we have found in any number in the deeper parts of the gulf.

The ctenophores (p. 365) are much more important in the natural economy of the plankton community than either of the groups just mentioned, for they are not only exceedingly abundant at times and locally in the gulf, but they are among the most voracious of pelagic animals (p. 108). Only one species of siphonophore (p. 377) is a regular inhabitant of the Gulf of Maine.[83]

Hydroid medusæ

Only a few of the many species of hydroid medusæ assume any numerical importance in the planktonic communities of the open Gulf of Maine outside the outer headlands and islands, except over the offshore banks.

Melicertum campanula (Fabricius)

This boreal neritic species is common on the North American coast from eastern Newfoundland southward to Cape Cod, and it occasionally occurs as far south as Woods Hole, whence Nutting (1901) recorded it once. It is represented in the northeastern Atlantic by a form (*M. octocostatum*) so closely allied that it may prove identical when the two are compared critically. The European Melicertum is known from Iceland and from many localities around southern Norway, from the Skager-Rak, all around Scotland, and along the northeast coast of Iceland.[84]

The hydroid stage of *M. campanula* was grown from the egg by Alexander Agassiz (1865) many years ago, hence there can be no question of its neritic nature, while the medusa stage is so large, so easily recognized, and so closely confined to the immediate vicinity of the land that it is one of the most valuable of neritic indicators. Hence, its distribution in the gulf deserves more attention than its slight importance in the natural economy of the plankton might suggest.

The youngest medusæ of Melicertum so far recognized were found by Alexander Agassiz in Massachusetts Bay toward the end of spring. Older stages are common all along the western and northern coasts of the gulf in June (Mayer, 1910, p. 208), and the sexually mature adults swarm in harbors and bays from Cape Cod to the Bay of Fundy during the late summer. It has been found plentiful, for example, in Salem Harbor, in Gloucester Harbor, about Nahant, and off Cohasset in Massachusetts Bay; equally at the mouth of the Piscataqua River below Portsmouth; in Penobscot Bay, where I have seen processions of these beautiful medusæ drifting with the tide in late July and early August; at Southwest and Northeast Harbors

[82] See also Fewkes, 1888; Mayer, 1910. I have elsewhere (Bigelow, 1914b) listed all the positive records of the pelagic cœlenterates on the New England coast.

[83] For lists of the cœlenterates collected during the summers of 1913 and 1914, see Bigelow 1915, pp. 308 and 316, and 1917, p. 302.

[84] Its occurrence is charted by Kramp, 1919, p. 54, chart 5

on Mount Desert Island; and in the bays of Grand Manan, where Fewkes found it one of the commonest medusæ in the summer of 1886 and I, myself, in August, 1910. Its breeding period endures from mid-July throughout August or even later, both in Massachusetts Bay and in Penobscot Bay, hence is no doubt uniform along the whole coast line of the gulf. The eggs are shed freely, are easily fertilized artificially, and the early stages in development can be followed without difficulty.

I have not seen Melicertum after August, but A. Agassiz (1865, p. 181) describes it as plentiful in Massachusetts Bay "in the fall at the time of spawning." How late in the season its medusæ may survive is not known. Perhaps it appears and dies earlier in the southwestern than in the northeastern part of the gulf, like Staurophora.

It is probable that the hydroid stage of Melicertum is invariably passed in the immediate neighborhood of the coast, there being no evidence that this ever takes place on Georges or Browns Banks or even on offshore ledges within the gulf, such as Cashes and Platts. And while the adult medusæ occasionally drift out to sea (for we have taken odd specimens over the western basin on August 9, 1913 (station 10088) and near Mount Desert Rock (station 10248) on August 13, 1914), it is very seldom that one strays beyond the 100-meter contour; nor have we ever found Melicertum in numbers anywhere outside the bays, river mouths, or harbors, except off Cape Cod and near Browns Bank (p. 33, footnote).[85]

Staurophora mertensii, Brandt

This is a boreal Arctic species, circumpolar in its distribution, ranging widely over the Arctic Ocean and adjacent parts of the North Atlantic, and also in the North Pacific. In the eastern side it is known from many localities about Iceland, from Spitzbergen, Nova Zembla, the White Sea, all along the west coast of Norway, between Scotland and Iceland, and from the northern part of the North Sea.[86] In the western Atlantic and its tributaries Staurophora has been recorded from the west coast of Greenland, from the east coast of Newfoundland, from many localities in the Gulf of Maine, as detailed below, at Woods Hole, and as far westward along the south shore of New England as Newport (Mayer, 1910) and Fisher's Island Sound (Verrill, 1875, p. 43). Its known range in the North Pacific area includes Bering Sea, the Aleutian Islands, and the coast of Alaska on the east, and Japan on the west; and if Kramp's (1919, p. 41) contention that the *S. falklandica* of Browne (1902) from the Falkland Islands is actually *S. mertensii* proves correct, it is bipolar.

This large hydromedusa is a very conspicuous member of the plankton of the Gulf of Maine during its periods of plenty, for it attains a diameter of upwards of 200 millimeters at maturity and is made easily recognizable by its white central cross. It has not been actually demonstrated that Staurophora passes through a hydroid stage, but its systematic relationships and its seasonal history, outlined below, make it practically certain that such is the case.

[85] For locality records of Melicertum during the summer cruises of 1912 to 1914 see Bigelow, 1914, p. 125; 1915, p. 316; and 1917 p. 303.

[86] Kramp (1919, p. 44), who has plotted its distribution in the northeastern Atlantic, has shown that the young "Staurophora" described by Hartlaub (1899) from Helgoland probably was not this genus, but that the *S. discoidea* described by Kishinouye (1910) from Japan is not distinguishable from *S. mertensii*.

The young medusæ of Staurophora appear off Cape Cod and probably elsewhere along the coast farther north during the last half of April.[87] In 1920, for

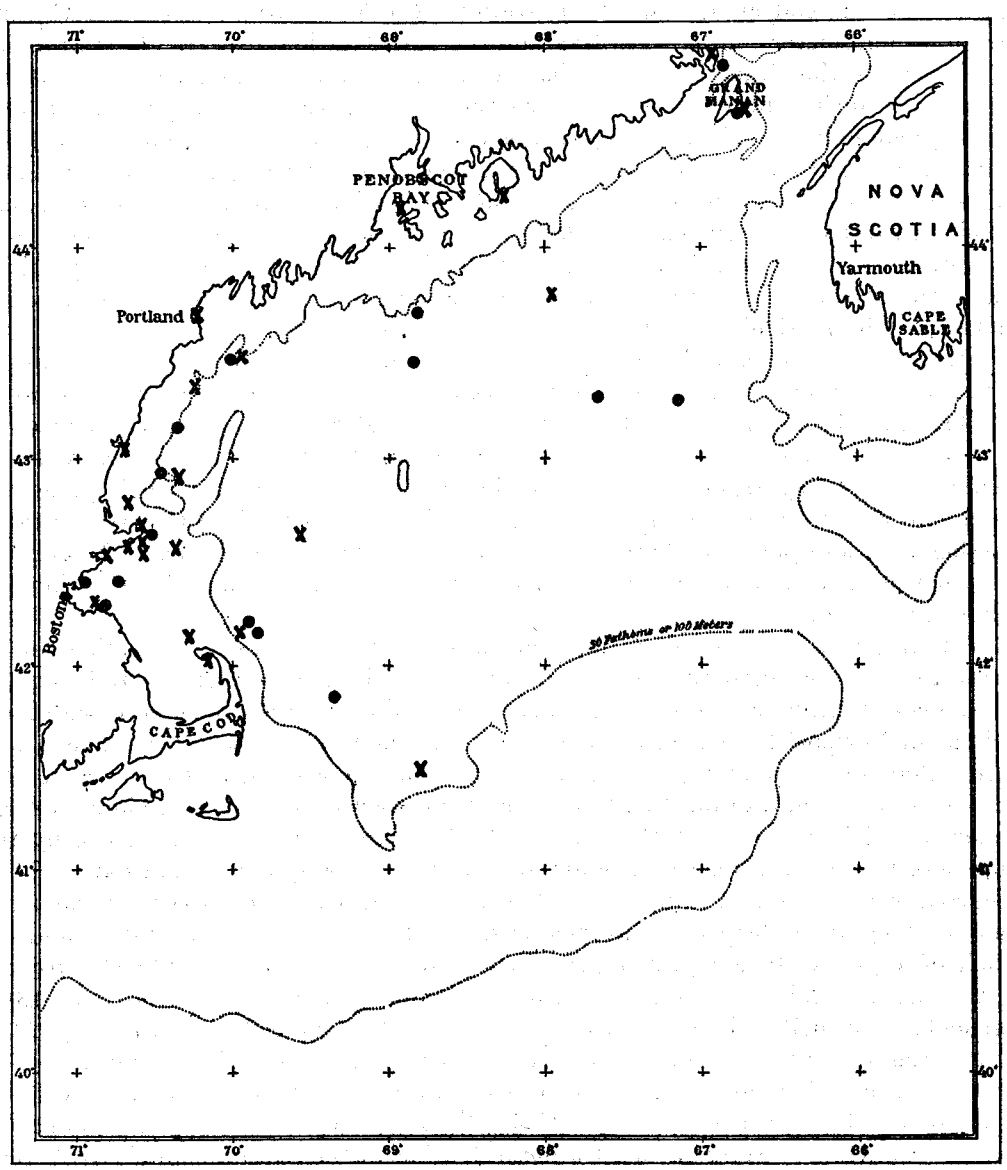

FIG. 95.—Occurrence of the hydromedusa *Melicertum campanula*, and of the ctenophore *Bolinopsis infundibulum*. X, locality for Melicertum; ●, locality records for Bolinopsis

example, we noted them first off the northern end of Cape Cod on the 17th of that month (station 20117) and found the tiny medusæ (about 5 to 15 millimeters in diameter) plentiful on the surface in Massachusetts Bay on the 20th (station 20119).

[87] According to Mayer (1910) this takes place early in the month, but such has not been our own experience.

Small specimens were again found there on May 4 (station 20120), in Ipswich Bay on the 7th and 8th (station 20122); less numerously at the Massachusetts Bay station (20124) and along Cape Cod (stations 20125 and 20126) on the 16th, and one of 40 millimeters on Georges Bank on the 17th (station 20127). It is probable that most of the Staurophora of that region are set free and reach recognizable dimensions during the last week in April and the first week of May, for in 1913 we found great numbers of the youngest stages in Gloucester Harbor on May 3 (Bigelow, 1914a, p. 407). In favorable years a tremendous production of Staurophora takes place in Massachusetts Bay, and the distribution of the adults suggests that this is true of the western coasts of the gulf as a whole, if not for its whole shore line. As yet, however, no search has been made for it in early spring anywhere north of Cape Ann in the inshore waters where the medusæ first appear, nor is it mentioned in Doctor McMurrich's plankton lists from St. Andrews.

Staurophora rivals the still larger scyphomedusæ in the rapidity of its growth, a fact long ago commented upon by Alexander Agassiz (1865) and more recently by Hartlaub (1899), who kept the young medusæ under observation for some weeks.

By the middle of May the medusæ attain a diameter of about 2 inches in the Massachusetts Bay region, and during the last week of that month I have seen specimens 3 to 4 inches in diameter cast up on the beaches of Cape Cod Bay in great numbers. Staurophoræ as large as 5 to 6 inches may be found early in June in Massachusetts Bay, and they attain a diameter of 6 to 9 inches there during the following month.

Staurophora reaches sexual maturity later, and the medusæ live until later in the season in the northern part of its range than in the southern, paralleling the differences of temperature with latitude. Thus, Mayer (1910) records mature individuals in Newport Harbor as early as the 5th to the 9th of June, 1895, while it is in spring that Staurophora appears most commonly at Woods Hole. In Massachusetts Bay it does not mature until early July, and our own experience corroborates Alexander Agassiz's statement (1865, p. 137) that Staurophora vanishes thence by the middle of that month, for we have found none there subsequent to that date. They occurred very generally, however, and often in large numbers over the northern half of the gulf, in deep water as well as shoal, during the last half of July and the whole of August of 1912, a year of plenty (Bigelow, 1914, p. 123), while Fewkes records it as common and of large size at Grand Manan during July and August, 1886, particularly in sheltered bays near the north end of the island (Fewkes, 1888, p. 233), and at Eastport until October. However, as we have not found it in September or later, it is probable that few if any of the medusæ of Staurophora survive much later than the end of August in the open gulf. Thus Staurophora disappears from most parts of the Gulf of Maine at least a month earlier in the season than either Aurelia or Cyanea; and it is probable that when specimens are seen in the southwestern part of the gulf as late as mid-August—for example, we noted it off Cape Ann and off Cape Cod on the 24th and 29th in 1912 (stations 10042 and 10043)—they are not the product of the shallows nearby but have drifted thither from the northern part of the gulf with the general eddylike circulation.

Staurophora fluctuates greatly in abundance in the Gulf of Maine from year to year. According to Willey and Huntsman (1921, p. 2) it was common in the channels leading into Passamaquoddy Bay in 1910. As just noted, also, the summer of 1912 was one of plenty. For example, great numbers were seen floating on the surface and a fathom or so down off Cape Elizabeth on July 29 and August 7; over Jeffrey Bank and near Monhegan Island on August 8; it swarmed off Penobscot Bay on the 13th; again a few miles off Seguin Island on the 22d; and 20 large medusæ, upwards of 8 inches in diameter, were taken in a haul from 30 meters a few miles north of Cape Ann on the 24th (Bigelow, 1914, p. 123). Staurophora occurred at more than one-third of our stations for 1912 (16 locality records), distributed very generally over the western and northern parts of the gulf, including Platts Bank, the Grand Manan Channel, and Eastport.[88] Willey and Huntsman (1921) also mention its presence in Passamaquoddy Bay and at St. Andrews during that summer.

If our hauls gave a true picture, the years subsequent to 1912 saw a progressive decrease in the numbers of Staurophora living in the Gulf of Maine. Thus, it was at only two localities that we found it in any numbers in 1913—in the southwest part of the gulf on July 8 and over Jeffreys Ledge off Cape Ann on August 11—with the other locality records based on occasional specimens only or on fragments, although it occurred at ten localities[89]—that is, at about the same proportion of our stations as in 1912. Straurophora proved even scarcer in the gulf in 1914, when we found it at only three stations in all (10214, 10224, and 10249), although we visited the same general localities as in the two previous summers and at about the same season.

In 1915 this medusa was so rare that we took only three specimens at as many stations (stations 10272, 10282, and 10290), although we towed in the coastwise waters of the gulf as well as offshore on many occasions from May onward throughout the summer; nor did we find it at all at our Gulf of Maine stations from Massachusetts Bay to Georges Bank in July or August, 1916. From that time forward the war caused a suspension of our work until the spring of 1920, hence nothing is known of the status of Staurophora for the years 1917, 1918, and 1919 except that none were seen at St. Andrews during that period (Willey and Huntsman, 1921). But young Staurophora were once more plentiful in Ipswich Bay, Massachusetts Bay, and along Cape Cod during the spring of 1920 (stations 20117, 20119, 20120 to 20122, and 20124 to 20126); and since it was found very generally in Passamaquoddy Bay and its tributaries during that July and August (Willey and Huntsman, 1921, p. 2), it had evidently reestablished itself in the gulf in its former abundance.

Although Staurophora, like the scyphomedusan genera Aurelia and Cyanea, and like the various smaller hydromedusæ (p. 340), is neritic, it is much less closely confined to the coastal zone in its medusan stage than is either of the former or than are most of the latter (p. 341), but occurs widely over the triangle between Nova Scotia and the Maine coast in its summers of plenty, offshore as well as in the coastal zone, and out to the 100-meter contour off the Massachusetts Bay region (fig. 96). But it seems to be wholly absent from the south-central and southeastern

[88] For these stations see Bigelow, 1914, p. 123.
[89] Stations 10057 and 10058 in July; stations 10089, 10090, 10091, 10093, 10100, 10103, and 10104 in August.

parts of the basin of the gulf, and it is only near shore or over comparatively shoal water that we have encountered it in any abundance (p. 345).

Staurophora, like Cyanea, breeds on Georges Bank as well as in the coastal zone—witness the young medusa taken there by Mr. Douthart in April, 1913 (Bigelow, 1914a, p. 414), and the specimen of 40 millimeters mentioned above at station 20127. Very likely it is commoner and more widespread there than the actual records suggest, its seasonal history in Massachusetts Bay suggesting that it may grow to maturity on Georges Bank and die there in the seasonal interval (late May to mid July) between the dates of our visits. Our failure to find it at all over the coastal bank west of Nova Scotia, including Browns Bank, may have been equally accidental. The preponderance of records for this medusa in the western side of the gulf, as contrasted with the eastern, evident on the chart (fig. 96), can not be explained away in this manner, however, but suggests that its chief center of abundance is in the zone between Cape Cod and Penobscot Bay.

Vertical distribution.—The youngest medusæ recognizable as Staurophora swarm on top of the water, as do the medium-sized specimens so often cast up on the beach, but although the large adults of midsummer occasionally rise to the top (most often at night and in regions of active vertical circulation—e. g., in the Grand Manan Channel) they are usually at least a meter or more below the immediate surface at this season, a fact that has been noted elsewhere (Bigelow, 1914, p. 124). On calm days they may often be seen from the ship's side as deep down as the limit of visibility, but, on the other hand, we have no evidence that Staurophora ever descends to any considerable depth, most of the records being from hauls shallower than 100 meters. As our largest catches have been made at 40 meters or less it is probable that this is the lowest level of its common occurrence and that the occasional Staurophoræ taken in the deep hauls have been picked up by the net on its way down or up through the water.

I should emphasize that the status of Staurophora as a regular endemic inhabitant of the Gulf of Maine is thoroughly established; was, indeed, to all intents and purposes by Alexander Agassiz (1865) many years ago. Inasmuch as its geographic range when it is in the medusa stage covers the whole of the inner waters of the gulf from Massachusetts Bay to the Bay of Fundy, no doubt it breeds successfully all along the New England coast north of Cape Cod and perhaps farther west as well, for the medusæ appear in most years both at Woods Hole (Hargitt, 1905a) and at Newport (Fewkes, 1888).

It is certain that many Staurophora pass through their hydroid stage in water as shallow as that of Gloucester Harbor, where we found the very young medusæ in great numbers in 1913 and 1920 (p. 43; Bigelow, 1914a, p. 407). In fact, it is probable that the majority of the stock live through their attached stage within 20 to 30 meters of the surface within a few miles of the coast line, as is the case in Massachusetts Bay. The wide distribution of Staurophora in the offshore parts of the gulf, however, and especially the fact that its medusæ are set free on Georges Bank suggest that it may also pass through its development in considerably deeper water. How deep is not yet known. Probably Platts Bank, Cashes Ledge, and Jeffreys Ledge are also nurseries for it.

The large Staurophora no doubt takes a very heavy toll of Calanus and smaller copepods, which are often to be found entangled along the elongated lips of its cruci-

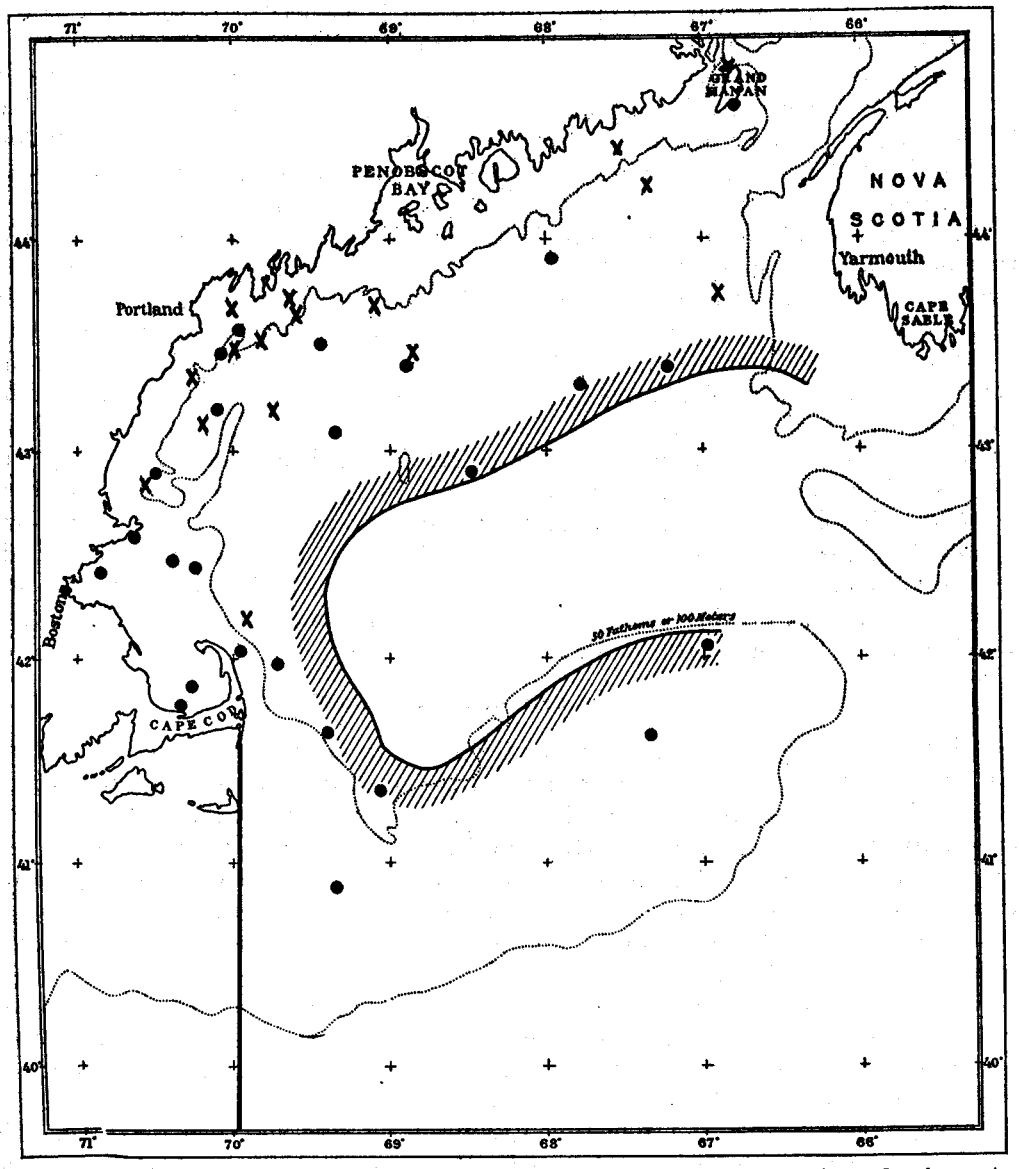

FIG. 96.—Occurrence of the hydromedusa *Staurophora mertensii*. X, locality records, summer of 1912; ●, subsequent years. The hatched curve includes its chief zone of occurrence within the Gulf of Maine

form mouth opening, and since the young Staurophora also feed on them greedily, according to Hartlaub (1899), this medusa must play an important rôle in the natural economy of the animal plankton wherever it is plentiful.

Ptychogena lactea, A. Agassiz

The importance of this Arctic hydroid medusa in the Gulf of Maine as an indicator of water from the north has been emphasized in an earlier chapter (p. 59). I need merely list here the following records of its occurence:

Massachusetts Bay at Nahant, "where they have only been found during a single fall, and then only for a few days, when they seemed quite abundant" (A. Agassiz, 1865, p. 139); eastern basin of the gulf, May 6, 1915 (station 10270); German Bank the next day (station 10271), one specimen at each station; and several examples near Lurcher Shoal on the 10th of the month (station 10272).

The presence of this Arctic medusa in Massachusetts Bay in the autumn of 1863, as recorded by Agassiz, contrasted with the fact that we have since found it only in spring at the time the Nova Scotian current is at its maximum, and in the opposite side of the gulf, is an interesting phenomenon and one yet to be accounted for.

The nearest locality record for Ptychogena to the northward with which I am acquainted is from the neighborhood of Halifax, Nova Scotia, where it was taken by the *Challenger* (Haeckel, 1881).

Ptychogena lactea is Arctic and circumpolar. It has been recorded from several localities along the west coast of Greenland and in Barents Sea between northern Norway and Spitzbergen, from Franz Josef Land, from the Kara Sea near Nova Zembla, from Bering Sea, and from the Sea of Okhotsk. Its most southerly records are the Gulf of Maine in the western side of the Atlantic, between Scotland and Iceland in the eastern side, and the east coast of Hokaido, Japan, in the Pacific (Bigelow, 1913; Kramp, 1919, p. 37).

Mitrocoma cruciata (A. Agassiz)

Mitrocoma cruciata, Staurophora, and Phialidium are the only hydroid medusæ that we have found generally distributed in the open gulf at any season. Mitrocoma is further interesting because it was not seen from the time it was first described by Alexander Agassiz (1865) from Nahant, Mass., many years ago, until the *Grampus* rediscovered it in the gulf in July, 1913 (Bigelow, 1915, p. 316). Although the development of this species has not been traced, there is every reason to suppose that its hydroid stage, like that of its close relative, the Mediterranean *M. annæ*, is a Cuspidella.

In the Gulf of Maine Mitrocoma is a spring species. In 1920 the *Albatross* towed specimens occasionally from February 23 (our earliest seasonal date for it) until May 4 (stations 20048, 20091, 20105, 20106, and 20120). In 1915 we found it not uncommonly in May and June (stations 10270, 10271, 10278, 10282, 10286 to 10288, 10290, 10291, and 10293). A. Agassiz's record was also for June. We have one July record of it in 1913, just noted, one in 1915 for July 15 (station 10301), one for August 4 (station 10303) and others for the 12th and 14th in 1914 (stations 10246 and 10250); but the middle of August apparently marks the end of its season of occurrence, for we have not found it on any of our cruises later in the season. Thus, its period of abundance precedes and somewhat overlaps that of Phialidium. The localities of capture are widely distributed in the

western, northern, and eastern parts of the gulf, over deep water as well as shallow, and include Browns Bank (fig. 97). We have not found Mitrocoma on Georges Bank, though a specimen was towed in the basin between the latter and

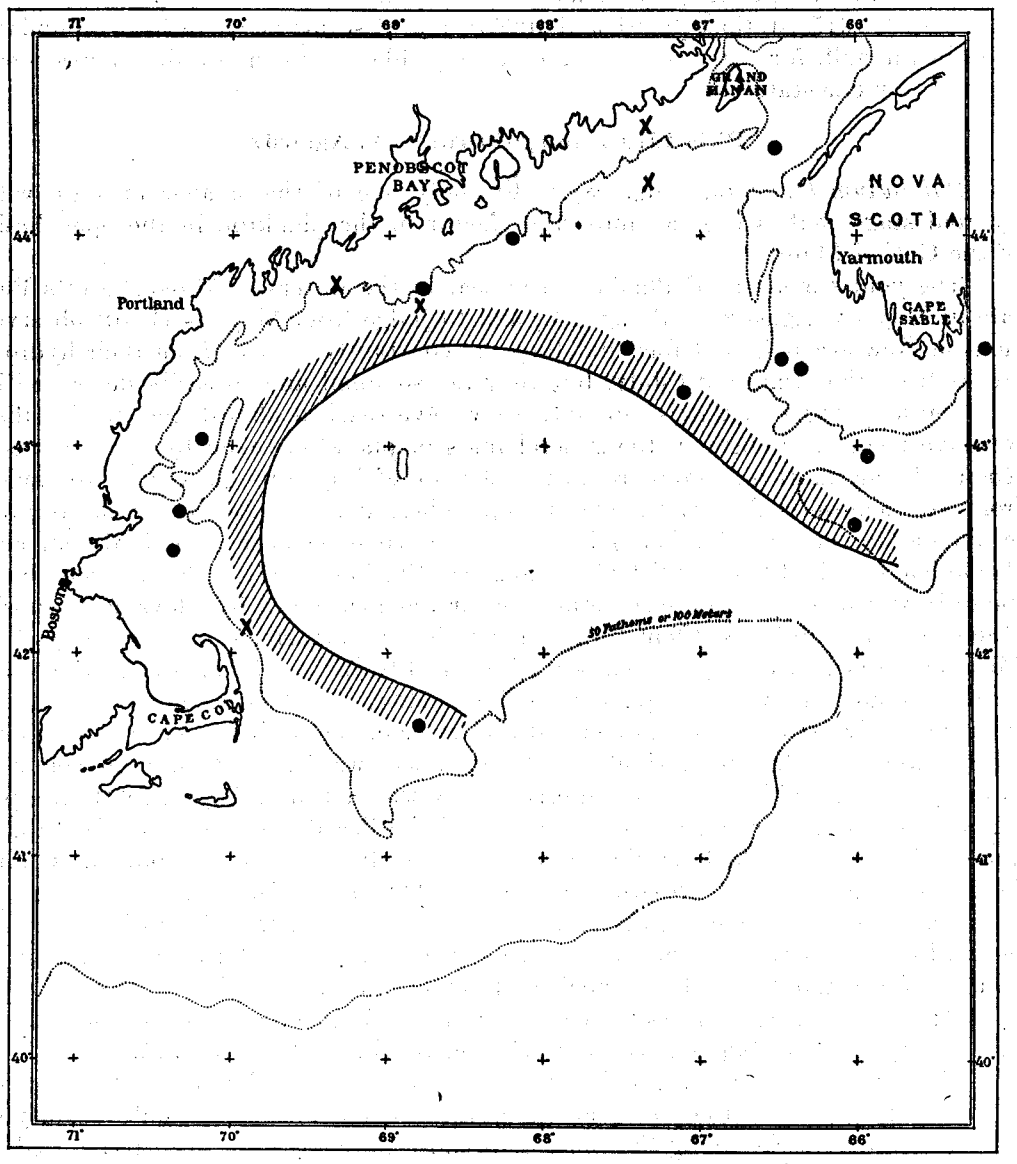

FIG. 97.—Occurrence of the hydromedusa *Mitrocoma cruciatar* ●, locality records, February to June; X, July and August

Cape Cod on July 8, 1913. Thus, the few locality records for Mitrocoma roughly parallel those for Phialidium (p. 350) in their geographic distribution, and so large a percentage of the captures have been made over one part of the basin or another

that Mitrocoma, like Phialidium, probably passes through its hydroid stage over rather a wide range of depth and perhaps down to 100 meters or more.

Up to the present time all known captures of *M. cruciata* have been from the Gulf of Maine except for a few taken off Shelburne, Nova Scotia, by the *Grampus* on June 23, 1915 (stations 10291 and 10293), and it seems nowhere to be abundant even in the gulf, for our tow nets have never yielded more than a dozen specimens or so at any one station.

Phialidium languidum[90] (A. Agassiz)

Phialidium languidum (fig. 98) is the only one of the smaller medusæ with hydroid stage that is ever an important factor in the plankton in the open basin of the Gulf of Maine.[91]

The young medusæ of Phialidium appear in the waters of Massachusetts Bay late in May (A. Agassiz, 1865, fig. 96), and to judge from Mayer's (1910) observations at Newport it is probable that they are constantly set free from their hydroid stocks from that time until July, but they are so small and so easily destroyed in their earliest stages that it is not until they have reached almost mature size that we have recognized them in the general mass of plankton taken by our tow nets. The adults are most numerous from the last week of July through August, to vanish from Massachusetts Bay by the end of September, and our latest autumnal records of Phialidium are for October 9 in the coastal zone between Grand Manan and Penobscot Bay in 1915 (for list of stations see Bigelow, 1917, p. 304). The abundance in which these medusæ sometimes occur was mentioned by Alexander Agassiz (1865, p. 73), who found them "in immense shoals on warm, sunny, still days" in Massachusetts Bay during September. Mayer (1910), too, observes that from July until September they are extremely abundant along the New England coast, particularly at Eastport, where they crowd the water of the harbor, and my own more recent experience has been similar. For instance, we found Phialidium common in every harbor and bay that we entered during the month of August in 1912, especially so in Gloucester Harbor, at the mouth of the Piscataqua River, at Boothbay, and at Eastport. I had previously seen this medusa in myriads both at Grand Manan during August, 1910 (whence Fewkes (1888) also records it), and along the southern shores of Massachusetts Bay. The *Grampus* likewise found it swarming near Mount Desert Rock on August 16, 1912 (station 10032), and near Seguin Island off the mouth of the Kennebec River on the 22d of that month (station 10040); even as far offshore as the eastern basin on August 13, 1914 (station 10249), and also in the Piscataqua River and off Rye, N. H., on July 23, 1915.

We have no record of Phialidium out in the open gulf prior to the first of August, either because the young medusæ are confined to the immediate vicinity of their shallow nurseries along the coast or because they have not been recognized in the tow, but during that month it occurs very generally right across the gulf north of a line from Cape Cod to Cape Sable.[92]

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[90] For description and figures see A. Agassiz, 1865, p. 71; Mayer, 1910, p. 269.

[91] Other species are plentiful locally on Georges Bank.

[92] For locality records, summers of 1912 to 1915, see Bigelow, 1914, p. 125 1915 p. 273 and 1917 pp. 303 and 304.

Although we have taken Phialidium over the basin as well as near shore, it occurs most regularly within a comparatively short distance of the land, as might be expected of any neritic animal that passes the greater part of the year attached

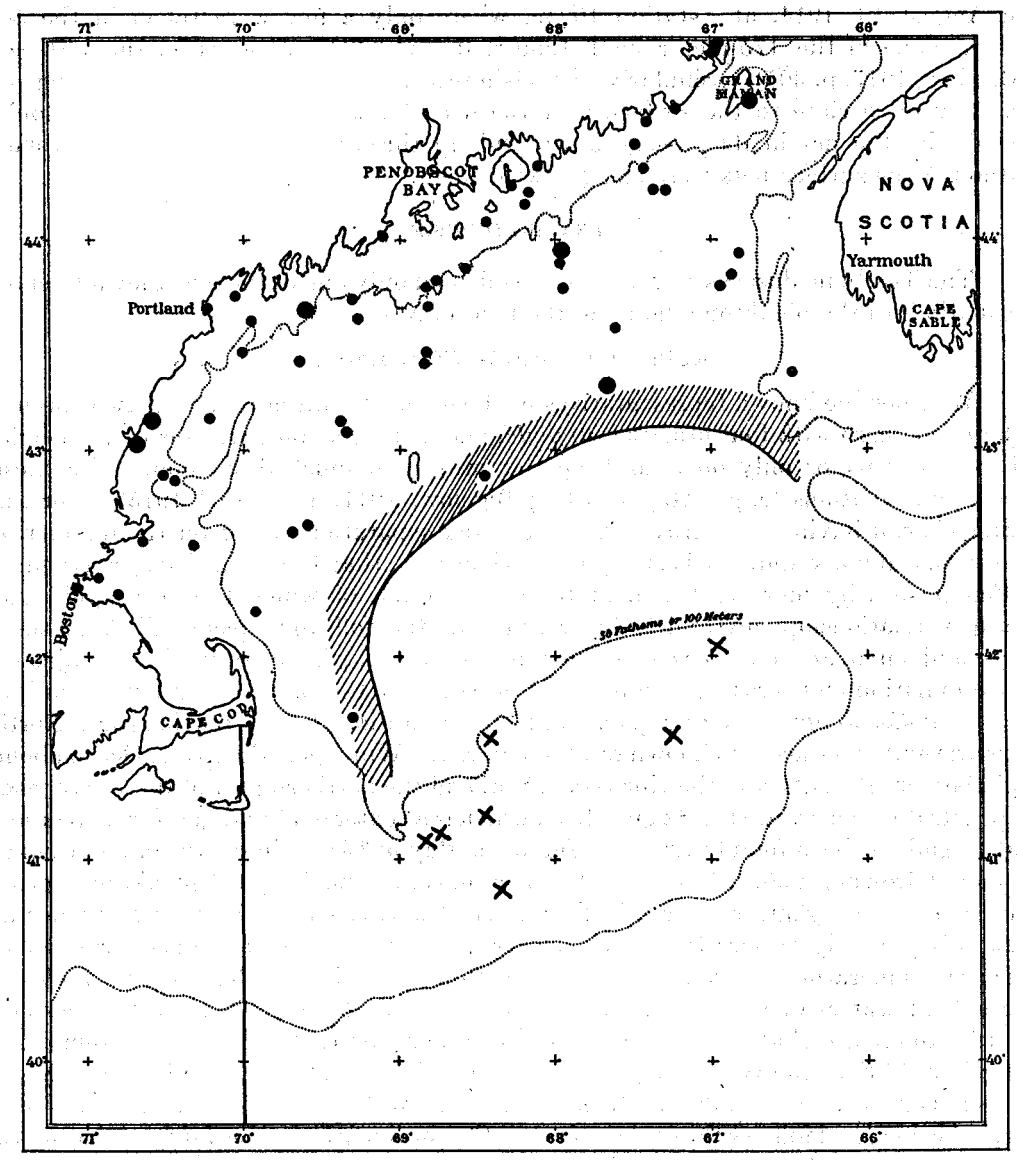

FIG. 98.—Occurrence of the hydromedusa *Phialidium languidium* (●) and of floating hydroids (X). The large symbols mark the swarms of Phialidium; the hatched curve its approximate offshore boundary

to the bottom in shoal water. There is evidence that Georges Bank and Browns Bank serve as nurseries for it, for we found it on the northwestern part of the former on August 13, 1926. We have no record for it in the southeastern part of the basin or in the Eastern Channel.

Our experience has been that the medusæ of Phialidium? are always most numerous at the surface or a meter or so down at most, no matter what the precise locality in the gulf or the time of day, a fact well illustrated in the eastern basin on August 13, 1914, at "station 10249, where only a few were taken in the 50-meter, none in the 175-meter haul, though it was very numerous on the surface" (Bigelow, 1917, p. 305). Similarly, the offshore swarms twice encountered in August, 1912, were so close to the surface that the deep hauls yielded very few (no doubt caught by the net in its passage down and up through the rich superficial zone), although the surface nets were clogged with them.

TRACHOMEDUSÆ

The Trachomedusæ as a group are oceanic and only one of them is known to enter regularly into the planktonic fauna of the Gulf of Maine.

Aglantha digitale (Fabricius)

Whether the known representatives of the genus Aglantha represent two species, a large northern with four otocysts (*digitale*) and a smaller southern (*rosea*) with eight of these organs, or only one, has been the subject of much discussion. The most recent observations (e. g., Mayer, 1910; Bigelow, 1911, 1913, and 1915) favor the latter view, it having been proved that the older separation, based on the number of otocysts, can not stand. It is still possible, however, that the genus is represented in different seas by more or less definite size varieties, of which the geographic and seasonal relationships are still to be traced. In the following pages all Aglanthas, large and small, are treated as a specific unit because they have not yet been subjected to examination more critical than has been necessary to establish their generic identity.

Aglantha digitale is circumpolar and boreal-Arctic. In the northeastern North Atlantic and tributaries its known range includes the White Sea, the Arctic Ocean about Spitzbergen, Barents Sea, the Norwegian Sea, and the northern part of the North Sea. It penetrates thence into the Skager–Rak, which is a center of abundance for it (Kramp, 1913), and has been found very plentiful in the Bay of Biscay in depths of 50 fathoms or more (Browne, 1906, as "*A. rosea*"). The collections made by the plankton expedition show that Aglantha is practically universal between Iceland and Greenland; in fact this probably applies to the whole North Atlantic north of the isotherm of 60° surface temperature. Aglantha is the commonest of the smaller medusæ in West Greenland waters (Vanhöffen, 1897), and the records for it off the coast of eastern North America include the east coast of Labrador, the east coast of Newfoundland (Bigelow, 1909a), the Grand Banks, and the continental shelf generally along Nova Scotia (Bigelow, 1917, p. 303). It occurs far and wide in the Gulf of Maine, as described below, and follows the cool water over the continental shelf as far west and south as the mouth of Chesapeake Bay in winter (Bigelow, 1918, p. 388); sparingly to the latitude of Delaware Bay even in summer. The high temperature of the inner edge of the Gulf Stream forms an insurmountable offshore barrier to Aglantha off the American littoral, as it does for so many other boreal members of the plankton.

Although the early development of Aglantha has not yet been traced, it is probable that it is direct, like that of its close ally, the genus Aglaura—that is, without

hydroid stage—and consequently that the medusa is independent of the coast line and of the bottom at all stages in development. Its distribution is therefore wholly independent of distance from land or from shoal water.

Aglantha, like many other medusæ, was first recorded from the Gulf of Maine by Alexander Agassiz (1865), who detected both large, sexually mature medusæ and young ones at Nahant, Mass., during the summers of 1863 and 1864, since when it has been reported both by Hargitt (1905) and by Mayer (1910) as common in spring off the shores of southern New England. Consequently it was no surprise to find it in our plankton hauls at many stations in the Gulf of Maine. The localities of capture, as appears on the chart (fig. 99), are concentrated in a peripheral zone 40 to 60 miles broad, paralleling the coast from Cape Cod to Cape Sable and spreading thence southward and westward across Browns Bank, the Eastern Channel, and following the southern half of Georges Bank westward; but we have never taken a single specimen of Aglantha in the central waters of the Gulf or over the northern part of Georges Bank.

The reader need but compare the chart of Aglantha with the corresponding chart for Beroë (fig. 102) or for *Pseudocalanus elongatus* (fig. 83), animals equally pelagic at all stages and of similar temperature affinity but regularly and constantly endemic in the Gulf of Maine, to note the sharp contrast between the definite localization of the records for Aglantha [93] and the universality of the others.

Although we have never found Aglantha with sufficient regularity (and seldom in sufficient abundance) to regard it as a characteristic member of the plankton of the gulf, it has occurred often enough and at stations indifferently enough spaced to show that it may be expected anywhere and at any season in the area inclosed by the curve on the chart. Within this area the locality records show no definite concentration in one side of the gulf or the other, nor do they correspond to the depth of water, and our experience has been that the local presence or absence of Aglantha in the gulf at any particular time is as independent of precise temperature or salinity as it is of depth, the close neighborhood of land, or the contour of the bottom. Its distribution closely mirrors the anticlockwise circulation of the upper strata of water in the gulf. The natural inference from this is that the continued presence of Aglantha within the gulf depends more on immigration from the east and north than on local reproduction. Once such immigrants have passed Cape Sable they follow right around the gulf, first north then west, southwest, and south in their involuntary journey, with little more tendency to spread toward the center of this great eddy than have the various fish eggs or other animals of neritic nature that are set free near the coast line. In this its distribution in the gulf parallels (though it does not exactly reproduce) that of the chætognath *Eukrohnia hamata*, another common visitor from colder seas to the east and north, which occurs far more regularly around the periphery of the deep basin than in its center and spreads southward along the slope of Georges Bank but at a deeper level than Aglantha.

[93] For locality records of Aglantha for the years 1913 to 1916, see Bigelow, 1915, p. 316; 1917, pp. 303 and 304; 1922, pp. 134 and 136. During the spring of 1920 it was taken at stations 20044, 20046, 20049, 20055, 20056, 20058, 20064, 20067, 20068, 20071, 20072, 20073, 20074, 20075, 20076, 20077, 20079, 20081, 20087, 20096, 20105, 20107, 20111, 20115, 20116, 20118, 20122, 20128 ,and 20129, and at stations 10490, 10491 and 10499 during December–January, 1920–1921.

Although Aglantha abounds on or near the surface in Arctic Seas its usual habitat in the Gulf of Maine is at some deeper level, with only six of our sixty-odd locality records for it from surface hauls;[94] but, although it so seldom rises quite to the top of

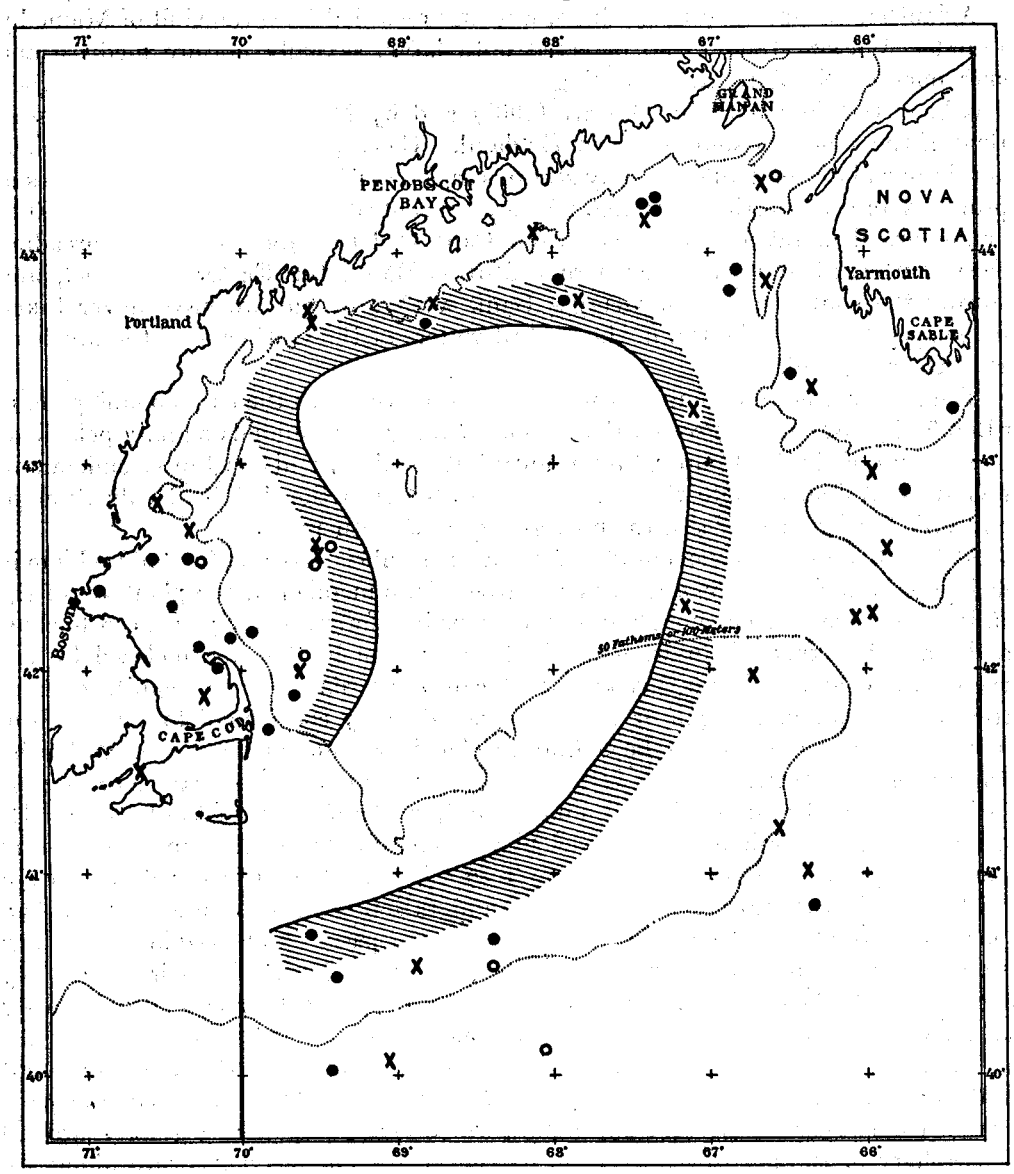

FIG. 99.—Occurrence of the trachomedusa *Aglantha digitale*. ●, locality records, July to October; ○, October to February; X, February to July. The hatched curve incloses the chief zone of occurrence for this species in the Gulf of Maine

the water in the gulf, we have occasionally taken it at not over 15 meters depth, often in tows from 50 or 60 meters, and usually within 150 meters of the surface.

[94] Aglantha has also been found on the surface at Woods Hole by Hargitt (1905), and at Nahant in Massachusetts Bay by A. Agassiz (1865).

Only eight hauls (whether with the open or closing nets) from deeper than 160 meters have yielded Aglantha. Evidently, then, this medusa lives chiefly in the upper strata of water in the Gulf of Maine, just as it does in the North Sea region (Kramp, 1913) and for that matter over the North Atlantic as a whole, though not on the surface. The frequency of captures in hauls made between 50 and 150 meters (a depth range which included about 40 per cent of all Gulf of Maine records for Aglantha) points to this stratum as its chief center of abundance. The greatest depth from which I can definitely establish the presence of Aglantha within the gulf is 180 to 140 meters (closing net, off Mount Desert Rock, March 3, 1920, station 20055). The only specimen we have taken in a tow from deeper than 200 meters (240–0 meters, station 20049, western basin, February 23, 1920) may have been picked up by the open net on its journey down or up; nor is it any more certain that the few Aglanthas which we have collected along the continental slope ostensibly from 400–0 and 500–0 meters (e. g., station 20077, March 19, 1920), but in open nets, actually came from so great a depth.

Aglantha is seldom abundant in the Gulf of Maine; in fact, most of the records obtained by the *Grampus*, *Albatross*, and *Halcyon* (now amounting to the respectable total just mentioned) are for single or occasional specimens. Only five times have we taken it in large numbers—that is, near Lurcher Shoal, May 10, 1915; near Gloucester, July 19, 1916 (station 10340); in Provincetown Harbor the next day (station 10243); off Gloucester, October 31 of that same year (station 10399); and on the southeast part of Georges Bank, March 12, 1920 (station 20069).

Aglantha is present in the gulf throughout the year, taken there during every month except October, when we have done little towing; nor is there anything in our records to suggest that it is notably more abundant at one season than another, for the rich hauls just mentioned were made in spring (March and May), summer (July), and autumn (October). It is probable, however, that a more intensive study of the local occurrence of this medusa in the gulf would show that its numbers there do wax and wane with the succession of the seasons. At Woods Hole it occurs most often in spring (March to May, according to Hargitt, 1905).

Although the distribution of Aglantha in the Gulf of Maine is more consistent with an extralimital source of supply than with widespread local production such as maintains the stocks of Calanus, *Thysanoessa inermis*, *Sagitta elegans*, or even Euchæta in the gulf, the fact that very young specimens as well as adults have repeatedly been taken there not only during our recent cruises but half a century ago (A. Agassiz, 1865) is evidence enough that it reproduces itself to some extent. Occasionally a local wave of production must take place to produce such an abundance of the young medusæ as we found off Cape Ann on October 31, 1916 (Bigelow, 1922, p. 136; station 10399).

Aglantha, large or small, is usually so scarce anywhere in the gulf that such events must be unusual. Additional information on this point would be very welcome, for it is not possible to appraise the faunal significance of the occasional swarmings of Aglantha as indices to influxes of northern water into the Gulf of Maine without knowing how regularly the stock of this species existing there is replenished by local breeding.

The dimensions of the specimens of Aglantha from the Gulf of Maine, compared with their states of sexual maturity, corroborate all previous studies of the genus to the effect that there is a wide range of variation with respect to the size attained by this medusa at maturity. At the one extreme is a large race in which the gonads do not reach full size until the bell is 20 millimeters high or even higher, and there seems to be every gradation from this down to specimens in which the sex organs are already well developed and the eggs plainly visible when the bell is only 6 to 10 millimeters high. The Aglanthas from Massachusetts Bay, described by Alexander Agassiz (1865) as upwards of 25 millimeters high when adult and with the gonads just appearing in specimens of 5 to 8 millimeters, were among the largest known representatives of the species. Most of the Aglanthas collected by the *Albatross* from February to May, 1920, were likewise large, as appears from the following table:

Station	Height of bell in millimeters	State of sexual development	Station	Height of bell in millimeters	State of sexual development
20067	9	No gonads.	20096	18	Gonads 6 to 7 millimeters long.
20129	10	Do.	20129	18	Gonads 4 millimeters long.
20129	12	Small gonads.	20069	21	Gonads 5 millimeters long.
20129	13	Do.	20088	23	Gonads 7 to 8 millimeters long.
20081	19	Gonads 2 to 3 millimeters long.	20116	26	Gonads mature, up to 6 to 7 millimeters long.

A large variety was also represented among the Aglanthas taken in May, 1915, and part (just what proportion is yet to be determined) of the swarm of young just mentioned as encountered off Gloucester on October 31, 1916, were also destined to grow large, for the series taken included many specimens up to 10 millimeters high but without visible trace of gonads. But that same swarm yielded many Aglanthas with gonads of good size and (in the case of the females) eggs already visible, although the bells were only 6 to 7 millimeters high. Our largest catches of the "small" Aglantha were in Massachusetts Bay and especially at Provincetown on July 19 and 20, 1916 (stations 10340 to 10343), when specimens sexually mature, though only 6 to 10 millimeters high, were abundant and no large ones were taken. Examples of this small variety have also been recorded by Hargitt [95] (1902 and 1905) from off Chatham, August 19, 1902.

These data suggest that the large race usually predominates in the gulf during the cold season, giving place to smaller specimens during the warm; and the occurrence of large and small specimens side by side in Massachusetts Bay in October, which I have just mentioned, may mark the transition from the season when most of the Aglanthas are small to that during which they average large. The presence of occasional large specimens in midsummer—for instance, off Grand Manan on August 13, 1913, and in Massachusetts Bay in summer and autumn—shows that there is no hard and fast rule.

To settle the true relationship of the two races to each other, to the physical state of the water, and to their origin in the gulf, whether local or immigrant, calls for a study more intensive than has yet been devoted to the genus. For the present the

[95] Described by him as a new species, "*A. conica.*"

most reasonable hypothesis is that the small form is evidence of conditions less favorable, the larger specimens of an environment more favorable, for growth, though both may mature their sexual products.

SCYPHOMEDUSÆ

Cyanea capillata var. arctica, Péron et Lesuéur

The distribution of the genus Cyanea, the largest of all the medusæ, is very wide along the coasts of both sides of the North Atlantic and Pacific Oceans and in the Arctic Ocean. The genus is likewise represented in south Temperate and Antarctic Seas, but not in the Tropics. Numerous supposedly distinct "species" of Cyanea have been described, separated for the most part by color, size, and minor anatomical differences, but these have been found to intergrade in so many cases that, as I have remarked elsewhere (Bigelow, 1913, p. 92), it seems impossible to distinguish more than one species of this genus in northern seas, where all its varieties are connected by intermediates. Several of the latter, however, deserve recognition in nomenclature, being not only well marked but occupying rather definite geographic ranges.

The Cyaneas which occur in the Arctic-boreal waters of the western side of the North Atlantic province, from West Greenland to the region of Cape Cod and Nantucket Shoals, are the largest of their race and usually of a rich brown and yellow color. They form the basis of the "species" *C. arctica* of Péron et Lesuéur and of most recent authors. Following the coast west and south from Cape Cod we find this northern form giving place to smaller, more yellowish Cyaneas (the var. *fulva*) along southern New England and the Middle Atlantic States to the Carolinas, and this form in turn to a still smaller and pinker race christened "*versicolor*" by L. Agassiz, which is very plentiful locally from Cape Hatteras to the southern boundary for the genus off Florida (Mayer, 1910, p. 600).

Cyanea, like Aurelia (p. 362), is neritic and its life cycle is similar. The egg [96] develops to the planula stage among the folds of the mouth parts of its parent, and when it is shaken free it attaches itself to the bottom, to develop there into the tentaculate scyphostoma from which the young medusæ (ephyræ) are produced serially by annular constrictions of the oral end.

The distribution of this common red jellyfish in the Gulf of Maine is interesting because its presence is a sure sign of coast or of banks water, and because it offers a refuge to the fry of the haddock [97]. Locality records for it in the gulf are now very numerous. In the neighborhood of Woods Hole (and probably this applies all along the southern shores of New England) the young medusæ of Cyanea appear in March; by the end of the month "the calm surface of the water in Great Harbor was literally spangled with the slightly protruding discs" (Bumpus, 1898, p. 487); by mid-April some have grown to a diameter of 7 inches (Mead, 1898); many are sexually mature at Woods Hole by May, though the youngest medusæ (ephyra stage) are still to be found there as late as the end of that month; and the mature

[96] On the development of Cyanea see L. Agassiz, 1862; Hyde, 1894; McMurrich, 1891; Hargitt, 1902.
[97] For an account of its movements in Norwegian waters see Damas (1909).

medusæ in the act of releasing their ova are taken in abundance from the early part of June (McMurrich, 1891) until September (Sumner, Osburne, and Cole, 1913a, p. 575).

North of Cape Cod it seems that the ephyræ of Cyanea are liberated later in the season, corresponding to the more tardy vernal warming of the water. I have no direct data as to the precise season when the ephyræ are set free in the Gulf of Maine,[98] for we have never seen a young Cyanea in the inner parts of the gulf during the spring months, but the few we have taken there during the last half of June have been only 2 to 3 inches broad (e. g., north of Georges Bank, June 25, 1915, station 10298). It is not until the first part of July that we have seen Cyanea as large as 6 to 10 inches in diameter in the Massachusetts Bay region, pointing to April and May as the season when their liberation commences. At that time the smallest medusæ of Cyanea must be extremely plentiful along the shores of the gulf. Alexander Agassiz (1865, p. 45) saw great numbers of them measuring ¼ to 3 inches in diameter on the surface in Provincetown Harbor in the early morning, all, however, sinking as the sun rose, and we have found them in abundance on Nantucket Shoals in April (p. 359). Our failure to take them in our tow nets elsewhere in the gulf during those months, in spite of the considerable number of hauls, recalls Louis Agassiz's remark (1862, p. 109) that "there must be something peculiar in the habits of the young Cyanea to render them apparently so rare, when in the adult state they are so common" along the coasts of Massachusetts Bay. His suggestion that they keep near the bottom during their early stages has been corroborated by Mayer's (1910, p. 600) observation that young Cyaneas rarely come to the surface in the aquarium but spend most of their time clinging to the bottom or side of the tank with their widespread oral fringes. The tendency of the small Cyaneas to seek the surface so much more regularly about Woods Hole than in the Gulf of Maine is an interesting local difference in habits still awaiting explanation.

It seems that Massachusetts Bay and the Gulf of Maine generally offer an especially favorable environment for the Cyaneas, which grow so rapidly there that many of them attain a diameter of 2 to 4 feet by the close of the summer. This is about the average size at the end of their lives, though Alexander Agassiz (1865, p. 44) records one monster from Massachusetts Bay that measured 7½ feet across the disk, with tentacles upward of 120 feet in length.

It is certain that the breeding season for Cyanea endures from June until mid-autumn in the Gulf of Maine, for on the one hand Hyde (1894) obtained developing eggs near Cape Ann early in summer, while on the other we have frequently found the medusæ, with mature eggs and carrying great numbers of the planulæ, cast up on the beach in September and early October. Probably Cyanea becomes sexually mature as soon as a certain size is attained, regardless of the precise season when this takes place, and continues to produce eggs or sperm throughout the remainder of its life, with the autumnal storms, which either cast the medusæ on the shore or batter them to pieces at sea, setting the natural period to their existence. We find no record of Cyanea in the Gulf of Maine after October.

[98] One ephyra was taken near Mount Desert on June 14, 1915, but it was probably among the latest produced there.

It is not easy to reconstruct the life histories of planulæ set free at the beginning of the breeding season, which may be in May at Woods Hole or early in June north of Cape Cod. It is possible that some of these pass through the scyphostoma stage, that these produce ephyræ, and that the latter grow to sexual maturity—but probably not to a large size—that same autumn; for Hargitt (1902) found that in high temperatures (19 to 20°, and upwards) the development of Cyanea may go forward so rapidly that the whole cycle, from planula to young medusæ, is sometimes compressed into a period of 18 days. McMurrich's (1891) experience, however, that planulæ of Cyanea produced in May, which he kept under observation in the aquarium at Woods Hole and apparently under favorable conditions, were still in the scyphostoma stage at the end of August is sufficient evidence that the rate of larval development is usually much slower than this even at summer temperatures. Nor is it likely that if any great number of Cyaneas passed through two generations a year at Woods Hole—that is, produced sexually mature medusæ in spring and again in autumn—the fact would so long have escaped detection there, with marine collecting carried on so intensively and continuously. It is also probable that in the Gulf of Maine, with its cooler water, few of the larval Cyanea that are produced in late spring and early summer (none of the late summer and early autumn crop) attain the stage at which the young medusæ are set free ("strobila stage") before autumnal cooling checks their further development.

What few precocious medusæ may be produced in the gulf during some unusually warm autumn or in some locality abnormally warm for its latitude probably perish at the onset of winter without leaving issue. In short, the evidence is strong that there is only one annual generation of Cyanea in the Gulf of Maine. Cyanea passes the winter in the attached ("scyphostoma") stage until stimulated to renewed devel-velopment by the rising temperatures of spring.

Because of its life history, Cyanea is strictly neritic in its faunistic status. It has generally been taken for granted that the American Cyanea, like Aurelia, passes through the attached phase of its life history close to tide mark only, this being the case in European waters where the larvæ are described as attaching themselves to stones, seaweeds, etc., along the strands where their parents are cast up by wind and wave in the storms of autumn (Damas, 1909). So far as I can learn the scyphostoma stage of the American form of Cyanea has not been found at liberty in its natural surroundings, but the fact that the newly liberated medusæ have often been found in partially inclosed waters—e. g., Woods Hole Harbor—and the facility with which the young can be reared from egg to medusa in the aquarium are sufficient evidence that at least a large part of the stock of Cyanea inhabiting the Gulf of Maine is produced in very shoal water. On the other hand, the presence of the young medusæ on Nantucket Shoals, where we saw many very small ones only one-half to 1 inch in diameter floating by the *Halcyon* while tagging codfish on April 23, 1923, and over the western, northern, and eastern parts of Georges Bank, where specimens 2 to 4 inches in diameter were plentiful on July 23, 1916 (stations 10347 and 10348), and August 13–20, 1926, proves that this medusa is equally able to pass through its scyphostoma stage in depths of from 30 to 70 meters.

We have never taken Cyanea smaller than 2 inches in diameter out in the open gulf, except as I have just noted; but by the time they have passed that size and have scattered farther from their birth places in shoal water, we have either captured them or seen them floating on the surface on many occasions and at many localitites in the gulf. Not only is Cyanea a familiar object to fishermen, for it often swarms in the more open bays from Cape Sable to Cape Cod, though never in our experience in the river mouths and other estuarine and slightly brackish situations where Aurelia so abounds (p. 362), but it is dreaded by swimmers with good cause because of its venomous tentacles. On July 29, 1921, for example, hundreds of persons suffered more or less irritation of the skin from touching red jellyfish while bathing at Nantasket Beach near the mouth of Boston Harbor,[99] and the tentacles retain their irritating power for some time after the medusæ strand on the beach.

Most of our locality records for Cyanea (fig. 100) have been from within or at most only a few miles without the 100-meter contour, which corresponds to its neritic nature. It is universal all around the coastal belt of the gulf, the absence of definite records along western Nova Scotia mirroring the fact that we have made no summer hauls there and not a scarcity of Cyanea. No doubt its range also covers the whole of Georges Bank, though the western part of the latter seems more prolific in Cyanea than the eastern. The *Grampus* found rather small specimens (2 to 4 inches in diameter) so plentiful on July 23, 1916 (station 10348), that one half hour's haul with the 1-meter net at 30 meters depth yielded 3 gallons of them. It is probable that Cyanea also occurs on Browns Bank, though we did not chance to find it there on our June and July visits.[100]

Cyanea shows little tendency to drift out into deep water in the northern and northeastern parts of the gulf east of Cape Elizabeth, but we have taken (or seen) it at several stations well out in the basin off Massachusetts Bay and thence southward toward Georges Bank, its distribution agreeing in this with that of other neritic animals as well as with the general distribution of salinity. The presence of a considerable number of rather small (2 to 3 inches) Cyanea floating over the deep basin in longitude 67° 30′ W., some 15 miles north of Georges Shoals on June 25, 1915, is likewise worth noting, though it is not clear whether they came from the neighboring bank or from Cashes Ledge to the north, which is likewise shallow enough to serve as a nursery for this jellyfish. There is nothing in our records to suggest that Cyanea disperses any more widely over the central portion of the gulf in autumn than in summer, and although it is so widespread in the peripheral zone of the gulf and so plentiful at times near shore, we have never found it in any abundance more than a few miles outside the outer headlands except on the offshore banks as just noted.

Cyanea hugs the coast of the Gulf of Maine much more closely than it does the Norwegian coast, where it may drift as much as 250 miles out to sea with the current by September (Damas, 1909). We found Cyanea similarly restricted to the coastal zone within the 100-meter contour from New York southward to Chesapeake Bay during our summer cruises of 1913 (a warm year) and 1916 (a cold year) (Bigelow, 1915, p. 318; 1922, p. 159).

[99] This event was widely reported in the daily press.

[100] For the offshore records for Cyanea see Bigelow, 1914, p. 124; 1915, p. 316; and 1917, p. 303.

It has long been known that Cyanea, like other large medusæ, often acts as a nurse to young fish, especially to gadoids, which live beneath the bells and follow them in their wanderings. In north European waters, where Cyanea often swarms

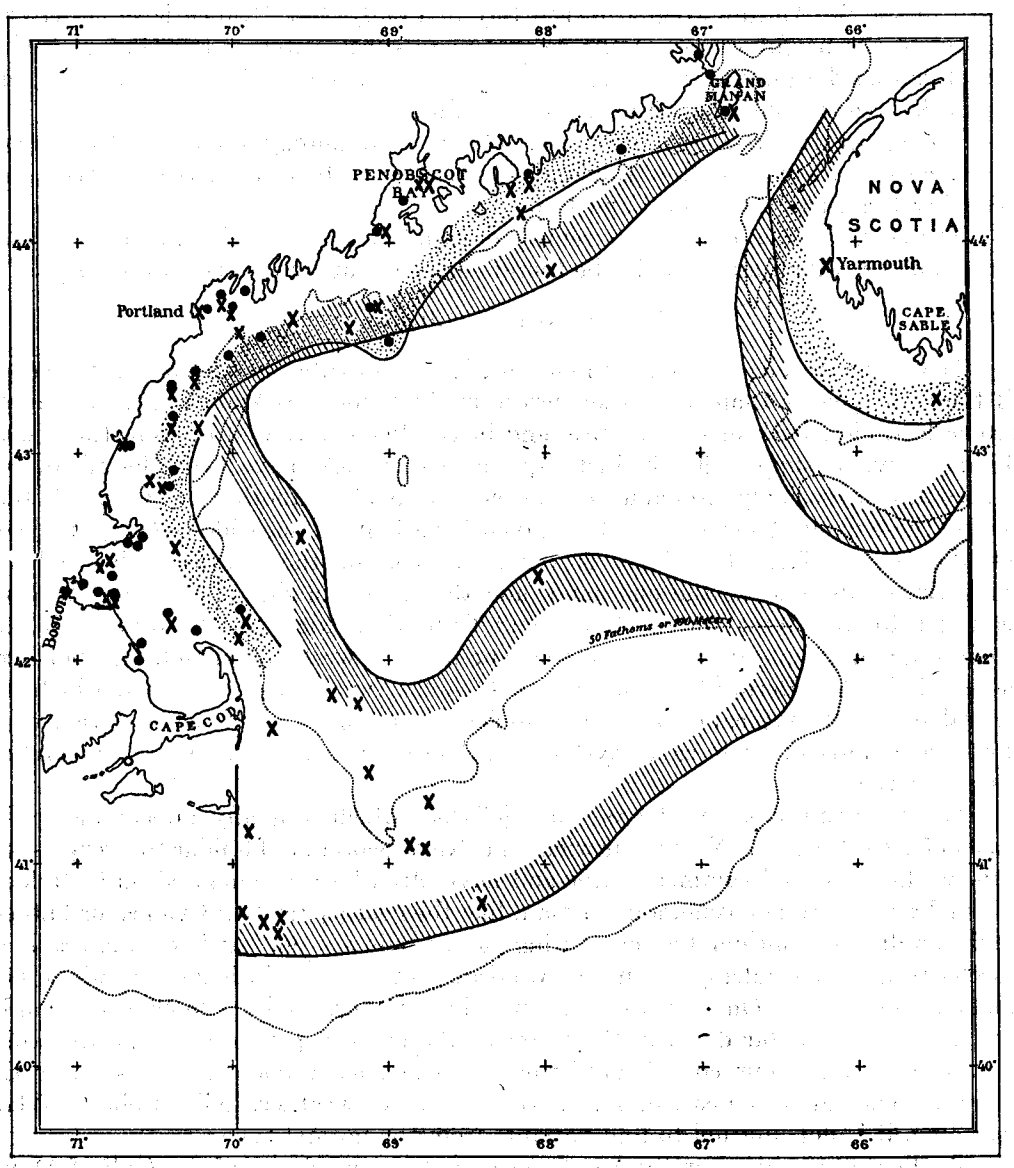

FIG. 100.—Occurrence of the scyphomedusæ *Aurelia aurita* and *Cyanea capillata*. ●, locality records for Aurelia, *Grampus* and *Halcyon* cruises since 1912; X, locality records for Cyanea, *Grampus* and *Halcyon* cruises since 1912. The stippled curve marks the approximate offshore boundary for Aurelia in the Gulf of Maine; the hatched curve the probable offshore boundary for Cyanea

well out at sea, this seems to be the chief means of dispersal for the young of the whiting (*Gadus merlangus;* Damas, 1909a). A large proportion of the European records for the pelagic young of the haddock have also been of specimens taken in

company with these medusæ, and young cod have also been found associating with them. We have found young haddock in company with Cyanea on Georges Bank on one occasion (July 23, 1916, stations 10347 and 10348), as has Huntsman (1922, p. 20) in the St. Andrews region in the Bay of Fundy, but Cyanea is so closely restricted to the neighborhood of the coast and to shoal water in the Gulf of Maine that it can hardly play as important a rôle there as in the northeastern Atlantic and North Sea region, unless it be over Georges Bank.

Young butterfish (*Poronotus triacanthus*) also commonly shelter under Cyanea off the coasts of southern New England (Goode, 1884), but they have not been seen following this habit north of Cape Cod.

The large Cyanea must be extremely destructive to copepods and other planktonic animals, which may usually be found entangled among its curtainlike lips.

Aurelia aurita (Linné)

The genus Aurelia is probably more nearly cosmopolitan in the coastal waters of all the great oceans than any other neritic medusa, for it is known from Arctic to Tropic latitudes, both in the Atlantic and in the Pacific, as well as from the Indian Ocean. Several supposedly distinct "species" of Aurelia have been described, but it becomes increasingly probable, as one collection after another is examined, that most of these names have actually been given to variants of one wide-ranging Aurelia—the *A. aurita*. This, I believe, is certainly true of the Aurelias that inhabit north European seas, on the one hand, and the American side of the Atlantic from Labrador to the West Indies, Cuba, and Gulf of Mexico, on the other. It still remains an open question whether the Aurelias of west Greenland, the northern shores of Alaska, Bering Sea, the Sea of Okhotsk, and northern Japan, which are separable from the typical *aurita* of boreal-Temperate and Tropic seas by a very complex anastomosis of their canal systems, are actually a distinct species or merely a variety of *aurita*.[1]

The multitudes of this large white jellyfish which annually appear along the coasts of New England, New Brunswick, and Nova Scotia are familiar to every fisherman, yachtsman, and summer visitor and have often been commented on.[2] Indeed, it is lucky they are not venomous to man, like their larger relative Cyanea, or bathers would be driven from our beaches during the Aurelia season. It is characteristic of Aurelia to appear suddenly in lines or windrows, often miles in length, as where two tidal currents meet. On such occasions, in calm weather, their shadowy forms can be seen shimmering as far down in the water as the eye can penetrate, while the white genital rings stand out conspicuously on the translucent bodies of those near the surface. They are often cast up on the shore in heavy weather, to lie in piles. When swarming, it is not unusual to find variants from the normal type.[3]

To illustrate how generally Aurelia occurs along the shores of the Gulf of Maine (fig. 100), I may note that we have encountered it in multitudes in Yarmouth Harbor

[1] The interrelationships of the various Aurelias have been discussed recently by Mayer (1910), Kramp (1913b), and by the author (1913, p. 98).

[2] L. Agassiz (1862, pp. 75 to 78) has given a graphic account of the habits of Aurelia in Massachusetts waters.

[3] I find in my notes that on the evening of July 23, 1912, we "saw one with seven, one with six, and two with five genital rings," the normal number being four, while watching them float by the *Grampus* lying at anchor at Kittery, Me.

(Nova Scotia), about Eastport, in Passamaquoddy Bay, at Grand Manan, about Mount Desert Island, in Penobscot Bay, in Boothbay Harbor, at the mouth of the Kennebec River, in Casco Bay, near Cape Porpoise, in Kittery Harbor, about the Isles of Shoals, in Gloucester Harbor, at many localities and on many occasions in Massachusetts Bay, and off Cape Cod, while I have no doubt that Aurelia may be found in season in every bay, harbor, or river mouth and all along the coast line from Cape Cod to Cape Sable. The localities marked on the accompanying chart fail to do justice to the universal distribution of Aurelia in the coastwise waters of the Gulf because most of our cruises and towings have been carried on outside the outer islands and headlands, whereas Aurelia is most plentiful and appears most regularly in more or less inclosed estuarine waters and bays.

Although Aurelia is so universally plentiful along the coast line of the gulf, it seldom strays more than a few miles offshore. We have only two records of it more than 15 miles from the nearest land, and only one more than a mile or two outside the 100-meter contour (fig. 100).[4] Thus its distribution is more strictly coastwise than that of the red jellyfish (Cyanea, p. 357).

The lack of locality records off western Nova Scotia is not due to any local scarcity of Aurelia (for I have seen it in abundance in Yarmouth Harbor in August) but merely reflects the fact that we have occupied no towing stations close in to this part of the coast during its annual season of plenty.

To emphasize more strongly how closely Aurelia is bound to the coast in the Gulf of Maine, I need only add that whereas it was frequently seen floating on the surface or taken in our tow nets during July and August of 1912, when we did much of our cruising close in along the shore, we saw very few in the open gulf (all of them near land) in July or August, 1913, when we worked mostly outside the 100-meter contour. We had only one specimen during our summer cruise of 1914, when the stations were located well out in the gulf, though Aurelia was plentiful enough during both these summers in bays and harbors. We have not found it on Georges Bank or on Browns Bank, nor has it been recorded from either, though the former is an important center of production for Cyanea (p. 359). Neither is there any record of Aurelia over Nantucket Shoals, although the proximity of Nantucket Island suggests that it will be found there.

The facts of distribution just outlined make it certain that in the Gulf of Maine the attached stage of Aurelia is invariably passed in very shallow water, probably never deeper than 20 meters or so. In fact, many of its planulæ are set free along the tide mark where their parents are cast ashore by the autumn gales. For this reason as well as because of its large size this medusa is perhaps the most trustworthy indicator of coast water in the Gulf of Maine.

Thanks to the definite seasonal periodicity of its occurrence and to the ease with which its early stages may be raised in aquaria, the life history of Aurelia is well known; in fact time has added little but corroboration to Louis Agassiz's (1860 and 1862) account, apart from the details of egg cleavage, histology, etc., which need not concern us here. The course of its life is, briefly, as follows:[5]

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[4] For the offshore records, see Bigelow, 1914, p. 124; 1915, p. 316; 1917, p. 303.

[5] Mayer (1910, p. 626) gives an excellent account of the development of Aurelia and of the different ways in which the formation of the gastrula has been described.

After fertilization the developing eggs remain in small pouches along the free margins of the mouth arms, where, by total and unequal segmentation, they form first a blastula, then a gastrula, and finally a ciliated pear-shaped planula. These planulæ, which swim actively, are shaken loose from the mouth arms of the parent, often accidentally by the stranding of the latter on the beach, and settle to bottom, where they become attached by the wide (anterior) end, to develop into the "scyphostoma," which finally grows to a height of about 4 millimeters with 24 tentacles. The "scyphostoma" then produces as many as 12 disklike "ephyræ," as the young medusæ are called, cutting them off by a series of annular constrictions.

In the northern part of its range one generation of Aurelia is produced each year, the winter being passed in the scyphostoma stage, and the young medusæ appearing later and later in the season from south to north, corresponding to the difference in temperature of the water with the latitude. Thus Bumpus (1898 and 1898a), Hargitt (1905 and 1905a), and Fish (1925) have found both the ephyræ and the slightly older medusæ near Woods Hole from March to May. Many have grown to a diameter of 1 to 2 inches there by April (Mead, 1898) and to 4 to 5 inches by mid May,[6] but few if any Aurelia appear in Massachusetts Bay before May (we found none there during that month in 1915 or in 1920), and it is not until July that they attain their full size of 6 to 10 inches north of Cape Cod.

According to Louis Agassiz (1862, p. 76), the Aurelia off Massachusetts become sexually mature late in July and through August, which I can corroborate, having found the mouth arms of all large adults examined at that season laden with developing eggs and planulæ. No doubt they continue producing young from that time onward, through September and October, until they are destroyed by the autumn gales, which seems to be their normal fate. According to Mayer (1910), Aurelia does not mature until September in the Eastport region, but I have never seen nor heard of one in the Gulf of Maine after October.

It is probable that the breeding season of Aurelia and the seasonal succession of its generations are not so definite in the warmer parts of its range, for I have seen large specimens in April in Santiago Bay, Cuba (according to Mayer (1910) Aurelia matures in May at the Tortugas, Fla.), others collected in Barataria Bay, La., during the last week in September, and half-grown individuals taken in the Indian River, Fla., as late as the second week of December.

Other Scyphomedusæ

Only one other scyphomedusa (*Phacellophora ornata*) has yet been reported from the inner parts of the Gulf of Maine, and it has been reported so seldom that nothing can yet be said of its distribution, either seasonal or geographic, except that it must be very rare there because it grows to so large a size (up to 18 inches in diameter) that it would be a very conspicuous object if abundant. It has a very wide distribution in latitude, for Browne (1908) has reported a Phacellophora, indistinguishable from the Gulf of Maine species, from the South Atlantic off Montevideo. The recorded captures in the gulf are Eastport, three specimens, 1868 (Verrill, 1869);

[6] An occasional ephyra of Aurelia has been found at Woods Hole as late in the season as mid June. Fish (1925) has also reported its ephyræ there in late summer and early autumn, but it is doubtful whether this second brood survives the winter.

Eastport, one specimen, summer of 1885 (Fewkes, 1888, p. 235); and Western Basin, March 24, 1920, 200–0 meters, *Albatross* station 20087.

Dactylometra quinquecirrha, a southern species, is fairly common as far east and north as the Woods Hole region, but has never been taken past Cape Cod.

The bathypelagic *Periphylla hyacinthina* has been credited to Georges Bank.[7] Actually, however, the specimens in question were taken off the southeast slope of the latter well out beyond the 500-meter contour (Smith and Harger, 1874, p. 52, as "*Charybdea hyacinthina*"). *Pelagia cyanella* and the large tropical rhizostome *Stomolophus meleagris* have been reported just outside the 100-meter contour south of Marthas Vineyard (Fewkes, 1886, and Hargitt, 1905a), and the cruises of the *Albatross* from 1883 to 1885 yielded a considerable list of tropical and bathypelagic scyphomedusæ (including Periphylla) outside the edge of the continent abreast of the Gulf of Maine (Smith and Harger, 1874; Verrill, 1885; Fewkes, 1886). However, except as just noted, none of these have ever been taken inside the 500-meter contour off the offshore banks of the gulf or within the latter.[8]

Ctenophores

Pleurobrachia pileus (Fabricius)

From the economic standpoint the ctenophore *Pleurobrachia pileus*[9] is the most important pelagic cœlenterate inhabiting the Gulf of Maine, for not only is it extremely voracious and locally abundant beyond all computation, but it is present there throughout the year, not for only a brief season annually, as are Aurelia (p. 362) and Cyanea (p. 357).

The abundance in which Pleurobrachia appears in Massachusetts Bay and elsewhere along the New England coasts in summer and early autumn has often been referred to in literature, but practically nothing was known of its occurrence in the gulf at any other season until the recent systematic exploration was undertaken. During March and April (which is a natural starting point in the seasonal history of any planktonic animal, being the time when vernal warming makes itself felt) we have found Pleurobrachia occurring very generally all around the periphery of the gulf from Cape Cod to Cape Sable (fig. 101), but so closely confined to shoal water that we took it only twice outside the 100-meter contour in the inner parts of the gulf in 1920 and not at all in the basin of the gulf except for the extreme northeastern corner. Nor did we find it on Georges Bank at any of our February, March, or April stations, though it was plentiful on Browns Bank on March 13 (station 20072) and again on April 16 (station 20106).

Our experience in 1915 suggested that Pleurobrachia remains confined to the shoal periphery of the gulf until well into May, if not later, as I have previously noted (Bigelow, 1917, p. 304), but we found it in abundance on the southwestern part of Georges Bank and less plentifully off the seaward slope of the latter on the 17th of that month in 1920 (stations 20128 and 20129), where there had been none

[7] I fell into this error myself (Bigelow, 1914b, p. 27).

[8] See also page 67 for a list of bathypelagic medusæ from our outermost station off Shelbourne, Nova Scotia, Mar. 19, 1920 (station 20077), and page 54 for tropical cœlenterates at the outer station off Georges Bank, July 21, 1914 (station 10218).

[9] For a description, with beautiful figures of the adult, see L. Agassiz, 1849. Mayer (1912) gives a more recent account.

in February. It extends its range offshore in the gulf during the following months until in midsummer and early autumn it is to be expected anywhere north of a line Cape Cod–Cape Sable, both near land and over the deep basin, and with no

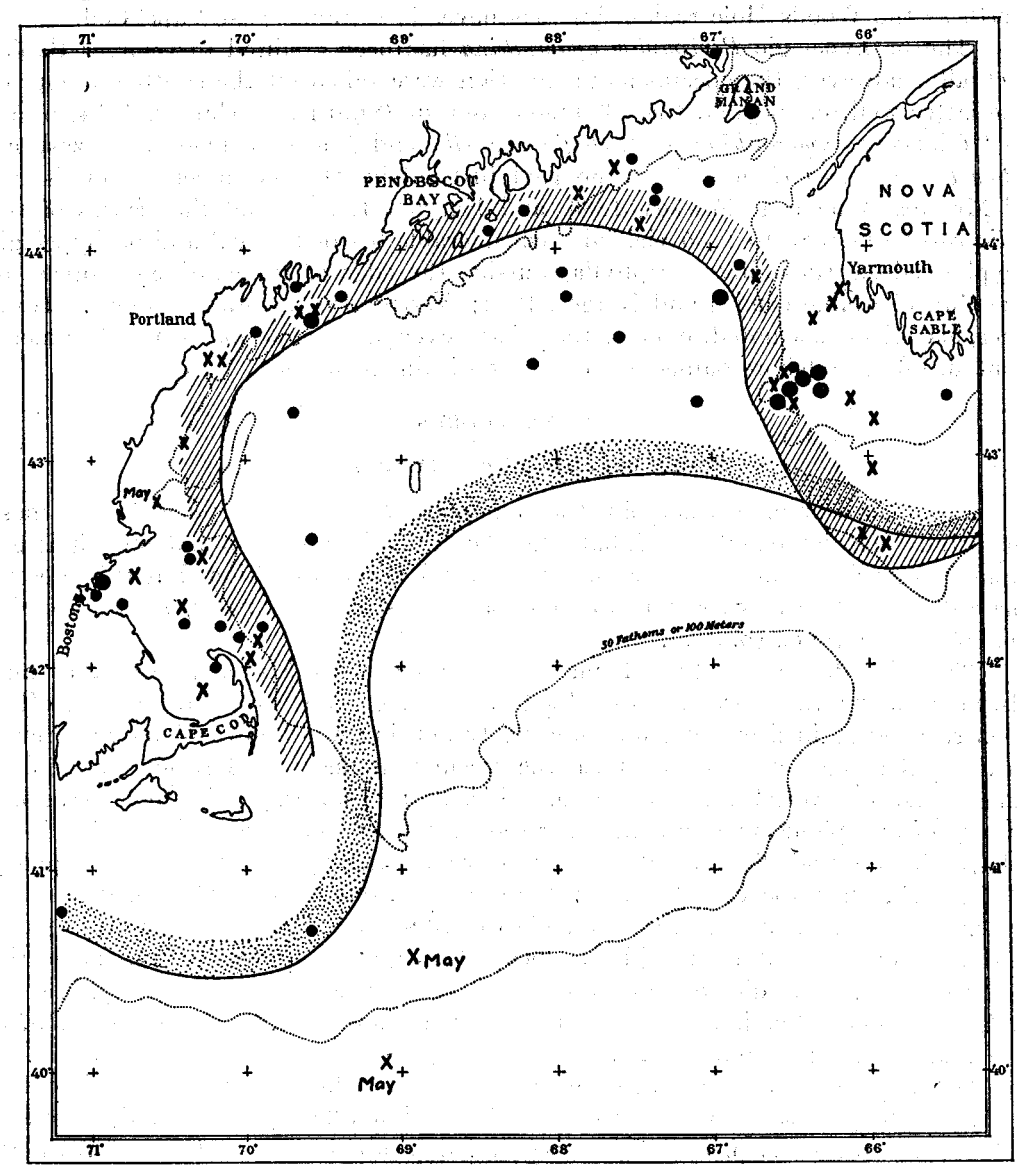

FIG. 101.—Occurrence of the ctenophore *Pleurobrachia pileus* in the Gulf of Maine. X, locality records, March, April, and May; ●, June through September. The hatched curve marks the approximate offshore boundary for this ctenophore in the Gulf in early spring; the stippled curve in summer

decided preponderance of the locality records in one side of the gulf or the other. We have found no Pleurobrachia in the southern deeps of the gulf, in the eastern channel, or over the eastern half of Georges Bank at any season, and the May sta-

tion (20129) just mentioned is our only record for it as far out at sea as the continental slope.

A. Agassiz (1865) describes Pleurobrachia as abundant within Massachusetts Bay in September. In October we have taken it off Cape Cod, off Penobscot Bay, near Mount Desert Island, and off Machias, Me. (Bigelow, 1917, p. 304, stations 10323, 10327, 10328, and 10329), and in Massachusetts Bay and over the western basin abreast of Cape Ann in November (Bigelow, 1914a, p. 403, and station 10401, November 1, 1916). During the last days of December and first week in January of the winter of 1920–21 (*Halcyon* stations 10488, 10491, 10492, 10497, and 10501) it occurred at the mouth of Massachusetts Bay, off Cape Cod, in Ipswich Bay, near Mount Desert, and close to Yarmouth, Nova Scotia, our failure to find it at any of our offshore stations on this last cruise suggesting that its area of distribution in the gulf contracts to the coastal zone as winter advances.

Thus, although Pleurobrachia does not depend on the bottom at any stage in its development, it is more neritic than oceanic in the Gulf of Maine, just as it is over the continental shelf south and west of Cape Cod (Bigelow, 1915, p. 320). This is equally true of it in other seas as well, for although it ranges from the Antarctic Ocean on the south to Spitzbergen on the north (it is not a regular inhabitant of true polar water) and occurs in waters varying as widely in salinity as the Mediterranean, on the one hand, and the inner parts of the Baltic, on the other (Kramp, 1913), it is chiefly confined to the general neighborhood of the land or of the coastal banks and has seldom been taken on the high seas far from the coast (Mortensen, 1912, p. 73).

The region of German Bank and the shoals west of Nova Scotia out to the 100-meter contour generally are the chief and the only constant center of abundance for Pleurobrachia within the limits of the Gulf of Maine. Whether in March, April, May, June, August, September, or in January, we have invariably found these ctenophores, either large or small, swarming there, except that on August 14, 1912, when it abounded at one station (10030), only a few were taken at another close at hand (10029).

We have also seen it in great abundance about Grand Manan in August and have found it numerous off Seguin Island both in August, 1912 (station 10040), and in March (March 4, 1920, station 20058). Rich catches have also been made in Massachusetts Bay in summer and autumn; likewise on April 20, 1920, when Pleurobrachia monopolized the water to the exclusion of almost everything else at a station (20118) in Cape Cod Bay, but when the swarm of these ctenophores was limited to an area so narrow that few of them were taken that same day at a station 30 miles to the northward (station 20119), where they were replaced by a comparatively plentiful Calanus community. The waters over Browns Bank likewise supported an abundance of Pleurobrachia in the spring of 1920, but we have not found it there on our visits in June and July.

Our records do not suggest that any definite ebb and flow takes place in the numbers of Pleurobrachia existant in the Gulf from season to season. There may be a general impoverishment in autumn and winter, but if this actually occurs the

local stock is fully reestablished by the first weeks of spring when (judging from the year 1920) Pleurobrachia may be fully as abundant locally as it is in summer. Its appearances and disappearances are so sporadic, not only in the Gulf of Maine but also in European waters, where it is an equally familiar member of the plankton (Kramp, 1913), that a long-continued series of records of its occurrence will be required before its seasonal fluctuations can be outlined more definitely.

We have no satisfactory data on the absolute numbers in which Pleurobrachia occurs in the Gulf of Maine, but obviously with so large an animal it requires only a fraction as many individuals for the tow-net catches to be measurable by quarts as for creatures as small as copepods to yield very moderate catches. Furthermore, quantitative hauls often fail to afford a true estimate of the local abundance of these ctenophores even when they are plentiful, for they are usually so streaky in their occurrence that the vertical net may catch only a few (or even miss them altogether) at a locality where the horizontal net with its longer journey through the water takes them in multitudes. For example, the quantitative haul yielded Pleurobrachia at the rate of only 220 per square meter of sea surface (less than 10 individuals per cubic meter) off Yarmouth on April 13, 1920 (station 20102), although half an hour's haul of the meter net at 25 meters brought back upwards of 4 liters of them, and a net of 20 centimeters diameter captured 1 liter at the surface. Again, in Massachusetts Bay on March 4, 1920 (station 20058), the vertical net did not yield a single Pleurobrachia (though its catch otherwise showed it to be working properly), whereas many hundreds were taken in the horizontal haul from 30 meters.

Economic importance.—Pleurobrachia is an important factor in the economy of waters where it abounds, chiefly as a destroyer of smaller planktonic animals but also in some small degree as food for certain fishes. Wherever these ctenophores swarm they sweep the water so clean and they are so voracious that hardly any smaller creatures can coexist with them. Copepods in particular are locally exterminated in the centers of abundance for Pleurobrachia, though in their own turn they may swarm nearby; and it is common to find these ctenophores packed with copepods or with euphausiid shrimps and larval fishes ingested and partially digested.

There is reason to believe, too, that Pleurobrachia is a serious enemy to the successful reproduction of sundry fishes (e. g., cod and haddock) by feeding on their buoyant eggs (p. 111), few of which can escape destruction in localities where ctenophores are numerous. Indeed, it is doubtful if more than a trifling proportion of the fish eggs of any sort that are spawned on German Bank can survive there, with Pleurobrachia so plentiful in that neighborhood the year round. In short, the local abundance of the latter may well determine the productivity or otherwise of any particular area in the Gulf as a nursery for gadoids or flatfish. Hence, it is fortunate for the inhabitants of New England that the spawning ground for haddock on the eastern part of Georges Bank seems practically free from Pleurobrachia. Neither did we find it in any number on the haddock-spawning grounds off Massachusetts Bay in May, 1920, notwithstanding its local abundance in the southern part of the bay a few weeks earlier (p. 367), nor on the Isles of Shoals–Boon Island grounds in April and May, 1913.

Although Pleurobrachia can hardly be classed as an important food supply for other animals, fish do prey on them more or less. In New England waters this applies especially to the spiny dogfish (p. 105).

Alexander Agassiz, to whom we owe an excellent account of the development of Pleurobrachia, found its eggs in Massachusetts Bay late in July, in August, and in September, when, as he writes (1874, p. 359), "the water round them is filled with eggs floating a few inches below the surface," and when he took the earliest stages after hatching. This, with our own observations, makes it certain that Pleurobrachia is regularly endemic and breeds in large numbers in the Gulf of Maine, of which it is as characteristic an inhabitant as *Calanus finmarchicus* or *Sagitta elegans*. But how many generations are produced there per year is not known. The older view was that there is only one, and that the product of eggs spawned in late summer and autumn live over winter, to mature and spawn in their own turn the following summer. The presence of large Pleurobrachia in winter and spring as well as in midsummer and autumn, together with the various sizes of the individuals which go to make up the different schools in different localities at any given season, makes it more probable that one generation succeeds another irregularly throughout the year.

In spite of conclusive evidence to the contrary, assembled by recent students of ctenophores, Pleurobrachia has often been termed a northern, even an Arctic, form in its occurrence off the New England coast. I must therefore reiterate that this is not the case but that its regular range along the coasts of eastern North America extends southward to Chesapeake Bay; in fact, nearly to Cape Hatteras in the cold season, for I myself have found it plentiful in the waters of Pamlico Sound in winter.

On both coasts of North America Pleurobrachia grows much larger in cool water (10° or colder) than in warm (Bigelow, 1915, p. 322; Esterly, 1914). Judging from the large size (upwards of 30 millimeters long) and local abundance of Pleurobrachia in the Gulf of Maine, the latter is as favorable an environment for it as are the colder waters off Newfoundland and Labrador; and if numbers of individuals present can be trusted as a criterion this applies equally to the coast water off New York and New Jersey, where rather smaller individuals are so abundant in some summers, for instance 1913, that they have been given a vernacular name ("sago") by local fishermen

Pleurobrachia is a creature of the upper strata of water. As Alexander Agassiz (1874, p. 359) remarked long ago, they come to the surface whenever it is smooth, at all times of day; "they are found in the greatest number between the hours of 9 and 11 in the morning, and from 4 to 6 in the afternoon in the summer," which is a common habit of this ctenophore in all parts of the gulf during summer and early autumn. In August, 1912, for example, we made our largest catches of Pleurobrachia at the surface; but they sometimes lie deep throughout the day in midsummer and even in bright calm weather, as was the case on German Bank on August 12, 1913, when we found no Pleurobrachia on the surface at 10 to 11 a. m., although a haul from 40 meters yielded them in abundance. At other times of year this ctenophore occurs more regularly a few meters (say 20 to 30) down than shallower, as exemplified

by the early spring of 1920, which corroborates Alexander Agassiz's suggestion that Pleurobrachia abandons the surface in the cold season.

Catches of Pleurobrachia in 1920[1]

Off Seguin Island	20058	Mar. 4	Surface	None.
			30–0 meters	Many.
Off Cape Elizabeth	20059	do	Surface	None.
			60–0	Few.
Near Isles of Shoals	20060	do	Surface	None.
			90–0	Few.
Off Boston Harbor	20062	Mar. 5	Surface	Many.
			30–0	Do.
Browns Bank	20072	Mar. 13	Surface	None.
			75–0	Many.
Off Shelburne, Nova Scotia	20073	Mar. 17	Surface	None.
			70–0	35.
Do	20074	Mar. 19	Surface	None.
			125–0	Few.
Do	20075	do	Surface	None.
			80–0	Swarm (2 liters)
Off Machias, Me	20080	Mar. 22	Surface	None.
			40–0	Many (1 liter).
Off Petit Manan	20081	Mar. 23	Surface	None.
			140–0	Occasional.
Off Yarmouth, Nova Scotia	20083	do	Surface	Do.
			30–0	Many (1 liter)
Off Seal Island, Nova Scotia	20084	do	Surface	Few.
			30–0	Many.
German Bank	20085	do	Surface	100+.
			60–0	Do
East side of basin	20086	do	Surface	None.
			150–0	Few.
Off northern Cape Cod	20088	Mar. 24	Surface	None.
			75–0	Few.
Off Cape Ann	20090	Apr. 9	Surface	None.
			60 (closing net)	Few.
Platts Bank	20094	Apr. 10	Surface	None.
			60–0	Few.
Off Cape Elizabeth	20095	do	60–0	2.
Off Seguin Island	20096	do	Surface	Few.
			35–0	Do.
Off Mount Desert	20099	Apr. 12	Surface	None.
			35–0	Few.
Off Yarmouth, Nova Scotia	20102	Apr. 13	Surface	12.
			30–0	Many.
German Bank	20103	Apr. 15	Surface	None.
			60–0	Swarm.
Off Seal Island, Nova Scotia	20104	do	Surface	Many.
			25–0	Swarm (4 liters)
Browns Bank	20106	Apr. 16	Surface	Few.
			40–0	Many.
Off northern Cape Cod	20117	Apr. 18	40–0	Few.
Cape Cod Bay	20118	Apr. 20	15–0	Swarm (6 liters).
Massachusetts Bay	20119	do	Surface	None.
			40–0	Few.
Off Merrimac River	20122	May 8	Surface	None.
			65–0	Few.
Southwest part of Georges Bank	20128	May 17	Surface	Many.
Continental edge	20129	do	Surface	None.
			50–0	Many.

[1] For records of Pleurobrachia from 1912 to 1916 see Bigelow, 1914, p. 126; 1914a, p. 402; 1915, pp. 318 and 320; 1917, pp. 303 and 304; 1922, p. 158. In the winter of 1920–21 it was taken at stations 10488, 10491, 10492, 10497, and 10501.

In most cases surface hauls alone would not have revealed the existence of the local swarms of Pleurobrachia at these stations, but occasionally they are evenly distributed downward through the upper 30 meters or so of water in the cold season, just as they often are in summer. On the other hand, this ctenophore seldom or never sinks into the deepest strata of the gulf, a statement justified by its absence over the basins as well as by the fact that most of our records and all the richest catches have been from hauls no deeper than 30 to 50 meters.

Since Pleurobrachia is present in the Gulf of Maine throughout the year, it necessarily experiences a wide range of temperature and salinity there. On the one

hand, its habit of rising to the surface on warm summer days brings it into water of 16° and upward, while, on the other, it has been taken in the gulf in water as cold as 2.5°, and there is no reason to doubt that it can survive the minimum to which the temperature of any part of the gulf ever chills. Nor is it surprising to find it in extremes as wide apart as this, for the species is practically eurythermal in its geographic distribution (p. 369). As I have previously pointed out (Bigelow, 1915, p. 323), its optimum salinity in North American waters is from about 32 per mille to about 34 per mille, but since it lives in decidedly more saline water in the North Sea region its absence from the saltest water of the Gulf of Maine does not mean that high salinities are unfavorable to it but is due to its neritic habit and to its preference for the uppermost stratum of water.

It is not unlikely that the vertical movements of Pleurobrachia are influenced by the density of the water in which it lives.[10] Although there does not seem to be any connection between the occurrence of Pleurobrachia and density within a range of 1.022 to 1.026, we have never found it (probably it can not float or swim) in water lighter than 1.022, seldom, indeed, in specific gravity lower than 1.023. On the other hand, the presence of Pleurobrachia has never been established in water heavier than 1.027 in the Gulf of Maine or anywhere off the coast of North America, which may explain its failure to sink into the heavier bottom water of the deep basin of the gulf.

Mertensia ovum (Fabricius)

This cold-water ctenophore, so abundant in Arctic seas (Mortensen, 1912) and especially along the eastern coasts of Labrador and Newfoundland (Bigelow, 1909a), reaches the Gulf of Maine only as an immigrant from the north and is shortlived there. Its faunal status being discussed elsewhere (p. 59), I need only add that recent records of it in the gulf are confined to spring and early summer at the following localities and dates:

Eastern basin, May 6, 1915 (station 10270), in surface, 50–0–meter, and 150–0–meter hauls, a total of about 20 specimens; near Lurcher Shoal, May 10, 1915 (station 10272); off the mouth of Penobscot Bay, June 14, 1915 (station 10287). It is present through a longer season off southern Nova Scotia, for we have taken it along the Shelburne profile both in March, 1920 (stations 20075, 20076, and 20077), and in June, 1915 (stations 10291 and 10294); and off Halifax in August (Bigelow, 1917, p. 249). During some years it appears in the Gulf of Maine in autumn, for Alexander Agassiz (1865, p. 29) records it as "exceedingly common in Eastport Harbor during the month of September," a record indisputable because of his excellent figures and description. Fewkes (1888, p. 212) similarly speaks of it as "the common tentaculated ctenophore" at Eastport and at Grand Manan during the summers of 1885 and 1886, but his failure to mention Pleurobrachia, which is actually so abundant there, suggests the possibility that he confused the two genera.

Large Mertensia are unknown south of Massachusetts Bay, and indeed only one adult has been taken even there (A. Agassiz, 1865), but its young may travel as far west and south as New Jersey during the cold season (Mayer, 1912).

[10] Rose (1913) has experimented on the flotation of this ctenophore in waters of varying densities

Bolinopsis infundibulum[11] (Müller)

This boreal-Arctic ctenophore is one of the most familiar of pelagic animals along the New England coast, for, as Alexander Agassiz remarked (1865, p. 15), "there is hardly a more common medusa than the *Bolina alata* on our coast." It is equally abundant off Newfoundland and Labrador, in Arctic seas generally, and southward to Norway and Scotland in the eastern Atlantic.

Unfortunately, Bolinopsis is so fragile that the specimens captured by the tow net are usually reduced to a mass of unrecognizable slime among the other plankton, hence our hauls throw no light on its occurrence in the Gulf of Maine. However, we have observed it often enough from the deck of the vessel (for it is a conspicuous and beautiful object at the surface of the water on the calm days so common in July and August) to show that it is to be expected anywhere in the coastal waters of the gulf. It occurs over the deep basin as well (fig. 95), though there we have observed it but rarely (on Georges Bank not at all).[12]

Our earliest spring record for Bolinopsis is May 6 (station 10270), but L. Agassiz (1849) records its presence in Massachusetts Bay in March and April. It is most abundant during the three months July to September, when, like previous observers, I have seen it in numbers in various bays and harbors from Cape Cod to the Bay of Fundy. It apparently disappears after September, for we have no late autumn or winter records of it anywhere in the gulf.

Bolinopsis, like Pleurobrachia, reproduces regularly and abundantly in the gulf. A. Agassiz[13] (1874) found it spawning in late summer and early autumn. This being the only season when large specimens are to be found in the gulf, probably but one generation is produced there annually.

Beroë cucumis Fabricius[14]

Beroë cucumis is as typically oceanic as Aurelia and Cyanea are neritic, and correspondingly it occurs over the basin of the gulf generally as well as in its coastal zone (fig. 102), instead of being chiefly restricted to the latter like the various medusæ that pass part of their lives attached to the bottom. Beroë seems first to have been reported in the Gulf of Maine in 1849, when L. Agassiz noted the occurrence of the genus (as "Idya") at Nahant and on the shores of Massachusetts Bay (L. Agassiz, 1849, p. 365). In 1852 he saw it in numbers in Provincetown Harbor in August, and he writes (1860, p. 272) that in 1858 "it appeared in such quantities upon our coast during the whole summer that at times it would tinge extensive patches of the surface of the sea with its delicate rosy hue during the warmest part of the day."

By 1860 he had established the presence of Beroë from Cape Cod to the Bay of Fundy, and more recent students have found it common all along the New England coast in summer. Being practically cosmopolitan in all oceans—Tropic, Temperate,

[11] Beautifully pictured by L. Agassiz (1849).

[12] For offshore records from 1912 to 1914 see Bigelow, 1914, p. 126; 1915, p. 316; and 1917, p. 303.

[13] A. Agassiz (1865 and 1874) describes and figures stages in its development.

[14] Probably this is the only species of Beroë which occurs in the gulf; at any rate all Gulf of Maine specimens examined so far, which have been in condition good enough to show critical characters, have proved to belong to it. For general accounts of the genus, of the interrelationships and general distribution of its several members, and of its development see A. Agassiz (1874), Mayer (1912), and Mortensen (1912).

as well as Arctic—indifferently on the high seas and in such inland waters as the Baltic (Mortensen, 1912; Kramp, 1913), *Beroë cucumis* was to be expected in the central parts of the Gulf of Maine as well as in its coastal belt; but it was only with

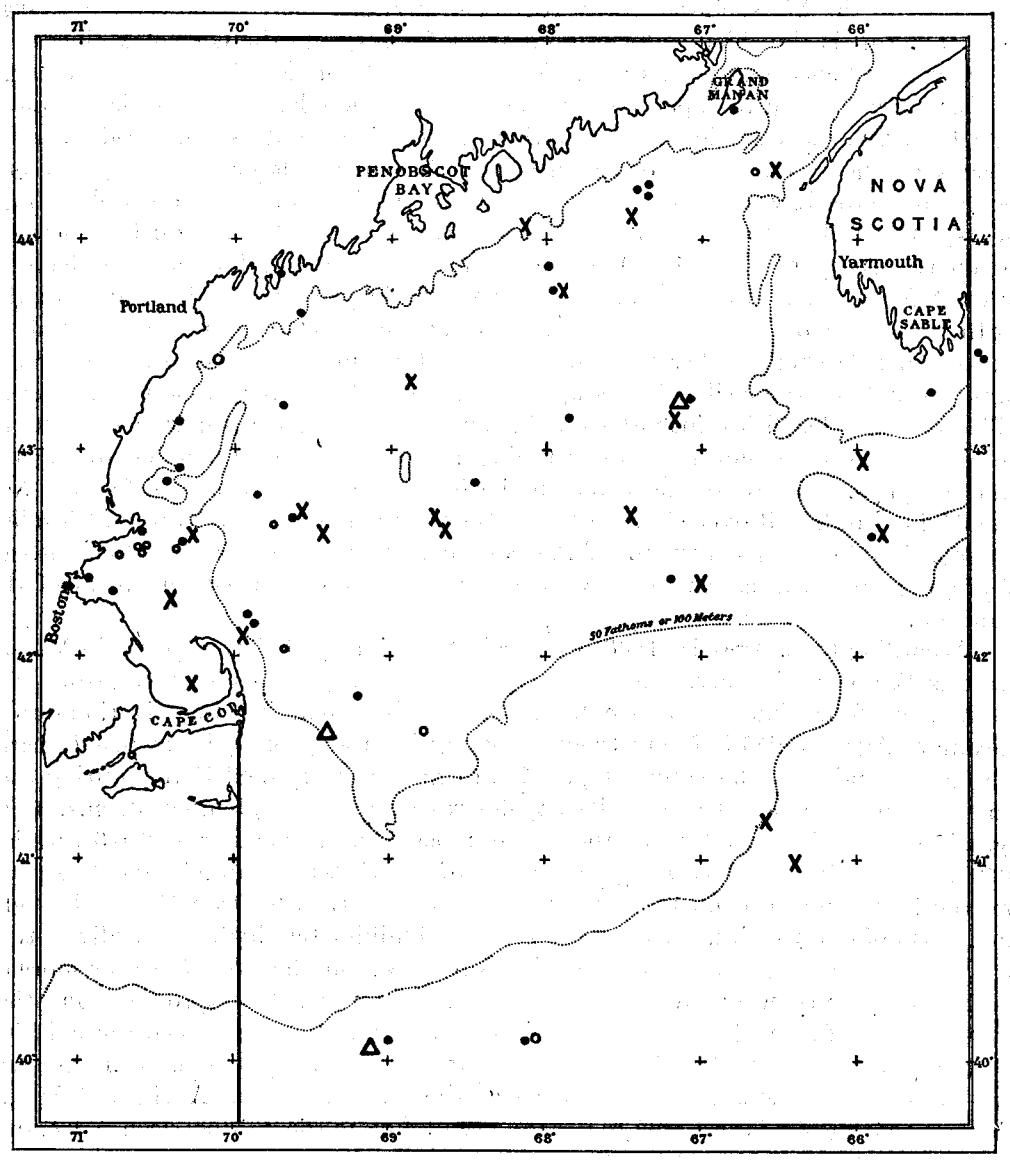

FIG. 102.—Occurrence of the ctenophore *Beroë cucumis* in the Gulf of Maine since 1912. ●, locality records, July to September 15; ○, November through February; X, March and April; △, May and June

the inception of the present explorations that definite information of its presence and distribution there was obtained.

Our locality records for Beroë (fig. 102) show that it is universal in the gulf north of Georges Bank, with the actual captures distributed indifferently over the deep

basin and the shoaler coastwise zone, except that we have not found it over the coastal banks along western Nova Scotia—that is, German Bank and near Lurcher Shoal. It is probable, however, that we have simply missed it there. The concentration of records in the Massachusetts Bay region, if anything more than accidental, suggests that this is the chief center of abundance for Beroë in the Gulf of Maine.[15]

Our experience has been that it is a rare event for Beroë to appear in large numbers anywhere in the open gulf; in fact, our tow nets have seldom yielded more than 15 or 20 at any station—a population quite insignificant as compared with the swarms of Pleurobrachia so often encountered—while a large percentage of our records of Beroë have been based on one or two specimens each or on broken fragments. Our failure to find a single Beroë on Georges Bank, either during the cold season (February to May, 1920) or the warm (July, 1914 and 1916) is difficult to account for when it occurs so nearly universally in the basin a few miles to the north, is not rare on Browns Bank to the east, and has been taken repeatedly along the continental shelf farther west and south. Certainly the shoal water over the bank can not be responsible for its apparent absence there, for Beroë is common at still shallower localities inshore—for instance, at Provincetown Harbor and in Massachusetts Bay—nor is there anything in temperature or salinity to suggest that the physical state of the water on the bank is locally unsuitable for it. Nor is our failure to find it over German Bank on any of our several visits to that locality less puzzling, for the local swarm of Pleurobrachia would serve Beroë as food instead of preying upon the latter, as they do on the sundry crustacean members of the plankton.

According to L. Agassiz (1860) the earliest specimens of Beroë appear in Massachusetts Bay early in July, when they are only 1 to 1½ inches long, to grow there to three or four times that size by August. Corresponding to this time-table, Alexander Agassiz (1874) found them spawning from July or early August to early September, and took the young stages, from egg to fully formed Beroë, during that same season. Not all of the adults are destroyed by the September storms, as L. Agassiz supposed, for a tow in the western basin on November 1, 1916 (station 10401, 80–0 meters) yielded many fragments of Beroë with turgid sexual organs, and the 75–0 meter tow off Gloucester, December 29, 1920 (station 10489), brought back parts of one which must have been 40 to 50 millimeters high when alive—that is, it was large enough to be mature. Thus it is evident that Beroë breeds more or less regularly until well into December off Massachusetts Bay (probably in other parts of the gulf as well), and it is certain that a few mature and breed there during the later winter, for we have taken very young specimens less than 10 millimeters long at several stations in various parts of the gulf in March, April, and May.[16] The fact that most of the Beroë that have been taken in the gulf between November

[15] For locality records for 1913 and 1914 see Bigelow, 1915, p. 316, and 1917, p. 303. It was also taken (or seen floating) at stations 10002, 10006, 10007, 10009, 10011, 10012b, 10019, 10023, 10036, 10040, 10043, and 10047 in 1912; at stations 20044, 20050, 20052, 20053, 20055, 20056, 20067, 20068, 20071, 20079, 20081, 20086, 20087,20088, 20097, 20105, 20112, 20114, 20115, 20118, 20119, 20126, and 20129 in the spring of 1920; and at stations 10488, 10489, 10491, and 10494 during December, 1920, and January, 1921.

[16] Center of gulf, Mar. 3, station 20053; off Mount Desert Rock, Mar. 3, station 20055; between Mount Desert Rock and Mount Desert Island, Mar. 3, station 20056; southeast slope of Georges Bank, Mar. 12, station 20067; Browns Bank, Mar. 13, station 20072; Fundy Deep, Mar. 22, station 20079; northern channel between Browns Bank and Cape Sable, Apr. 15, station 20105; southeast of Cape Cod, May 17, station 20126; and on the southwest slope of Georges Bank, May 17, station 20129; all in 1920.

and May have been small (15 to 20 mm. long) and immature—that is, were the product of the spawnings of the preceding summer and autumn—is evidence that no considerable production of this ctenophore takes place in the Gulf of Maine during the cold half of the year, and it is probable that the coming of spring sees the stock of this ctenophore at its lowest ebb for the year in all parts of the gulf.

Beroës 30 millimeters long and upwards, such as we have taken in mid-April in Massachusetts Bay (station 20119), may be expected to grow so rapidly under the favorable conditions of food supply and temperature prevailing in May as to attain spawning size in June or early in July at latest. It is probable that the few that spawn in winter are the offspring of these early summer spawners, the development of those produced in late summer and autumn being arrested by the low temperature of winter, so that they do not mature until the following summer. Thus, particular groups of Beroë may produce either one or two broods per year, according to the rapidity with which they grow and the season at which they mature; and while the chief production takes place from July to September, probably some spawn at all seasons except perhaps in early spring.

It is worth emphasis here that A. Agassiz's studies on the development of this ctenophore, corroborated by our own captures of its young in almost every month and at localities widely scattered, prove that Beroë is regularly endemic in the gulf, hence that the maintenance of the local stock depends chiefly on local production though it may be recruited more or less by immigration.

Recent captures of Beroë support the suggestion made by Louis and Alexander Agassiz that it passes the winter at some little depth, for only 4 of our records for the cold half of the year (November to April) out of a total of 30 (and these for occasional specimens only) were from the surface, with one other from a 15-meter haul (Cape Cod Bay, station 20118, April 20, 1920). All our other winter–early spring captures of Beroë have been from depths of 40 meters and more. It may sink to a considerable depth in the Gulf during the cold season, for we took it with the closing net at 140–160 meters, and at 125–190 meters in the central part of the basin, March 2 and 3, 1920 (stations 20052 and 20053).

In summer Beroë frequently comes to the surface, most often during the midday hours, to sink again toward the end of the afternoon. This habit, long ago described by Louis Agassiz (1860) as well as by more recent authors, has repeatedly come under our own observation on the *Grampus*, notably during July and August of 1912, when we frequently saw large specimens of this ctenophore floating alongside the ship, usually in calm weather. On stormy days Beroë lies deeper, probably sinking below the limit of destructive wave action, and it is frequently taken at depths of 40 to 100 meters, summer as well as winter. We have no evidence that this ctenophore ever descends into the deepest strata of the Gulf of Maine at any season (a single Beroë taken in a haul from 240 meters in the southeast part of the basin, July 23, 1914, station 10225, may have been picked up by the net on its journey down or up).

The voracity of Beroë being commented on elsewhere (p. 108), I need only remark here that it has been described as preying greedily on other ctenophores in the Gulf of Maine, devouring Pleurobrachia and Bolinopsis whole if they are not too large for its widely distensible mouth to engulf, with digestive process so rapid that

a large Bolinopsis is completely absorbed by a Beroë in four or five hours' time (L. Agassiz, 1860, p. 274). Copepods, also, are often found in its digestive cavity.

Beroë, like all the other pelagic animals that inhabit the gulf throughout the year and are widely distributed there vertically as well as horizontally, necessarily experiences nearly the whole gamut of temperatures and salinities that prevail there at one season or another; and although its habit of sinking in winter results (whether voluntarily or not) in its avoiding the very coldest water, with 2 to 3° the lower limit to its regular occurrence in the gulf, it has been found living actually among the ice in the Arctic Ocean (Mortensen, 1912), apparently thriving, to judge from the large size of the specimens in question. Nor does heat act as a barrier to its vertical migrations within the extremes normal to the gulf—witness how often it comes to the surface on calm days in summer and how abundantly it spawns at that level at the season when the gulf as a whole is at its warmest. Beroë is equally catholic with respect to salinity, except that it has not been found in the very freshest water of the gulf at the time of the spring freshets—that is, in salinities lower than about 31 per mille.

Other ctenophores

No other ctenophores have actually been recorded of recent years within the geographic confines of the Gulf of Maine as here limited. Another lobate species, *Lesueuria hyboptera*, was described by A. Agassiz (1865) from Massachusetts Bay, but has never been seen since. Mayer (1912, p. 20) has suggested that it was actually Bolinopsis with the oral lobes torn off and the edges healed over to produce a rounded contour, he having seen many in that condition in Halifax harbor after a storm. Its status remains problematical.

Mnemiopsis leidyi, a southern neritic form very abundant along the coasts of the middle Atlantic States, is common as far north as the Woods Hole region during some summers, but it has never been known to round Cape Cod.

The Venus' girdle (*Cestum veneris*) was taken off the southeastern slope of Georges Bank in 1872, among an assemblage of other tropical plankton (Smith and Harger, 1874).

Siphonophores

Although the siphonophores are well represented in the warm oceanic waters off the continental slope abreast of the Gulf of Maine, only one member of this group of oceanic cœlenterates—*Stephanomia cara*—is anything but a rare stray within the latter. It is probable that the low salinity of the gulf, as much as its comparatively low temperature, makes it inhospitable to siphonophores, for, as I have previously pointed out (Bigelow, 1911a, p. 381), they "are almost a negligible factor in the plankton in waters with a salinity less than 35 per mille" and "are entirely absent when the salinity is below about 30 per mille," a generalization that applies as well to the North Sea region on the eastern side of the North Atlantic as to North American coastal waters on the western.

Stephanomia cara (A. Agassiz)

Although this siphonophore is widely distributed in the gulf both in time and in space, we know little more of its natural history or of its status in the economy of the plankton than when Alexander Agassiz (1865) first recorded and beautifully pictured young specimens of it from Massachusetts Bay; and although Fewkes (1888) has since given a description and figures of the adult, it is still doubtful whether the "*S. cara*" of northern seas is identical with or distinct from the "*S. bijuga*" of warmer latitudes. Unfortunately our Gulf of Maine collections can not settle this question, because these very delicate animals are usually battered almost past recognition in the tow nets; but the presence of a spherical red or yellow oil globule at the base of each palpon (a conspicuous character first described by Fewkes and visible in the least damaged of the Gulf of Maine series) is apparently peculiar to the northern *cara*, and since *cara* grows much larger than its warm-water relative, besides differing from it in minor anatomical details, it probably deserves recognition as a distinct species. The relative ranges of the two—*cara* and *bijuga*—are consistent with this, for while *S. cara* is common in the Gulf of Maine [17] we did not find it along the coast south or west of Cape Cod during the summers of 1913 or 1916, the autumn of 1916, the winter of 1914 (Bigelow, 1918), or in February of 1920. On the other hand, the southern *bijuga* is not known to occur north of Key West in the western Atlantic, which leaves a gap of something like a thousand miles between the southern limit of the one and the northern limit of the other, as now known. Similarly, there is a long gap between the most southerly known record of the northern and most northerly record of the southern race or species in the eastern Atlantic.

Just what relationship the *S. cara* of North American waters bears to the Arctic-boreal Stephanomia of the northeastern Atlantic is also uncertain, no detailed account having appeared of the specimens most recently recorded thence (Sloan, 1891; Browne, 1900); but probably the two are identical; in fact, it would run counter to all our experience of the northern pelagic fauna as a whole to find them otherwise.

During our recent cruises we encountered Stephanomia in the months of January, March, July, August, September, and December, and at the various localities indicated on the chart (fig. 103), but it is not safe to base a definite statement of its status in the gulf on these records, both because it is decidedly erratic in its occurrence and because its bells are so fragile that they are apt to be battered past recognition by the other plankton taken with them in the tow nets.

Stephanomia may usually be found in one part of the gulf or another during the summer months, but it can not be very generally distributed at that season, for we have never taken it at more than a small percentage of our stations during any one summer's cruise. In 1913, for example, it was detected at three stations only, once, however, in abundance (p. 19; station 10058). There are only four records of it in the July and August towings of 1914; none for 1916. If the years 1920 and 1921 can be taken as representative, it is decidedly more abundant and widespread during the winter, for it occurred at about half our December and Janu-

[17] Some long-stemmed physophore, and probably this species, ranges northward as far as Lady Franklin Bay on the west coast of Greenland (Fewkes, 1888a) and to Robeson Channel (Moss, 1878).

ary stations and again at four stations in early March, 1921; but it was detected at one station only (20048) in February, 1920, and not at all during that March, April,

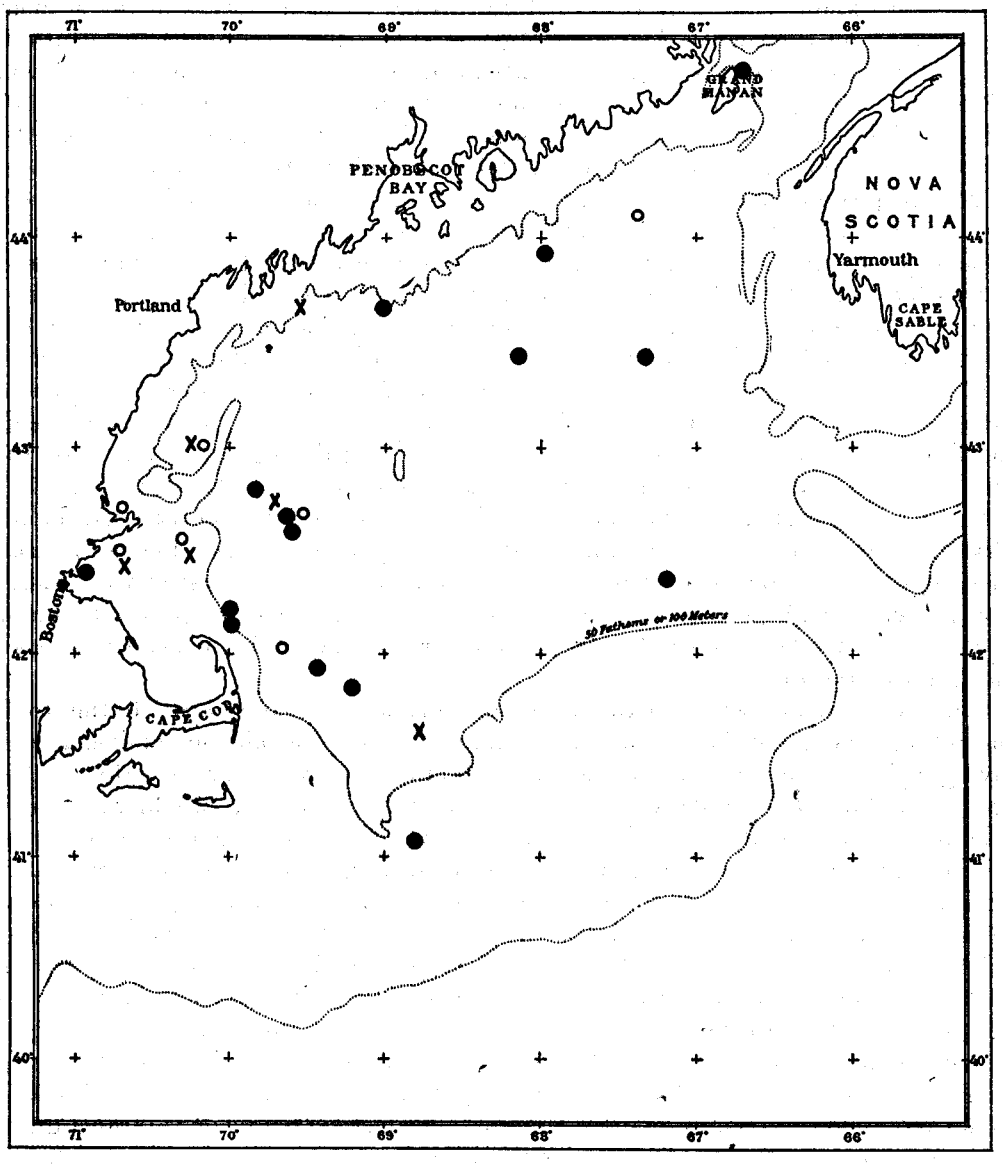

FIG. 103.—Occurrence of the siphonophore *Stephanomia cara* in the Gulf of Maine. ●, locality records, June through November; ○, December, January, and February; X, March through May

or May, in spite of the considerable number of tows, both horizontal and vertical, made during that cruise. Neither did we find it in May or June of 1915.[18]

[18] For records of Stephanomia from 1912 to 1914, see Bigelow, 1914, p. 126 (as "*Agalma elegans*"); 1915, p. 316; and 1917, pp. 303 and 306. Fragments tentatively referred to it were taken at stations 10488, 10489 to 10491, 10493, 10497, 10502, 10508, 10509, 10510, and 10511 during the winter and early spring of 1920–1921

The obvious inference from this is that there is a winter maximum and spring minimum for Stephanomia in the Gulf of Maine. Other years might yield quite different results, however, and it is questionable whether the concentration of Stephanomia in the southwestern part of the gulf, suggested by the chart (fig. 103), and its apparent rarity in the southeastern part and on Georges Bank, are anything more than accidental, especially when we remember that the neighborhood of Grand Manan is the only locality in the gulf where it has ever been found of large size (Fewkes, 1888).

Alexander Agassiz's (1865) discovery of very young stages of this species in Massachusetts Bay in early summer is undeniable evidence that it breeds in the gulf, but how regularly it does so from year to year, what proportion of the local stock results from local reproduction and what from immigration, and what relationship the fluctuations in the local stock of Stephanomia bear to hydrographic conditions are questions for the future.

Diphyes arctica Chun

The faunal status of this species is discussed in an earlier chapter (p. 64). The Gulf of Maine records are as follows: Southeast slope of Georges Bank, July 22, 1914 (station 10220); outside the continental edge off Shelburne, Nova Scotia, June 24, 1915 (station 10295), and March 19, 1920 (station 20077); near Lurcher Shoal and in the Eastern Channel, April 12 and 16, 1920 (stations 20101 and 20107).

Other siphonophores

The occurrence of Physophora and Physalia is discussed above (p. 55). To complete the record of the group in the Gulf of Maine I have only to mention a single *Diphyes truncata* [19] from the northeast slope of Georges Bank, July 22, 1914 (station 10220), a few more examples of this species from our deep stations off its southwest face in February and May, 1920 (stations 20044 and 20129), and two taken in the northeastern basin of the gulf off Grand Manan on April 12 of that same year (station 20101). The beautiful *Agalma elegans*, so common in the inner edge of the Gulf Stream and which sometimes even reaches the coast west of Cape Cod (Fewkes, 1881), has never been taken within the Gulf of Maine.[20]

Pelagic hydroids

In an earlier chapter (p. 33) the floating hydroids that we have encountered over Georges Bank are mentioned. The records on which this observation is based are as follows:

On April 14, 26, and 27, 1913, campanularian hydroids were found floating on the top of the water over the bank (Bigelow, 1914a, p. 414; lat. 41° 37′ N., long. 67° 18′ W., and about lat. 41° 40′ long. 68° 30′), some of the specimens being complete—that is, with all the ends of the stems rounded, closed, and apparently growing, as Dr. S. F. Clarke reported on examining them. On the 9th of the following July

[19] For a discussion of this species see Bigelow, 1913, p. 73; 1918, p. 422; and Moser, 1913, p. 232.

[20] Agalmid fragments taken during the summer cruise of the *Grampus* in 1912 were provisionally referred to this species, but subsequent study leads me to believe that they were in reality the common *Stephanomia cara* (p. 378)

our surface net took great numbers of them over the northwest part of the bank (station 10059). These were submitted to Dr. C. McLean Fraser for study, and the reader is referred to his report (in Bigelow, 1915, pp. 268 and 306) for details. It will suffice to say here that the catch of hydroids was not only considerable in amount but included no less than 13 species, belonging to 4 families. Most of these were represented by broken fragments only, or by colonies attached to bits of eelgrass (Zostera); but the hundreds of colonies of *Clytia cylindrica* (the predominant species) were floating free of any support, and not only in a perfectly healthy state as far as appearances go, but so completely regenerated that there were few or no broken ends visible.

As it can hardly be supposed that these colonies had passed through their whole development, from the planula stage onward, at the surface of the sea, the most reasonable explanation for their presence afloat is that they had been torn from their attachments on the bottom by the strong tidal currents and kept suspended in the water by this agency. Finding a rich food supply in their pelagic surroundings, with nothing fatal in such an environment, they regenerate, grow, and even propagate their kind, as appears from their development of gonophores. After all, there is nothing surprising in such a phenomenon, for it is "not unusual to find fragments of hydroid colonies torn from their support or from the rest of the colonies, living for a considerable time as they float on the surface" (Fraser, 1915, p. 307). Similar congregations of floating hydroids have been encountered thrice since 1913, always on Georges Bank—viz., July 23, 1914 (station 10224), July 23, 1916 (stations 10347 and 10348), and February 23, 1920 (station 20047). Judging from the geographical grouping of these stations (fig. 98) their place of origin is probably on the shallows known as "Georges" and the "Cultivator" Shoals.