SEASONAL DISTRIBUTION OF THE PLANKTON OF THE WOODS HOLE REGION

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Contribution from the U. S. Fisheries Biological Station, Woods Hole, Mass.

CONTENTS

	Page
Introduction	91
Methods	93
Location	96
Salinity and density	98
Temperature	100
General discussion of plankton	101
Diatoms and other plants	104
Protozoa	121
Cœlenterata	123
Annulata and Vermes	130
Mollusca	136
Echinodermata	138
Crustacea	139
Phyllopoda	139
Ostracoda	140
General discussion of plankton—Contd.	
Crustacea—Continued.	
Copepoda	141
Cirripedia	147
Arthrostraca	149
Cumacea	152
Schizopoda and Stomatopoda	152
Macrura	155
Brachyura	159
Pycnogonida and Xiphosura	161
Chordata	162
Fish	164
General conclusions	172
Bibliography	176

INTRODUCTION

In the plankton section of the report of the Conseil Permanent International pour l'Exploration de la Mer, published in September, 1922, it was pointed out that greater attention should be paid to the seasonal variation and range of marine plankton. As early as 1880, Prof. S. F. Baird remarked to Commander Z. L. Tanner, after the initial cruise of the United States Fish Commission steamer *Fish Hawk*, that "the profitable study of useful sea fishes can not be prosecuted without a knowledge of their food, the food of their food, their respective friends and foes, the habitat of the several species, and their means of passing from one region to another in the embryonic as well as in the adult stage. The temperature, currents, and specific gravity, also, should be studied in connection with the migrations and habits of pelagic forms." Since that time only one area of the Atlantic coast of the United States has been investigated with the object of completely surveying and determining the distribution of the plankton, currents, salinity, and temperature. The interesting results of these investigations, which were carried on by Dr. H. B. Bigelow, are published in a series of bulletins from the Museum of Comparative Zoology at Cambridge, Mass., and a more complete account of these investigations and explorations is now in process of publication.

It has long been known that Woods Hole occupies a unique position on the Atlantic coast. It is the northern limit of many southern forms and the southern limit of many northern forms. Oceanic animals, also, are often carried into this pocket on the coast by the southerly winds and strong tides that prevail in the summer months. For that reason Woods Hole was selected as an ideal location for the study of plankton and the interrelationships of the various pelagic faunas.

Under "plankton" I have included all animals occurring in surface collections, whether free-swimming or carried by currents. Such a broad definition includes a great many benthonic forms carried from their natural habitat by storms or high winds, but in a littoral region one can not always decide accurately which species have been accidentally carried to the surface and which are free-swimming.

The present paper is the result of a continuous investigation of the plankton in Great Harbor, Woods Hole, Mass., covering a period of two years. The purpose was to make an exhaustive qualitative study of the plankton of this region, the seasonal distribution of the various species, their interrelationships, and the general factors governing their distribution.

The investigation consisted of three parts: (1) An examination of plankton samples taken daily during the years 1899 and 1900 in Great Harbor by the late Vinal N. Edwards, collector for the United States Fish Commission; (2) a survey of all records of surface collections of previous years; and (3) examination of living material taken daily in surface collections in Great Harbor, observations on temperature, salinity, and other factors governing the seasonal distribution of the plankton, and a survey of the general geography of the region as a factor affecting plankton distribution.

The first part of the investigation occupied the entire time of the author during the year 1921–22 and was carried on in the biological laboratory at Brown University. Many of the fragile animals had become disintegrated during the 22 years in which the material had remained untouched, and the preservatives in some of the samples had evaporated. Over 200 vials remained intact, however, and offered ample material for study.

The second part of the work involved much time and proved to be a very tedious task. The results, however, were very important, as they covered the daily records of surface collections extending over a period of 15 years—1893 to 1907, inclusive. The larval fish and cœlenterates taken during this time had been carefully identified by Vinal N. Edwards. Diatoms, copepods, amphipods, annelids, and other planktonic forms were recorded as groups, the relative abundance for each day being carefully noted. Complete records of the weather, wind, and temperature for most of this period were available and proved indispensable in explaining peculiarities in the seasonal distribution of many species. This part of the work was done by Marie D. P. Fish, who aided me in the study of the larval fish also.

The final part of the work was carried on from June 22, 1922, until December 31, 1923, at the laboratory of the United States Bureau of Fisheries at Woods Hole, Mass. From June 22, 1922, until May 1, 1923, observations were made daily at the same spot where all my previous material had been taken. Fortunately a series of collections had been made by R. A. Goffin during the spring of 1922. From these I was able to trace the first appearance of the summer species. From May 1 to December 1, 1923, the collections were made three times a week, except during the interval from August 22 to October 4. The records for the past summer are therefore not as complete as those of 1922, although they serve as a basis for comparison.

A kind invitation from Dr. P. S. Galtsoff to assist him in his monthly surveys of Long Island Sound from September, 1922, to August, 1923, made possible valuable observations on the distribution of certain pelagic organisms, particularly the diatoms, in relation to their presence at Woods Hole.

It is a pleasure to express my especial gratitude to Prof. A. D. Mead and Prof. R. M. Field, of Brown University, who furnished me helpful assistance and guidance throughout my work. I am especially indebted to Marie D. P. Fish for her careful tabulation of Vinal N. Edwards's records of surface collections and temperatures collected over a period of 15 years. I am indebted to Dr. P. S. Galtsoff, who made possible my observations on salinity at Woods Hole and the plankton of adjacent regions, and I wish also to express thanks to Dr. Henry B. Bigelow, Dr. Hugh M. Smith, Dr. Paul Bartsch, Dr. Albert Mann, and Prof. A. E. Verrill, for helpful advice and criticism rendered at various times during the progress of my work.

METHODS

My first plans provided for daily observations on temperature of the air and water (surface and bottom), salinity, oxygen, wind, weather, sea, transparency, vertical hauls, and surface and bottom collections with plankton nets of No. 2 and No. 20 bolting cloth. Because of the amount of time required to identify the many species of zooplankton and phytoplankton it was found desirable to discontinue certain of these observations. The following schedule was finally adopted:

1. Daily temperatures of surface water and air.
2. Salinity (at certain periods) and density.
3. Daily meteorologic observations on wind, weather, sea, etc.
4. Vertical hauls at weekly intervals with No. 20 net.
5. Daily surface hauls with No. 2 and No. 20 nets. (Later, No. 20-net hauls were reduced to twice a week except during the diatom maxima.) Nets 3 feet by 12 inches with a brass bayonet-lock bucket on bottom were used.

The temperature was taken each day at the time of setting the plankton nets. A series of observations later proved conclusively that at all times the bottom temperature at my station is exactly the same as that of the surface (Table 2, p. 101). Bottom observations then were made only during periods of rapidly declining or rising temperatures.

For a period extending over four months salinity was determined daily by titration with nitrate of silver. When these could not be made at once, they were preserved in the standard "citrate of magnesia" bottles of the sort used for that purpose by the United States Bureau of Fisheries. After it was found that there were usually no important variations observations were made only on certain occasions to indicate the influx of Gulf Stream and other ocean water. Had it been possible continuation of the daily tests would have been very desirable.

Observations on the condition of the weather, sea, wind, and sky were taken daily. These factors are of great importance, particularly the winds, in determining the distribution of planktonic animals.

Vertical hauls were made weekly, but they yielded rather disappointing results. The water is only 11 feet deep at low tide, and for that reason a very small net of the Birge type, with a special bucket, was adopted. The material collected was centrifuged for two minutes at about 1,000 revolutions per minute in a graduated glass tube, and the result measured in cubic centimeters. The figures obtained are not included in this report because I did not have time to make individual counts of the various species, and the total mass was meaningless, being made up of diatoms, dinoflagellates, particles of dirt and detritus, larval copepods, larval mollusks, and an occasional adult copepod. All the large planktonic forms had successfully evaded the net as it was being drawn to the surface, and the resulting mass did not give a fair estimate of the amount of plankton in the water at the time. To get these various-sized animals, a series of nets of at least 10 different meshes would be necessary, and even with these there would be so much overlapping that the results would be of little value. The pump has not succeeded in overcoming this difficulty in the case of the marine plankton. On eight occasions during the past year I centrifuged over 100 samples taken by pump in Long Island Sound, and invariably the deposit contained a larger proportion of small forms and a smaller proportion of large forms than did the vertical hauls made at the same time. A successful method of accurately determining the real volume of marine zooplankton as well as of phytoplankton is yet to be devised.

The most valuable results were obtained with surface nets. The waters are so churned up in Great Harbor that there was no difference in the collections taken at the surface and those taken at the bottom, except that the latter often contained more sand and small detritus. For that reason the bottom hauls were discontinued.

The daily routine of plankton collecting and investigation, consisted of three parts. First, the nets were suspended from the end of the dock by means of pulleys attached to outlying piles in such a position that one was suspended in a northerly direction and the other in a southerly one (fig. 1, p. 97).

When the nets were hauled the contents were emptied into a flat glass dish entirely covered with black paint except for a small area at one corner. A tight-fitting top completely shut out all light except in the corner over the clear glass. A light placed at this end caused all the Crustacea, larval annelids, and, in fact, most of the free-swimming planktonic organisms that are positively phototropic to crowd at the lighted corner, where they could be picked out individually with a pipette or drawn out in bunches with a long glass tube and deposited in a watch glass or petri dish for examination. A second collection was then made from the detritus in the bottom, consisting of dead organisms and any forms that had not been attracted to the light. Finally, the last bit of sediment, after all the rest of the tow had been poured into a silk bag to be strained, was placed in a dish. This was often found to contain large numbers of small mollusks, ostracods, and Foraminifera.

After the living specimens had been observed they were killed with a 2 per cent solution of formalin and reexamined. The species not readily identified were placed in separate watch glasses and subjected later to a more careful examination with a higher-power lens. For a general examination of zooplankton a binocular microscope with low-power lenses (Nos. 55, 40, and 24) is very satisfactory. Smaller forms were mounted on slides and examined with a compound microscope.

Several samples of phytoplankton were placed in watch glasses and examined alive. This made possible a rapid survey of a large amount of material. Next some of the material was mounted on slides, with barium mercuric iodide as a mounting medium, and examined with a higher-power lens.

The common species were tabulated daily on charts, records being made of the rarer specimens. If these began to appear frequently, they were given a place on the chart. This method proved to be very simple and convenient. The material was later put in 2 per cent formalin and labeled for future reference.

The direction of the currents in Great Harbor during the flood tide (fig. 1, p. 97) was determined in two ways. The first method was very simple, consisting of observations made while great masses of broken ice were floating through the passage during the spring months. The results obtained in this way could be checked up as often as desired. The second method was used to determine the smaller currents near shore, and the course of the back eddy along the shore of Nonamesset. This was accomplished by placing large quantities of shavings in the water on a calm day and plotting the courses which they took. The results may not be entirely accurate in minute details, but they show the general movements of the water in the harbor during flood tide.

The combined results of my observations on material of 1899-1900 and those of Mr. Edwards have been plotted on quadrille paper. The charts based on the work of the past two years are on Keuffel and Esser No. 334D graph paper.

A great difficulty presented itself when I started to assemble my results. In qualitative work the greatest amount of material possible is essential, and the only way to obtain this is by surface towing, which obviously does not lend itself to any accurate measurement. Even if figures could be secured the daily variation in the winds and tides is so great at Woods Hole that the results would be more confusing than helpful. One can state when the first specimen of a species appears and when its season ends, and the fact that the numbers may be increasing daily can also be seen, but to present this information in a satisfactory manner is difficult.

The plan finally adopted consisted of the use of four categories—very scarce, scarce, abundant, and very abundant. These served as calibrating points from which the seasonal distribution of a species could be plotted in a fairly accurate manner. Of course, the basis for measuring the abundance of copepods was not the same as that for the diatoms; 500 of the former might be considered abundant, while the same number of diatoms would be considered very scanty. Again, 50 specimens of the oceanic annelid, Tomopterus, would be considered abundant, but 50 specimens of a common copepod would be thought scarce. The measurement, therefore, is relative; that is, *the symbol given to a particular animal for a* *particular day indicates its relative abundance for that day compared with its abundance for all the preceding days or weeks since its appearance and is not to be compared with that of the species of any other phylum.* To eliminate as far as possible the confusion arising from daily variation, three-day averages were used in plotting the points on the charts. There may be objections to my method of presenting the data in graphic form where definite figures were not available. However, I feel that the seasonal variation can best be shown in this way, and that any method which simplifies the work and makes it more easily understood is justifiable. The symbols used on the charts are as follows: *V. A.*, very abundant; *A.*, abundant; *S.*, scarce; *V. S.*, very scarce; and *N.*, none.

LOCATION

All material for the present investigation, with the exception of a few observations made in Vineyard Sound, was obtained from the water at the end of the Bureau of Fisheries dock at Woods Hole, Mass. This spot was selected, first, because it offered such excellent possibilities for qualitative plankton investigation, and, second, because the bottom fauna, whose larvæ make up a large percentage of the summer plankton, had already been carefully surveyed.

The location is an exceptionally fortunate one for an investigation of seasonal distribution, although impossible for a study of diurnal migration. On the flood tide the local current rushing through the narrow passage of Woods Hole sometimes reaches a speed of 8 miles an hour. Figure 1 shows that one of the three main branches of this current heads directly for the Fisheries dock. Here it divides, one half turning to the south and the other to the north. By placing nets at the two ends of the dock one hour after the tide has turned to flood and hauling them one hour before the ebb it is possible to have a strong current of water passing through the nets continuously for four hours. More material can be collected in this way than would be possible in several hours' towing from a boat. To determine the complete pelagic fauna of a region, the largest possible number of daily samples are needed. Even then many scarce forms probably pass through their seasonal cycle without once being observed in surface collections.

Another advantage of the position of this particular station is the uniformity of the plankton both during the day and during the night. Extended observations showed that the mixture of the waters during the flood tide so churns up the plankton that there is almost no difference between the hauls of the day and those taken in the evening. I know of but two exceptions to this statement. These are the amphipods and certain annelids, which remain under rocks in the daylight and emerge after dark. Then they are picked up by the strong currents and appear in the greatest numbers in evening collections. As these are not true pelagic animals, they do not seriously affect the problem. Thus, the collections made at any time showed equally well the representative plankton for that day.

The features of the coast adjacent to Woods Hole have much to do with its fauna. It has long been thought that the arm of Cape Cod to the east constitutes a barrier that changes the course of the cold northern ocean current and deflects it away from the continent. Not all oceanographers agree as to the above, but even

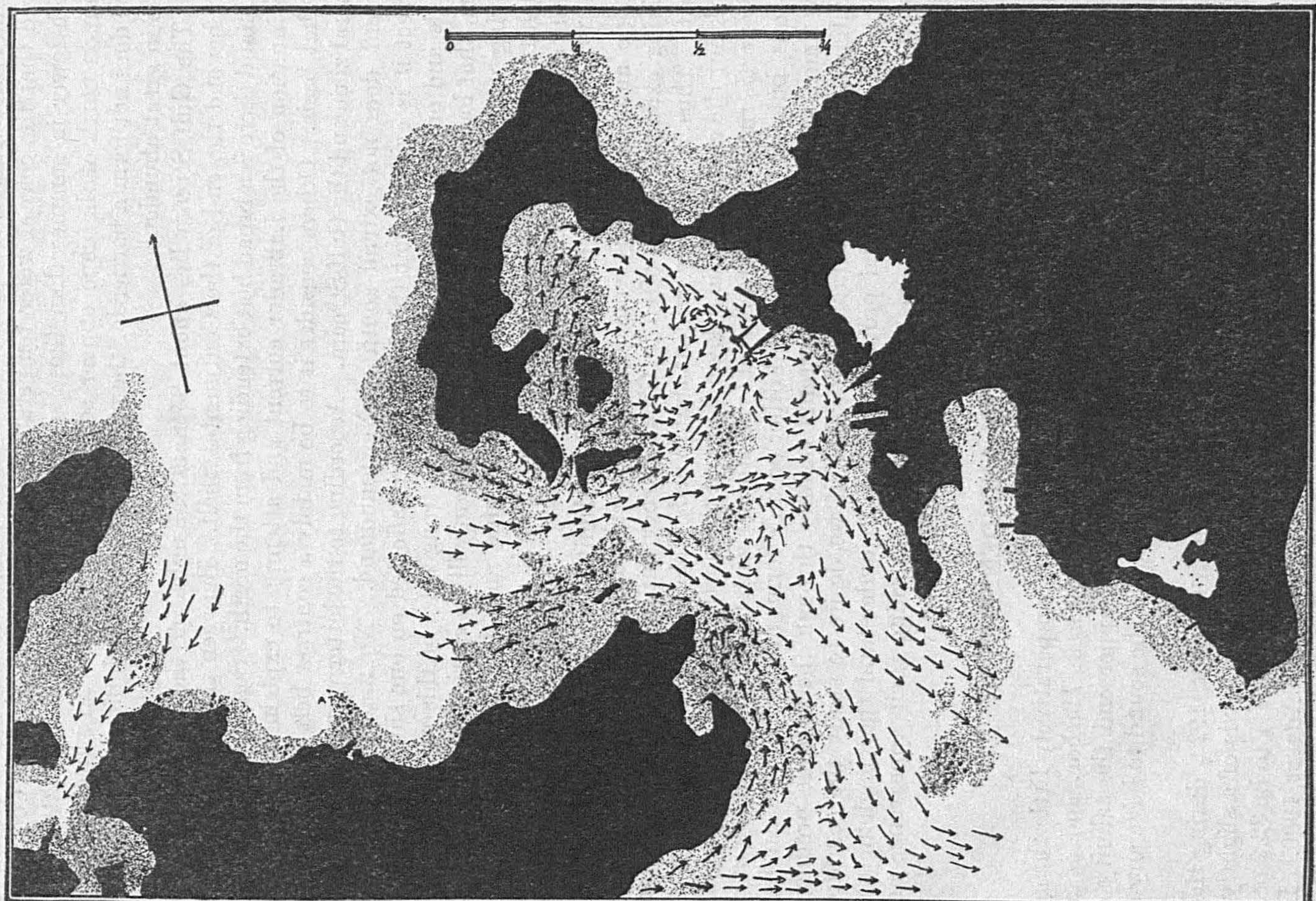

FIG. 1.—Currents of Great Harbor, Woods Hole, Mass., during flood tide. Light shaded area, shallow water; black area, land; +, rocks; ●, location of plankton nets. Scale in statute miles

if this is not true, Verrill and subsequent authors, including Bigelow (1914–1922), found that the coastal water temperatures north and east of Cape Cod were very much lower in summer than those south of it. None of the planktonic animals common north of the cape appear south of it in summer. In winter, however, the cape does not form a barrier for the neritic plankton, which often appears at Woods Hole in great abundance.

The Gulf Stream lies about 85 nautical miles off the Massachusetts coast, just beyond the end of the Continental Shelf. Between this warm area and the mainland there is a broad belt extending from the north. Some consider this to be a continuation of the Labrador current and attempt to explain faunal distribution on that basis. Others consider it to be mainly a contrast belt between the warm littoral zone and the Gulf Stream. According to the latter viewpoint, the Labrador current does not extend south of Newfoundland. No matter which theory is correct it is evident that this broad belt is affected on one side by the southerly winds and on the other by the unusually strong tides of this region. Any forms, then, that have blown in from the Gulf Stream will be carried farther inland by the moving water. This peculiar alliance of wind and tide probably explains why much tropical plankton, which is taken so often in this locality, occurs at no other points along the coast.

Woods Hole also forms the northern limit of most of the southern boreal pelagic animals. Many copepods and cœlenterates, of which Mnemeopsis is a striking example, occur often in Great Harbor but never farther north along the coast. Thus, it is clearly evident that Woods Hole is a very unsatisfactory spot to work out the characteristic pelagic fauna of the north Atlantic coast region, for not only northern and southern boreal types appear with the littoral plankton at certain seasons, but the Gulf Stream and other oceanic forms are likely to be carried in at any time. Again, the swift currents rushing through the passage produce local peculiarities in the plankton. However, if we desire to study the conditions at Woods Hole as a special problem and try to understand the conglomeration of faunas, their interrelations, and the factors governing their appearance and disappearance it becomes highly interesting and instructive.

SALINITY AND DENSITY

The salinity at Woods Hole normally varies comparatively little throughout the year. No streams of importance empty into Great Harbor, and as all the larger rivers of Buzzards Bay are situated at the upper end the salinity of the southern area is not sufficiently different from that of the sound to have any appreciable effect on the plankton.

Titrations made almost daily from July until October, 1922, during the flood tide (Table 1) indicate that the water entering Great Harbor is of a slightly lower salinity than that of Vineyard Sound, found by Bigelow (1915) to be 32.2 per mille in August, 1913, and by Sumner (1913) to be 32.2 per mille in August, 1906. In 1922 the average salinity at the Fisheries dock for late July and August was 31.57 per mille, and for September and early October, 31.03 per mille.

TABLE 1.—*Salinity of surface water at Woods Hole from July to October, 1922*

Date	Degree of salinity	Date	Degree of salinity	Date	Degree of salinity	Date	Degree of salinity	Date	Degree of salinity	Date	Degree of salinity
July 27	31.53	Aug. 6	30.30	Aug. 16	31.58	Aug. 27	31.85	Sept. 8	31.22	Sept. 24	31.40
July 28	31.46	Aug. 7	31.20	Aug. 17	31.53	Aug. 28	31.31	Sept. 9	31.18	Sept. 27	31.44
July 29	31.62	Aug. 8	31.29	Aug. 18	31.82	Aug. 29	31.49	Sept. 10	31.33	Sept. 29	31.40
July 30	31.31	Aug. 9	32.01	Aug. 19	31.60	Sept. 1	31.36	Sept. 11	31.02	Sept. 30	31.62
July 31	31.31	Aug. 10	32.01	Aug. 20	31.65	Sept. 2	31.36	Sept. 12	31.06	Oct. 1	30.88
Aug. 1	31.31	Aug. 11	31.73	Aug. 21	31.85	Sept. 3	31.09	Sept. 13	31.15	Oct. 2	31.35
Aug. 2	31.56	Aug. 12	31.82	Aug. 22	31.85	Sept. 4	30.91	Sept. 14	31.18	Oct. 5	31.35
Aug. 3	31.71	Aug. 13	31.53	Aug. 23	31.85	Sept. 5	31.18	Sept. 16	31.15	Oct. 10	31.49
Aug. 4	31.64	Aug. 14	31.60	Aug. 24	31.65	Sept. 6	31.04	Sept. 17	31.06	Oct. 11	31.20
Aug. 5	31.46	Aug. 15	31.67	Aug. 25	31.71	Sept. 7	31.49				

After southerly winds a slight increase in salinity usually can be noted. This would naturally be expected, for the outlying waters always have a higher salinity—in the case of the Gulf Stream upwards of 35 per mille. It was to determine to what extent this influx of ocean waters takes place after storms that the titrations were made in Great Harbor. They covered the period when most tropical oceanic animals appear in the plankton. The results showed that very little change takes place even during hard southerly winds unless they extend over a long period of time. This is probably due to a dilution resulting from a mixture with the fresher waters of the southern part of the bay. Marked changes may have occurred in Vineyard Sound but were not evident farther inland.

On August 6 and 7 a heavy southwest storm took place, reaching its height on the second day. During this time the wind blew continuously and much Sargassum was noticed in the sound. A slight increase in salinity from 31.29 to 32.01 per mille on August 9 and 10, followed by a gradual decline, was the only evidence of outside water, and this was below the usual average for the Sound in August. However, this again may have represented a mixing of the bay water with that of a higher salinity than is usually found in the sound.

Hard southerly winds extending over a long period of time replace the waters of the region to such an extent that the dilution by bay water is hardly noticeable except after a hard rain or a period of melting snow. This was shown by the density records during the spring of 1922. Figures 2 and 3 give the daily variation in the density at Great Harbor, taken by Mr. Hamblin at the Fisheries dock at 12 o'clock noon. As these unfortunately have no relation to the tides, they can only indicate in a general way the conditions existing at any particular time. Standard hydrometers, certified by the Bureau of Standards, were used, the error being probably not greater than $\pm$ 0.0001.

The density in shallow waters is governed by two factors, temperature and salinity, the comparative influence of each being clearly shown in Figures 2 and 3. A comparison of Figures 2 and 3 with Figures 4 and 5 indicates the effect of the temperature. During the warmest seasons a minimum density is found, and during the coldest months it reaches its highest point. Were there no change in the salinity the curve would rise and fall evenly, corresponding to the rise and fall in the temperature of the water. The sudden increase or decrease in the curve at any particular time is due to an increase or decrease in salinity. As previously stated, there are no rivers in the immediate vicinity of Great Harbor, although melting snow and hard northerly winds cause the sudden appearance of waters of comparatively low density. Prevailing southerly winds extending over a long period of time cause high density. In the spring of 1922 (fig. 2), combined with the usual low temperature, the density almost equaled that of ocean water and remained that way until the middle of May.

The effect of melting snow shows clearly (fig. 2) in the first week of April, 1922, and (fig. 3) on January 2 and 3, 1923. On the latter dates a marked increase in the number of diatoms was also noticeable. The greatest change took place on March 31, when the density dropped from 1.0260 to 1.0244 in one day. A heavy snowstorm had occurred on March 30, followed by rain and snow on March 31 and April 1. The rapid rise took place during a period of constant hard southwesterly winds. The extreme point reached on April 9 (1.0270), accompanied by a drop of 1° in temperature, is impossible to explain on the basis of local conditions. Southerly winds prevailed, but were not unusually strong. Some hydrographical change beyond the limits of the immediate region must have accounted for it.

It is probable that the salinity plays little or no part in the seasonal distribution of the planktonic animals of this region. The fresh waters of the upper bay no doubt form a barrier for the oceanic species and the brackish water forms probably do not go far out to sea. Such conditions, however, are not found in this immediate region.

TEMPERATURE

The subject of the temperature at Woods Hole and adjacent regions is so fully discussed by Sumner in his report that only the particular conditions existing in Great Harbor during the past two years need be considered here.

Figures 4 and 5 show the variations in the temperature of the air and water for the years 1922–23, inclusive, to December 31. The figures were obtained from the records taken daily at 8 a. m. by Mr. Hamblin, of the Bureau of Fisheries. This hour was selected because it eliminates the temporary midday rise of surface temperature typical of all shallow water. Figure 6 was compiled by Sumner to show the mean average temperature of the air and water for a period of five years. A comparison of this chart with that of the past year shows many important points. The fact that Sumner's chart is based on noon records must be considered, although it probably had little effect on the water curve. The highest point on this curve is on August 12, when the mean temperature was slightly over 71° F. The highest point reached in 1922 was 71° F., on August 8. The curve for 1922 agrees well with that of the average temperature for other years. The lower point of the latter (30° F.) was reached only once, on February 19. In 1922 the curve fell below this on two occasions (January 25 and February 17–19), and reached it on February 4.

During the spring of 1923 very unusual conditions prevailed. The temperature went below 30° F. on January 29, and never rose above this point until March 14. Throughout this period the temperatures fluctuated between 28.5 and 29° F., reaching 28° F. on February 24. This unusually cold water, occurring for such an extended period, accounts for certain peculiarities in the plankton of the present

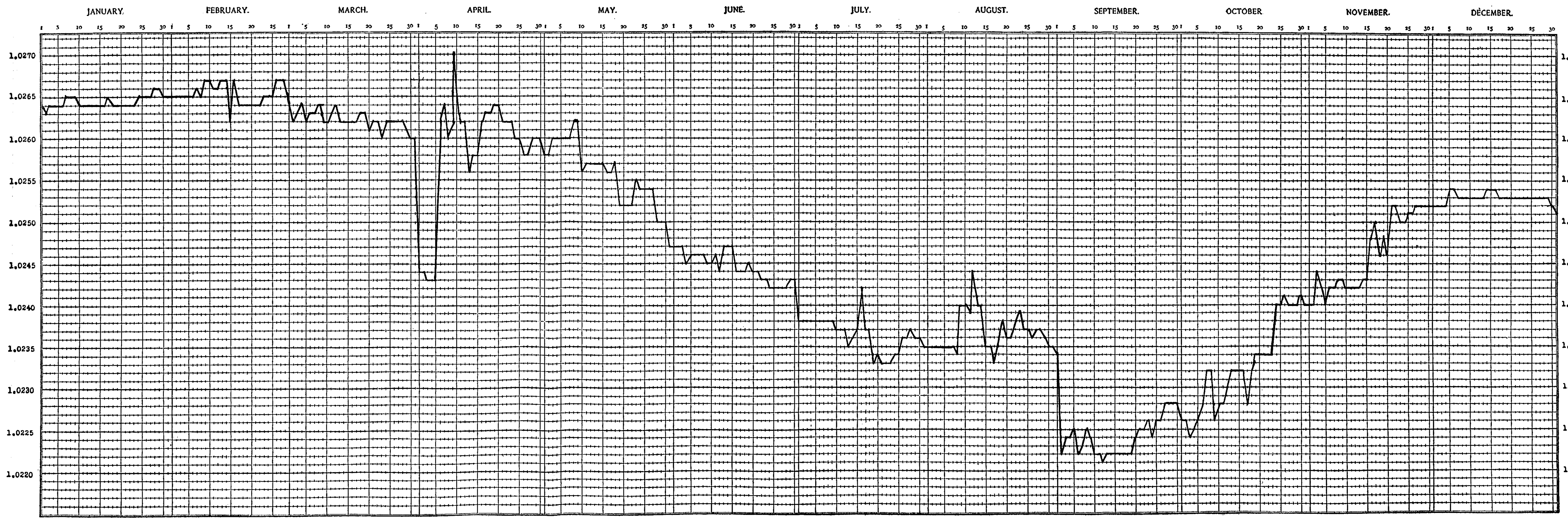

FIG. 2.—Diagram showing density of water at Woods Hole, Mass., for each day of the year 1922. Observations made at 12 o'clock noon. Density at the temperature in situ

8242°—25†. (Face p. 100.) No. 1

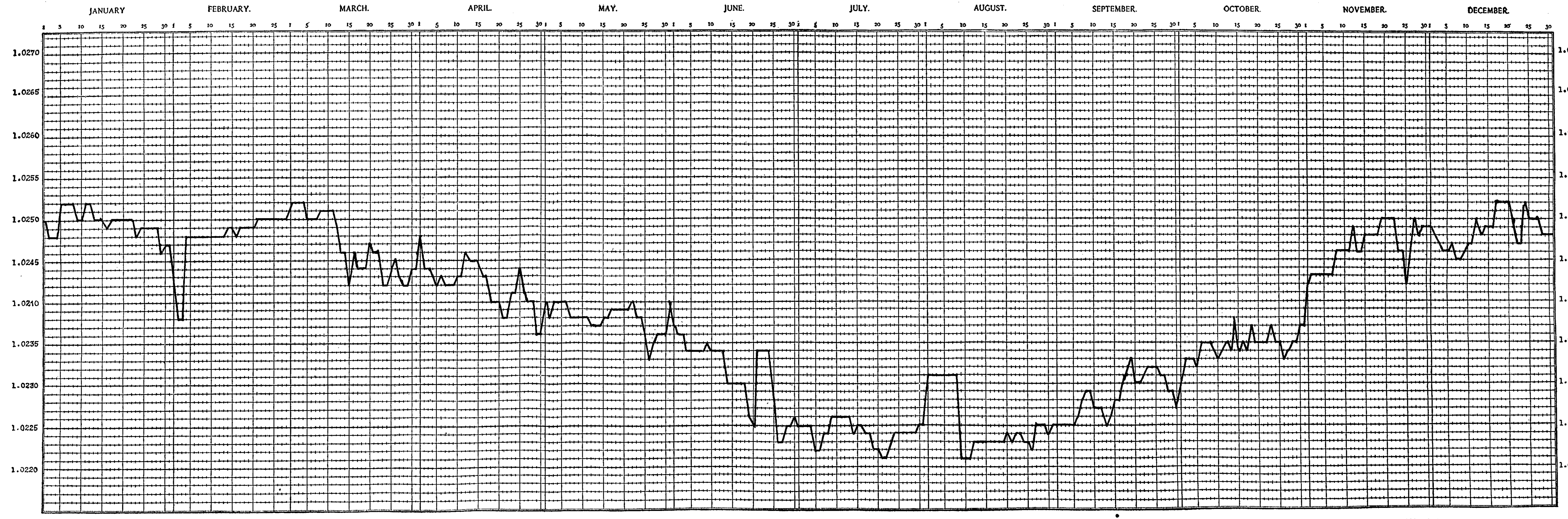

FIG. 3.—Diagram showing density of the water at Woods Hole, Mass., for each day of the year 1923. Observations made at 12 o'clock noon. Density at the temperature in situ

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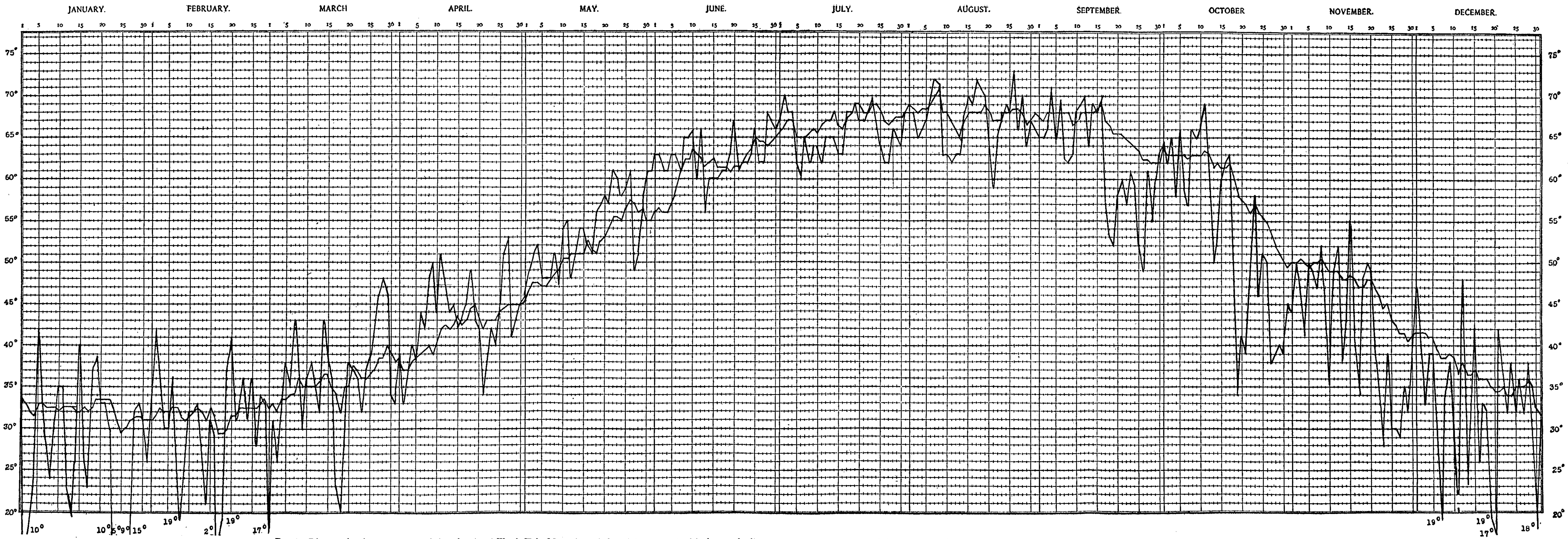

FIG. 4.—Diagram showing temperature of air and water at Woods Hole, Mass., for each day of the year 1922. The less regular line represents air temperature and the more regular line water temperature. Readings are in Fahrenheit, and observations were made at 8 a. m.

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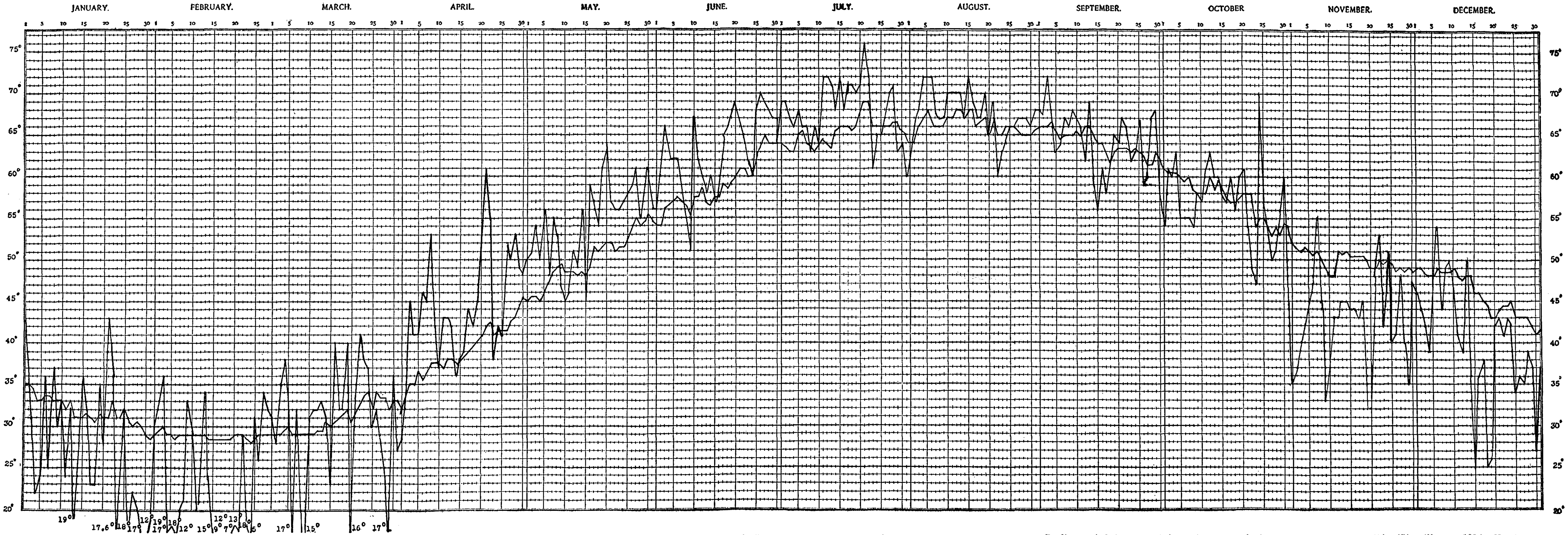

FIG. 5.—Diagram showing temperature of air and water at Woods Hole, Mass., for each day of the year 1923. The less regular line represents air temperature and the more regular line water temperature. Readings are in Fahrenheit and observations were made at 8 a. m.

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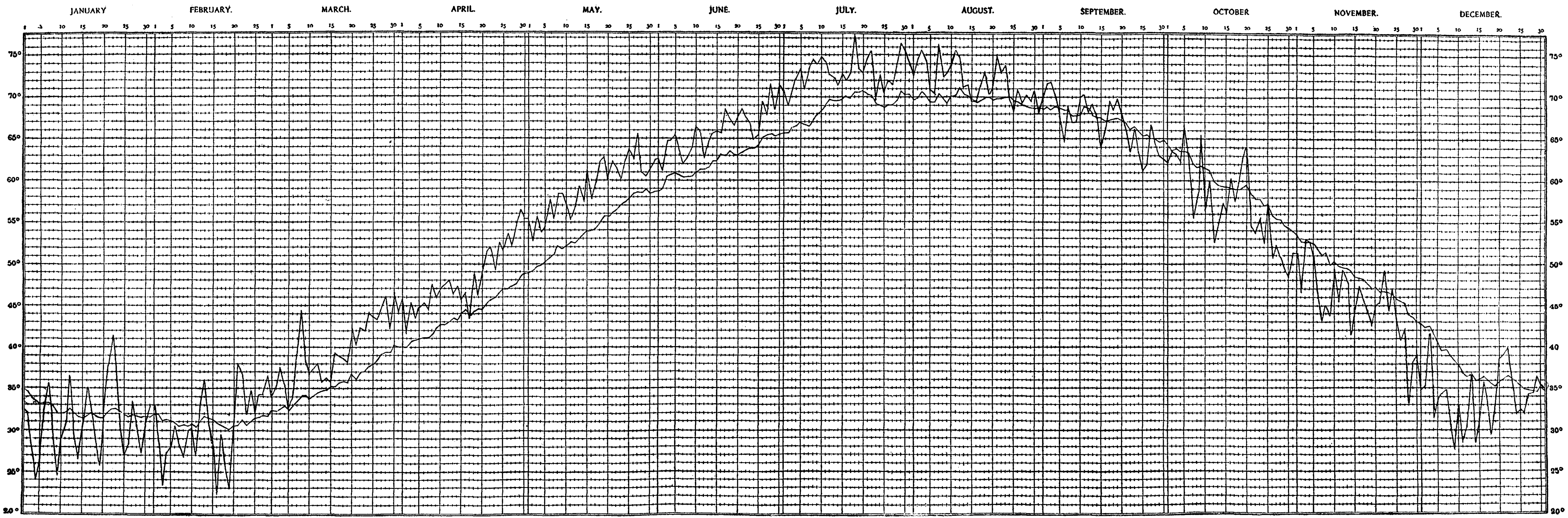

FIG. 6.—Diagram showing mean air and water temperatures at Woods Hole, Mass., for each day of the year, 1902 to 1906, inclusive. The less regular line represents air temperature and the more regular line water temperature

8242°—25†. (Face p. 100.) No. 5

spring. The warmest months were July and August; the coldest were January, February, and March.

The strong currents rushing through the "Hole" on the flood tide churn the water to such an extent that any change in the temperature of the air affects the bottom water as quickly as it does that of the surface. Table 2 gives a series of temperature observations taken when the temperature was suddenly rising or falling. These show the result of the mixing of the waters.

TABLE 2.—*Surface and bottom temperatures taken at Woods Hole in 1922–23*

Date	°C. at surface	°C. at bottom	Date	°C. at surface	°C. at bottom
July 29, 1922	20.2	20.2	Dec. 17, 1922	3	3
July 30, 1922	21.2	21.2	Dec. 18, 1922	1	1
July 31, 1922	22	22	Dec. 19, 1922	−0.5	−0.5
Aug. 13, 1922	20.5	20.5	Mar. 19, 1923	2	2
Aug. 14, 1922	21.8	21.8	Mar. 20, 1923	−1	−1
Aug. 15, 1922	22	22	Mar. 21, 1923	1.5	1.5
Sept. 6, 1922	22	22	Mar. 22, 1923	2	2
Sept. 7, 1922	21.4	21.4	Mar. 23, 1923	0.3	0.3
Sept. 8, 1922	20.4	20.4			

GENERAL DISCUSSION OF PLANKTON

Marine plankton at Woods Hole falls naturally into two great groups—the oceanic and the neritic—each of which has quite distinct characteristics.

The oceanic plankton consists for the most part of adult animals existing throughout life as a part of the pelagic fauna. The only immature forms normally occurring are the young of these oceanic species. Occasionally larval animals from the neritic plankton are blown out in offshore winds, but this does not occur often. However, it would be impossible to draw a line denoting the boundary between the two types. There exists a broad intermingling area into which each species extends to a point where external conditions form a natural barrier. As all forms are not subject to the same conditions, this wide intermingling zone results.

The neritic plankton, in contrast to the oceanic, consists for the most part of immature forms which in adult life are not a part of this community. There are, of course, many truly pelagic animals common to the littoral zone, but these are usually greatly outnumbered by the temporary intruders, except during the winter and spring months, when the larval forms reach their minima at the same time that many copepods and Sagittæ have their maxima.

Figure 7 illustrates in a general way the constituent parts of the zooplankton at Woods Hole at different times during the year. It will be noticed that the summer and winter plankton are made up of representatives from the same groups. The great difference in the relative abundance of these in the two seasons will be discussed later.

The influx of oceanic species occurs both in summer and winter, although the number of different forms occurring in the colder months is comparatively small. During the summer, however, swarms often appear. Great masses of Sargassum, with its many inhabitants—Physalia and other floating forms—often fill the waters of the Sound after a southeast storm or a continued hard wind. Wheeler noticed that such copepods as *Pontella meadii* and *Anomalocera patersoni* appeared in the tow only after this weather. Dr. H. M. Smith attributes the presence of practically all of the small tropical fish that are taken each year in the Sound and at Katama Bay to southerly winds. The floating Sargassum offers shelter for these animals after they have been passively transported up from the south, and as the weeds are blown inland the fish accompany them. During the winter months such winds are fatal, but in summer the broad expanse of water extending from the coast reaches a temperature as high as that of the stream. Here any forms

Variation in the constituent parts of the plankton at Woods Hole during the year

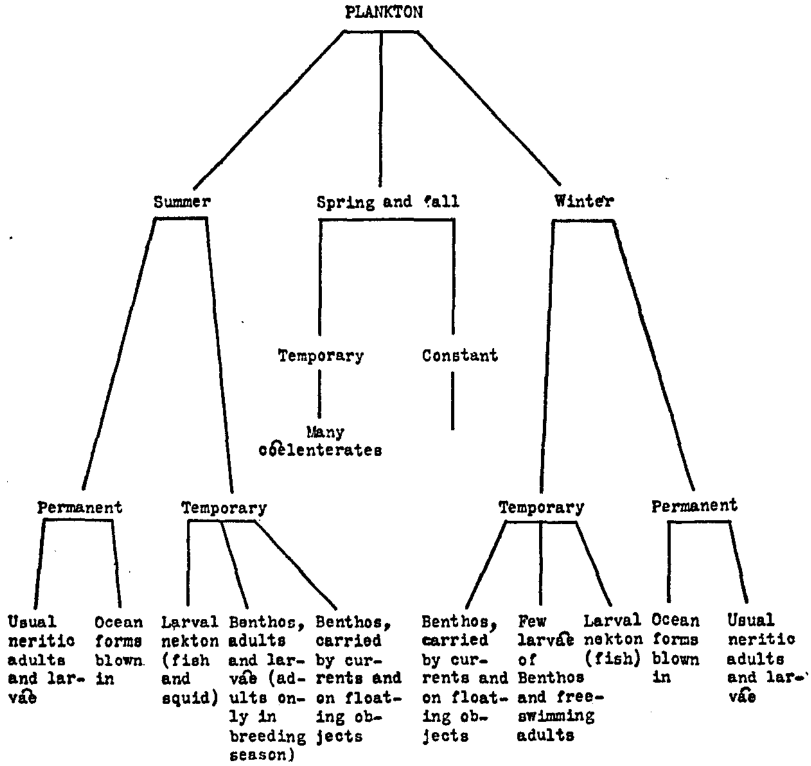

FIG. 7

carried out of their courses can exist very well until the temperature drops in the fall, when all perish.

The shallow waters of the immediate region, sheltered as they are by the arm of Cape Cod, respond very quickly to changes of weather, heating rapidly and cooling suddenly. In summer Buzzards Bay is warmer than Vineyard Sound, the maximum temperature occurring at the head of the bay, the minimum around Cuttyhunk. Such conditions continue through August and into October. With the sudden drop in air temperature the bay water responds immediately and results in an exact reversal of the conditions found in August. At this time the water of the bay becomes colder than that of the Sound. That has an important effect on the plankton of Woods Hole, for as long as the bay remains warmer than outside waters all animals carried into it will survive and be carried through the passage during the flood tides. As soon as the temperature drops in the bay the tropical forms entering it will perish and not return to the Sound. Such a condition is very noticeable in the fall, when all Gulf Stream forms suddenly disappear from the plankton of Great Harbor, although they may be taken in abundance in the Sound or at Katama Bay throughout October and November. The arrival of southern forms is usually noted as soon at Woods Hole as in the Sound.

In some parts of the eastern Atlantic a great many animals having a double breeding season are found. These forms appear in the spring and again in the fall. At Woods Hole examples of this group are limited to one phylum—the Cœlenterata. Figure 26 (p. 124) shows clearly that almost all Hydromedusæ common to this region have been taken both in spring and fall, the spring swarm being the largest and lasting for the longest time. The Scyphomedusæ rarely have this double periodical appearance. During the past year, however, early ephyræ of *Aurelia flavidula* were taken in November and again in April. The Ctenophora have been taken in small numbers throughout the winter, but usually swarm in the fall and early spring.

I know of no permanent planktonic animals at Woods Hole having this biannual distribution. Certain copepods are most abundant in the fall or spring, but never at both seasons. Such forms are also plentiful in the winter and have been included in the winter plankton. Two species of importance belong to this group—*Tortanus discaudata* from December to June and *Pseudodiaptomus coronatus* from August to January.

Under normal conditions the zooplankton, although varying considerably in its constituent parts, is always abundant at Woods Hole. The dominant winter or summer form of one year may be totally absent the next, but some other species usually takes its place. During the winter of 1899 and 1900 *Temora longicornis* formed the greater part of the plankton, while in the fall of 1922 and the spring of 1923 hardly an adult specimen was found, the dominant species that year being *Pseudocalanus elongatus*. In the winter of 1923 the temperature of the water remained so high that neither of these winter species had appeared by December 29. *Centropages hematus* and *Acartia bifilosa* constituted the bulk of the collections. Temperature and weather conditions, no doubt, determine to what extent the northern forms pass south of Cape Cod and enter local waters. Almost no cold-water species were found in the early winter of 1923. Such diatoms as *Rhizosolenia alata*, *Skeletonema costatum*, and *Ditylium brightwelli* appeared rarely or not at all, and even the cod apparently sought deeper water, for no young were taken in surface collections.

Normal diatom maxima have no noticeable effect on the larger planktonic forms. When the unusually large swarms of phytoplankton appear, however, the zooplankton decreases rapidly and may even totally disappear for a time. Such conditions are often found during the summer maxima of *Rhizosolenia semispina*. Usually the winter maxima do not affect the larger forms. In the winter of 1922–23 the phytoplankton and zooplankton were both abundant at the same time. At this time *Rhizosolenia alata* was the dominant diatom. In 1923–24 *Nitzschia seriata* occurred in such abundance that the zooplankton disappeared almost entirely from November 16 until February 1. During this period top and bottom collections in the shallow water of the bay and sound yielded nothing but diatoms. The zooplankton was found to be fairly abundant in the deeper waters at the western end of the Sound. As soon as the diatoms declined in numbers the larger forms returned to the shallow water. Figures 8 and 9 show the relative abundance of the zooplankton and phytoplankton in 1922 and 1923.

DIATOMS AND OTHER PLANTS

The diatoms of this locality may be divided into two great groups—the pelagic and the bottom forms. In certain parts of Great Harbor the bottom diatoms are very abundant, and often large numbers occur in surface collections after storms or particularly strong winds. As no fresh-water streams of importance are found in the vicinity of Woods Hole to carry the various chemicals needed for diatom production, much essential material must be carried through the "Hole" from Buzzards Bay by the strong currents. For that reason bottom diatoms were found to be more abundant in eddies and pockets about the entrance of the bay than elsewhere in Great Harbor and not scattered about evenly on the bottom in shallow water, as might otherwise be expected.

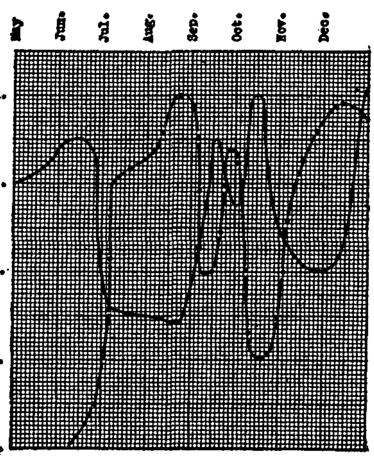

FIG. 8.—Relative abundance of zooplankton and phytoplankton in surface collections from May to December, 1922. ——, zooplankton; —·— phytoplankton

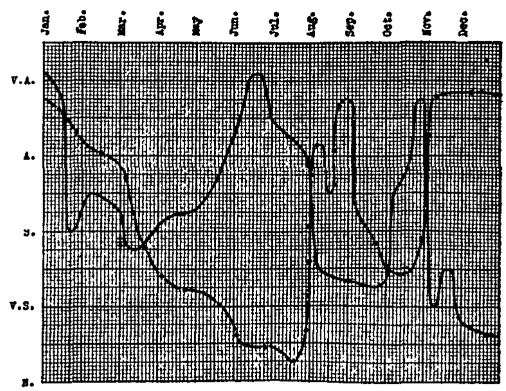

FIG. 9.—Relative abundance of zooplankton and phytoplankton in 1923. ——, zooplankton; —·—, phytoplankton

Together with the dinoflagellates, the pelagic diatoms make up the greater part of the phytoplankton of the region. On all but two occasions the former were far outnumbered by the latter. In every haul made during the year with a No. 20 net diatoms were found. They had regular seasonal variations which were very similar to those of previous years (figs. 10 and 11). There is a regularity in the quantitative variation as well as in the qualitative. The maximum of one year may be larger, smaller, earlier, or later than that of another, but the basic characteristics of the rhythm remain for the most part unchanged. An exception to this rule is found in the appearance of certain oceanic forms, which will be discussed later. Extremely unusual physical factors may even eliminate a part of the cycle, but as soon as normal conditions are restored the progression continues as before. Such was the case in December, 1923, during an unusually warm period (fig. 11). Although quantitatively the winter diatom maxima remained approximately the same as in the previous year, qualitatively it was very different (fig. 10).[1]

To understand the seasonal distribution we must know something of the nature of the various forms that enter Great Harbor. The individual species of neritic phytoplankton are much more widely distributed than the zooplankton, and factors governing their appearance and disappearance are for the most part quite different. As in the case of land plants, the diatoms are able to form organic substances from

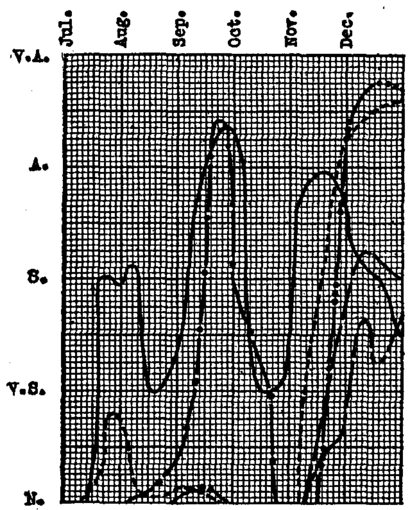

FIG. 10.—Seasonal distribution of most abundant diatoms occurring in surface collections from June to December, 1922. Rhizosolenia excluded. ———, Chætoceros; —.—, *Corethron valdiviæ*; — —, *Ditylium brightwelli*; -----, *Leptocylindrus danicus*; —--—, *Nitzschia seriata*; —...—, *Skeletonema costatum*

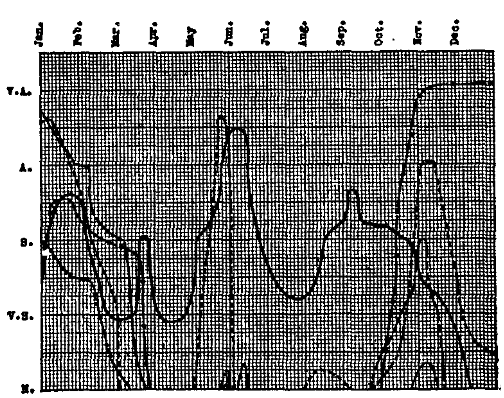

FIG. 11.—Seasonal distribution of most abundant diatoms occurring in surface collections of 1923. Rhizosolenia excluded. ———, Chætoceros; —--—, *Corethron valdiviæ*; —...—, *Ditylium brightwelli*; --------, *Leptocylindrus danicus*; —.—, *Nitzschia seriata*; — — —, *Skeletonema costatum*

the various inorganic chemicals. Together with the littoral marine flora they form the basic source of food supply in the sea. Since all plankton animals are consumers and depend solely on the organic materials produced by the plants, the importance of the diatoms and the necessity for information regarding the sources of their production can not be overestimated.

Obviously the two fundamental necessities for diatom growth are sunlight and food material. Secondary factors, such as temperature, salinity, necessary resting periods, etc., limit the geographical and seasonal distribution of certain species but do not usually affect the group as a whole. Physical conditions fatal to one species may be particularly favorable to another. Sunlight limits the vertical range of the species to the narrow zone penetrable by the light (photic zone). This usually does not form a limiting factor of production in local waters or littoral plankton in general.

[1] See paragraph 1, page 119.

It is of extreme importance in ocean waters, however. Food material is the dominant governing factor for all diatoms. The supply of the substances not common to all sea water arises from two sources—outwash from the land and the replacing of chemicals by the breaking down of the organic substances in the sea. For this reason diatoms are much more abundant in the coastal waters, particularly near the mouths of large rivers (Table 3). No doubt the large amount of disintegrating material often found in coastal water (Bigelow, 1914) after a diatom decline forms an important item in the replacement of essential chemicals such as silicic acid and nitrates, but in comparison with the source of supply from the land it must be rather small. Conversely, in the open ocean it probably forms the most important source in regions where the land areas exert little or no influence. In this respect the oceanic and coastal conditions are widely different.

TABLE 3.—*Distribution of diatoms in Long Island Sound in early March, 1923. Volume determined from vertical hauls*

Locality	Date	Volume	Depth
		c. c.	*Meters*
Throgs Neck	Mar. 5	4	5
Hempstead Harbor	do	6	5
Matinicock Point	do	2.5	5
Cold Spring Harbor	do	2.5	5
Pecks Ledge	Mar. 6	4.5	5
Pine Creek Point	do	4	5
Off Bridgeport Harbor	do	8	5
Stratford Point	do	20	5
Housatonic River, near breakwater	do	12	5
New Haven Harbor	do	10	5
Stations inside of Harbor No. 1	Mar. 7	8	5
Stations inside of Harbor No. 2	do	6.5	5
Stations inside of Harbor No. 3	do	6.5	5
Five-fathom Rock	do	7	5
Sachem Head	do	10.5	5
Hammonasset Point	do	8.5	5
Falkner Island	do	2	5
Gardiners Bay	Mar. 8	1.5	5
Little Peconic Bay	do	1	5
Hortons Point	do	4.5	5
Eaton Point	Mar. 9	3.3	5
Mid-Sound positions 40-59-54 N.; 73-23-18 W	do	4	5

In the ocean, where uniform physical conditions often exist to comparatively deep water, Nathansohn (1909) found that the diatoms are most abundant in localities where the greatest amount of vertical circulation takes place. (Gran, 1912, gives maximum abundance often as deep as 50 meters and large numbers at 100 meters.) Large quantities of organic material are constantly sinking to the deeper water, and the decomposition of dead plants and animals at these levels sets free the nutritive substances, which are returned to the photic zone in the ascending currents. In anticyclonic systems like that of the Sargasso Sea, where little or no vertical circulation takes place, the diatoms were found to be very scanty. Nathansohn's (1909) theory, no doubt, does not apply to all conditions found in the sea, but remains as the best explanation of the source of production of oceanic diatoms. Ocean currents, which themselves change according to the seasons, cause the diversity of high sea plankton in fixed geographical positions. The occurrence of certain species far beyond the limits of their natural range is usually attributed to currents.

In the coastal waters an entirely different condition of affairs exists. Over the deeper parts of the neritic zone plant life usually is limited to a very thin surface layer, which is differentiated from the deeper water masses by a lesser density and higher temperature. In seasons when there is great outwash from the land the neritic diatoms often form great swarms. In localities where upwelling or vertical circulation takes place under these conditions the surface layers, with their flora, are blown away from the shore and replaced by infertile water drawn up from the bottom layers. The outwash of this fertile water is very favorable to the offshore plankton but causes a diminution of diatoms near the coast, the few that were not carried out having adverse conditions to combat. An inshore wind, on the other hand, heaps up the surface waters and is conducive to luxuriant plant growth. Repeated investigations (Gran, 1912; Nathansohn, 1909; Leder, 1917) of this problem have confirmed the belief that often the rapid appearance and disappearance of diatom maxima is not so much a biological question as a hydrographical one. Gran and Nathansohn in 1909 observed, "We find an intensive plant life, and consequently also an intensive animal life, everywhere at the surface of the sea where an influx of water masses takes place, which has not, or at least has not immediately previous, served as a source of nourishment for phytoplankton."

Sometimes a diatom society is found in summer in the lower strata, with its higher density and lower temperature, which was present in the surface waters earlier in the spring. Such conditions are common among the zooplanktonic forms and are occasionally found among the diatoms. Miss Ogilvie found the same diatoms in the lower strata off the south coast of Ireland in August as were present at the surface from January to April. This is an indication that certain neritic forms, which are apparently periodical in their occurrence, might remain as permanent members of the plankton if conditions of existence were more uniform. This is interesting in view of the fact that many investigators have considered that a resting period (spore formation) is a necessary part of the existence of truly littoral species.

It is impossible in local waters accurately to determine the real relationship of the local conditions of existence and the development of the diatoms, because the currents often cause variations much greater than those actually due to conditions of existence. Gran (1912), realizing this, substituted a study of the rate of growth as a measure of production in place of quantitative chemical analysis of food materials present in the water. In the vicinity of Woods Hole, where the currents are unusually strong, the production would have to take place at an extremely high rate in order to maintain itself were it not for the many "pockets" of quiet water which are supplied with abundant land outwash. In certain less protected sections of the coast this may be an important factor in the sudden disappearance of certain species. As soon as the rate of production declines the species is unable to maintain itself, and this inability to replace the numbers carried away by the currents may cause the maxima to disappear long before the food supply is exhausted.

In dealing with the conditions of production it is very important to know just where the production of floating forms takes place before attempting to explain their appearance or disappearance. Two theories are now held. One contends that all production of pelagic neritic diatoms takes place off the coasts, the sudden swarming in inland rivers and small bays being the result of tides and winds. The second theory is that production also takes place within certain limits in inland waters. To be sure, winds may blow quantities of diatoms into open harbors and small bays, but this does not explain the conditions as they are often found. Since Woods Hole is a particularly unfortunate location to observe the factors of diatom production, I shall cite results obtained in Long Island Sound in 1922 and 1923.

The first indication of local production was the variation in the species of pelagic diatoms found in the different harbors and river mouths along one shore. Had winds carried them there, one would expect to find the same species in all the harbors. This was not the case except during the greatest swarms, when the Sound seemed filled with a single species. In succeeding cruises it was noted that the volume of phytoplankton in the vertical hauls taken at the mouths of rivers and in harbors connected with inland streams was much greater than that of the mid-Sound or harbors containing no land outwash. Table 3 (p. 106) shows the centrifuged volume, in cubic centimeters, taken with a Hensen medium-sized vertical net at various points in the Sound. The predominant species was *Skeletonema costatum.* A strong west wind had prevailed for several days before the collections were made. Had the distribution of diatoms resulted from this they should have occurred most abundantly along the southeast shore near the eastern end. The table clearly shows that the greatest swarms occurred at the mouths of the rivers and harbors where the most land drainage is carried into the waters. The salinity is low in all parts of the Sound, and for that reason the diatoms do not penetrate far into the mouths of the rivers and harbors. No great tides sweep the Sound at any place except at the "race," and even there Galtsoff found that 8 miles is the maximum distance that the water is carried in a single tide.

Another source of evidence can be found in Peck's (1896) report on diatom collections in Buzzards Bay. His stations were laid in two lines, one at right angles to the other, extending the length and width of the bay. A series of observations at various points along these courses showed that the greatest abundance of diatoms occurred at the two inshore stations. The other two ends of the courses were located in Vineyard Sound and the rapids at Woods Hole, and therefore are not considered. He concluded from these records that there was a shallow area of diatoms surrounding all the shores of Buzzards Bay. A glance at Figure 12 will show that the two inshore points he selected (indicated by ▲) were near the mouths of the greatest harbors of the entire Bay. The large rivers at the head of the Bay empty their waters near Peck's north station, while the waters of the Acushnet and Nasketucket Rivers join at the point of his western station. Undoubtedly Peck would have found his hauls less rich if he had selected spots along the eastern shore.

A noticeable characteristic of neritic plankton flora is the variety of diatoms that is usually found in every swarm. One or two species predominate, but the many other species occurring in smaller numbers make up the so-called "diatom society." Allen, in 1920, made the following statement:

> Detailed study of the records has clearly shown the important fact that when there is an increased production of the most prominent forms there is also increased production of the less prominent forms and an increase in the number of different forms. Such facts naturally lead to the assumption that conditions favorable to high productivity of diatoms in the sea affect a large number of forms in the same way. They also lead to the inference that determination of the species that shall lead in production is due largely to the biological factors, such as rapid multiplication and vigorous development.

As most rules have exceptions, so, too, an exception to this rule is often found at Woods Hole during the summer months when the oceanic diatom (*Rhizosolenia semispina*) occurs in such abundance that almost every other form of animal and plant life disappears for a time. The occurrence of this interesting species will be discussed later.

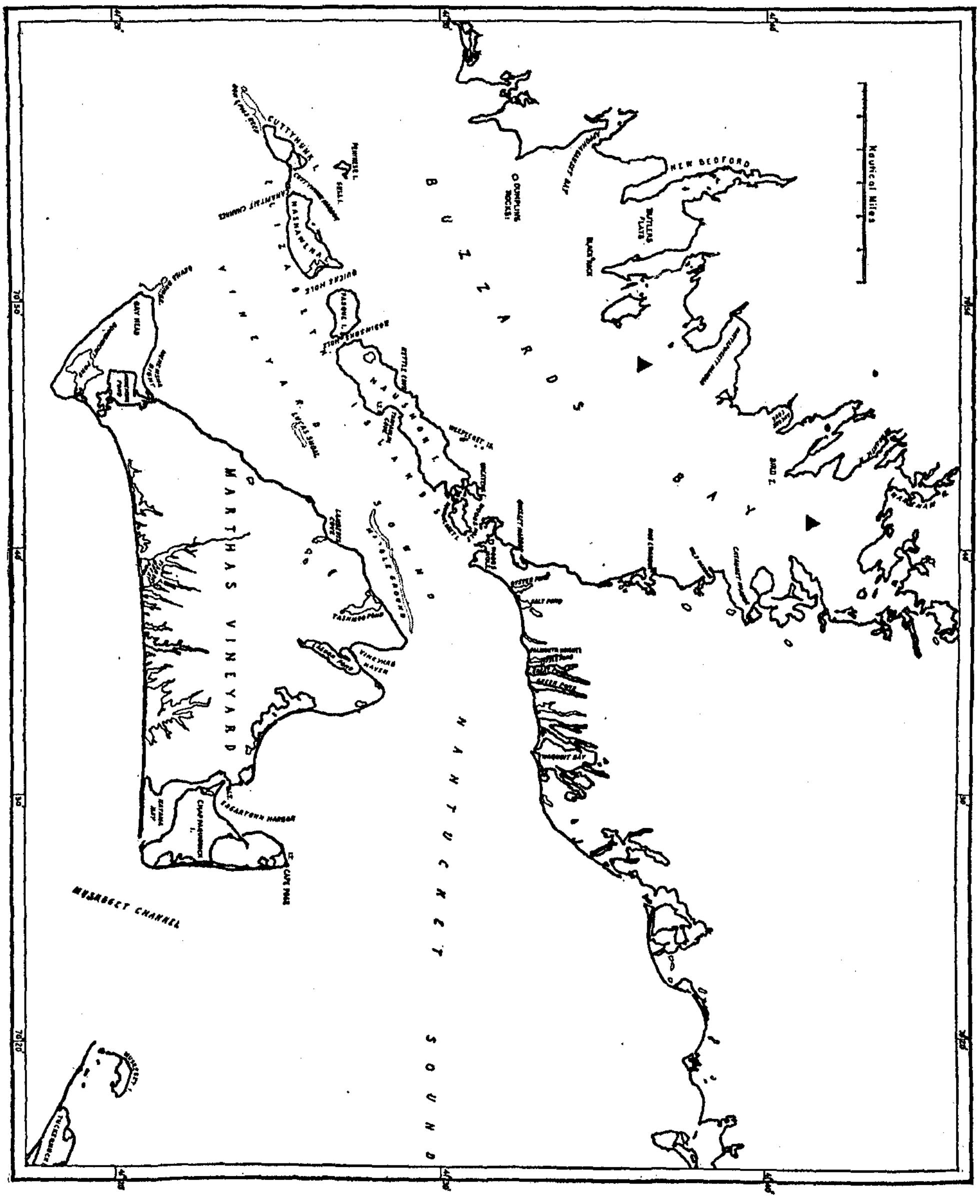

FIG. 12.—Map of Buzzards Bay and Vineyard Sound

The diatom spores are no doubt at all times exceedingly numerous in local waters and are carried about by the currents and winds. When conditions become favorable for those already present or those transported to a harbor or river mouth where rich food material has been washed from the land, the spores germinate and increase rapidly in numbers. The development will continue until the food supply is exhausted or other unfavorable conditions arise. In discussing spore formation in diatoms Gran (1912) stated:

> When we subsequently find the same species once more in abundance, we have every reason for surmising that the resting spores on the bottom were the principal source from which these forms have been derived. Ability to form resting spores must be of the utmost importance for the existence of the species in coastal waters. The chief difference between coastal seas and the ocean, so far as hydrographical conditions are concerned, lies in the extreme and rapid changes in such fundamental conditions of existence as salinity and temperature in coastal waters. Resting spores, therefore, must be the means by which many species continue in coastal seas, notwithstanding the fact that there conditions of existence are favorable only for a limited portion of the year. The Arctic diatoms, for instance, which sometimes are to be found in the plankton of the Skager-Rak, are very easily affected by a rise in temperature, but their development takes place during the winter months from February to April, when the temperature is at its minimum. In the summer they are not to be seen, but their resting spores are then most probably on the bottom. In the same way a whole series of warmth-loving species pass through the winter as resting spores and are to be found along our shores only in the warmest months of summer and autumn.

As in the case of the littoral pelagic fauna, the winter diatom flora throws an interesting light on the effect of the arm of Cape Cod on the winter forms in local waters. In summer the cold waters north of the cape form a barrier for southern neritic plankton. Samples taken by Bigelow in August, 1922, in Massachusetts Bay, contained the same diatoms as those which appeared in Woods Hole in greatest abundance in December. No doubt many of the northern diatoms are carried south in the summer, but the sudden rise in temperature apparently is sufficient to cause them to form resting cells or die. The effect of a slight change of temperature was evident at the end of March, 1923, when the winter forms suddenly disappeared. In winter, on the contrary, those carried south find a favorable climate with a supply of food material that has accumulated since the disappearance of the summer forms. Together with local winter neritic species they form a maximum the extent of which depends upon the supply of silicates, nitrates, etc., in the water, and remain until the food is exhausted or the temperature becomes unfavorable. In this way the arm of Cape Cod forms a southern barrier for northern littoral plankton only in summer and not at all times, as in the case of many benthonic species.

If this assumption were based upon the neritic diatoms alone, it could hardly hold, because, combined with the evidence of the existence of diatom spores in all coastal waters, the factor of temperature alone could explain the condition, and transportation by currents around Cape Cod would not be necessary. However, as the most abundant species (*Rhizosolenia alata*) north of the cape in August was a truly oceanic form and proved to be the first to appear in large numbers at Woods Hole, I think it justifiable to attribute it to the currents, just as in the case of the northern copepods appearing about the same time which were certainly transported in that manner.

None of the so-called "pulses" which Allen observed on the Pacific coast occurred at Woods Hole in 1922 or 1923. The seasonal curves rose and fell evenly. On April 3, 1913, Bigelow found the waters of Massachusetts Bay filled with diatoms. These were not evenly distributed but appeared as brownish-colored bands alternating with clear areas. It may be that patches like these formed the pulses of which Allen speaks, for his collections were on the open coast and taken from the end of a wharf past which the belts of uneven abundance would drift.

The seasonal variation of the diatom maxima and the appearance of oceanic species in local waters can be understood best by considering the geographical position of Woods Hole as compared with other areas of the eastern and western Atlantic. Steuer (1911) found that in general the maxima of the various species,

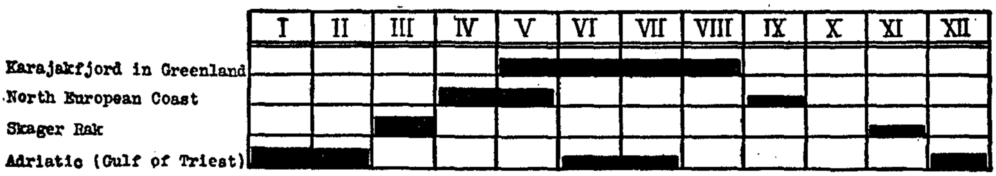

FIG. 13.—Schematic diagram of the seasonal distribution of the diatom maxima in the northern and southern parts of the eastern Atlantic. After Steuer

both neritic and oceanic, is closely related to temperature, and thus varies according to the latitude. It has long been known that on both the European and American coasts the most luxuriant diatom growth does not take place in the warmest months even as far north as Norway and Newfoundland.

At Karajakfjord, in Greenland, Vanhöffen (1897) found only one maximum, from May until the beginning of September. South of this there occurs the typical spring and fall maxima, which retreat farther and farther from the warmest seasons as one approaches the Tropics. Steuer (1903) found that this constant succession of diatom maxima toward the south necessarily leads to the assumption that somewhere in the south there will be a meeting of the two maxima in winter, and this was found to occur in the Adriatic Sea by Leder (1917), Steuer (1903), Stiasny (1908), and Gran (1909) (fig. 13). A smaller maximum was also found to occur in June and July. Conditions on the American coast are surprisingly similar to those of the eastern Atlantic (fig. 14).

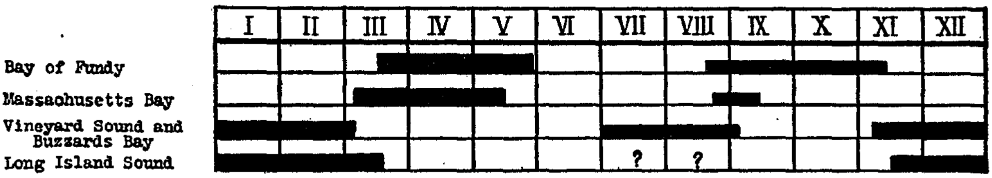

FIG. 14.—Schematic diagram of the seasonal distribution of the diatom maxima on the western Atlantic coast

Observations in eastern Canadian waters by Bailey, MacMurrich, and Fritz show that the greatest maxima occur in the spring and fall. Bigelow (1917) commented on the similarity of the diatom distribution in the Gulf of Maine and that of the North Sea, Irish Sea, and Skager-Rak. He also found a great maxima in Massachusetts Bay in April and early May, 1913, and a smaller one in September, 1915, and one in late August, 1922.

The striking effect of the arm of Cape Cod on the plankton is again evident here, for within 20 miles of latitude of Massachusetts Bay conditions similar to those of the Mediterranean and Adriatic Seas are found in Buzzards Bay. Here and throughout the shallow waters south of Cape Cod a rich winter diatom plankton

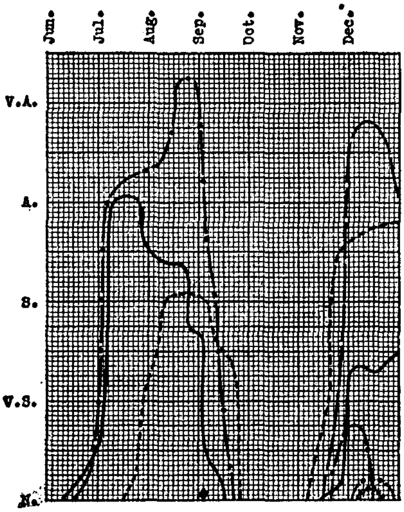

FIG. 15.—Occurrence of Rhizosolenia in surface collections from May to December, 1922. —·—, *Rhizosolenia semispina;* ---------, *R. setigera;* ——, *R. shrubsolei;* — — —, *R. alata genuina;* ♦. *R. alata gracillima;* ooooooooo, *R. styliformis;* —···—, *R. færœensis*

starts usually in November and continues until March, reaching a maximum in December. This compares very closely with the maxima found year after year at Trieste. Corresponding to the short summer maximum of that region, a summer swarm occurs also at Woods Hole, starting usually in July and remaining until September. A comparison of the seasonal distribution and breeding seasons of the zooplankton of the two regions shows that the conditions at Trieste are of a more southerly nature than in this region, although it is farther north. Its relation to the Mediterranean makes the reason for this obvious. The summer maximum is very variable, because the local neritic species play a minor part, the greater part consisting of a single oceanic form (*Rhizosolenia semispina*). Obviously, conditions beyond the limits of the adjacent coast have much to do with the appearance of this form. In 1922 and 1923 it was particularly abundant (figs. 15

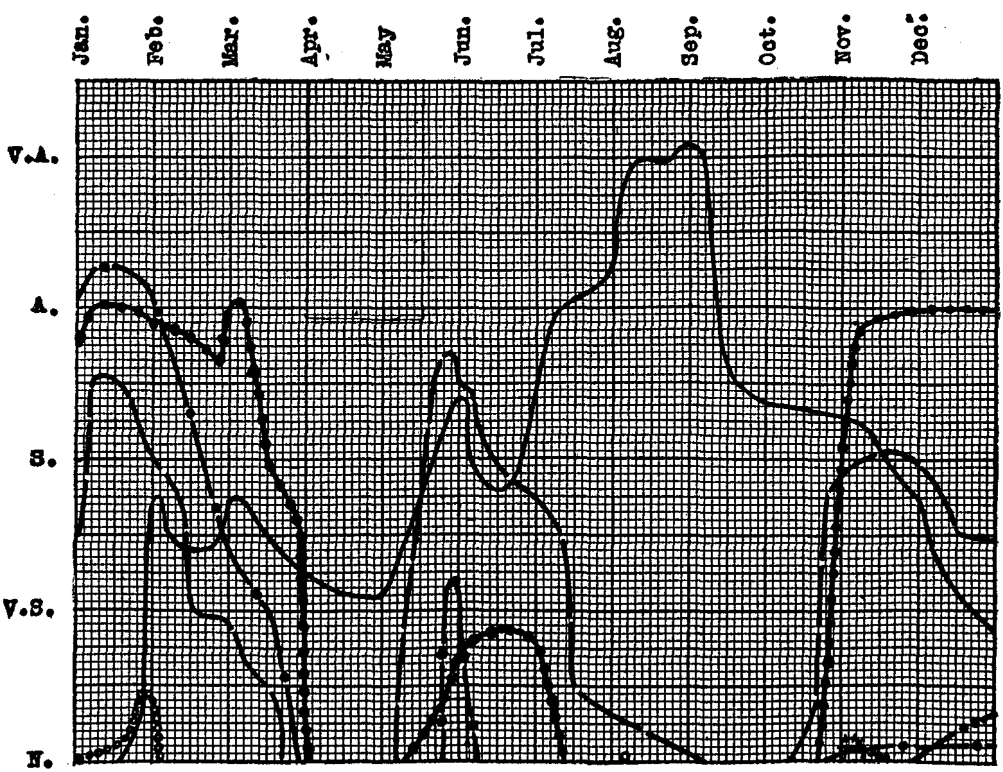

FIG. 16.—Occurrence of Rhizosolenia in surface collections of 1923. ———, *Rhizosolenia semispina;* —·—·—·—, *R. setigera;* — — —, *R. shrubsolei;* —·—, *R. alata genuina;* ooooooo, *R. styliformis;* ++++++++, *R. calcar avis;* —··—, *R. delicatula*

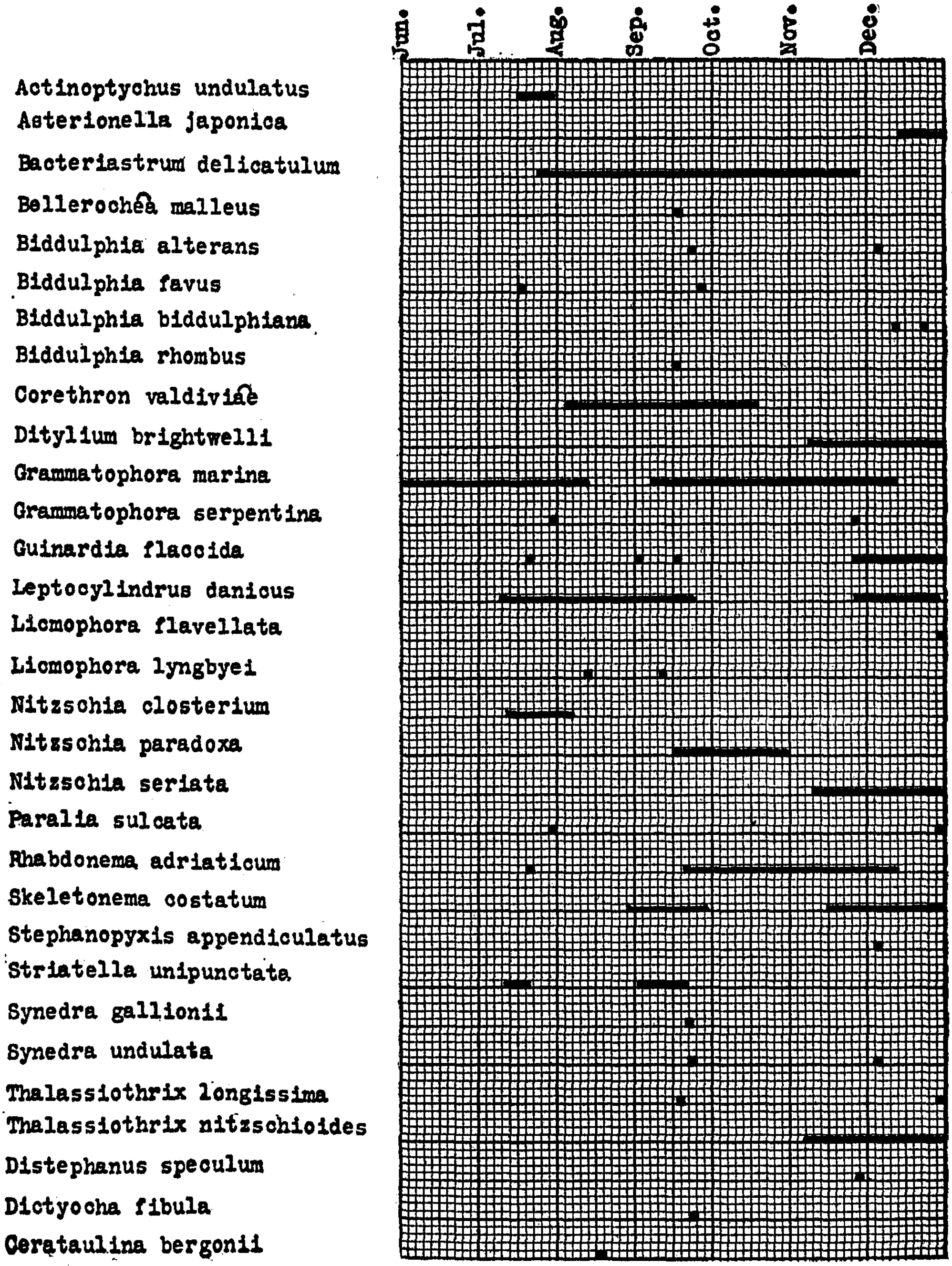

FIG. 17.—Distribution of diatoms and Silicoflagellata in 1922 (excluding Chætoceros and Rhizosolenia)

and 16), filling the waters of the bay and the eastern part of Vineyard Sound. The seasonal distribution of diatoms in Long Island Sound in 1922–23, during the winter months, was found to be very similar to that of Woods Hole except that the swarms appeared slightly later.

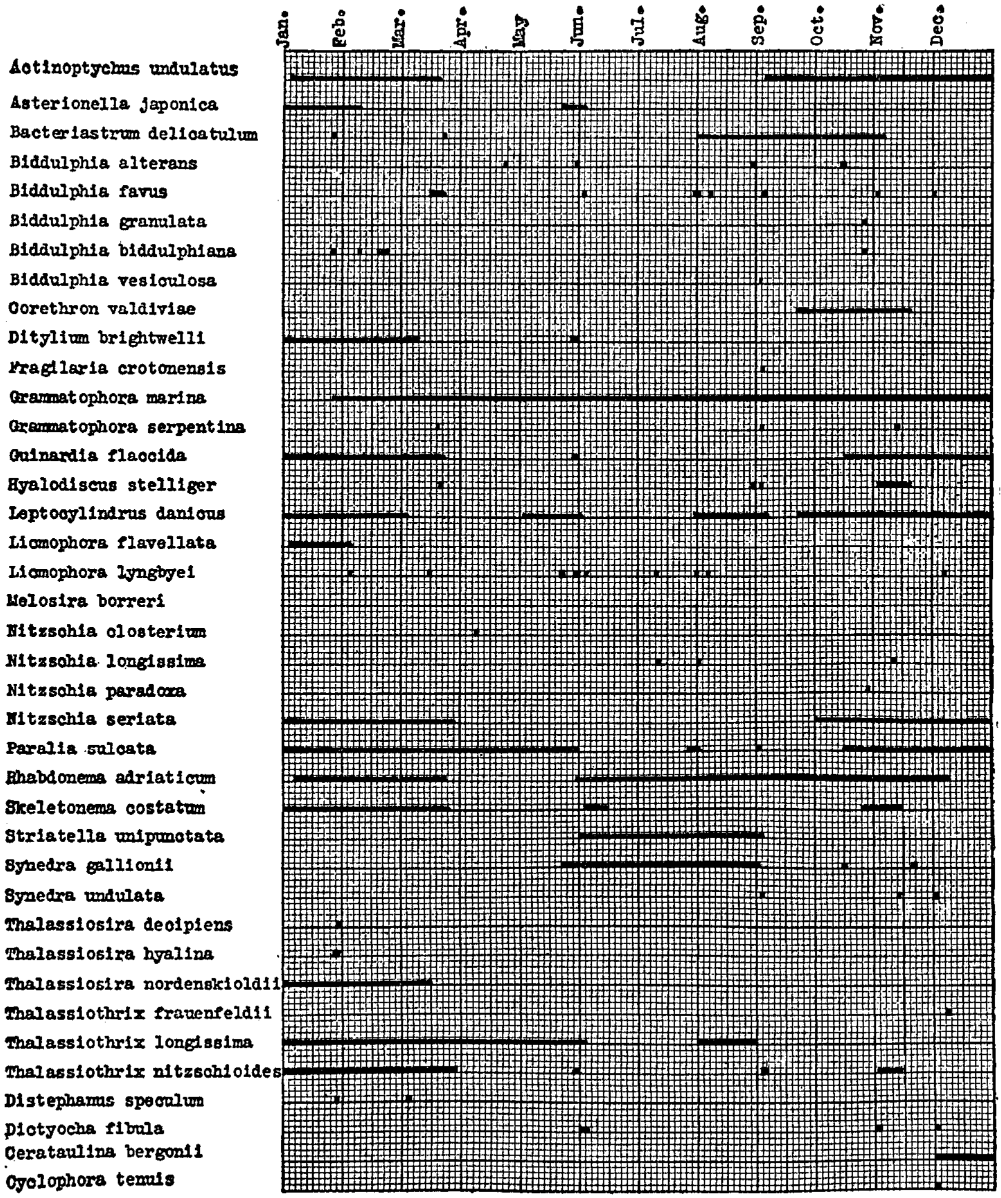

FIG. 18.—Distribution of diatoms and Silicoflagellata in 1923 (excluding Chætoceros and Rhizosolenia)

The pelagic diatoms of the Woods Hole region may be grouped under three headings—tychopelagic, oceanic, and neritic. The tychopelagic group is made up of semi-bottom forms, which often occur in coastal waters in enormous numbers. They are carried about by the winds and tides, usually without relation to any particular season (figs. 17 and 18). The following common tychopelagic forms appeared in the surface collections of the past year: *Actinoptychus undulatus*, *Biddulphia alterans*, *B. favus*, *B. granulata*, *B. biddulphiana*, *B. rhombus*, *B. vesiculosa*, *Hyalodiscus stelliger*, *Melosira borreri*, and *Paralia sulcata*. All of these species are temperate forms.

The oceanic and neritic diatoms that have a distinct periodicity in occurrence may be grouped according to the latitudes in which they are distributed. This method, originated by Cleve, has been used by almost all planktonologists. The various groups into which Cleve divided the characteristic plankton diatoms are represented at Woods Hole by the following species:

Neritic	Boreal Arctic	Chætoceros mitra.
		Nitzschia closterium.
		Thalassiosira hyalina.
		nordenskiöldii.
	North Temperate	Chætoceros danicum.
		debile.
		diadema.
		sociale.
		teres.
		Leptocylindrus danicus.
		Licmophora flavellata.
		Nitzschia longissima.
		Rhizosolenia færoeensis.
		setigera.
		Skeletonema costatum.
		Stephanopyxis appendiculatus.
		Synedra gallionii.
		Thalassiosira decipiens.
		Thalassiothrix nitzschioides.
	South Temperate	Asterionella japonica.
		Bacteriastrum varians.
		Chætoceros cinctum.
		contortum.
		didymum.
		laciniosum.
		lorenzianum.
		schüttii.
		Ditylium brightwelli.
		Fragilaria crotonensis.
		Grammatophora marina.
		serpentina.
		Guinardia flaccida.
		Nitzschia paradoxa.
		Rhabdonema adriaticum.
		Rhizosolenia calcar avis.
		delicatula.
		shrubsolei.
		Striatella unipunctata.
		Synedra undulata.
	Tropical	Bellerochea malleus.
		Rhizosolenia calcar avis.
		shrubsolei.

Oceanic	Boreal Arctic	Chætoceros atlanticum.
		boreale.
		criophilum.
		decipiens.
		Nitzschia seriata.
		Rhizosolenia hebetata (semispina).
		Thalassiothrix longissima.
	Temperate	Chætoceros densum.
		peruvianum.
		willei.
		Rhizosolenia alata f. genuina.
		f. gracillima.
		Thalassiothrix frauenfeldii.
	Tropical	Chætoceros coarctatum.
		peruvianum.
	Antarctic	Corethron valdiviæ.

In 1922 the summer swarm was composed almost entirely of members of the genus Rhizosolenia (figs. 15 and 16). *Rhizosolenia semispina* and *R. shrubsolei* appeared about June 15, followed in July by *R. setigera.* The latter two species were never as numerous as the former. *R. semispina* increased rapidly until July 5, when the swarms literally filled the waters of the bay and sound, clogging even the coarsest plankton nets with a slimy brown ooze. Shortly after this it began to decline, disappearing about September 9. The 1923 maximum was very similar, except that the two minor species terminated their season earlier than in the previous year, while *R. semispina* declined more slowly, remaining in small numbers throughout the fall and early winter.

The occurrence of this species at Woods Hole during the summer months is rather interesting. It is a northern oceanic form, known from both the Arctic and Antarctic regions, and was found by Ostenfeld (1913) to thrive best in the areas of the North Atlantic where cold currents seek southward. It is particularly abundant in the spring in the region of the Labrador Current about Newfoundland and Nova Scotia. Bigelow (1917), in July, 1914, found a large maximum off Marthas Vineyard at the time when the great swarms appear in local waters. In 1923 the author found them extending from Cape Cod along the eastern side of Marthas Vineyard to Nantucket and in Vineyard Sound as far as Menemsha Bight. None were found at the western end of the Sound or in the waters about No Man's Land. This indicates that they enter the region from the northeast, as would be expected. Miss Ogilvie (1923) found a maximum in July, 1920, off the south coast of Ireland.

The summer maximum at Woods Hole, then, is not wholly dependent upon local conditions. Either of the two neritic species, *Rhizosolenia shrubsolei* and *R. setigera* might dominate if hydrographical conditions prevented the appearance of *R. semispina.* The abundance of the latter species will depend partly on the numbers blown into the bay and sound and partly upon the food material present there. Although it is a northern form it must have an extremely broad temperature range, because its distribution in Buzzards Bay in 1923 showed conclusively that great production was taking place there at a time when the temperature was ranging from 19 to 21° C.

As the numbers of *Rhizosolenia semispina* diminished in the late summer of 1922, Chætoceros (fig. 19) increased, but lasted for only a short time. Another diatom (*Corethron valdiviæ*) then became very abundant and reached its maximum about September 20 (fig. 10, p. 105). A rapid decline took place after this, followed by another Chætoceros increase. In 1923 Corethron appeared on September 21, reaching its maximum on November 3 (fig. 11, p. 105). All available records for Corethron show it to have its flowering season in the fall. In European waters Ostenfeld (1913) reports it to be most abundant in autumn. Ogilvie (1923) found it abundant on the south coast of Ireland in July, 1920, and in August and November, 1921. Fritz (1921) records it from the Bay of Fundy in October, 1916, and in September and October, 1917.

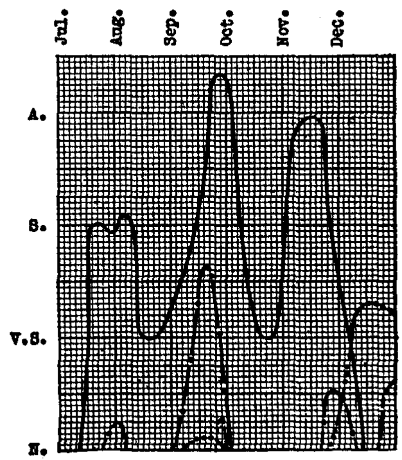

FIG. 19.—Occurrence of the more abundant species of Chætoceros from May to December, 1922. -----, *Chætoceros decipiens;* —•••—, *C. didymum;* —•—, *C. laciniosum;* ——, *C. schüttii;* —-—, *C. sociale*

The winter maximum at Woods Hole consists usually of a greater variety of abundant species than that of the summer. In 1922 many species appeared suddenly about November 8. As the season progressed different forms predominated on different days, but all were usually abundant. At first *Rhizosolenia alata f. genuina*, a temperate oceanic

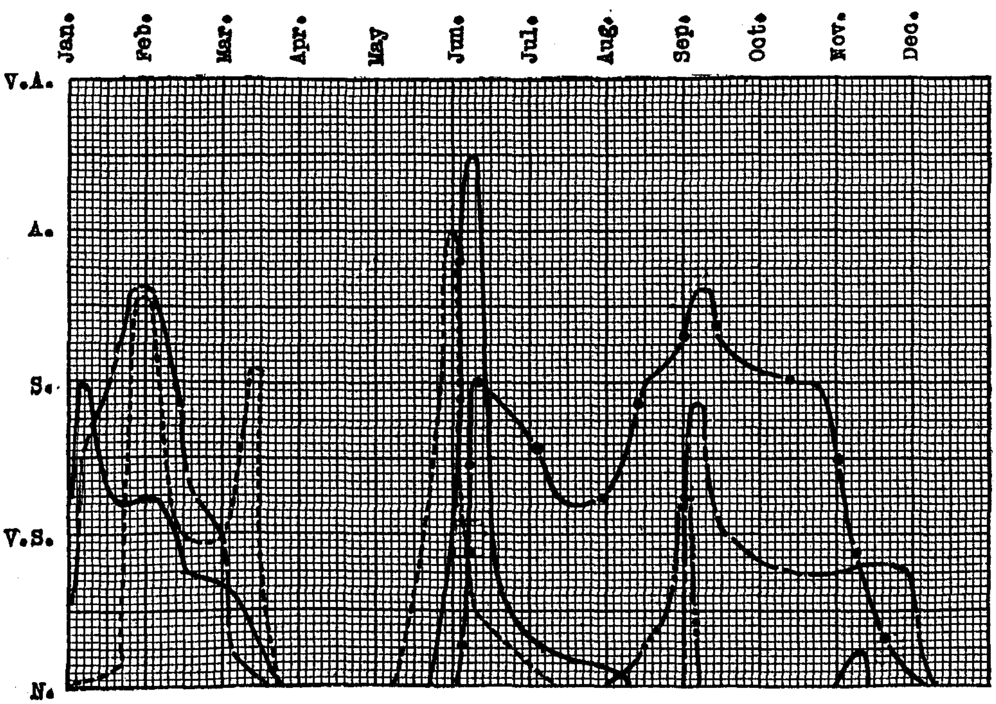

FIG. 20.—Occurrence of the more abundant species of Chætoceros in surface collections of 1923. -----, *Chætoceros decipiens;* ——, *C. didymum;* —•••—, *C. laciniosum;* —•—, *C. schüttii;* —-—, *C. sociale*

species, proved to be the most conspicuous form (fig. 15). Later this was replaced by *Leptocylindrus danicus* and *Skeletonema costatum.* Both of these species are north temperate neritic forms, which are supposed by Ostenfeld to exist all the year round on the bottom, being carried up among the plankton in the flowering season and during high winds. The distribution at Wood Hole appears to substantiate this very well (figs. 10 and 11, p. 105). The winter flowering

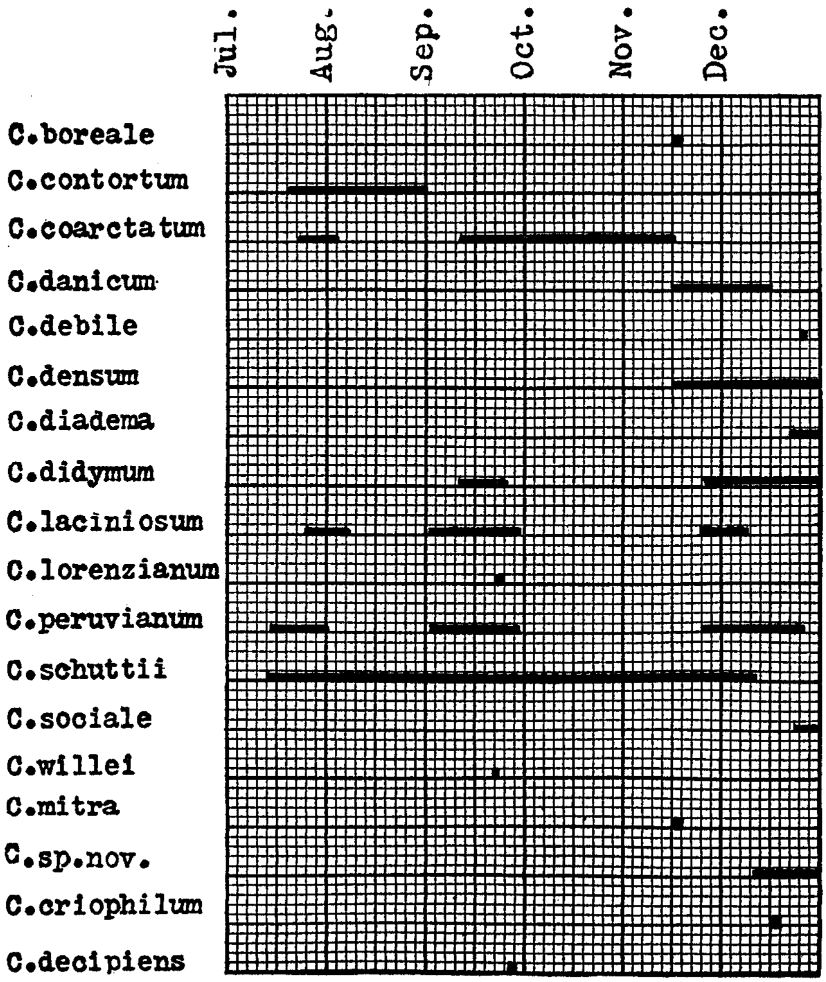

FIG. 21.—Distribution of Chætoceros from June to December, 1922

season is evident, and the scattered occurrence throughout the year can be best explained by Ostenfeld's theory. Although very similar to tychopelagic forms, these two species differ in that they multiply greatly while members of the plankton. Other abundant members of the 1922–1923 winter society were *Ditylium brightwelli, Thalassiothrix nitzschioides, Rhizosolenia setigera, R. shrubsolei,* and *Chætoceros sociale,* all of which are neritic species (figs. 10, 11, etc.). Two oceanic forms

(*Nitzschia seriata* and *Chætoceros decipiens*) were fairly numerous ât times but always played a minor rôle.

As previously stated, unusual physical factors may cause great variation in the time when the maxima appear as well as in the constituent parts. Such was the case in the winter of 1923 (figs. 4 and 5, p. 100), when, after an unusually warm season, although quantitatively the winter diatom maximum was approximately the same as in the previous year, qualitatively it was very different. *Rhizosolenia alata*, the first dominant species to appear in the 1922 swarm, occurred only as scattering forms in 1923; while *Nitzschia seriata*, a rather scanty form in 1922, outnumbered all others during the entire winter maximum by more than 1,000,000 : 1 (fig. 11, p. 105). Certain other members of the 1922 maximum, of which *Ditylium brightwelli* is an example, did not appear at all.

FIG. 22.—Distribution of Chætoceros in 1923

The absence of *Rhizosolenia alata* (excepting scattering forms) might have been caused by the extremely mild weather of the early winter. However, as it is a common oceanic species there are many other factors which may have affected it. Certainly the unusual temperature influenced the neritic forms. During the short time when the temperature was normal in the early fall (fig. 11) many species—*Chætoceros didymum*, Skeletonema, Leptocylindrus, etc. (figs. 21 and 22)—appeared and began their normal flowering season. When the unusual temperature conditions continued, however, they declined and remained as scattering forms or disappeared; but one species, *Rhizosolenia setigera*, which has an extremely wide temperature range (fig. 16), apparently thrived with Nitzschia during the period.

Nitzschia seriata is an Arctic oceanic species which often appears in large numbers off the Norwegian coasts. It is very variable in occurrence, being present some years and entirely absent in others. In all areas investigated it forms its greatest maxima in the spring. In the spring of 1923 it reached its maximum in January, remaining throughout March. The following winter it arrived slightly earlier and increased rapidly, swarming early in November (figs. 10 and 11, p. 105). Throughout the winter season it remained as the most dominant species.

The distribution of diatoms during the past year may have been unusual. Certainly two seasons' changes are not sufficient from which to draw conclusions. However, as all available records for past years seem to indicate similar summer and winter maxima, it is probable that yearly variations will be in the date of the appearance of these same species and not so much in the species themselves. Winds may carry in unusual oceanic species, but these may be considered accidental visitors whose appearance again can not be predicted. The following diatoms appeared in surface collections of the past year:

Actinoptychus undulatus (Bailey).
Asterionella japonica, Cleve.
Bacteriastrum varians, Lauder.
Bellerochea malleus (Brightwell).
Biddulphia alterans (Bailey).
B. biddulphiana (Smith).
B. favus (Ehrenberg).
B. granulata, Roper.
B. rhombus (Ehrenberg).
B. vesiculosa (Agardh).
Cerataulina bergonii, Peragallo.
Chætoceros atlanticum, Cleve.
C. boreale, Schütt.
C. cinctum, Gran.
C. coarctatum, Lauder.
C. contortum, Schütt.
C. criophilum, Castracane.
C. danicum, Cleve.
C. debile, Cleve.
C. decipiens, Cleve.
C. densum, Cleve.
C. diadema (Ehrenberg).
C. didymum, Ehrenberg.
C. laciniosum, Schütt.
C. lorenzianum, Grunow.
C. mitra (Bailey).
C. peruvianum, Brightwell.
C. schüttii, Cleve.
C. sociale, Lauder.
C. teres, Cleve.
C. willei, Gran.
Corethron valdiviæ, Karsten.
Cyclophora tenuis, Castracane.
Ditylium brightwelli (West).
Fragilaria crotonensis (M. Edwards).
Grammatophora marina, Kützing.
G. serpentina, Ehrenberg.
Guinardia flaccida (Castracane).
Hyalodiscus stelliger, Bailey.
Leptocylindrus danicus, Cleve.
Licmophora flavellata, Smith.
L. lyngbyei (Kützing).
Melosira borreri, Greville.
Nitzschia closterium, Smith.
N. longissima (Brebisson).
N. paradoxa, Grunow.
N. seriata, Cleve.
Paralia sulcata (Ehrenberg).
Rhabdonema adriaticum, Kützing.
Rhizosolenia alata f. genuina (Gran).
R. alata f. gracillima (Cleve).
R. calcar avis, Schultze.
R. delicatula, Cleve.
R. færœensis, Ostenfeld.
R. hebetata var. semispina (Hensen).
R. setigera, Brightwell.
R. shrubsolei, Cleve.
R. styliformis, Brightwell.
Skeletonema costatum (Greville).
Stephanopyxis appendiculatus, Ehrenberg.
Striatella unipunctata (Lyngbye).
Synedra gallionii, Ehrenberg.
S. undulata (Bailey).
Thalassiosira decipiens (Grunow).
T. hyalina (Grunow).
T. nordenskiöldii, Cleve.
Thalassiothrix frauenfeldii (Grunow).
T. longissima, Cleve and Grunow.
T. nitzschioides, Grunow.

After southerly storms during the summer Vineyard Sound is often filled with floating *Sargassum bacciferum* (Turner). This is a tropical plant from the Gulf Stream, which is usually accompanied by a community of pelagic animals. As it has never been known to reproduce in the region, it is probable that all die in the fall when the temperature of the water drops. Although not true oceanic plankton, this plant must be mentioned, for many pelagic forms enter Woods Hole attached to it. A local species (*Sargassum filipendula* Agardh) is commonly found attached to rocks and piles below the low-water mark in the harbor, but this has no relation to the plankton.

PROTOZOA

The protozoa were omitted in the present investigation, with the exception of the large forms that at times were numerous enough to form an important part of the plankton. Unless special methods are used no real estimate of the abundance of the many minute organisms of this phylum can be made. Lohmann (1911) showed that at least 50 per cent of the living forms entering the finest silk nets available pass through the meshes and escape. It is very possible to grow cultures of protozoa, as Peck has already done at Woods Hole, but it was not my purpose to create artificial complexes, so that method was not employed. It is of value, however, in obtaining many of the rarer species.

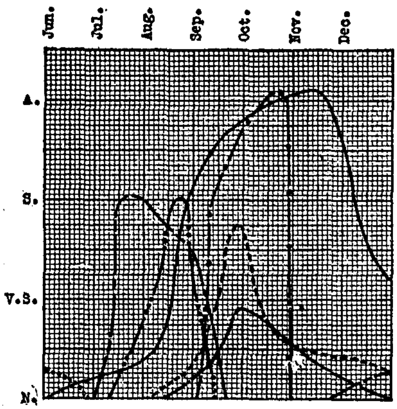

FIG. 23.—Occurrence of most abundant forms of Protozoa in surface collections from June to December, 1922. ———, *Ceratium tripos;* - - - - - - -, *C. macroceros;* — — —, *C. fusus;* ooooooo, *Peridinium depressum;* — - — Tintinnopsis sp.; — • —, *Heterophrys sol;* — • • —, *Peridinium oceanicum* var. *oblongum*

Certain of the larger protozoa were very abundant at times, particularly *Ceratium tripos*, *Peridinium depressum*, *P. oceanicum*, and several species of the genus Tintinnopsis. The distribution of these animals often appears to be very definitely related to that of the plants. During a heavy diatom maximum very few of the larger forms appear, particularly the dinoflagellates. It may be that as soon as the plants have exhausted their food supply and disappeared the protozoa that utilize the nitrates and not the silicates increase rapidly. Just why they should follow immediately after the diatoms is a puzzle, but it is clearly noticeable and can readily be seen by comparing Figures 15, 16, 23, and 24. Thus, after the great *Rhizosolenia semispina* maximum of the summer, *Ceratium tripos* swarmed, followed closely by *C. macroceros* and *C. fusus* in smaller numbers. These would have reached a maximum earlier, I believe, had it not been for the influx of *Corethron valdiviæ*, which came in September, 1922 and 1923. For that reason their normal high point was never reached. Throughout November and December, 1922, they declined as the winter diatom maximum increased, disappearing shortly before the diatoms ceased in April. This may have been caused by the gradual rise in temperature at that time.

Within three days after the bulk of the diatoms disappeared two species of protozoa fairly swarmed in the plankton. The most abundant of these was an unidentified species of the genus Tintinnopsis, although the other (*Peridinium depressum*) was also taken in great numbers. Hundreds of the thimblelike cups of Tintinnopsis could be seen at one time in the field of the microscope. Certain other forms were noticed at different periods throughout the year, but they never formed an important part of the plankton.

A second species of Peridinium (*Peridinium oceanicum* var. *oblongum*) had a maximum in the fall of both years. This is a much smaller form than *P. depressum* and was never present in such large numbers. In 1922 it appeared on July 9, reaching its maximum late in August and disappearing about Spetember 15. In 1923, as in the case of almost all the planktonic forms of that season, the period was later, commencing about September 2 and remaining until November 20.

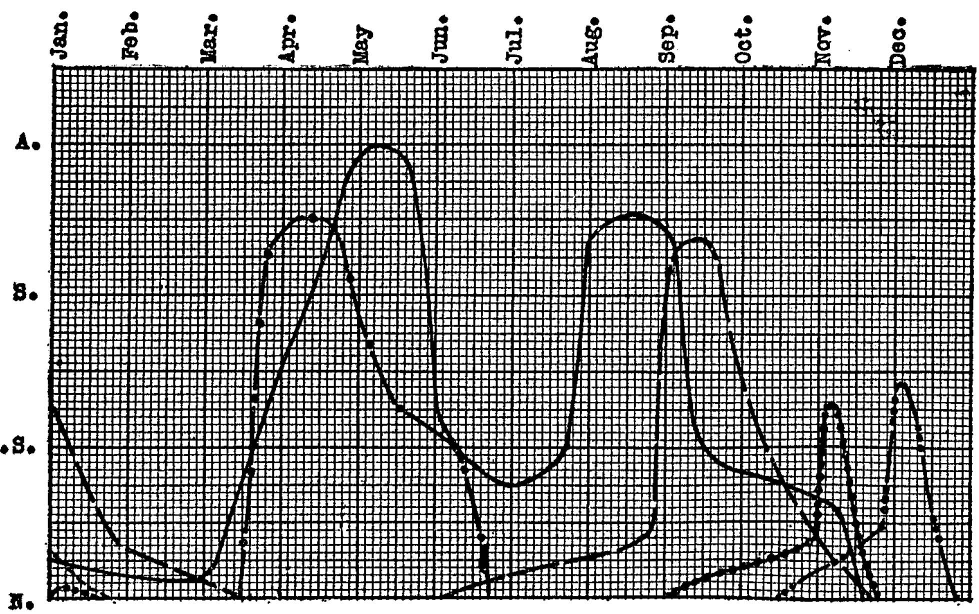

FIG. 24.—Occurrence of most abundant forms of Protozoa in surface collections of 1923. ———, *Ceratium tripos;* - - - - - - -, *C. macroceros;* —• • • —, *C. fusus;* —•—, *Peridinium depressum;* -•-•-•-•-, *P. oceanicum* var. *oblongum;* ——, Tintinnopsis sp

During the fall maximum of Ceratium the water fairly blazed with light when disturbed. They caused the net to gleam like a lantern, and often bottom forms not normally taken at the surface were attracted to it.

An interesting radiolarian (*Heterophrys sol*) also occurred in the fall. During September and October, 1922, the numbers gradually increased until they became exceedingly abundant, often being found in bunches of 20 or 30 specimens. After the 26th of October the number rapidly diminished until November 1, when the last one was seen. None appeared in the collections of 1923.

Of the Silicoflagellata, *Distephanus speculum* and *Dictyocha fibula* occurred as scattering individuals throughout the year except in the warmest months. Distephanus was most abundant from November, 1922, to March, 1923, and Dictyocha appeared from September to May. Many Foraminifera appeared, usually after a storm. These, however, sank quickly to the bottom again and were rarely taken in surface collections in calm weather. Some six species were distinguished, but positive identification was impossible because there was not sufficient literature available at the time.

The following protozoa were identified from the surface collections of 1922–23:

Acineta tuberosa, Ehrenberg. March 4, 1923.
Ceratium fusus (Ehrenberg). See Figures 23 and 24.
C. longipes (Bailey). February to June, 1923.
C. macroceros (Ehrenberg). See Figures 23 and 24.
C. tripos (Müller). See Figures 23 and 24.
Dictyocha fibula, Ehrenberg.
Distephanus speculum, Hæckel.
Glenodinium compressa, Calkins. March 4, 1923.
Gonyaulax tricantha, Jörgensen. April 21, 1923.
Gymnodinium gracile, Bergh.
Heterophrys sol, Ehrenberg.
Peridinium depressum, Bailey. See Figures 23 and 24.
P. oceanicum var. oblongum, Aurivillius. Figures 23 and 24.
Tintinnopsis davidoffi, Daday. October 14, 1922.
Tintinnopsis sp. See Figures 23 and 24.

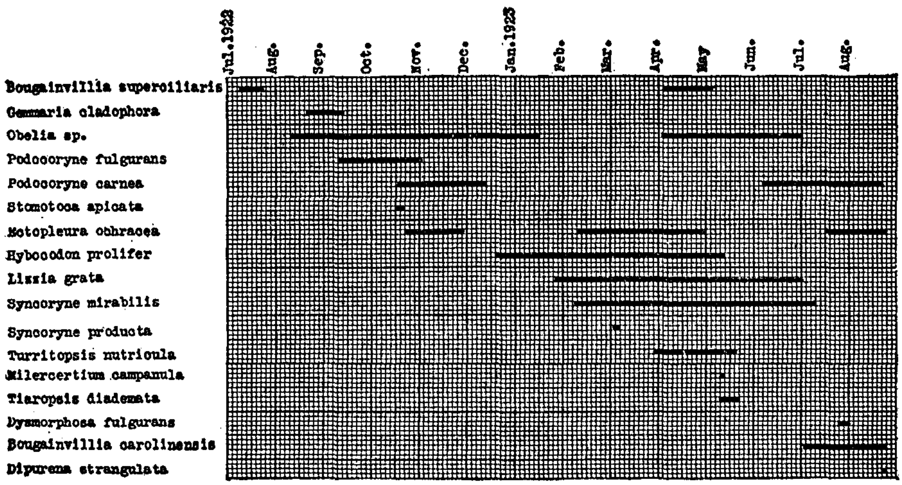

FIG. 25.—Occurrence of Hydromedusæ in surface collections from June, 1922, to December, 1923

CŒLENTERATA

One hundred and sixty species of cœlenterates were recorded from the Woods Hole region by Sumner. Of these, 132 were Hydrozoa, 5 were Scyphoza, and 8 were Ctenophora. Thirty-eight species are listed in the tow records of Vinal N. Edwards for the years 1893–1907. Figures 25, 26, and 27 show the maximum occurrence of the more common species, while in Table 4 the rarer forms, together with the particular dates of appearance, are noted. The records of the more common Scyphomedusæ and ctenophores are also recorded on individual charts.

The diagrams show clearly that there are definite seasons of occurrence for the various species of cœlenterates. In most cases the species have a long spring maximum and also a short one in the fall. Such a semiannual appearance is not

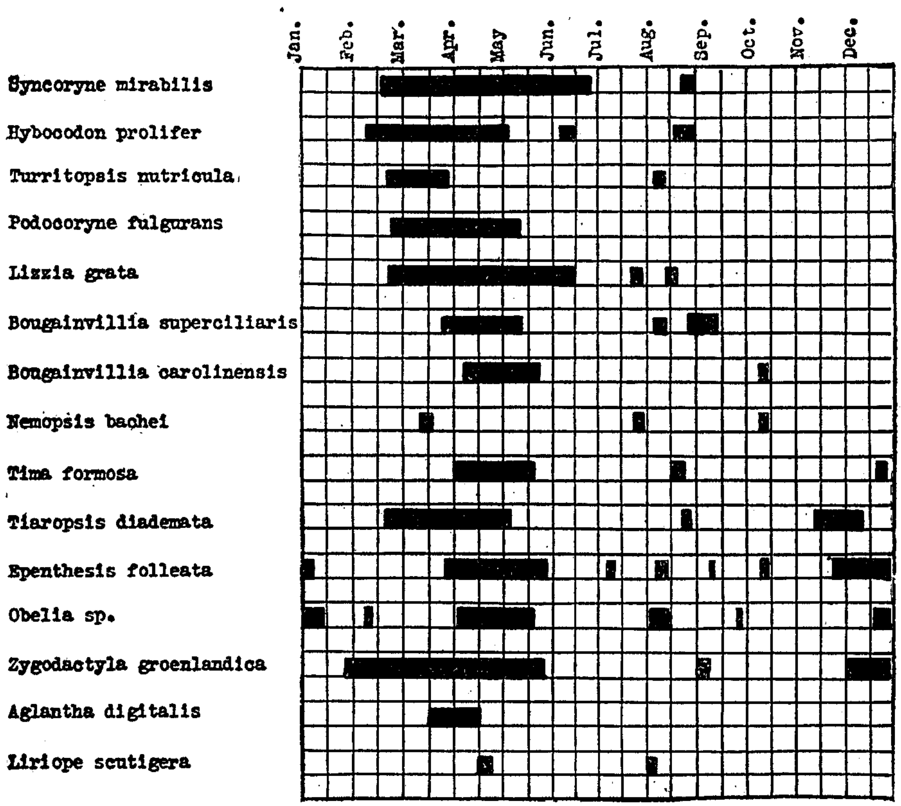

FIG. 26.—Hydromedusæ occurring commonly in surface towings. Maximum occurrence based on records of years 1893 to 1907

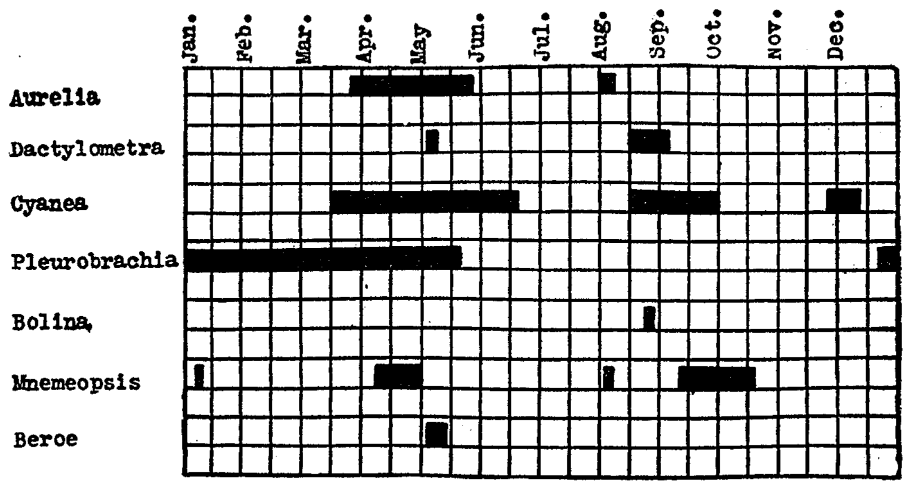

FIG. 27.—Maximum seasonal distribution of Scyphomedusæ and Ctenophora, based on records of the years 1893 to 1907. See individual charts for Aurelia, Pleurobrachia, and Mnemeopsis

common among marine animals. *Bougainvillia superciliaris*, *Hybocodon prolifer*, *Nemopsis bachei*, *Tiaropsis diademata*, *Podocoryne fulgurans*, and *Tima formosa* are examples of Hydromedusæ having double seasonal distribution. However, hardly a single species that occurs normally in the spring has not also been taken in small numbers in the fall. With the exception of *Podocoryne carnea* none of the summer visitors have this biannual appearance.

A regular progression of the more common species of Medusæ can usually be noticed in the spring. *Hybocodon prolifer* appears first, followed closely by *Syncoryne mirabilis* and *Lizzia grata*. In early July, as these species reach the end of their season, *Podocoryne carnea* and *P. fulgurans* appear, followed in August by *Dipurena strangulata* and *Bougainvillia carolinensis*. The summer and fall species always occur in smaller numbers than the spring forms. Certain forms appear to be distributed throughout the year. *Epenthesis folleata* has been recorded for almost every month.

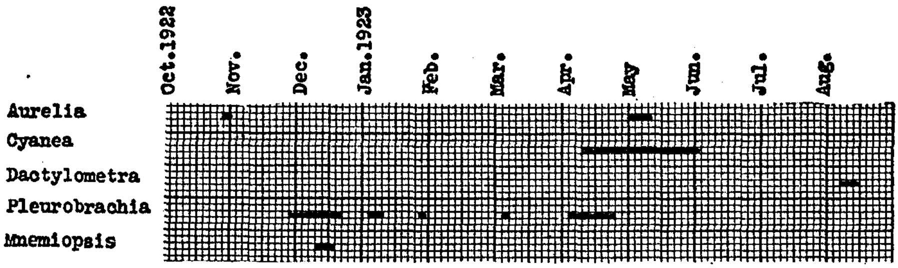

FIG. 28.—Occurrence of Scyphomedusæ and Ctenophora in surface collections from June, 1922, to December, 1923

Three species of Scyphomedusæ are taken frequently in surface collections (fig. 28). The most common (*Aurelia flavidula*) appears usually in March, April, and May, although ephyræ have been taken from August to October.

TABLE 4.—*Occurrence of uncommon Hydromedusæ in surface towings*

Species	Date	Abundance
Ectopleura ochracea	Aug. 9, 1904	Few.
Corymorpha pendula	Apr. 28 and 29, 1905	Many.
Stomotoca apicata	Apr. 27, May 1, and Aug. 15, 1903	Few.
Staurostoma laciniata	Apr. 9, 1906	Do.
Eutima mira	Apr. 7, 1902	Many.
Oceania languida	May 16 and 17, 1904	Do.
Genus Clytia (probably C. bicophora)	May 16, 1905	Few.
Rhegmatodes tennuis	Sept. 2 and 14, 1907	Many.
Aglantha conica	Apr. 24, 25, and 30, and May 2, 1906	Few.

Every year in Waquoit Bay immense swarms of strobelias and ephyræ of Aurelia appear before the ice leaves. They also occur in varying abundance in all local protected coves and shallow bays where eel grass (*Zostera marina*) grows in abundance. The young apparently rests on the bottom during the ebb tide, rising with the flood tide. During this period the water is often filled with them, while a few hours later none may be seen. In the spring of 1923 ephyræ were particularly numerous at Waquoit Bay, although only a single specimen appeared in my collections from Great Harbor. By April the medusæ had increased in size, varying from 1 to 3 inches in diameter. Shortly after this they disappeared. The disappearance probably took place when all strobilization had stopped and the currents carried the medusæ away. Occasionally at a later date swarms of large adults have been seen in Vineyard Sound or Buzzards Bay. No adults were noted during the past summer (1923) in local waters, although large swarms of mature Aurelia were seen on two occasions in neighboring localities—Mount Hope Bay on July 14, and at the entrance of Oyster Bay in early August.

It is difficult to understand how the planulæ get back into the harbors (particularly Waquoit Bay) in such large numbers when apparently no adults remain in the region. The eggs can not be deposited before the medusæ leave in the summer because the animals are not mature at the time. I have never seen a mature specimen in Waquoit Bay. There seem to be but two possibilities—either enough adults remain in the bay until the breeding season (perhaps on the bottom) to repopulate it or the planulæ are drifted in by the tide. I believe that the first assumption is more probable; that is, that sufficient adults remain to restock the waters even though none may be seen at the surface. The difficulties besetting the second possibility make it almost impossible except under rare conditions when Vineyard Sound is filled with adult Aurelia at the correct time. In the first place the medusæ are entirely at the mercy of the winds and tides. They may be widely scattered in coastal waters or piled together in great banks, as described by Hargitt and Agassiz. The latter author considered that the animals gathered together in the breeding season, but this is not probable. After storms large numbers of disks, minus lobes and tentacles, of both Aurelia and Cyanea are often found at the surface in local waters. All are destroyed before winter arrives. As the sexes are separate in Aurelia it is largely a matter of chance whether fertilization takes place at all, because the adults are likely to be widely separated before reaching sexual maturity. Under these conditions it would hardly be possible for the species to maintain itself, because it is apparently beset with more difficulties than the cod and has a proportionately much smaller number of eggs. Therefore, the few adults that remain in the bays may serve to maintain the species during seasons when fertilization in the open waters is impossible, while a fortunate gathering of adults during the breeding season may account for the enormous swarms present in certain years. This dependence on a chain of circumstances to bring the sexes together at the right time probably goes far to explain the irregularities in this and allied neritic species.

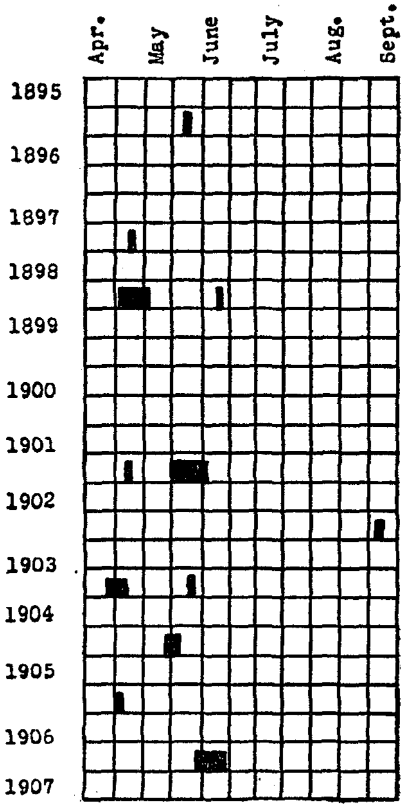

FIG. 29.—Occurrence of *Aurelia flavidula* during successive years, 1893 to 1907

Cyanea capillata appears commonly in spring and fall, but not in as great numbers as Aurelia. On April 14, 1923, the first specimen appeared. Throughout May and early June specimens varying from 10 to 50 mm. could be seen daily at the surface in Great Harbor, often in large numbers. Alexander Agassiz observed great numbers of Cyanea at the surface between 4 and 5 a. m. at Provincetown. "By 7 a. m. all had returned to deeper waters, although not a breath of air had disturbed the surface." A variation in abundance was clearly noticeable in local waters during the past year, but the vertical migration did not affect the whole group, some specimens occurring at the surface throughout the day. Their numbers increased rapidly, however, during the flood tide. It may be that Agassiz's observa-

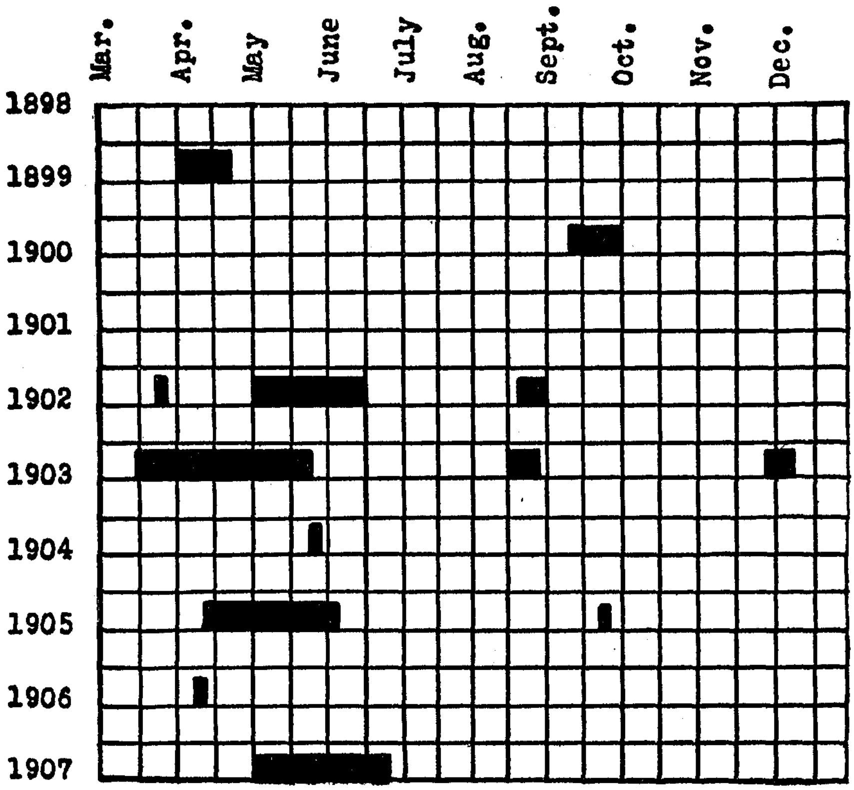

FIG. 30.—Occurrence of *Cyanea capillata* during successive years, 1893 to 1907

tions could be explained on that basis. Unfortunately no records of the tide were given.

Dactylometra quinquecirra occurs occasionally in Vineyard Sound and Buzzards Bay, although in very small numbers. In Narragansett Bay it is usually very abundant in September and October. On August 8, 1923, a single specimen was taken in Lackeys Bay, and several days later a few were observed in Vineyard Sound. George Gray records large numbers taken on several occasions, together with *Salpa democratica-mucronata*, off Nonamesset Island at the mouth of Great Harbor. This species is known to be nocturnal, and for this reason the local appearance may be greater than the records indicate because very little night collecting has been done except from the Fisheries dock. This species appears to prefer the relatively impure water of bays and rivers, rarely being taken in coastal waters.

Ctenophora present a very difficult problem to anyone attempting to determine seasonal distribution. They are found scattered throughout the year in many places. In this region the limits of the seasonal appearance are very definite, although the abundance varies greatly. *Pleurobrachia pileus* (figs. 27, 28, and 31)

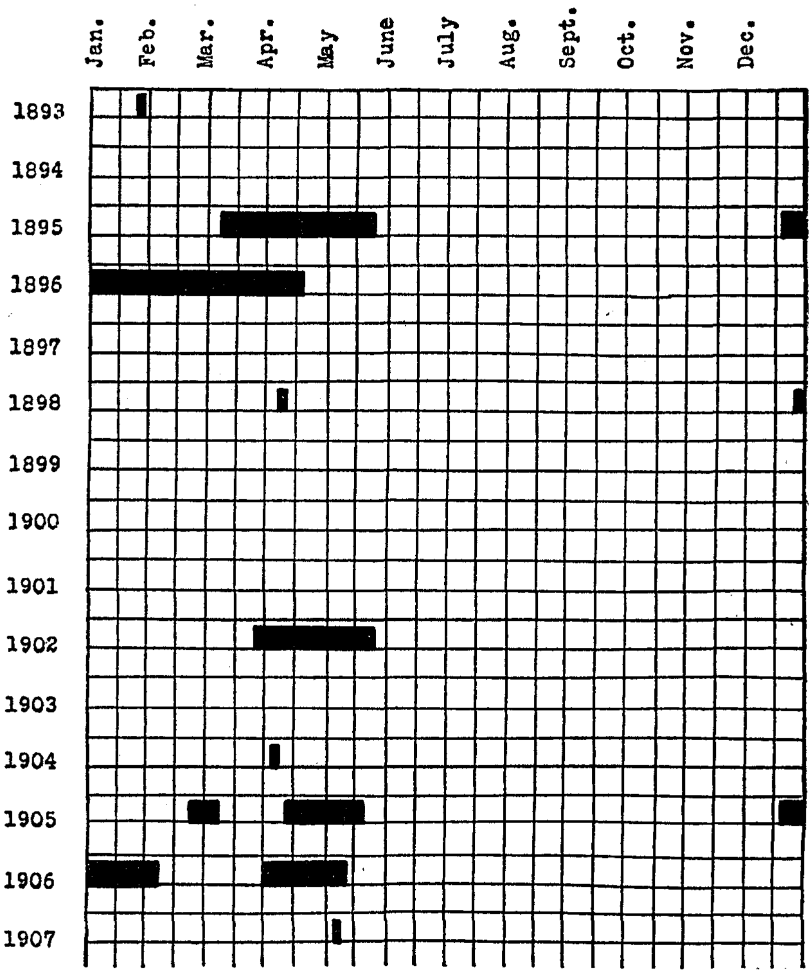

FIG. 31.—Occurrence of *Pleurobrachia pileus* during successive years, 1893 to 1907

appears in late December and remains until the latter part of May. The occurrence during 1923 was very scattered. For a few weeks in December, 1922, they were abundant in all collections and then diminished gradually until February. From February until April few were seen, but on April 1 many appeared and remained throughout the month. In certain seasons immense swarms occur. During the latter part of April, 1895, Mr. Edwards often noted that the nets filled in a few minutes with these jelly-like organisms.

Mnemiopsis leidyi appears in smaller numbers at Woods Hole. In Long Island Sound there is a very large fall maximum in August and a large winter maximum in December and January. They are rarely found in Buzzards Bay in large numbers, and were taken in only 3 years during the 15 for which the author has records. During the past year a single specimen appeared on December 11 and three on December 15. Cape Cod is, no doubt, the northern limit of this species, and its appearance in local waters depends upon the winds. Specimens taken this spring were stragglers from the winter maximum of more southern waters. No remnants of the fall maximum found their way into Great Harbor in 1922 (figs. 27, 28, and 32).

Bolina alata has been taken at Woods Hole in September by Mr. Edwards. Agassiz described it as being one of the commonest species in Massachusetts Bay, but rare south of Cape Cod. None was seen in Great Harbor during the past year.

Beroe cucumis is usually very rare in this region, although Mr. Gray found it abundant on one or two occasions in late April and May. It is a northern form

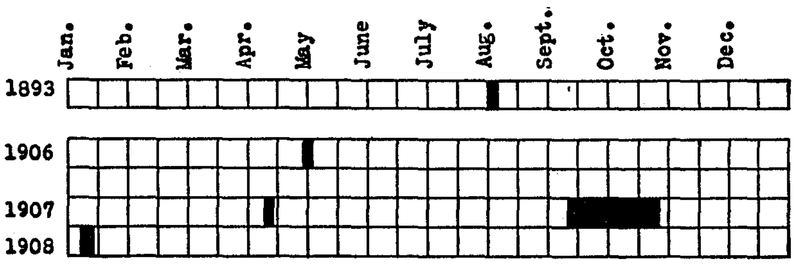

FIG. 32.—Occurrence of *Mnemiopsis leidyi* during successive years, 1893 to 1908

whose appearance in local waters is accidental, depending upon strong easterly winds.

The following cœlenterates appeared during the years 1922 and 1923:

Hydromedusæ:
- Bougainvillia carolinensis (McCrady).
- B. superciliaris, Agassiz.
- Dipurena strangulata, McCrady.
- Ectopleura ochracea, Agassiz.
- Gemmaria cladophora, Agassiz.
- Hybocodon prolifer, Agassiz.
- Lizzia grata, Agassiz.
- Melicertum campanula, Agassiz.
- Obelia sp.
- Podocoryne carnea, Sars.
- P. fulgurans (Agassiz).
- Stomotoca apicata (McCrady).

Hydromedusæ—Continued.
- Syncoryne mirabilis, Agassiz.
- S. producta, Hargitt.
- Tiaropsis diademata, Agassiz.
- Turritopsis nutricula, McCrady.

Scyphomedusæ:
- Aurelia flavidula, Peron and Lesueur.
- Cyanea capillata, Eschscholtz.
- Dactylometra quinquecirra (Desor).

Ctenophora:
- Mnemiopsis leidyi, Agassiz.
- Pleurbrachia pileus (Fabricius)

Cœlenterates recorded from 1893 to 1907 were:

Hydromedusæ:
- Aglantha conica, Hargitt.
- A. digitalis, Müller.
- Bougainvillia carolinensis (McCrady).
- B. superciliaris, Agassiz.
- Clytia (probably C. bicophora), Agassiz.
- Corymorpha pendula, Agassiz.
- Ectopleura ochracea, Agassiz.
- Epenthesis folleata, McCrady.
- Eutima mira, McCrady.
- Hybocodon prolifer, Agassiz.
- Liriope scutigera, McCrady.
- Lizzia grata, Agassiz.
- Nemopsis bachei, Agassiz.
- Obelia sp.
- Oceania languida, Agassiz.
- Podocoryne fulgurans (Agassiz).
- Rhegmatodes tenuis, Agassiz.

Hydromedusæ—Continued.
- Staurostoma laciniata (Agassiz).
- Stomotoca apicata (McCrady).
- Synocoryne mirabilis, Agassiz.
- Tiaropsis diademata, Agassiz.
- Tima formosa, Agassiz.
- Turritopsis nutricula, McCrady.
- Zygodactyla grœnlandica (Peron and Lesueur).

Scyphomedusæ:
- Aurelia flavidula, Peron and Lesueur.
- Cyanea capillata, Eschscholtz
- Dactylometra quinquecirra (Desor).

Ctenophora:
- Beroe cucumis, Fabricius
- Bolina alata, Agassiz.
- Mnemiopsis leidyi, Agassiz.
- Pleurobrachia pileus (Fabricius).

ANNULATA AND VERMES

The free-swimming annelids may be grouped under three headings—true pelagic adults, benthonic adults swimming during their breeding season, and the early larval stages of all marine Polychæta. A fourth group may be added in this case to include the bottom forms carried by strong currents during storms.

Of the true pelagic annelids only one species occurs frequently in the waters of Buzzards Bay and Vineyard Sound, although Moore (1903) has described two other types from this region. *Tomopteros helgolandica* is taken from December to April at Woods Hole. During seasons when southerly winds are prevalent they have been taken in considerable abundance. The greatest number recorded was in 1906, when many specimens were taken almost daily throughout April until May 2. During the spring of 1923 there were almost no winds from the south, and as a result oceanic forms have been rare. One specimen of Tomopteros appeared on February 5, that being the only specimen taken during the year.

Benthonic annelids often appear at the surface in great numbers, particularly in the evening, during their breeding season. In the groups where the sexual products are discharged directly into the water the active period is comparatively short, sometimes lasting less than a week. This occurs in the various species of the family Nereidæ. The adults swarm at certain definite places, usually along sandy beaches or protected harbors, and literally fill the water with cloudy masses of eggs and sperm.

From July 20 to 24, 1922, *Nereis limbata* swarmed in immense numbers at the surface in the eel pond. A few were noticed at other spots along the shore, but none appeared in the daily surface collections. On April 1, 1923, the beach at Nobska Point was the scene of a swarming of *N. virens*. On many occasions during the first two weeks of April ripe males were seen swimming among the Fucus about the Fisheries dock. In this case, as in the case of *N. limbata,* free-swimming larvæ appeared in great numbers in the tow, but few adults were taken. The usual swarming season for *N. limbata* ranges from June to September. A few adults of *N. pelagica* were taken during the year, but none of these contained ripe sex products. The breeding season of this species is in August and September. *Platynereis megalops* is also commonly taken at the surface from July to September. Although the young were taken on several occasions, but one adult appeared in the collections

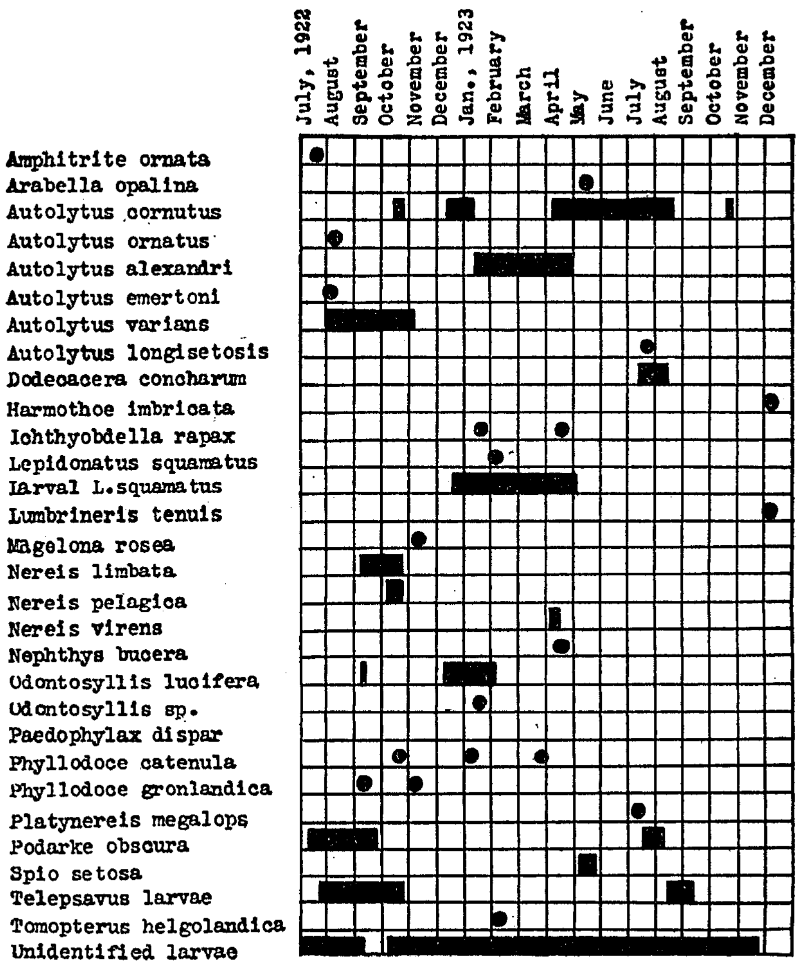

FIG. 33.—Occasional occurrence of annelids in surface collections from June, 1922, to May, 1923.
●, single specimen taken

of the past two summers. All of the members of this family undergo extensive physical changes in adapting themselves for pelagic life during the breeding period. The anterior, nonsexual part remains the same, but in the posterior, sexual region the parapoda become broad and flat and the chætæ increase greatly in length. In this form the worm is known as Heteronereis and is able to swim very rapidly.

In contrast to the Nereidæ stand the families Syllidæ and Hesionidæ. The different species of Autolytus carry their eggs and swim about for varying lengths of time, often occurring for periods of more than four months. For the greater part of the year they remain attached to hydroids and algæ on rocks and piles as nonsexual individuals. In this form they are not free-swimming and their occasional appearance in surface collections is accidental. In the breeding season certain of these nonsexual individuals develop eggs in the posterior part of the body (posterior to the gizzard), while others develop sperm. Strobilization then occurs, and sexual individuals, which immediately become pelagic, are broken off. The females that break off carry clusters of eggs in a pouch on the ventral side. The stolons are either male or female, the two sexes never developing from the same stalk. Occasionally chains of five or six worms, which have not yet separated, may be seen at the surface. Free-swimming males and male chains are usually more abundant than the females. Alexander Agassiz fully described this alteration of generations in 1862. The sexual species of Autolytus are highly phosphorescent and are often extremely numerous in the tow.

Podarke obscura is a very characteristic member of all evening surface collections of the summer. On calm, dark nights swarms of them appear at the surface in protected harbors. The first specimen taken in 1922 appeared on July 6, the last on September 27. In the strong currents about the collecting station the occurrence of Podarke was more scattering than is usual, although many were carried into the nets during both day and night. In daylight, however, the number was much smaller, because at that time the adults seek protection under rocks and among the Fucus.

Larvel annelids appear in the plankton at all seasons of the year. During the early spring they form almost the only representatives of the benthos in the tow. A very small percentage of the species has been worked out, and for that reason it has been impossible to identify a large number of the larval forms that were taken during the past year. Larval Nereis were very abundant during April and May in 1899, 1900, and 1923. These spring forms probably were *Nereis virens*. Another large increase in the latter part of October in each of the years recorded may have been *N. limbata*, although the date is rather late for this species. Such conclusions must remain as mere speculation until further data on the breeding seasons can be obtained. This can readily be realized if one considers that there are six species of the family Nereidæ represented at Woods Hole, and larval Nereidiformia have been taken in every month of the year except September.

Two very characteristic larval annelids appear each year in large numbers. The first occurs in late July and continues throughout October. Fewkes has described it from Newport as a species of the genus Telepsavus. His identification is doubtful, however, for no adult of the species has been recorded from this section of the Atlantic coast. In 1922 it appeared first on July 26 and continued to be taken until October 25. The second larvæ (*Lepidonatus squamatus*) appeared first on December 19. Throughout the spring it was taken daily in large numbers. The season lasted until the last of April. This fact is rather unusual for Sumner records the breeding season as late April, May, and June. An adult female of this species taken on February 2, 1923, was filled with ripe eggs. During May and June, 1922, no larvæ appeared in the surface collections. From these observations the breeding season is seen to be much more extended than has hitherto been supposed.

Occasionally postlarval forms occur after northeast storms. As these are not true free-swimming larvæ they are listed with adults taken under similar conditions. During the past year several nonplanktonic annelids have been taken. Certain of these may swim freely in their breeding season, but the occurrence in the collections was so scattering that I have not considered it as normal. *Dodecacera concharum* offers a peculiar problem. Scattered specimens, often quite numerous, varying from 15 to 20 mm. in length, appeared from July 16 to August 15, 1923. The presence of these immature specimens over such an extended period of time could hardly have been accidental, and yet Dodecacera is known to be a truly benthonic annelid.

Comparatively few leeches have been taken from the Woods Hole region. Sumner records five species, all of which were taken from fish. One species (*Ichthyobdella rapax*) appeared twice in the surface collections of 1922–23—once on January 20 and once on April 7. Both occurrences were during the breeding season of the winter flounder (*Pseudopleuronectes americanus*). Former records give the summer flounder as its host, but it is highly probable that it will be found on both species.

The following annelids were taken in 1922–23:

Amphitrite ornata (Leidy).
Arabella opalina (Verrill).
Autolytus cornutus, Agassiz.
A. ornatus, Verrill.
A. alexandri, Agassiz.
A. emertoni, Verrill.
A. varians, Verrill.
A. longisetosis, Agassiz.
Dodecacera concharum, Öersted.
Harmothöe imbricata, Malmgren.
Ichthyobdella rapax, Verrill.
Lepidonatus squamatus, Leach.
Lumbrineris tenuis, Verrill.
Magelona rosea, Moore.
Nereis limbata, Ehlers.
Nereis pelagica, Linnæus.
N. virens, Sars.
Nephthys bucera, Ehlers.
Odontosyllis lucifera, Verrill.
O. sp.
Pædophylax dispar, Webster.
Phyllodoce catenula, Verrill.
P. grönlandica, Öersted.
Platynereis megalops (Verrill).
Podarke obscura, Verrill.
Spio setosa, Verrill.
Telepsavus larvæ?
Tomopterus helgolandica, Greef.
Unidentified larvæ of several species.

Sagitta is the only true pelagic representative of the phylum Vermes found in this region. It usually appears in December and remains until June. In listing the Sagittæ of past years no attempt was made to distinguish between *Sagitta elegans* and *S. serrodentata*. The former is more littoral and northern in its distribution, while the latter is a southern oceanic form often occurring in the Gulf Stream. During the spring of the present year (1923) no specimens of *S. serrodentata* were taken. This may be explained by the fact that the prevailing winds have been from the north and comparatively few oceanic forms of any sort have found their way in. However, since *S. serrodentata* forms such an unimportant part of the outside plankton, its presence in the region of Woods Hole is, no doubt, so rare that the distribution curve of Sagitta for any year can be considered to be the seasonal variation of *S. elegans*. A sudden appearance after July and before November would probably follow a southwest wind, and in this case the species might be *S. serrodentata*, although deep-water collections off the coast in warm weather often reveal large numbers of *S. elegans*. Such a condition may have taken place in August 1903 (see fig. 35). On August 4, 1922, one specimen of *S. serrodentata* was taken and another on August 5.

In the 16 years that *S. elegans* has been recorded, with one or possibly two exceptions, none appeared before November or remained after July. The usual time of appearance is December. In 1899 a few were taken on December 23, and in 1898 many suddenly appeared on December 12. In 1922 two specimens were found on October 4, one on October 5, two on October 10, and gradually increased from then until early December, when large numbers appeared. The highest point is usually reached in February. During this month they swarm.

It is interesting to compare these results with those of Dr. H. B. Bigelow (1914) in Massachusetts Bay. In late December he found *S. elegans* in the tow. Through-

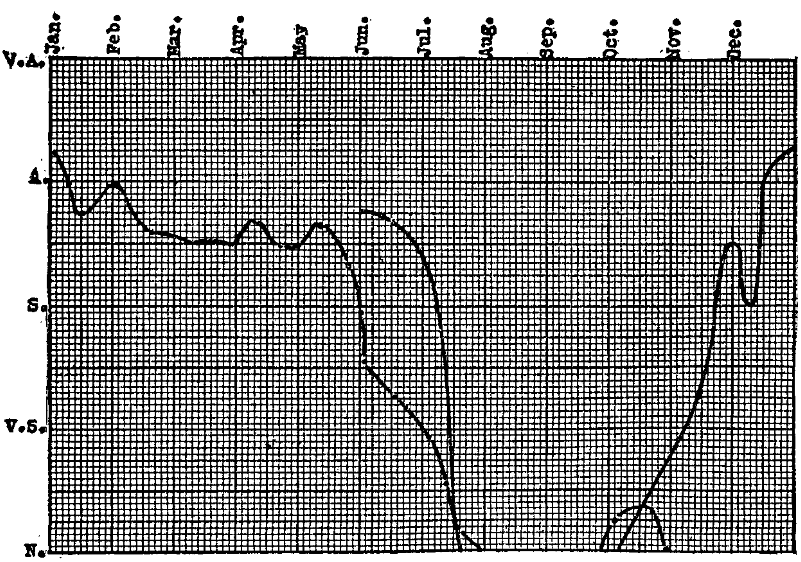

FIG. 34.—Occurrence of *Sagitta elegans* in surface collections from June, 1922, to December, 1923. ——, distribution in 1922; —·—, distribution in 1923

out January and February the numbers increased until they formed the bulk of the plankton. Occasionally *S. serrodentata* was taken, but always *S. elegans* was by far the most abundant. When the water began to grow warmer in early March, the numbers fell off rapidly, so that on March 4 only 12 specimens were taken. The last Sagittæ appeared on April 14. This is merely additional evidence of the similarity of plankton north and south of Cape Cod in winter.

In March and April, 1923, swarms of *S. elegans* with ripe eggs were abundant in Great Harbor. During the latter part of April large numbers of eggs appeared and, together with the eggs of the mollusk *Littorina litorea,* made up the greater part of the tow. On May 2 the first young were observed. These increased rapidly in number and were very abundant throughout May and June. The last specimen was taken on July 18, although the numbers had been very small since June 20. In August, 1923, large numbers of small Sagittæ of the spring brood were taken off No Man's Land in deep water.

Many species of Platyhelminthes and Nemathelminthes have been recorded from surface collections, but these have been accidental in occurrence and, with the exception of certain early larvæ, do not form a part of the littoral plankton. Most members of the phylum, excluding internal parasites, live among the marine plants

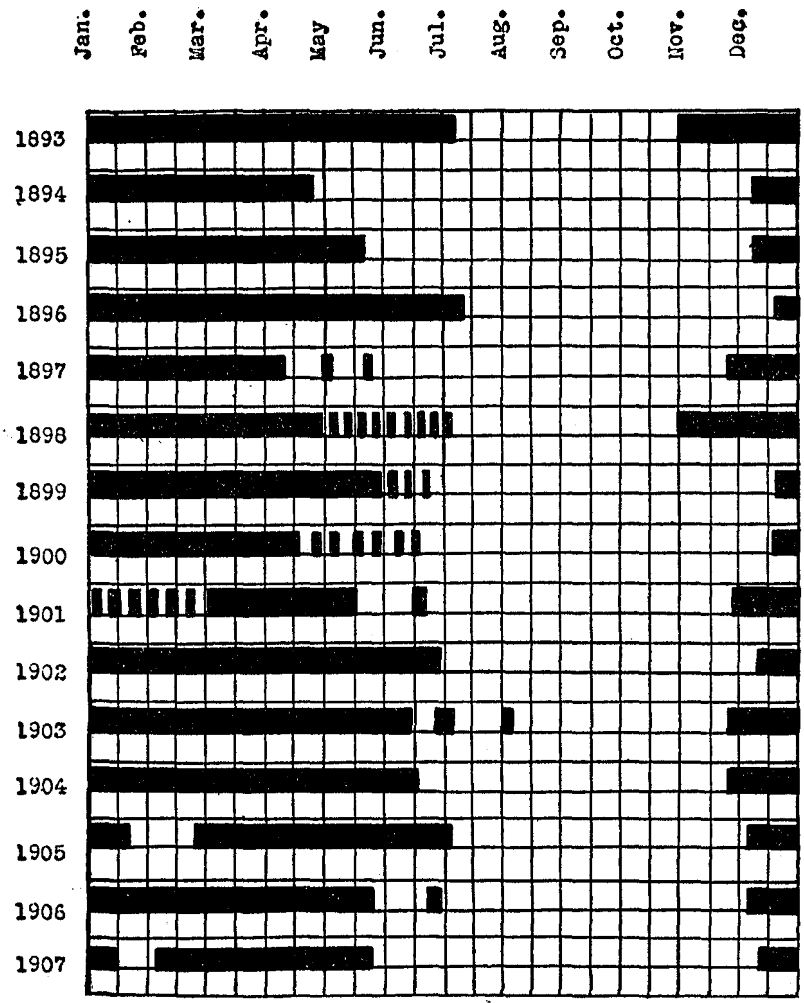

FIG. 35.—Occurrence of *Sagitta elegans* in surface collections during successive years. Broken lines indicate scattering occurrence

and detritus on muddy bottoms or on piles. Some forms like the rotifers, of which a few marine genera occur at Woods Hole, swim about freely, but even these are not a part of the open-water plankton. Only one rotifer (*Synchæta triopthalma* Lauterborn) was observed during the past year, and this was seen but once.

Often in summer planarians appeared, but no attempt was made to identify them. One species, however (*Microstomum davenporti* Graff), was taken in the harbor on two occasions, August 5 and 16, and in the Sound on August 18 and September 21. A single specimen of *Nectonema agile* Verrill was found among much detritus after a hard wind on July 11.

MOLLUSCA

Gastropod larvæ are found throughout the year in all surface collections from inshore waters. There is considerable doubt as to the percentage of forms whose early stages are free-swimming. Many species, such as *Busycon canaliculatum* (Say) and *Buccinum undatum* Linnæus, secrete cases in which the young pass their early stages, emerging in the form of the adults. Others deposit eggs in jelly-like masses attached to the underside of rocks and on marine plants. *Littorina palliata* (Say) is an example of this type. Still other forms, such as *L. rudis* Maton, are viviparous. The eggs of all of these are never found floating, and the young normally do not appear in the plankton. Certain young after emerging from the egg cases may accidentally be carried along by the currents. This probably explains the presence of many species taken during the summer and fall.

A fourth group of gastropods no doubt contribute the bulk of the planktonic larvæ. This group, of which *Littorina litorea* and *Lacuna vincta* are examples, discharge their eggs directly into the sea water. In these two species each egg is especially adapted for floating by a surrounding ring of jelly, which gives the appearance of the trench helmets worn by the American soldiers in the late war. This device serves also as a means of protection. The eggs and free-swimming larvæ are found in great numbers from March until July. This is also the breeding season of *Littorina litorea* in English waters, according to Tattersall, who made extended observations upon that species. *Lacuna vincta* also swarms in February and March, some eggs having been found as early as December by Sumner. The eggs of this species may be distinguished by a light greenish tinge. In March of the present year (1923) great numbers of Littorina eggs appeared daily and increased throughout April. None were found in collections of the previous June. There was a maximum of eggs identical to those of Littorina in the fall, which the author has not been able to identify. There can be little doubt that this floating condition explains the rapid expansion of *Littorina litorea* after it was once established on the western Atlantic coast.

An interesting adaptation to pelagic existence is found in a larval vitrinellid, the species of which I have been unable to ascertain. Shortly after the nucleus has formed, a broad shield grows out as an extension of the shell. This shield appears like the wide brim of a straw hat and enables the larva to float. Later, as older specimens showed, the shield is lost and the young mollusk sinks to the bottom. It is an interesting adaptation and has never before, to my knowledge, been noted.

In the summer of 1922 Dr. Paul Bartsch kindly aided me in identifying the gastropod larvæ that appeared during June, July, and August. The many forms often bear no resemblance to the adults, but are identified by comparing the nuclear whorls. These never change and offer an excellent means of identification. The nucleus is now used as a basis for classification among adult mollusks also.

Apparently none of the larger gastropods have free-swimming stages, the bulk of the summer forms coming from those minute species that live on the floating Fucus and Sargassum. The following gastropods were distinguished in surface collections of 1922:

- Littorina litorea (Linnæus).
- Bittium alternatum, Say.
- Astyris lunata (Say).
- Skenea planorbis, Fabricius.
- A combellid, probably Anachis avara (Say).
- Tritonofusus stimpsoni (Morch).
- Triphoris nigrocinctus, Stimpson.
- Lacuna vincta, Montagu.
- A vitrinellid genus (?).

But one Nudibranch mollusk has been recorded by Edwards from surface collections. This species (*Facelina bostoniensis* (Couthouy)) appears each spring, often in large numbers. This year it appeared on January 21 and continued to be taken until May. Upon examination many females were found to contain dozens of small larvæ, which were very similar in form to the adults. Four other species were represented by single specimens taken during the year—*Elysiella catula* (Agassiz), June 1; *Doto coronata* (Gmelin), September 6; *Alderia harvardiensis* (Agassiz), March 29; and family Dotonidæ, November 8.

Clione limacina (Phipps), a pteropod, is often taken in large numbers around Marthas Vineyard. It is a member of the oceanic plankton and is occasionally blown into Great Harbor during southern storms. The author has five records of its appearance in surface collections. The first four—September 10, 1888, March 20, 1896, April 28, 1911, and May 2, 1911—were taken by V. N. Edwards; the fifth, on May 3, 1918, by R. A. Goffin. Another pteropod (*Heterofusus retroversus* (Fleming)) had been recorded once in local waters (Sumner, 1913a). A single specimen was taken in Great Harbor on January 12, 1924.

The larval Pelecepoda present a most difficult problem to the plankton investigator. The early larvæ all look alike and can be distinguished, with any degree of certainty, only by careful measurements. During the summer the author was able to make few such measurements and for that reason the results are very incomplete. The late larval stages are more easily distinguished. J. Stafford's excellent paper on bivalve larvæ made the identification of these forms a rather simple matter. At this stage, however, the bivalves sink to the bottom and are taken in much smaller numbers.

The most common pelecepods of this region live in the shallow waters of protected bays and harbors. For that reason they are quickly affected by the increase in temperature during the spring. The length of time required for the ripening of the gonads is not known, but many larvæ of *Mytilus edulis* were found early in June, 1922. Later in July larvæ of a slightly different shape were noted. These proved to be the young of both *Venus mercenaria* and *Mya arenaria*. Many Pecten larvæ were taken near Block Island in September, but none appeared at Woods Hole. Mya, Venus, and Mytilus remained throughout the summer and until late in the fall. By August 10 Mytilus had almost acquired the adult shape and appeared less frequently in the collections, although many were taken throughout November and December. By this time the larvæ had long since passed the

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swimming stage and were carried into the nets by the strong currents. No oyster larvæ were noted during the summer of 1922.

Of the Amphineura one species (*Chætopleura apiculata* Carpenter) was taken on September 23, 1922. The larva was at that time in a late stage of development, the shell measuring 1.2 mm. in length. However, the free-swimming period had not ceased, for the little animal continued to float about in a watch glass for several hours.

Throughout the latter part of May and June the eggs of *Loligo pealii* Le Sueur are found in great abundance. Scattering young forms appeared on June 2, 1922, and increased rapidly until July 11, when the largest number was taken. On clear, calm days small schools of these little cephalopods could be seen swimming at the surface in much the same manner as the adults. Such schools were particularly common about the fish traps, where large numbers of adults are frequently captured.

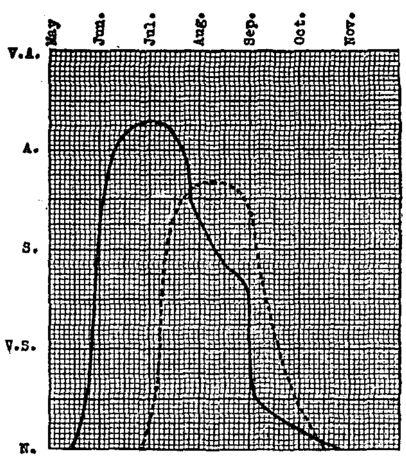

FIG. 36.—Occurrence of larval forms of *Loligo pealii* in surface collections of 1922 and 1923. ———, distribution in 1922; - - - - - - -, distribution in 1923

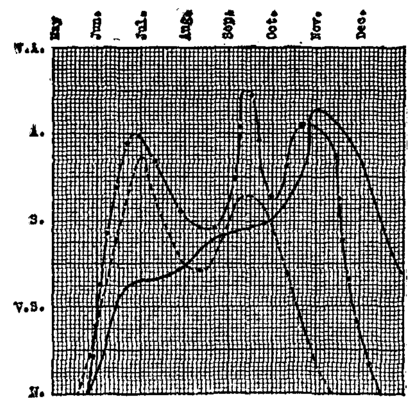

FIG. 37.—Occurrence of Phyllopoda in surface collections from May to December, 1922. —.—, *Podon intermedius;* ———, *Evadne nordmanni;* - - - - - - - -, *E. tergestina*

In August there was a decrease in the abundance. This continued throughout that month and early September. Two specimens were taken in October and one on November 20. The last occurrence is rather surprising, because no young forms had been seen since October 18, and then only one specimen was found. In 1899 the last specimen was taken on October 24. In 1923 the season lasted from June 26 until October 16 (fig. 36).

ECHINODERMATA

Practically all of the echinoderms of the Woods Hole region have a free-swimming stage. A few holothurians and one starfish (*Henricia sanguino lenta* (Müller)), are viviparous, but these are uncommon forms. In certain years great numbers of the larvæ of Asterias have been taken in surface towings. None were found in collections of 1898–99 nor during 1922, although Asterias is known to breed throughout the summer months in this region. In 1923 a single brachiolaria of Asterias appeared on July 16, it being the only specimen taken that year. In Narragansett Bay the season is usually completed in a few weeks in late June; after that hardly a ripe adult can be found. As four species of Asterias have been recorded from Woods Hole it is probable that all do not breed at the same time. This might account for the extended breeding season.

A specimen of *Leptosynapta inhærens* (Müller), 20 mm. long, was taken on September 19 after a hard northeast storm. This was not a free-swimming form and would not normally occur in surface collections.

CRUSTACEA

PHYLLOPODA

Two species of marine Phyllopoda (*Podon leuckarti* and *Evadne nordmanni*) have been recorded from the Atlantic coast of the United States. D. L. MacDonald records three species from St. Andrews, New Brunswick, two of which (*E. spinifera* Müller and *Podon finmarchichus*) have never since been taken. As the name of the original describer does not appear on the list, I am unable to find any other record of *P. finmarchichus*. This name is not given in any available literature on the subject. *E. spinifera* is a southern form that has not appeared in this region during the past year.

Two species of Evadne were taken at Woods Hole in abundance during the summer of 1922. *Evadne tergestina*, new to this region, appeared on May 20, becoming very numerous by July 1. During the summer diatom maximum the numbers decreased but rose again in September. After that they declined until November, the last being recorded on November 15.

Evadne nordmanni appeared shortly after *E. tergestina*, but never became abundant in the summer months (fig. 37, p. 138). In October they increased and reached their highest point about November 1, at a time when *E. tergestina* was fast disappearing. Throughout December they declined rapidly and disappeared about January 20. *E. nordmanni* is easily distinguished by its pinkish color as well as its different appendage formula. *E. tergestina* is usually quite colorless and very transparent.

Podon intermedius was first recorded from the western Atlantic by MacDonald at St. Andrews, New Brunswick. This species appeared in the surface collections of Great Harbor on May 27, 1922, and increased rapidly, reaching a high point in the last week of June. The numbers declined during the period of the diatom swarms, but rose again, reaching the peak in the middle of September. Another diatom maximum in early October reduced the number a second time, but they once more rose and remained until the last of the month. During November *P. intermedius* became scarcer and disappeared about December 15. In general, the season is the same for the various species. *Evadne nordmanni* has the longest occurrence. The distribution of *P. intermedius* in 1923 was very similar to that of the previous year, except that it arrived later (fig. 38).

No specimens of *Podon leuckarti* (Sars) were taken during the past year, and a careful search through the collection of 1899 and 1900 failed to show any, although

Pratt and Sharpe recorded them as occurring in great abundance. No specimens have been placed in the National Museum, and as Sharpe's collections were lost I have been unable to find any identified material. It seems strange, however, that a species not recorded from the region appeared in such great abundance, while the common form was absent during those three years.

On July 28, 1923, *Podon polyphemoides* appeared in the surface tow. No specimens of this species had been observed in the collections of the previous year or in 1899 to 1900. The season was very short, lasting less than four weeks. The last specimen was taken on August 22. At the mouth of New Haven Harbor in Long Island Sound, August 1 to 3, 1923, swarms of this species were observed. They

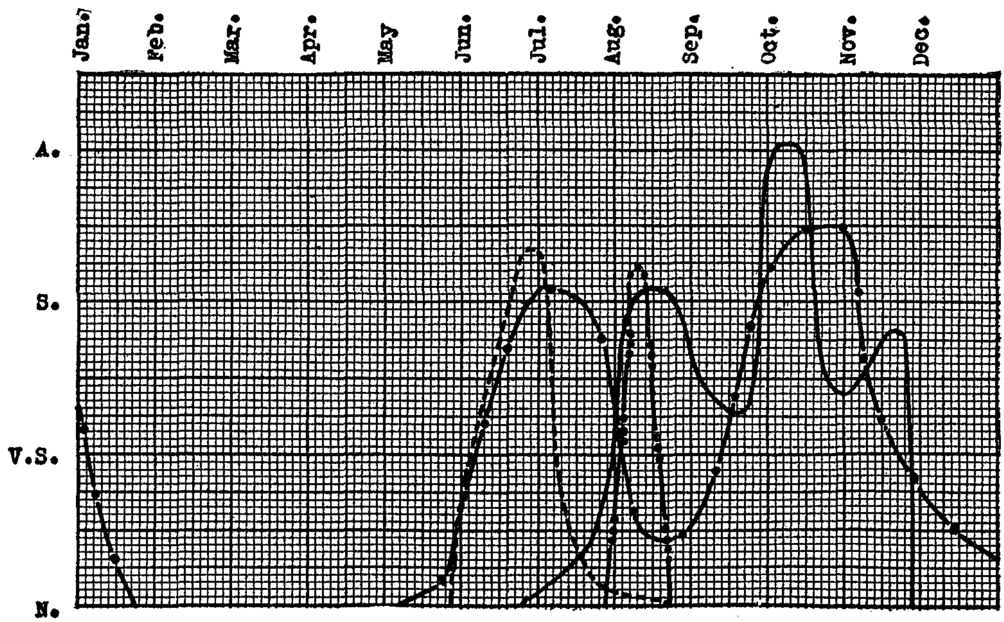

FIG. 38.—Occurrence of Phyllopoda in surface collections of 1923. ——, *Podon intermedius;* —. . . .—, *P. polyphemoides;* —.—, *Evadne nordmanni;* --------, *E. tergestina*

were so numerous that a surface tow of 15 minutes yielded 80 c. c. of *P. polyphemoides* and almost nothing else.

The following phyllopods appeared in the surface collections of 1922–23: *Podon intermedius* Lilljeborg, *P. polyphemoides* (Leuckart), *Evadne nordmanni* Loven, and *E. tergestina* Claus.

OSTRACODA

With few exceptions the ostracods are not true planktonic animals. None of the Woods Hole species belong in the pelagic group, although many appear in surface collections after storms or hard winds, along with particles of sand, Foraminifera, and other bottom forms.

Cushman found that, excepting one specimen, all species of the Myodocopa taken in the survey of Vineyard Sound and Buzzards Bay came from the "Gut of Canso," directly across the harbor from the fisheries station.

In the collections of the past year one of this tribe (*Cylindroleberis mariæ*) appeared with greater frequency than any other one species, even though the Podocopa are much more abundant at certain spots in Great Harbor. This instance shows how easily wrong conclusions may be made in the study of littoral plankton if the bottom fauna is not clearly understood. It illustrates, also, an important point about the fauna of the harbor. The bottom forms dwelling here are so distributed that they are protected from the rushing currents, although they are able to derive benefit from the food material carried by these waters. For that reason, even under unusual conditions, the benthos occurring in surface collections probably is transported from Buzzards Bay. This is quite evident in the case of amphipods where the distribution is very well understood. Even the animals of the "Gut of Canso" are carried away rarely, and the ostracods become dislodged only when the hydroids and Fucus, to which they attach themselves, are torn from their bases.

The following ostracods were taken in 1922–23: *Sarsiella americana* Cushman, *Cylindroleberis mariæ* (Baird), *C. zostericola* Cushman, *Loxoconcha impressa* (Baird), *Cythereis emarginata* Sars, and genus Cythereis (several species).

COPEPODA

Together with the Phyllopoda and an occasional euphausid or hyperid, the Copepoda form the only truly pelagic Crustacea of the local plankton. Except in the seasons of diatom maxima, they are always present in abundance. Farran found that whenever a species is present in sufficient numbers a distinct periodicity in its occurrence is noticeable. This is true at Woods Hole. Although copepods are always present in varying numbers, certain species are continually disappearing and being replaced by others. The copepods of Great Harbor may be divided roughly into two great groups—the summer community and the winter community.

The summer forms may arise from three sources: (*a*) Annual appearance of local coastal species common to the region, (*b*) the young of these common forms, appearing often in large numbers during the breeding season, (*c*) southern oceanic forms blown in by winds from the Gulf Stream during the warm weather.

The first of these sources accounts for most of the summer species. These may again be grouped under two headings: (1) True pelagic species and (2) bottom forms appearing after hard winds. The most typical summer pelagic species are *Acartia tonsa* and *Centropages typicus*. These form the bulk of the summer copepod fauna. Later in the fall *Pseudodiaptomus coronatus* reaches its maximum and outnumbers all other forms. This, however, is not a true summer species, but serves as a connection between the warm and cold water copepods. *Tortanus discaudata* serves in a similar capacity in the spring and early summer. Benthonic adults of the family Harpacticidæ are often taken in surface collections. These are usually found among bottom plants and algæ but are capable of swimming quite as well as the Gymnoplea. The most common summer Copepoda are *Acartia tonsa*, *Centropages typicus*, *Pseudodiaptomus coronatus*, *Labidocera æstiva*, *Oithona similis*, *O. brevicornis*, *Alteutha depressa*, *Parategastes sphæricus*, *Amphiascus obscurus*, *Ilyopsyllus sarsi*, and *Dactylopusia vulgaris*.

The young of the summer copepods never appear in large numbers, as in the case of winter breeders, and only three species—*Acartia tonsa*, *Pseudodiaptomus coronatus*, and *Centropages typicus*—were identified.

The third summer group varies considerably in different seasons. If the prevailing winds through June, July, and August are from the south, great numbers of Gulf Stream forms may appear. Such was the case in 1922, and for that reason several species new to this coast were taken. The common annual visitors also appeared in abundance. The southerly winds did not continue in the fall, however, and the result was that the usual tropical fish and cœlenterates were not observed at Katama Bay and in Vineyard Sound. No doubt these conditionsa ffected copepods as well. As an illustration of this *Microsetella rosea* appeared in great numbers on September 2 in vertical hauls taken off Block Island. Later during this month (fig. 46, p. 145) scattering specimens were observed at Woods Hole. Much larger numbers would probably have been found here if hard south winds had

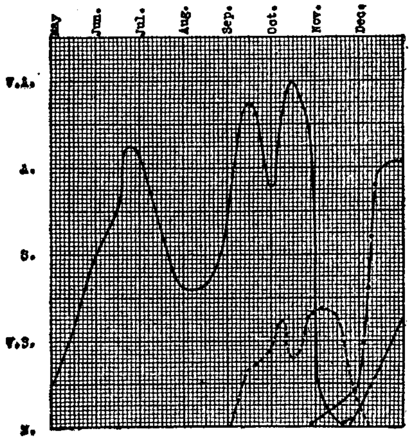

FIG. 39.—Occurrence of species of Acartia in surface collections from June to December, 1922. ———, *Acartia tonsa;* - - - - - -, immature *A. tonsa;* — — —, *A. bifilosa;* —•—, *A. clausii*

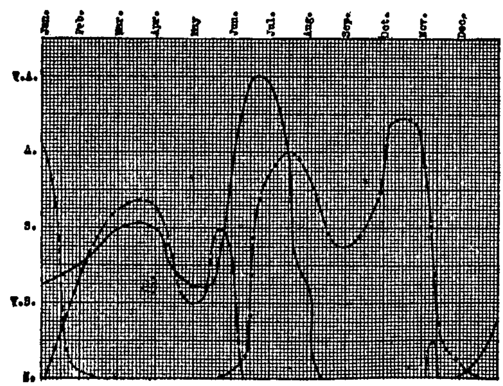

FIG. 40.—Occurrence of species of Acartia in surface collections of 1923. —•—, *Acartia tonsa;* ———, *A. bifilosa;* - - - - - - -, *A. clausii;* — — —, *A. longiremus*

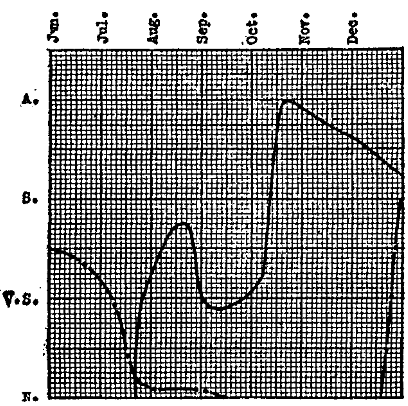

FIG. 41.—Occurrence of *Pseudodiaptomus coronatus* and *Tortanus discaudata* in surface collections from June to December, 1922. ———, *P. coronatus;* —•—, *T. discaudata*

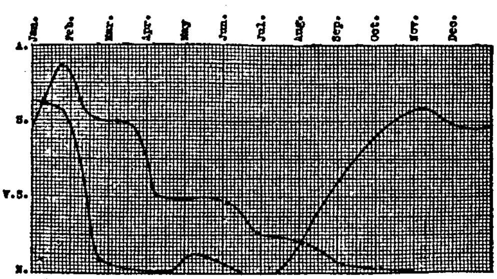

FIG. 42.—Occurrence of *Pseudodiaptomus coronatus* and *Tortanus discaudata* in surface collections of 1923. ——— *P. coronatus;* —•—, *T. discaudata.*

prevailed. The summer forms from the Gulf Stream taken in 1922–23 were *Pontella pennata*, *P. meadii*, *Anomalocera patersoni*, *Microsetella rosea*, *Setella gracilis*, and *Thaumaleus claparedii*.

No distinct division can be made dividing the summer forms from the winter ones. Figures 40, 42, 44, etc., show clearly how much the seasonal distributions of the various species overlap each other. Certain forms, such as *Centropages hematus*, appear as early as August and remain until May. As the breeding season is in December and January, they are considered to be true cold-water forms.

The winter copepods may roughly be divided into four groups: (*a*) Those northern species that remain in deep water or north of Cape Cod during the summer, entering this region every winter in great numbers, (*b*) the young of the winter species, (*c*) northern oceanic forms occasionally finding their way in, (*d*) Harpacticidæ, usually accidental members of the plankton, but in a few cases rising to the surface during the breeding season.

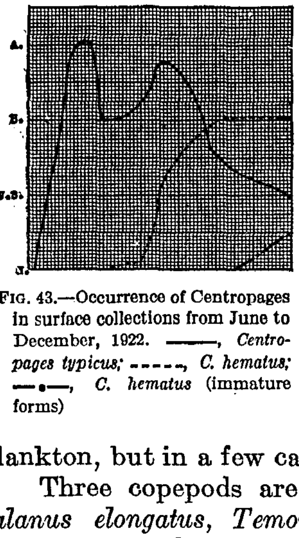

FIG. 43.—Occurrence of Centropages in surface collections from June to December, 1922. ———, *Centropages typicus*; - - - - -, *C. hematus*; —•—, *C. hematus* (immature forms)

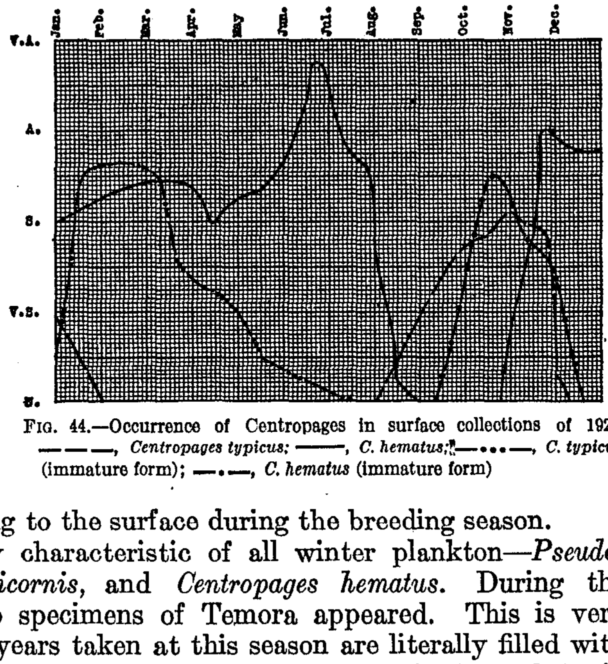

FIG. 44.—Occurrence of Centropages in surface collections of 1923. — — —, *Centropages typicus*; ———, *C. hematus*; —•••—, *C. typicus* (immature form); —•—, *C. hematus* (immature form)

Three copepods are usually characteristic of all winter plankton—*Pseudocalanus elongatus*, *Temora longicornis*, and *Centropages hematus*. During the years 1922 and 1923 almost no specimens of Temora appeared. This is very unusual, for all samples of past years taken at this season are literally filled with them. As they appear in the greatest numbers in February, March, and April, the unusually cold weather of the spring of 1923 (fig. 5, opp. p. 100) may have affected them as it has many of the other animals. The young of Pseudocalanus and Centropages became so abundant in January and February that they far outnumbered the adults, a condition which was never found among summer forms. A few immature Temora were noted, but their appearance was not common.

Northern species are sometimes plentiful in the waters of Vineyard Sound and often appear in surface collections in Great Harbor. *Calanus finmarchicus* is the most common of these cold-water forms. *Metridia lucens*, *Eurytemora herdmani*, and *E. hirundoides* were taken often during the spring of 1924. No other northern copepods to my knowledge have ever been recorded from Woods Hole.

Members of the family Harpacticidæ sometimes appeared during the winter months. Only one species (*Tachidius brevicornis*) had a definite free-swimming period. Egg-bearing females were taken in towings throughout the spring, often in great abundance. This, apparently, was the only one of the group that had a pelagic period during the year. Others may have been free-swimming but did not occur in sufficiently large numbers to indicate it.

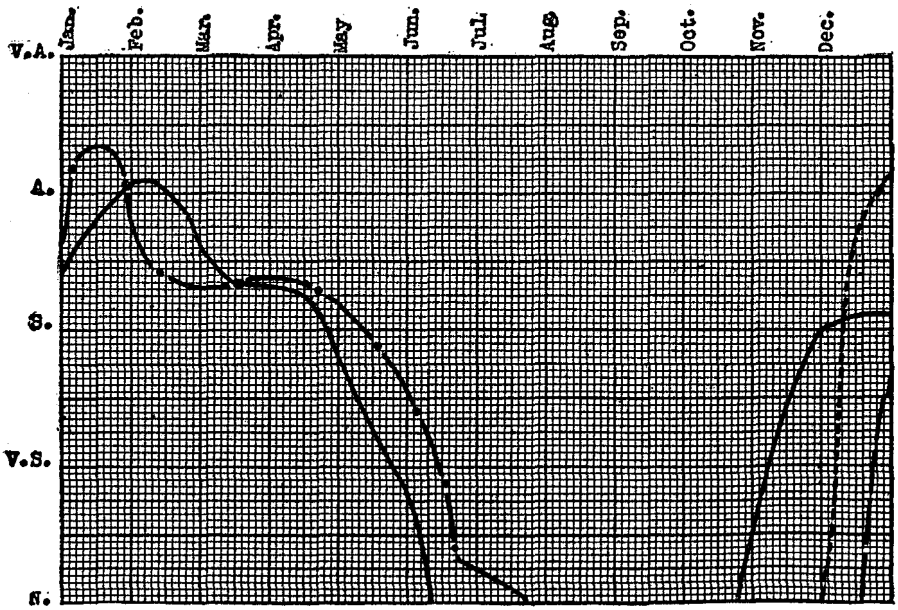

FIG. 45.—Occurrence of *Pseudocalanus elongatus* in surface collections from June, 1922, to December, 1923. -----, distribution of adults in 1922; — — —, distribution of immature specimens in 1922; ———, distribution of adults in 1923; —·—, distribution of immature specimens in 1923

The winter forms collected during the past year were as follows:

Pseudocalanus elongatus.	Acartia clausii.
Calanus finmarchicus.	A. longiremus.
Centropages hematus.	A. bifilosa.
Temora longicornis	Tortanus discaudata.
Eurytemora herdmani.	Microsetella norvegica.
E. hirundoides.	Idya furcata.
Metridia lucens.	Tachidius brevicornis.

Over 50 species of parasitic copepods have been recorded from Woods Hole. Often they are taken in surface collections, but they do not normally form a part of the plankton except in their larval stages. None appeared in 1922. In 1923 a male *Caligus schistonyx* was taken.

Three lists of free-swimming copepods have been made for this region. Wheeler recorded 30 species, but most of these were taken in the vicinity of the Gulf Stream and are extralimital. Sharpe recorded 60 species in 1911, of which only 23 occurred at Woods Hole. Twelve others were quoted from Williams's report on Narragansett Bay, and the remainder were taken from Wheeler's list. Sumner, in 1911, compiled 25 (plus 1?) species from the combined data of Wheeler and Sharpe, no new additions being made.

During the past year 42 species of free-swimming copepods appeared in the surface collections taken from the end of the Fisheries dock. Of these, 19 belong to the tribe Gymnoplea and 22 to the tribe Podoplea. In Sharpe's list 12 species from this region belong to the Gymnoplea. The list for this tribe, I believe, is

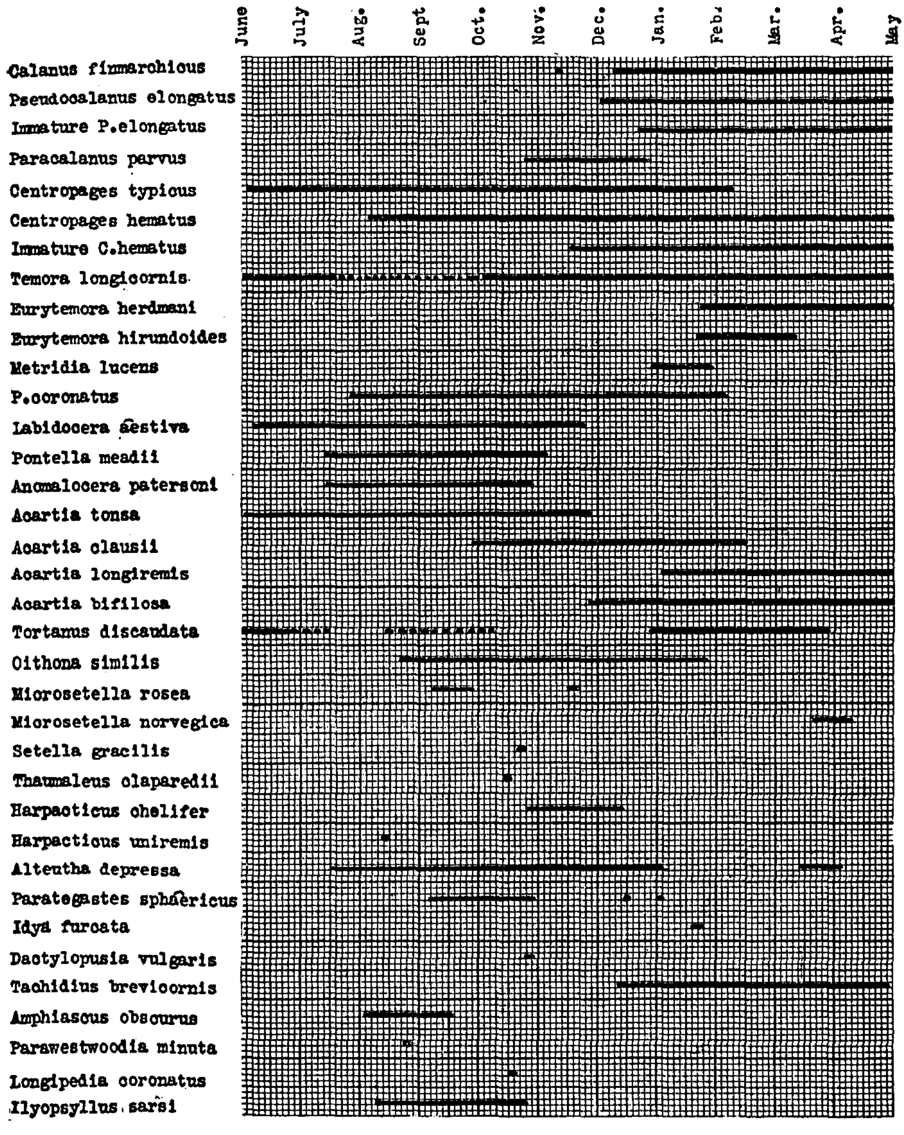

FIG. 46.—Occurrence of Copepoda in surface collections from June, 1922, to May, 1923. (*Oithona brevicornis* is not distinguished from *O. similis*)

now fairly complete. The Podoplea, however, have scarcely been touched and will, no doubt, yield many more species when carefully studied. Twelve species taken in 1922–23 are new to the Woods Hole region. I have not listed as new any forms previously recorded from Narragansett Bay.

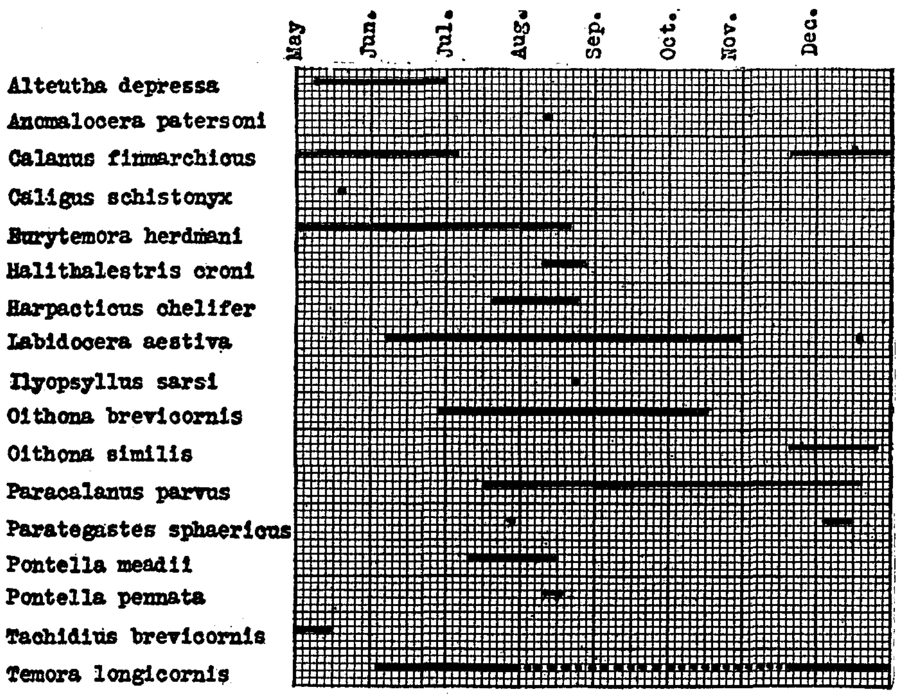

FIG. 47.—Occurrence of certain copepods in surface collections from May to December, 1923

The following Copepoda were taken during 1922–23:

Tribe GYMNOPLEA

Family Calanidæ:
- Calanus finmarchicus (Gunnerus).
- Pseudocalanus elongatus (Bœck).
- Paracalanus parvus, Claus.[1]

Family Centropagidæ:
- Centropages typicus, Kröyer.
- C. hematus (Lilljeborg).
- Temora longicornis (Müller).
- Eurytemora herdmani, Thompson and Scott.
- E. hirundoides (Nordquist).
- Metridia lucens, Bœck.
- Pseudodiaptomus coronatus, Williams.

Family Pontellidæ:
- Labidocera æstiva, Wheeler.
- Pontella meadii, Wheeler.
- P. pennata, Wilson.[1]
- Anomalocera patersoni, Templeton.
- Acartia tonsa, Dana.
- A. longiremis (Lilljeborg).[1]
- A. bifilosa, Giesbrecht.[1]
- Tortanus discaudata (Thompson and Scott).
- Acartia clausii, Giesbrecht.

Tribe PODOPLEA

Family Cyclopidæ:
- Oithona similis, Claus.
- O. brevicornis, Giesbrecht.[1]
- Hermanella sp.

Family Harpacticidæ:
- Microsetella rosea, Dana.[1]
- M. norvegica, Bœck.
- Setella gracilis, Dana.[1]
- Thaumaleus claparedii.[1]
- Harpacticus chelifer (Müller).
- Alteutha depressa, Baird.
- Harpacticus uniremis, Kröyer.
- Parategastes spæricus (Claus).
- Idya furcata (Baird).
- Dactylopusia vulgaris, Sars.
- Laophonte sp. A.[2]
- L. sp. B.[2]
- Tachidius brevicornis (Müller).
- Amphiascus obscurus, Sars.[1]
- Parawestwoodia minuta, Claus.[1]
- Longipedia coronata, Claus.
- Ilyopsyllus sarsi, Sharpe.
- Asellopsis sp.
- Halithalestris croni (Kröyer).

Family Caligidæ: Caligus schistonyx, Wilson.

[1] New to Woods Hole.

[2] Both differing distinctively from *L. longicaudata* Bœck. New to Woods Hole.

CIRRIPEDIA

At certain seasons of the year barnacle larvæ are very abundant in the plankton. In both the nauplius and "cypris" stages they swim freely, although as a rule the "cyprids" settle on the Fucus soon after the metamorphosis and are not taken in large numbers in surface collections. At such times often thousands can be taken in a single sweep of a hand net drawn through the Fucus near the water's edge. The nauplii of the three species of Balanus are so much alike that even the most careful identification is often rather uncertain. However, the difference in the breeding periods makes the identification easy in the field, although in certain years the seasons of *Balanus crenatus* and *B. eburneus* overlap.

Balanus crenatus is not as abundant in the immediate vicinity of Great Harbor as are the other species of the genus, and for that reason the larvæ occur in much smaller numbers in surface collections. The breeding season starts early in June and generally continues until the middle of July. In 1922 (fig. 48) the first larvæ

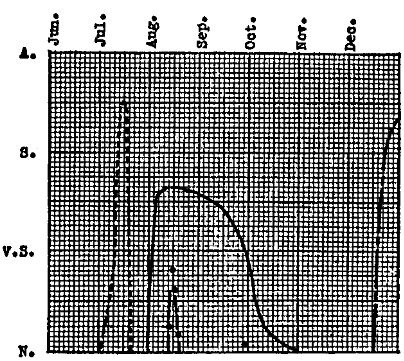

FIG. 48.—Occurrence of barnacle larvæ in surface collections from June to December, 1922. — - —, *Balanus balanoides;* - - - - - - -, *B. crenatus;* — • —, *Chthamalus stellatus;* ———, *B. eburneus;* +, Lepas sp.

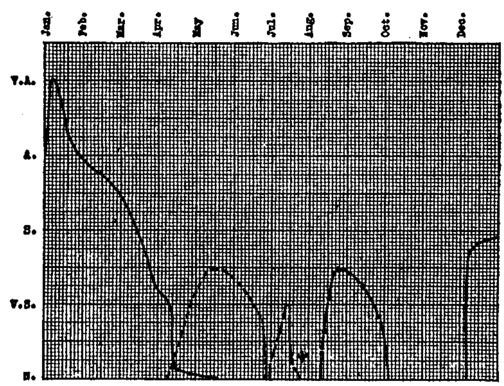

FIG. 49.—Occurrence of barnacle larvæ in surface collections of 1923. ———, *Balanus balanoides* nauplii; - - - - - -, *B. balanoides* "cyprids"; — — —, *B. crenatus;* — • —, *B. eburneus;* +, *Chthamalus stellatus*

appeared on July 2; the last on July 16. They were abundant on only one day—July 13. After this a single specimen was taken on July 15 and one on July 16. It is possible that nauplii may have occurred after August 1, when fairly large numbers of *B. eburneus* suddenly appeared. However, as an interval of 15 days elapsed between the two periods, the possibility of a stray *B. crenatus* nauplius being present would probably be so small that it need not be considered. In 1923 the first specimen appeared on June 29 (fig. 49). Scattered nauplii and "cyprids" were taken until July 23. Off Coney Island, N. Y., swarms of early nauplii (no doubt *B. crenatus*) were taken on June 12, 1923.

Balanus eburneus is usually found in August, although the nauplii seldom form an important part of the surface collections. This may be due to the fact that the summer plankton is particularly rich and the barnacles, therefore, are greatly outnumbered. It is certain, however, that they never appear in such swarms as does *B. balanoides.* The first nauplii in 1922 (fig. 48) appeared on August 1, scattering individuals being taken until November 12, when the last specimen was observed. In 1923 the first nauplii appeared on August 12 (fig. 49).

Balanus balanoides appeared first on December 16, 1922 (fig. 48). By January 1 great numbers filled the tow. An examination of adults at this time showed that almost every specimen was filled with young and all seemed to be at exactly the same stage of development. In 1923 the first nauplii appeared on December 7 (fig. 49). On February 8, 1923, the first "cypris larvæ" appeared. These were at all times far less abundant that the nauplii. Throughout February and March they continued to appear, declining in April, although a few specimens were found in every haul. In certain parts of Long Island Sound, on March 5 and 6, the "cypris larvæ" were exceedingly abundant. The season in 1899 and 1900 coincided exactly with that of 1922 and 1923.

A comparison of this locality with other places along the coast is necessary in order to understand the relative position of Woods Hole. In Massachusetts Bay Bigelow found nauplii of *Balanus balanoides* throughout March and early April, 1913. Nauplii swarmed off Boon Island on April 5 of the same year. By April 9 large numbers of the "cyprids" with few nauplii were observed, while collections of seven days later revealed only "cyprids." These were most numerous from April 25 to 30, when they formed the bulk of the macroplankton, and continued to appear as scattered forms until the middle of May, when all had practically disappeared.

In early March swarms of Balanus were found in the "cypris stage" among the Fucus along the shores of upper Narragansett Bay. Some were already attached. In Newport Harbor the author found large numbers of nauplii from January 25 to 31, 1922. The largest swarm appeared on January 30. On March 4 of the same year "cyprids" literally filled the waters in the harbor of Bristol, R. I. It was not possible to carry on further observation in this locality, so the duration of the season was not determined. The author has taken nauplii in upper Narragansett Bay in large numbers in late January.

From these records it appears that the breeding season in Narragansett Bay and vicinity is somewhat later than at Woods Hole. This may be because the water responds more quickly to sudden drops in air temperature and retards the developing eggs. As one goes farther north the season grows later. Thus, Dr. Bigelow found that the breeding time starts in March in Massachusetts Bay and terminates quickly, due to the apparent rapid development of the larvæ. In Newfoundland the breeding season of this species is in June and July.

Chthamalus stellatus, although quite abundant locally, appeared in very small numbers in the plankton on only two days in 1922—August 15 and 16. No "cyprid larvæ" were found. In 1923 a single specimen was taken on July 23.

A single nauplius of Lepas appeared in the collections on September 30, 1922. This larva often occurs locally, although the adults are not real residents of the region but are blown in by southerly winds and often appear in great numbers on floating logs and Sargassum. During such seasons the larvæ of several species are frequently found.

ARTHROSTRACA

Twenty-seven species of Amphipoda were taken in surface hauls during the past year. But one of these (*Euthemisto bispinosa*), belongs to the pelagic family Hyperiidæ. Young specimens were found on five occasions in January. The adults, which are often parasitic in Aurelia and Cyanea, are usually seen after southerly winds, when the medusæ are blown into the harbor. All other amphipods belong to the benthos. During the breeding season, however, some species swim at the surface, both in daytime and at night, and are often taken in the tow in large numbers. Thus, the bottom forms may be divided into three groups, viz: (1) Those that swim during the breeding season, (2) those that are carried by the currents, and (3) those forms that for some reason other than the breeding season are attracted to the surface.

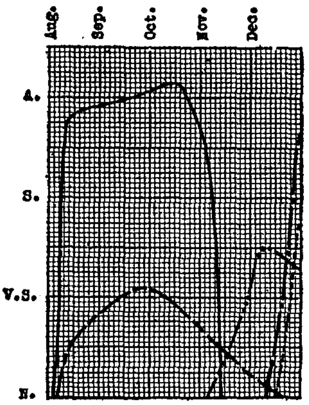

FIG. 50.—Occurrence of amphipods in surface collections from June to December, 1922. Free-swimming period during the breeding season. ——, *Batea secunda;* —. . . —, *Monoculodes edwardsi;* —. —, *Gammarus annulatus;* - - - - - - -, *Calliopius læviusculus;* — - —, *Stenothoë cypris*

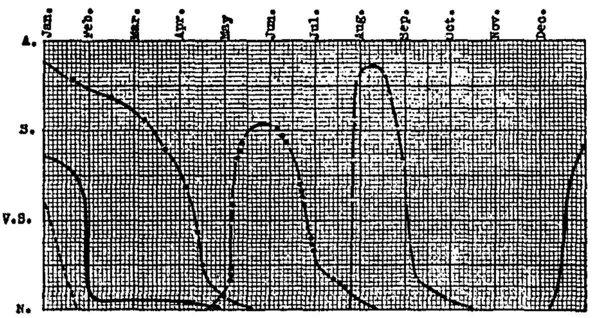

FIG. 51.—Occurrence of amphipods in surface collections of 1923. Free-swimming period during breeding season. ——, *Calliopius læviusculus;* —. : . —, *C. læviusculus* (young); - - - - - - - -, *Monoculodes edwardsi;* — — —, *Batea secunda;* — . —, *Gammarus annulatus*

In the first group there are two very conspicuous summer breeders. These can be found in Figure 52, designated by a long line. Certain forms, like Caprella, appear to have such a season, but this is caused by another condition. They live on hydroids, and as many of these are found floating after every strong wind the amphipods attached to them will float long after other forms have sunk again to the bottom. Of the summer forms *Batea secunda* and *Stenothoë cypris* are very noticeable. At times hundreds of specimens were taken in a single haul, many of the females carrying eggs or early embryos.

On November 6, 1922, *Monoculodes edwardsi* started breeding (fig. 50). Many were taken throughout December and on a few occasions in January, the last occurring on January 21. About the middle of December two other species (*Calliopius læviusculus* and *Gammarus annulatus*) suddenly appeared in abundance. The former often swarmed at the surface in large numbers, and individuals could be seen darting about in the water around the Fisheries dock throughout the spring months. *G. annulatus* reached its maximum after Calliopius had started to decline, although the collections of April often contained many specimens of both species. Verrill records great swarms of Calliopius far out at sea during this season. On one occasion they were found to be very abundant in the Gulf Stream.

After heavy northeast or southeast storms great numbers of amphipods are often found in the tow. At such times, however, many species usually appear. This condition characterizes the group and contrasts it with the first group, where

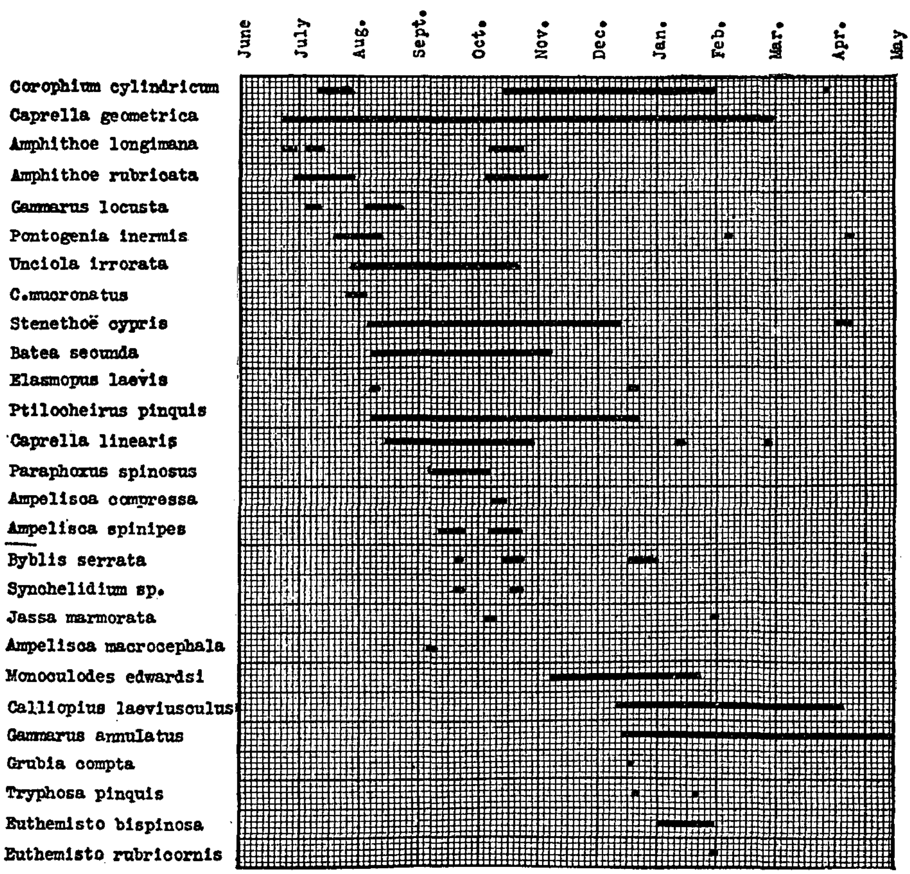

FIG. 52.—Occurrence of amphipods in surface collections from June, 1922, to May, 1923

one or two species make up tne entire amphipod representation. These conditions are particularly obvious in summer. On July 24, 1922, after a hard northeast storm, seven species of amphipods and two species of isopods were taken in one day's collection. Such heavy offshore winds carry the surface waters out and cause an upwelling of bottom waters, carrying many of the bottom animals with them.

The third group appeared only in summer. It was made up of the same species as the second group, but these occurrences were the result of different causes. Throughout the summer and particularly after the great diatom maximum the water was extremely phosphorescent. At such times the net appeared like a ball of fire as it swayed back and forth in the current. As the amphipods are positively phototropic, many, no doubt, are attracted by the light and are drawn into the net. Another factor as well may influence these collections which were always found more abundant at night. Experiments have shown that many amphipods rise to the surface at night and go down in the daylight. If this is true for many of the species, we should expect to find them more abundant in surface collections taken in the evening. How much effect this really has upon the plankton hauls I do not know, but I offer it as a possible explanation. I found no conditions in winter that could have resulted from such causes. Possibly the evening migrations do not take place during the cold season.

The following amphipods were taken in surface collections during 1922 and 1923:

Euthemisto bispinosa (Bœck).
Tryphosa pinquis (Bœck).
Paraphoxus spinosus, Holmes.
Ampelisca spinipes, Bœck.
A. macrocephala, Lilljeborg.
A. compressa, Holmes.
Byblis serrata, Smith.
Stenothoë cypris, Holmes.
Monoculodes edwardsi, Holmes.
Calliopius læviusculus (Kröyer).
Pontogenia inermis (Kröyer).
Batea secunda, Holmes.
Gammarus locusta (Linnæus).
G. annulatus, Smith.
Carinogammarus mucronatus (Say).
Elasmopus lævis (Smith).
Ptilocheirus pinquis, Stimpson.
Amphithöe rubricata (Montagu).
A. longimana, Smith.
Jassa marmorata, Holmes.
Grubia compta (Smith).
Ericthonius rubricornis, Stimpson.
Corophium cylindricum (Say).
Unciola irrorata, Say.
Synchelidium sp.
Caprella linearis, Linnæus.
C. geometrica, Say.

The Isopoda, with the exception of certain parasites, do not normally form a part of the plankton. They are most abundant in surface collections in summer. This is because numbers of Idothea and allied genera are found on floating Sargassum and Fucus, which, when carried into the nets or forced by them, often deposit many of their passengers. In winter this condition does not exist and few species are taken. On one occasion in the spring of 1900 many adult *Cirolana concharum* appeared in the tow. No doubt these were floating on a piece of wood or a dead fish which may have been carried into the net.

The most interesting by far of the isopods taken during the summer were four minute species of the family Bopyridæ, which are parasitic on copepods. These occurred in large numbers at certain times. Two species were found on *Acartia tonsa*, one on *Centropages typicus*, and one on *Labidocera æstiva*. They were most abundant from July to October, one specimen appearing unattached on December 20. None of the winter copepods seemed to be infested. No species have been recorded from this coast, and as a paper on these forms, now in the course of publication in England, is not yet completed, it was decided to wait for it before attempting to identify these isopods.

The following species were taken in 1922–23:

Idothea baltica (Pallas).
I. phosphorea, Harger.
I. metallica, Bosc.
Edotea triloba (Say).
Circolana concharum (Stimpson).
Tanais cavolinii, Milne Edwards.
Chiridotea cæca (Say).
Leptochelia savignyi (Kröyer).
Erichsonella filiformis (Say).
Family Bopyridæ, four species.

CUMACEA

The Cumacea occupy a place in the plankton similar to that of the amphipods. Large numbers are often taken at the surface during the breeding season, the females carrying eggs or larvæ. This particular group differs from the Arthrostraca in the length of the breeding season. Females of two species (*Diastylis sculpta* and *Cyclaspis variens*) were found carrying eggs at various times between July and January, although both species were most abundant in September and October. Females of *Oxyurostylis smithi* were also found with eggs on October 19. With the exception of the greater number taken during the breeding season, no particular time can be given for the occurrence of Cumacea in the plankton. They are found to be most abundant usually after a storm. *D. quadrispinosa*, which is reported to be abundant in this region, was not taken during the past year. The following forms were taken in 1922–23: *Cyclaspis variens* Calman, *Leptocuma minor* Calman, *Oxyurostylis smithi* Calman, *Diastylis polita* Smith, and *D. sculpta* Sars.

SCHIZOPODA AND STOMATOPODA

The larval stages, and often the adults (*Neomysis americana*) of the Mysidæ, at certain times of the year are very characteristic members of the Woods Hole plankton. The euphausiids, however, are "outside" forms and appear with other oceanic plankton only after southwest winds.

The Mysidæ, living among the eelgrass in shallow water, are not true pelagic animals, but an occasional adult may be carried into the net at any time. Certain species apparently never swim freely during the breeding season. *Heteromysis formosa* and a species of the genus Erythrops (new to the region) are examples of this type. The former species has been recorded for every month of the year. *Neomysis americana*, on the contrary, has a definite pelagic period and swarms in surface waters from December to April, inclusive. The larvæ appeared during the last week of April in 1899 and 1900 and continued in small numbers until July, the young being liberated in the form of the adults. In 1923 the first adult appeared on May 17.

Adult euphausiids have been recorded at various times by Edwards, but none are permanent inhabitants of this region. Their occurrence will be better understood when the distribution of the various species off the coast is more fully worked out. Five species from the surface collections of 1898, 1899, 1922, and 1923 were identified. On December 12, 1898, after a hard southwest storm, two *Thysanoëssa inermis* and one *T. longicaudata* were taken. There may be something in the occurrence of the former species to give a clue to its distribution. Zimmer gives it a wide range. It is a cold-water form, extending from the Vineyard Sound to the Gulf of Maine in the North Atlantic, always being found within the 50-fathom line. Records made to date seem to indicate a northerly migration throughout the summer months. The specimens recorded from Woods Hole were taken on December 12. The *Albatross* found scattered individuals in the deeper parts of Vineyard Sound in late July and August. Bigelow found it most abundant north of Cape Ann in early July and on German Bank in August, with minor centers of abundance off Penobscot Bay and in the northeast corner of the Gulf during the same month. Just as a northerly movement takes place in summer a southerly one is noticeable in late fall and winter. More complete data will be necessary to verify these statements, but it is evident that this species is most likely to be taken at Woods Hole from late fall until early spring.

The young of *Thysanoëssa longicaudata* in the late "cyrtopia" stage were comparatively abundant from May 10 to June 24, 1899. From this data it would seem that the adults enter the shallow waters during the breeding season of May and June. Bigelow found them abundant only in the center of the Gulf of Maine during the fall. This species, according to Zimmer, is also a cold-water form. It occurs occasionally in Vineyard Sound and quite frequently out beyond the Gulf Stream. As the young have never been taken since 1899, it is probable that the occurrence is not annual, but was due to unnatural conditions. Figure 53 gives the seasonal distribution for that year.

One specimen of *Euphausia krohnii* was taken on June 22, 1899, and another on November 9, 1922. Off the Atlantic coast they were taken in abundance in July and August. This is a southern species and may be expected to enter Vineyard Sound in the summer months. A single specimen of *E. tenera* appeared on October 30, 1923.

A battered specimen of the genus Thysanopoda was taken on June 23, 1922. The condition of the carapace made a determination of the species impossible. This was unfortunate because, although three species are recorded from the western Atlantic, each has been taken on only one occasion. *Thysanopoda æqualis* (H. J. Hansen) was recorded nearest the Woods Hole region.

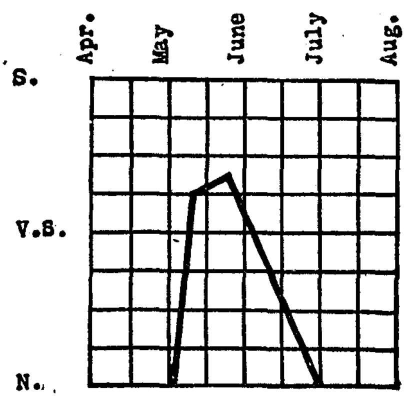

FIG. 53.—Occurrence of young of *Thysanoessa longicaudata* in surface collections of 1898 and 1899. (One adult on December 12, 1898)

A single specimen of *Meganyctiphanes norvegica*, taken April 25, 1906, was found in the surface collections of Mr. Edwards. This is a very common boreal Atlantic species, and it is surprising that more have not been taken in Great Harbor.

The following Schizopoda were taken in surface collections at Woods Hole: *Thysanoëssa inermis* (Kröyer), *T. longicaudata* Kröyer, *Euphausia krohnii* Brandt, *Meganyctiphanes norvegica* (Sars), *Thysanopoda* sp., and *Euphausia tenera* Hansen.

Seven species of stomatopod larvæ have been recorded from the Woods Hole region, although but two species of adults occur here. Most of the larvæ are East Indian forms carried north by the Gulf Stream. The various members of the order are known to have an extremely long pelagic life with many larval stages. This, no doubt, accounts for the tropical larvæ occasionally appearing in Great Harbor. The larval Squillidæ are of two forms—the *Alima* and the *Erichthus* form. All the species recorded locally, with the exception of Chloridella, belong to the latter form.

Adult *Chloridella empusa* (Say) are rather scarce in the immediate vicinity of Woods Hole, and for that reason the larvæ are not abundant in the plankton.

In 1899 a single specimen was taken on August 7. None were observed in 1922. Figure 54 shows that the normal season is in August. Edwards's earliest record was in 1895, when several specimens were taken in August. His largest captures were made in 1905, when many appeared on October 21 and 22. Heretofore adults of Chloridella have been comparatively plentiful, but during the past few years they have gradually disappeared until they are now very rarely found. This explains the absence of larvæ in surface collections of recent years.

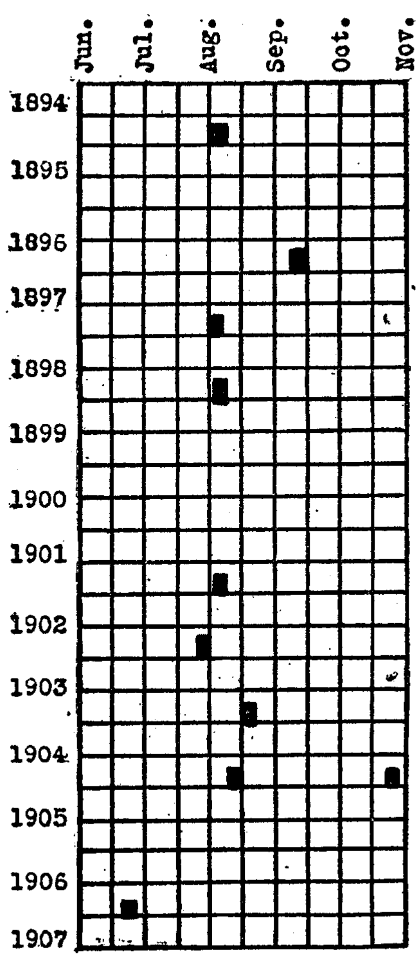

FIG. 54.—Occurrence of larval forms of *Chloridella empusa* in surface collections of successive years from 1893 to 1907

The Erichthus larvæ of *Lysiosquilla armata* Smith are among the most common on the southern coast of New England. They are usually found farther from the coast than Chloridella, probably because the adults are found in moderately deep water. *Chloridella empusa* is found on the muddy bottoms of bays and rivers. Vinal Edwards took 12 specimens of Lysiosquilla larvæ off Gay Head on September 12, 1902. Two specimens were taken in the same locality on August 15 and one on August 25, 1923, in Muskeget Channel.

Erichthus larvæ of two species of the genus Odontodactylus are recorded by R. P. Bigelow from this region. One was taken off Nantucket October 3, 1883, and the other at Woods Hole August 22, 1876. One of these appears to be the same as that incorrectly identified by S. I. Smith (1874) as the larva of *Chloridella empusa.* His specimens were taken in Vineyard Sound on August 11. In 1923 two specimens of Smith's species appeared in surface collections from Great Harbor on August 21 and three on August 22.

Bigelow considers these larvæ to be West Indian forms carried north in the Gulf Stream. Considering conditions existing during the past summer, this appears to be questionable. In 1922, when tropical plankton was abundant in local waters, none were found. In 1923 no Gulf Stream plankton or fish were taken, either in Vineyard Sound or Katama Bay. If these stomatopod larvæ are from the south, they are apparently the only tropical forms that found their way into shallow water this year. This seems hardly possible.

On July 17, 1908, Edwards found over 2,000 Erichthus larvæ in the stomach of a small mackerel taken at Woods Hole. Upon examination the author found them to be the young of the species of Odontodactylus figured by Smith. The specimens were for the most part entire and were probably found not far from Great Harbor. As one fish was able to capture more than 2,000, they must have been extremely abundant. It is difficult to see how such large numbers could have remained together in the long journey from the West Indies (where they never form a very considerable part of the plankton) to our coast and then not be scattered by the strong winds, which were necessary to blow them in. It is more probable that they are the young of an unknown species of the genus Odontodactylus inhabiting the deeper waters off the New England coast, possibly beyond the range of

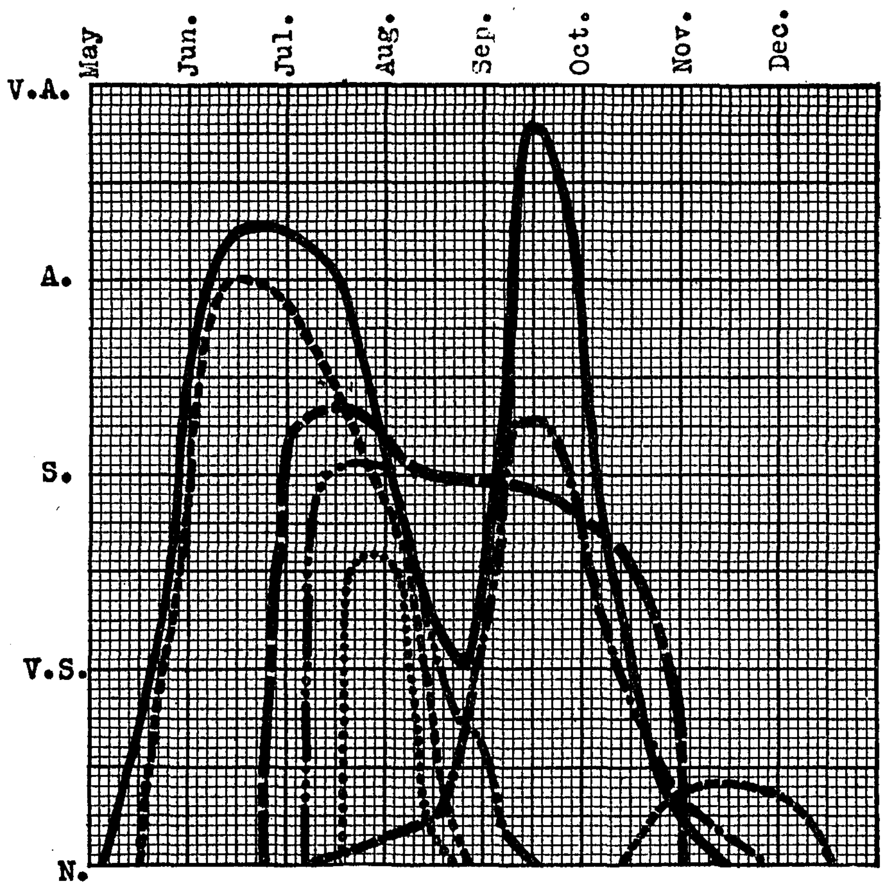

FIG. 55.—Occurrence of larval Macrura in surface collections of 1922. ———, Pagurus; • • • • •, *Crago septemspinosus;* — • —, *Palæmonetes vulgaris;* — • • • —, *Naushonia crangonoides;* — • —, *Hippolyte zostericola;* • • • • • • •, *Callianassa stimpsoni*

Lysiosquilla armata. Two unidentified species of Erichthus larvæ were taken by Verrill off Marthas Vineyard in August. One he suggests to be the larva of *Pseudosquilla ciliata* Miers. Both species were no doubt southern forms.

MACRURA

The Macrura form a very important part of the summer plankton. None of the members of this group are pelagic in adult life except some of the Caridea during the breeding season, but in all the larvæ are planktonic.

Usually the first larvæ to appear in the spring are those of *Crago septemspinosus*, but the spring of 1922 was unusually cold and for that reason none occurred during April. On April 21 several adult females bearing eggs were taken at the surface. This is characteristic of the species. In Narragansett Bay, on May 7, 1922, great numbers of adult females bearing eggs, as well as a few young, were taken in surface collections on a bright sunny day. Bumpus found young forms appearing in March at Woods Hole, while Thompson observed them as late as September 19. The first young were seen on February 1 in 1900. After this none were taken until April 3. From that day on they were abundant, declining in July and August. On October 17 the last specimen was taken. In 1922 the first of this species was noted on May 15, and great numbers were taken throughout July and early August. During the latter month there was a rapid decline, and none were taken from August 27 until October 29. On this date four specimens appeared. Scattered individuals were found in almost every haul until December 13, when a single Crago, 10 mm. long, occurred. In 1923 the first larvæ appeared on May 9 and the last, a specimen 6 mm. long, was taken on December 13. The maximum was reached early in July. All

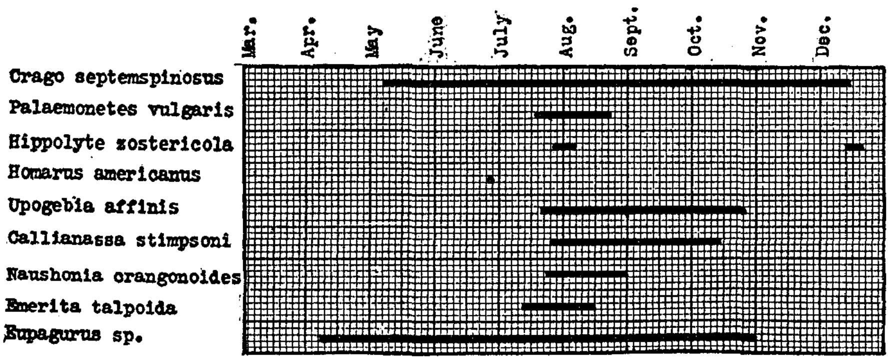

FIG. 56.—Occurrence of larval Macrura in surface collections of 1923

available records indicate that the normal season starts early in April, reaches its maximum in June or July, and usually ends in November.

Palæmonetes vulgaris appears usually much later than Crago (figs. 55 and 56). Bumpus found females with early eggs on June 20. Throughout July and August the larvæ are very abundant, but all breeding ceases by September, according to Thompson. In 1899 larval Palæmonetes appeared suddenly in great numbers in the tow of June 15. Scattered specimens had been taken for a few days previous. From June until September 18 young in all stages of development were very abundant. From this date they declined rapidly and had practically disappeared by September 28, few specimens occurring after this. A single postlarval individual was taken on October 31. The first larvæ appeared on June 25, 1922. A gradual increase continued until the middle of July, when the maximum abundance was reached, followed by a gradual decline through August and September, late stages being taken throughout the month of October. The early larvæ are rarely found after the middle of September, however. In 1923 the first specimen was taken on July 16; the last on August 22.

Hippolyte zostericola was observed first in collections taken in the second week of July, 1922. Earlier records show that the young may occur at any time after July 1. The season is much more extended than that of either Crago or Palæmonetes, for very young specimens are often abundant throughout October. Scattering older larvæ were taken in November, the last appearing on November 18. Figure 55 shows the distribution of this species, which reached its maximum in September, 1922. In 1923 four early larvæ were taken on July 26. One late larval stage (4 mm.) appeared on December 13 and one on December 17.

Only three adults, including the type specimen, of the rare species *Naushonia crangonoides* have been found. Two of these were taken on the island of Naushon and one on the smaller of the Weepecket Islands. The distribution is much broader than has been supposed, however, because numerous larvæ appeared in surface collections from Katama Bay on the seaward side of Marthas Vineyard. Although the larval forms are never exceedingly abundant in the surface collections of Great Harbor, they occurred regularly in small numbers in almost every tow taken during the breeding season. The first specimens appeared on July 8, and the last were taken on September 19, 1922. The greatest numbers were found on July 24, although the average abundance was higher around August 1 (fig. 55). Figure 56 shows the distribution in 1923.

In spite of the fact that *Homarus americanus* breeds in great abundance in all the deeper waters of the region, larval forms are rarely taken in the plankton. During the summer of 1922 none were found in Great Harbor, although a single specimen appeared in surface collections from Vineyard Sound on July 24. As this larva was in rather a late stage, no doubt it had been clinging to the floating weeds, which were abundant in the net. The few captures of past years (fig. 57) were, with one exception, made during June and July. This appears to be the normal maximum season for the species in this region. A specimen taken on September 12, 1902, probably resulted from heavy winds, which were prevalent that year. On June 26, 1923, one was found after a hard southwest wind. A natural conclusion in the matter is that the larval lobsters under normal conditions do not form a part of the surface plankton but remain

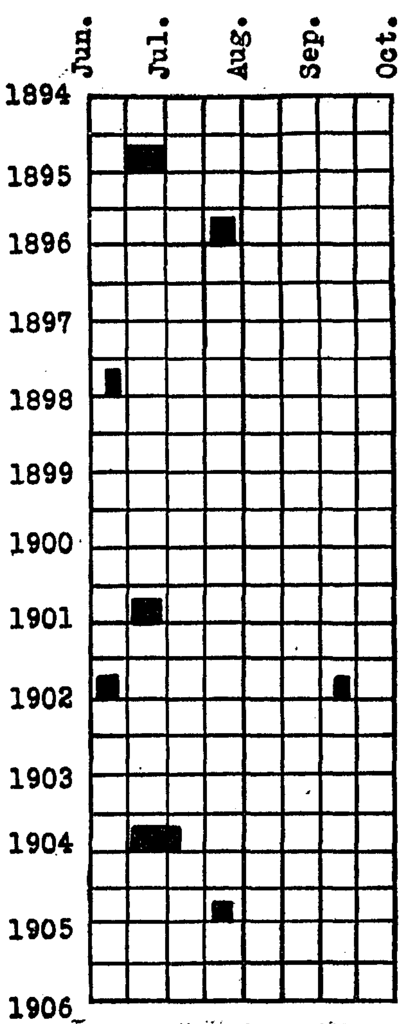

FIG. 57.—Occurrence of larval forms of *Homarus americanus* in surface collections of successive years, 1893 to 1907

near the bottom. Storms and strong currents may carry them to the upper strata, but the fact that they usually appear on only one or two days a year at the most indicates that their presence there is not normal.

Certain other Macrura were found occasionally in summer surface collections. *Emerita talpoida* was first taken on July 22, 1922, and continued to appear in small numbers until September 1, when four appeared, the greatest number found on any one day. Invariably these larvæ when placed in a watch glass would cast their shells and acquire the adult form within 24 hours. It was interesting to observe the little creatures as they labored continuously to dig into the glass bottom of the dish. After a time they would drop exhausted but could be made to resume their activity by disturbing the surface of the water.

Upogebia affinis was taken twice in August, 1922. In English waters larvæ of this genus are extremely numerous, but such is not the case at Woods Hole. The adults are not uncommon in this region, and in some years the larval forms may occur in greater numbers. In 1923 they were fairly abundant. The first specimen appeared on July 20; the last on October 25. The largest numbers were taken in early August.

The transparent larvæ of *Callianassa stimpsoni* Smith are frequently found in surface collections. Like Upogebia they are never found in abundance, although small numbers can usually be taken throughout July and August. In 1922 the first specimen appeared on July 16. After that scattered individuals were taken until the middle of August. The first larvæ were observed on July 26, 1923. From August 12 to 15 they were unusually numerous but soon declined again. The last specimen was taken on October 4.

The young of the many species of Paguridæ found in this region are always present in large numbers throughout the summer months. They are very similar to the larvæ of various Caridea but may be distinguished by the cephalothorax, which is drawn out in two points on the posterio-ventral margin. M. T. Thompson (1903) made a careful study of this group and described the development of the interesting larvæ. The early stages of the various species are almost identical, and in the case of the two most abundant forms—*Pagurus longicarpus* Say and *P. annulipes* (Stimpson)—it is impossible to distinguish them apart. Thompson found that *P. longicarpus* has the longest breeding season, extending from May until mid-September. Other species with eggs were found at different times during the summer. On April 8 of the present year (1923) two second-stage larvæ appeared. This is unusually early and far antedates any records for the region. No other specimens occurred during the month. On May 8, 1922, a single larva was taken. After this scattering forms appeared until June 1, when they became very abundant. Together with all other macroplanktonic animals they decreased during the summer diatom maximum (see figs. 15 and 55). In September the swarms appeared for a short time but soon declined, the last one disappearing on November 9. The first Glaucothoë was seen on July 13. After this scattering forms appeared throughout the summer, although they never were as abundant as the zoëæ. Their distribution in 1923 is shown on Figure 53.

The following Macrura were taken in the surface collections for 1922–23:

Crago septemspinosus (Say).
Palæmonetes vulgaris (Say).
Hippolyte zostericolà (Smith).
Naushonia crangonoides, Kinglsey.
Callianassa stimpsoni, Smith.
Homarus americanus, Milne-Edwards.
Emerita talpoida (Say).
Upogebia affinis (Say).
Pagurus sp.

BRACHYURA

Larval crabs are always present in the summer plankton in large numbers and form very important food for many fish. As few of the zoëæ had been worked out, they were a source of much trouble until the many forms were finally identified. The development of the various species will be taken up in a later paper.

All the crabs of this region have free-swimming larval stages, although certain species are seldom taken in surface collections. The megalops are found in smaller numbers than the zoëæ. Investigation showed that in this stage the young crab is usually found among the eelgrass and Fucus. It can swim as well as the zoëa but remains closer to the bottom. After hard winds large numbers were often taken in the nets. The megalops transforms into the "young crab" stage in a single molt. The "young crabs" are very rarely found swimming, except in the species *Pinnixa chætopterana* and *P. sayana.* These have no megalops stage but change directly from the zoëa into a young crab, which may be compared with the megalops of other species, for they swim about in much the same manner and are often very abundant in the plankton.

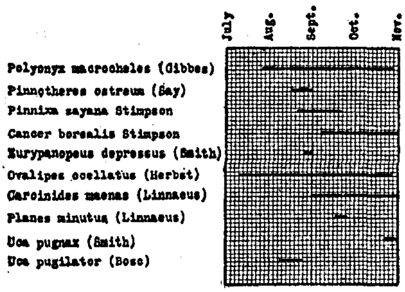

FIG. 58.—Brachyura occurring rarely in surface collections of 1922. Eggs of *Planes minutes* (Linnaeus) from an adult taken in the tow were hatched in the laboratory

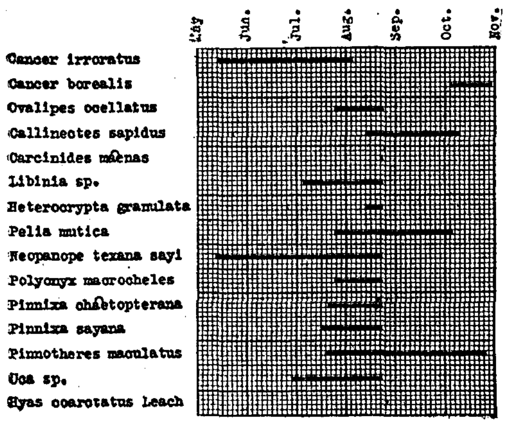

FIG. 59.—Occurrence of larval forms of Brachyura in surface collections of 1923. No observations were made from August 22 to September 18. Megalops of *Hyas coarctatus* Leach were obtained from Muskeget Channel on August 25

The zoëæ of Uca were rarely taken at the surface. Megalops appeared on only two occasions, after storms. This seems very strange, because Uca is probably the most abundant crab found in this region. Hymen reports the zoëæ as being very abundant in the surface collections at Beaufort, N. C., at all times during the summer. I believe that the fiddler crabs of this region have a very short larval period in which the zoëæ as well as the megalops remain at or near the bottom. *Carcinides mænas* larvæ may have similar habits, in this locality at least, for zoëæ were taken on only three days in October, 1922, and on one occasion in 1923 (figs. 58 and 59).

The females of *Pinnotheres maculatus* are commensal in Mytilus. The males swim freely about and were often taken during the breeding season but never after. Young males in all stages of development were frequently seen swimming. The young of this species formed one of the most abundant members of the plankton from July 6 to November 1, 1922 (see fig. 60). *P. ostreum* has similar habits but is not as common as *P. maculatus*.

The unusual larvæ of *Polyonyx macrocheles* occurred scatteringly from July 26 to October 29, 1922. These peculiar zoëæ differ from all other forms in the great length of the rostrum. On July 16, 1892, a sample of towings from Taunton River, Mass., was found to contain swarms of this species. Hardly anything else appeared. Faxon found the zoëæ swarming at the mouth of Massachusetts Bay in August, 1878. The adults are exceedingly rare. Agassiz found one adult at Newport under a stone, and Doctor Tennent collected one on Devil's Foot Island in a Chætopterus tube. G. Gray reports that several were found in Chætopterus tubes at Woods Hole in 1922. In 1923 the zoëæ were taken from July 20 until August 22 (see fig. 59).

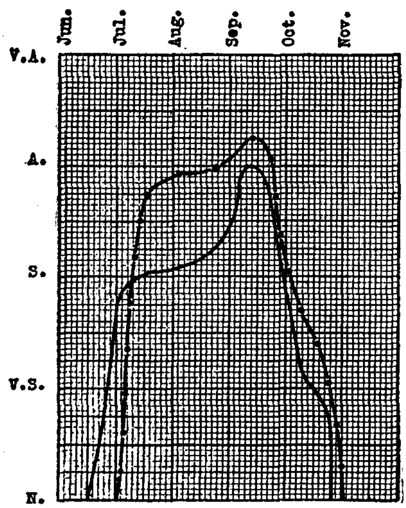

FIG. 60.—Occurrence of common grapsoid larvæ in surface collections of 1922. ——, *Pinnixa chætopterana*; —.—, *Pinnotheres maculatus*

The various species of crabs have definite breeding seasons, which often overlap each other. *Cancer irroratus* appears first, followed closely by *Neopanope texani sayi* (fig. 62). In 1922 the first zoëa of Cancer was observed on May 10. None appeared during April of the present year (1923), although many females bearing late eggs were taken on April 10 in lobster pots. Figures 60, 61, and 62 show the breeding seasons of the most abundant species taken in 1922, while the scarcer forms appear on Figure 58.

In 1922 another zoëa, almost identical to that of *C. irroratus*, was first found on September 8 and continued until October 31. This was undoubtedly *C. borealis*, although the megalops were smaller than those of *C. irroratus*, a smaller species. Adult specimens of *C. borealis* taken at No Man's Land on August 31, 1923, contained ripe eggs. The first larvæ appeared in Great Harbor on October 4; the last on October 28 (fig. 59).

The following brachyuran larvæ were taken at Woods Hole in 1922 and 1923.

Cancer irroratus, Say.
C. borealis, Stimpson.
Ovalipes ocellatus (Herbst).
Callinectes sapidus, Rathbun.
Carcinides mænas (Linnæus).
Libinia emarginata, Leach.
L. dubia, Milne-Edwards.
Eurypanopeus depressus (Smith).
Planes minutus (Linnæus).
Heterocrypta granulata (Gibbes).
Pelia mutica (Gibbes).
Neopanope texana sayi (Smith).
Polyonyx macrocheles (Gibbes).
Pinnotheres ostreum, Say.
Pinnixa sayana, Stimpson.
P. chætopterana, Stimpson.
Pinnotheres maculatus, Say.
Uca pugnax (Smith).
U. pugilator (Bosc).

PYCNOGONIDA AND XIPHOSURA

Pycnogonids are not pelagic animals, but live on hydroids and among the algæ, occurring in surface collections only when the objects to which they are attached float into the nets. For this reason they are usually taken during the summer months. Only one specimen appeared in collections made after October 1. That was on March 29 of the present spring (1923), when a single *Pallene brevirostris* Johnston was observed. This species is very abundant in the immediate region of Woods Hole and occurred almost daily during July and August. Females carrying eggs were found on August 21. On October 1, 1922, a male of *Tanystylum orbiculare* Wilson appeared. This was the only member of the species taken during the past year. A specimen of an unidentified genus new to the

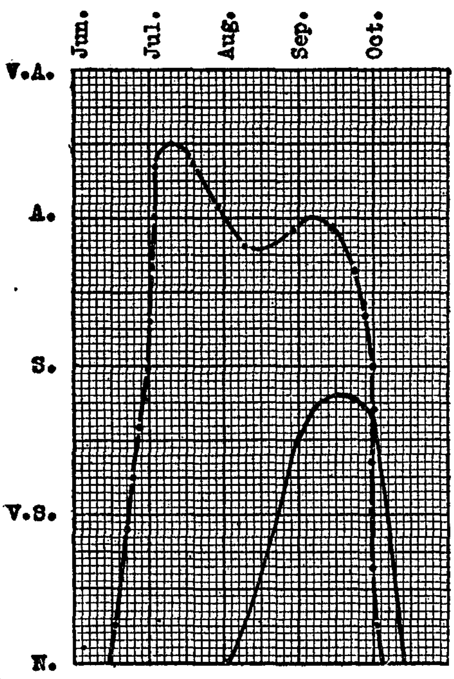

FIG. 61.—Occurrence of common larvæ of the tribe Oxyrhyncha in surface collections of 1922. —•—, *Libinia emarginata* and *L. dubia*, species not distinguished; ——, *Pelia mutica*

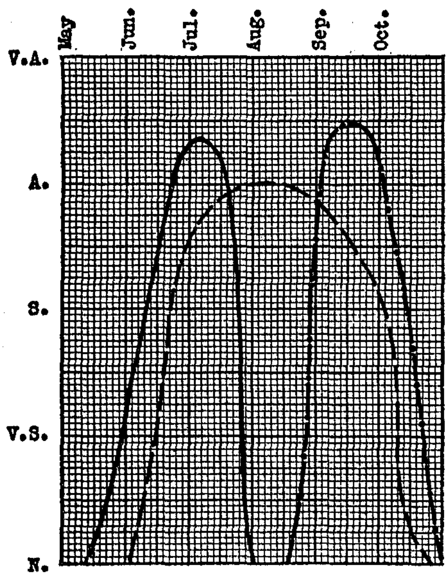

FIG. 62.—Occurrence of common larvæ of the tribe Cyclometopa in surface collections of 1922. ——, *Cancer irroratus;* — —, *Neopanope texanâ sayi;* —•—, *Callinectes sapidus*

region appeared in August, 1922, and on July 23, 1923, a single *Anoplodactylus lentus* Wilson.

Limulus polyphemus deposits eggs on sandy shores below the low-tide line. There are not many such spots about the bay in the vicinity of the "Hole," and for that reason few young are carried into Great Harbor. In certain localities, such as the sand flats at Duxbury, Mass., and Cold Spring Harbor, L. I., great numbers of the young forms in the so-called "trilobite" stage swim about at the surface. However, heavy shells prevent these animals from being very active members of the plankton, and consequently they are usually taken only in calm, shallow water. When disturbed, they become motionless and sink to the bottom, where it is almost impossible to distinguish them from the sand. None were taken in the surface collections of 1922; in fact, they are recorded only twice by Edwards in 15 years. In 1899 a few were taken on July 11 and again on July 12. In 1904 several appeared on August 9. On August 14, 1923, a single specimen was taken. As these are the only times that they have been seen here, it is probable that they are usually absent in surface collections except after northeast storms, when specimens may be transported from Buzzards Bay. The specimen taken in 1923 appeared after a hard northeast wind.

CHORDATA

After a storm on July 16, 1922, a postlarval *Balanoglossus aurantiacus* (Girard) was taken. On September 9 and 11 of the same year a single acidian larva, 1 mm. in length, appeared. They were the only representatives of this phylum seen during the year, excepting the Appendicularia, which at times appeared in great abundance. There were two species of the latter, one occurring during the summer and fall and

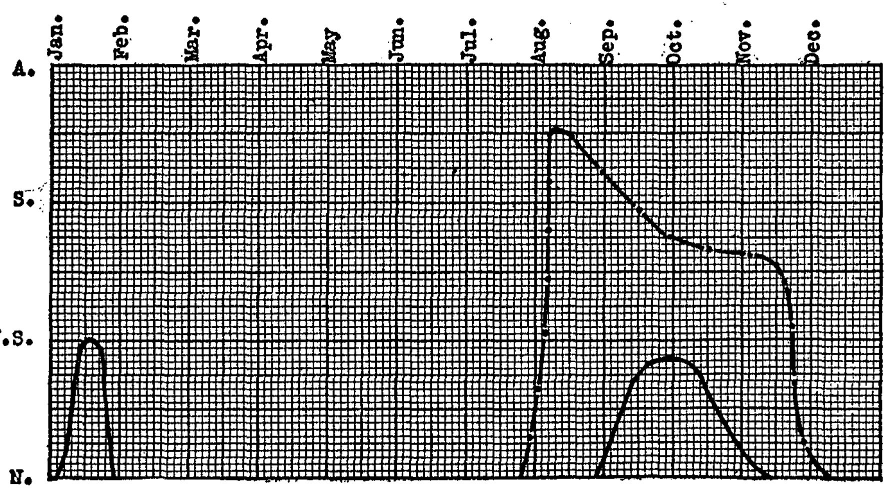

FIG. 63.—Occurrence of Appendicularia in surface collections from June, 1922, to December, 1923. —•—, distribution in 1922; ———, distribution in 1923

the other in winter, the seasons almost overlapping. Both belong to the genus Oikopleura. On several days in the latter part of July, 1922, single specimens were noted. In August the number increased until they became very abundant. Throughout September, October, and November they grew scarcer, rapidly disappearing in December (see fig. 63).

During October and November the "Haus," characteristic of Oikopleura, was taken. At times the tow contained hundreds of these pink "Häuser," each filled with copepods. One, on October 24, 5 mm. in length, was found to contain exactly 100 copepods; 97 of these were *Acartia tonsa*, 2 were *Centropages hematus*, and 1 was *Labidocera æstiva*. The contents of all had been removed, leaving only the outer transparent shell. Lohmann found that this "Haus" was often so delicate that the most minute organisms, which normally pass through the finest nets, were captured. In some forms the mesh gradually becomes finer toward one end. Undoubtedly those taken in my collections were not complete, for the wall mesh was comparatively coarse and both ends were broken. Lohmann gives 17 mm. as the average length of the "Haus" of *Oikopleura albans* Loeck. It is difficult to understand how copepods could be induced to enter such a small opening. Possibly, as in *O. albans*, the complete "Haus" is made up of two compartments—one of coarse and the other of fine mesh. The currents of water produced by the movement of the animal's tail cause microorganisms to collect in the fine mesh. This rich food center may attract the copepods, which crowd into the outer opening. The removal of the soft parts of the copepods was no doubt the work of protozoa. I have observed them completely clean out a decapod megalops in two days. The difficult thing to imagine, however, is how so many copepods could get into such a small amount of space. Lohmann found that a new "Haus" is secreted every six hours. This fact accounts for the great number taken.

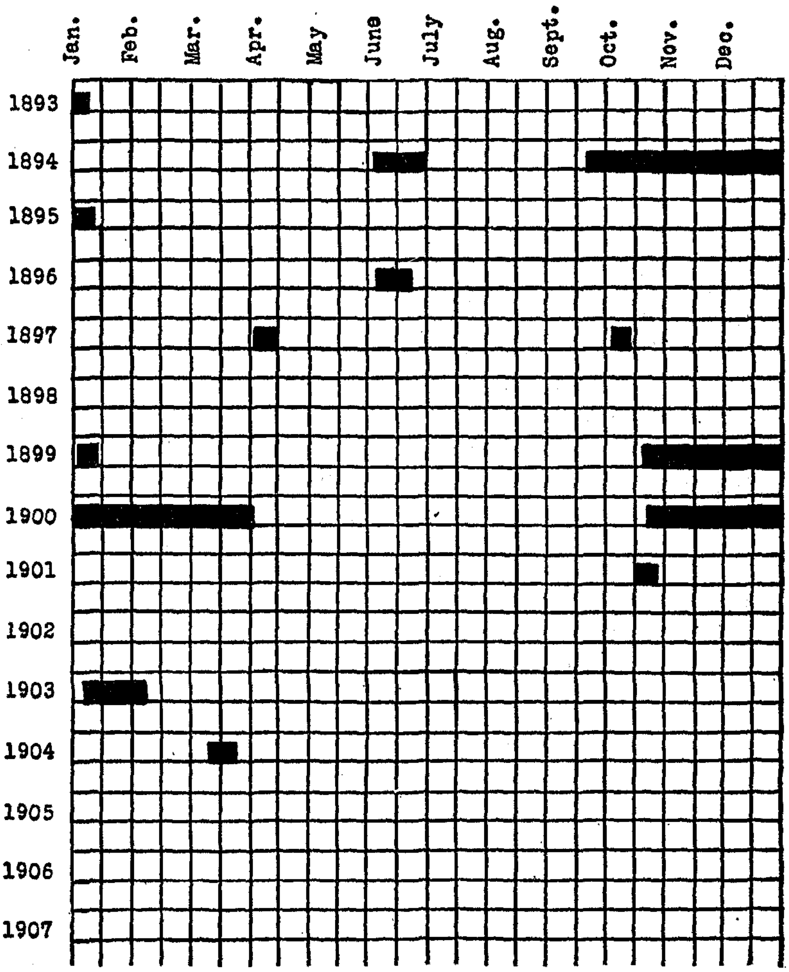

FIG. 64.—Occurrence of Appendicularia during successive years. No record was made after 1904

Only one species (*Oikopleura longicauda* (Vogt), listed by Pratt as *Appendicularia longicauda* (Vogt), has been recorded from the region. Neither member of the genus taken this year contains the "Kapuze" characteristic of Pratt's species. The winter form agrees very closely with, and probably is, *O. vanhoffeni* Lohmann, while the summer form has many of the characteristics of *O. dioica* Fol. At the time lack of sufficient literature prevented a final determination, and the preserved forms are not in a sufficiently good state of preservation to be identified positively.

In records of past years (fig. 64) the overlapping of fall and winter species shows very clearly. The winter type often appears as late as April, but disappears as soon as the temperature of the water rises. In 1894 and 1896 appendicularians appeared in large numbers in June. This is very unusual and may have been caused by an influx of Gulf Stream water.

Swarms of *Salpa democratica-mucronata* Forskäl blew ashore at Menemsha Bight in Vineyard Sound on January 11, 1901. None are recorded from surface collections in Great Harbor, but they may be expected at any time during that month after hard southwest winds.

FISH

Ehrenbaum states (in his excellent volume on the "Eier und Larven von Fischen") that the young stages of all fish, even those belonging to the bottom dwellers, are usually true planktonic forms during and often after their larval period.

From the standpoint of the planktonologist, fish of the Atlantic coast may be grouped roughly under two headings—those that have pelagic larvæ and those that have not. The latter group, of which *Opsanus tau* (Linnæus) is a striking example, contains very few members and does not enter into the plankton problem.

The first group is of great importance. A division may again be made here to separate those fish having pelagic eggs from those having demersal ones. No relationship exists between the condition of egg laying and the habits of the fish or between the various species of fish having these habits. Bottom-living forms, such as *Gadus callarias* and *Tautoga onitis*, have pelagic eggs while *Clupea harengus*, a surface dweller, has demersal ones. As a rule, most of the larger fish of this region belong to the group having buoyant eggs, the demersal group being composed of such small forms as Ammodytes, Pholis, Apeltes, Cyprinodon, Lucania, Fundulus, and Menidia. As many investigators have shown, special adaptations enable both types of eggs to have the best possible chance to survive.

In order to overcome the many difficulties besetting pelagic life, fish with buoyant eggs extrude enormous numbers of ova. These are small, translucent, and practically invisible against the bright sky, which forms the background. A very few species have pelagic eggs, which float together in a gelatinous membrane, often many feet in length. Such a condition is characteristic of *Lophius piscatorius*. The incubation period of pelagic eggs is comparatively short, largely governed by the temperature of the water. The young fish hatch in a very immature condition, and these, too, are translucent except for the eyes and scattering yellow and black chromatophores. For several days they are quite helpless, and undoubtedly during this period enormous numbers are destroyed. Later they become very lively, darting about and feeding ravenously on copepods. It is interesting to note that the eggs become translucent just before spawning. During development they are rather opaque, and the yolk is deeply colored.

Demersal eggs are laid in bunches on the sea bottom or attached to plants by fine threads. Here, again, there are special adaptations for fertilization and protection. Contrasted with the former group, where the females outnumber the males, McIntosh found that fish of this group are mostly males. This condition he believed to be necessary, for the milt rises and is likely to be lost before the eggs can be fertilized. The eggs are usually quite opaque and heavily laden with yolk. By being grouped in large bunches they are not so easily preyed upon by the bottom-feeding animals, although no doubt many are lost in this way. The eggs are comparatively fewer in number and have a longer incubation period.

Young fish of this group are often just as numerous in surface collections as those hatching from pelagic eggs, for they usually hatch in a much more advanced stage, thus greatly reducing the mortality.

Gadus callarias and *Pholis gunnellus*, characteristic members of the spring plankton, are excellent representatives of these two groups. The former emerge from the

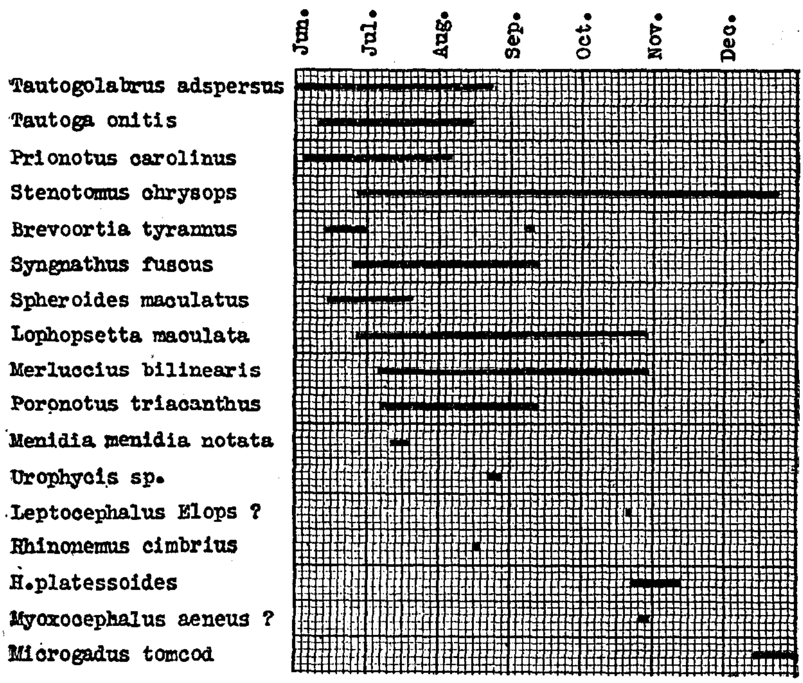

FIG. 65.—Occurrence of fishes in surface collections from June to December, 1922

egg in a helpless condition and for some time are tossed about at the mercy of the waves as delicate little transparent larvæ. (The black chromatophores arrange themselves in vertical bands and may camouflage the young fish in much the same way that similar designs served to protect our ships during the late war.) The other species (*Pholis gunnellus*) is never found in an entirely helpless condition. The young, which are much farther advanced than those of the cod when they appear in surface collections, are always very lively and swim rapidly toward the light when placed in a glass tray. (The larval cod were always dead when removed from the nets.) Copepods were always found in the intestines of even the smallest specimens. This is further evidence of the activity of this species in its very early pelagic existence. The eggs are laid on the bottom in a compact mass and are guarded by the adult fish until hatched.

In summer the most abundant larvæ are *Tautogolabrus adspersus* and *Tautoga onitis*. Both have pelagic eggs and appear in June, remaining until August. During this time the eggs are often very numerous, appearing like masses of minute bubbles on the surface in the examining dish.

Mr. Edwards took 34 species of larval fish in the 15 years recorded in Figures 67 to 81. During the past year 20 species were identified. Of the summer forms all but one (leptocephalus of Elops ?) are common to this region. The leptocephalus is not that of an eel but of a true fish, as the tail is well developed and forked. I have placed it in the genus Elops because that is the only common southern fish recorded from this region that has a leptocephalus stage.

Of the winter larvæ all were of species breeding in the region except *Gadus callarias*. This is a northern species common off southern New England, the adults of which never enter the immediate region. As the nearest important spawning

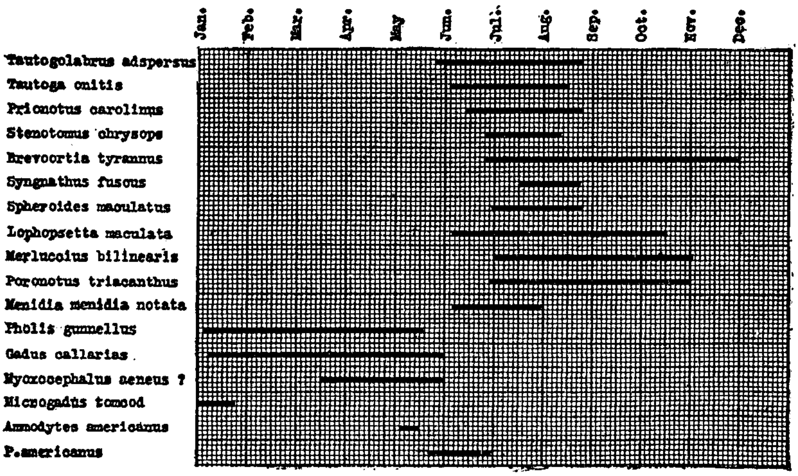

FIG. 66.—Occurrence of fishes in surface collections of 1923

grounds are on Nantucket Shoals, the appearance of early larvæ at Woods Hole probably results from southerly or easterly currents. Postlarval forms, usually about 20 mm. in length, find their way into this region and are often taken in May (fig. 67) in large numbers, depending upon the season. Still later postlarval stages (40 to 50 mm.) are always present in the shallow coastal waters in May and June. Many were taken within the boat basin at the Fisheries dock on May 24, 1923, with a fine net. During this period they are destroyed in large numbers by *Loligo pealii*. A school of over 200 of these squid, all about 5 inches in length, seined in Great Harbor, were found to be feeding entirely upon young cod. Several specimens were observed with a young fish protruding from the beak and one or more others held securely in the tentacles.

In 1923 early larval stages of cod appeared in small numbers in the tows of January, February, and early March. Surface collections made in Vineyard Sound at various times during this period showed that they were present there also, but likewise in small numbers. Just what effect the artificial conditions created by the hatchery had is not known, but probably the 351,000,000 larvæ liberated during

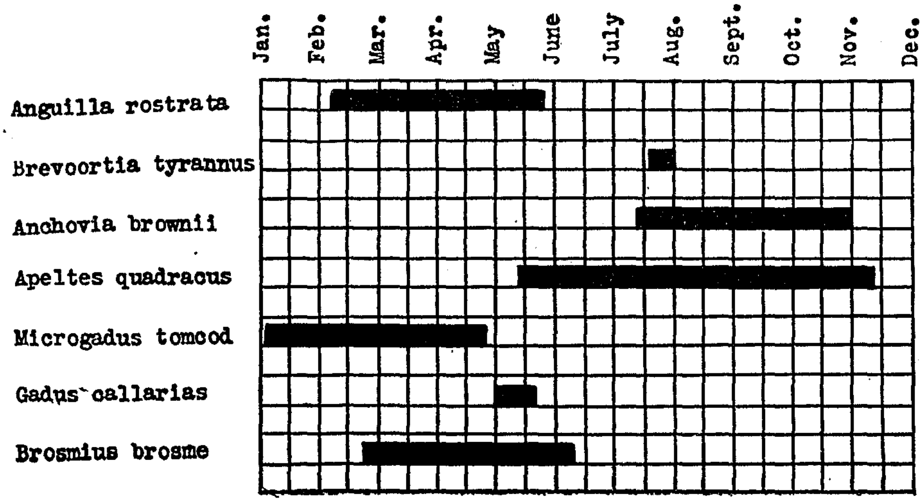

FIG. 67.—Maximum seasonal distribution of fishes not common in surface collections, based on records of the years 1893 to 1907

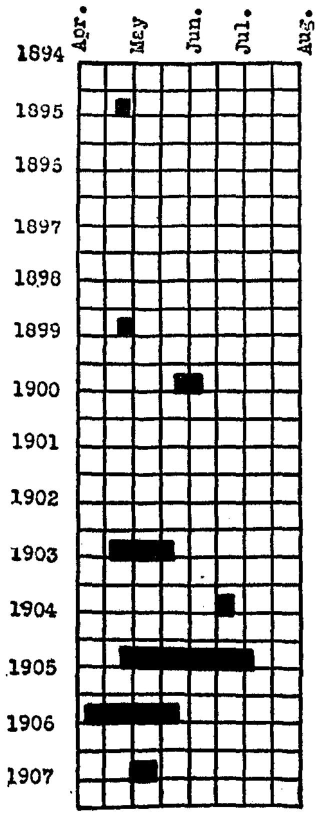

FIG. 68.—Occurrence of *Pholis gunnellus* during successive years, 1893 to 1907

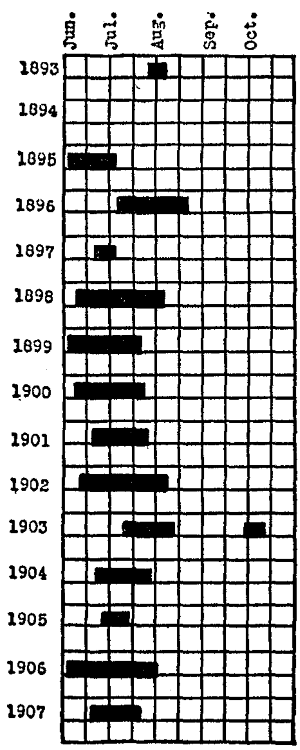

FIG. 69.—Occurrence of *Tautogolabrus adspersus* during successive years, 1893 to 1907

the spring less than a mile from the collecting station increased the surface catch somewhat. It is barely possible that all early specimens taken may have originated from that source. Their absence in records of past years, combined with their total absence during the early spring of 1924 (when no larval cod were liberated at Woods Hole), seems to substantiate this possibility. It must be remembered, however, that the unusually warm weather existing during the early part of the past winter apparently prevented the adult fish from spawning on their usual grounds, and for that reason no eggs were available at the hatchery. The cod may have sought deep areas so far from the coast that the early forms, which were never abundant in this region anyway, could not be transported into these waters. Fishermen reported that they had never known the cod catch to be so small on the southern New England grounds as during the early winter of 1923. They were totally unable to supply the Woods Hole station with any spawning fish. The usual fall school which annually enters Narragansett Bay also failed to appear. It will be interesting to learn whether the postlarvæ appear as usual in May, 1924.

In Figure 67 and Table 5 several fish taken rarely in past years are listed. Most of these are southern forms and occur only in the summer when the Gulf Stream inhabitants are blown in. *Lactophrys trigonus*, *Cryptacanthodes maculatus* *Anarhichas lupus*, and *Seriola zonata* are representatives of this fauna.

TABLE 5.—*Fishes very rarely taken in surface collections*

Species	Date	Abundance
Leptocephalus conger	Jan. 13, 1903	One.
Osmerus mordax	Feb. 28, 1895; July 14 and 15, 1896; and June 19, 1899	Many.
Poronotus triacanthus	Aug. 9 and 10, 1898	Few.
Lactophrys trigonus	Sept. 26, 1893	Many.
Cyclopterus lumpus	June 20, 1898; June 5, 1905; and June 18, 1907	Do.
Cryptacanthodes maculatus	Apr. 22, 23, 25, and 26, 1907	Do.
Anarhichas lupus	May 1 and 2, 1899, and June 3 and 5, 1899	Few.
Rhinonemus cimbrius	Apr. 1, 27, 28, and 30, 1900; June 2, 3, 4, 5, and 6, 1906; and July 17, 1906	Very many.
Lophius piscatorius	June 10, 1899	Few.
Pseudopleuronectes americanus	Apr. 13, 1897	Many.
Limanda ferruginea?	Jan. 4, 1908	One.
Seriola zonata	Aug. 30, 1907	Few.
Pomolobus pseudoharengus	July 13, 1896	Do.

The remaining figures show clearly that the fish have a definite breeding season within certain limits, usually determined by temperature. Temperature chart for the spring of 1923 (fig. 5, opp. p. 100) indicates how unusually cold the water was. The result was that many of the fish, as well as other larval forms, did not appear. The approximate temperature throughout the breeding season of each common species may be found by comparing the individual figures with Figures 4, 5, and 6. This particular temperature, however, must not be regarded as the complete governing factor. At some time earlier in the year a rise or fall in temperature caused the ovaries and testes to ripen. When the sex products have completely matured they will be extruded within certain limits irrespective of temperature. After this extrusion the immediate temperature then plays its part. Cod eggs have been made to hatch in 9 days or 64 days by varying the temperature of the water.

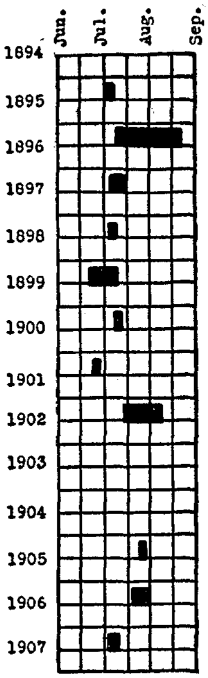

FIG. 70.—Occurrence of *Tautoga onitis* during successive years, 1893 to 1907

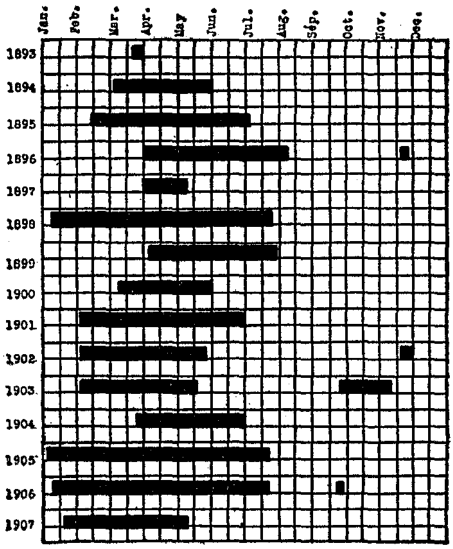

FIG 72.—Occurrence of *Ammodytes americanus* during successive years, 1893 to 1907

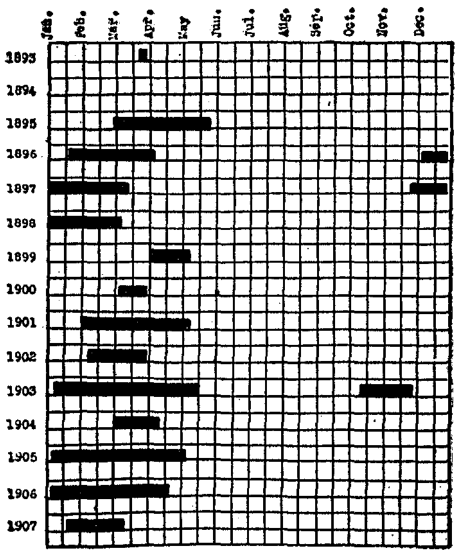

FIG. 71.—Occurrence of *Myoxocephalus æneus* during successive years, 1893 to 1907

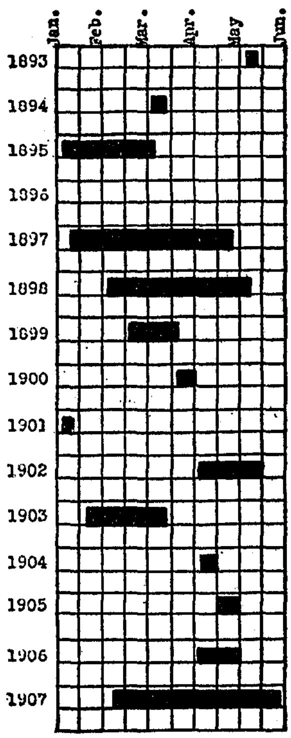

FIG. 73.—Occurrence of *Pollachius virens* during successive years, 1893 to 1907

As the salinity of Woods Hole is not noticeably different from the outer waters, it probably plays no part in the distribution of the larval fish of this region. The governing factors are, then, temperature and food, if we omit the effect of winds and currents, which at times may influence the distribution greatly.

The abundance of food has a powerful effect on the lives of the young fish. Given favorable temperatures, the larvæ will develop rapidly and in great numbers if food is plentiful. If food is scanty, few larval fish will be found. During the winter and spring months copepods make up practically the entire food of the young forms. The most abundant copepods during colder weather are usually *Temora longicornis* and *Pseudocalanus elongatus*. No doubt both of these species contribute equally to the food supply. As the spring of 1923 was exceptionally cold, Temora did not appear. Scattering forms were taken during the winter, but never more than three or four specimens on any one day. Out of 200 examinations of stomach contents of larval fish this spring not a single Temora was found. *Pseudocalanus elongatus* and *Centropages hematus* were very plentiful, particularly the former, and these constituted their food, the bright red color of the Pseudocalanus showing clearly through the thin walls of all the young fish collected.

The summer fishes have a much greater variety of food and for the most part do not limit their menu to Copepoda, although *Acartia tonsa* and *Centropages typicus* are eaten in great numbers. A young puffer (*Spheroides maculatus*), 3.5 mm. in length, examined on June 28, 1922, was found to contain 12 *Littorina litorea*, 9 *Venus mercenaria*, and 2 *Acartia tonsa*. Often a young fish was taken with a large copepod or phyllopod protruding from its mouth.

The relationship of the larval fish to its food supply is therefore very close, and one must determine it accurately in order to understand the distribution of a species. Such a study was attempted at the Plymouth laboratory by Doctor Lebour, who obtained some interesting results. More extended observations will be necessary before the relationship of the many factors can be clearly understood.

The following forms were taken in surface collections of 1922–23:

Tautogolabrus adspersus (Walbaum)	Cunner.
Tautoga onitis (Linnæus)	Tautog.
Prionotus carolinus (Linnæus)	Sea Robin.
Stenotomus chrysops (Linnæus)	Scup.
Brevoortia tyrannus (Latrobe)	Menhaden.
Syngnathus fuscus Storer	Pipefish.
Spheroides maculatus (Bloch and Schneider)	Puffer.
Hippoglossoides platessoides (Fabricius)	Sand dab.
Merluccius bilinearis (Mitchill)	Whiting.
Poronotus tricanthus (Peck)	Butterfish.
Menidia menidia notata (Mitchill)	Silversides.
Pholis gunnellus (Linnæus)	Rock eel.
Urophycis	Hake.
Gadus callarias Linnæus	Cod.
Leptocephalus, Elops?.	
Microgadus tomcod (Walbaum)	Tomcod.
Myoxocephalus æneus (Mitchill)?	Sculpin.
Lophopsetta maculata (Mitchill)	Window-pane.
Rhinonemus cimbrius (Linnæus)	Rockling.
Ammodytes americanus De Kay	Sand launce.

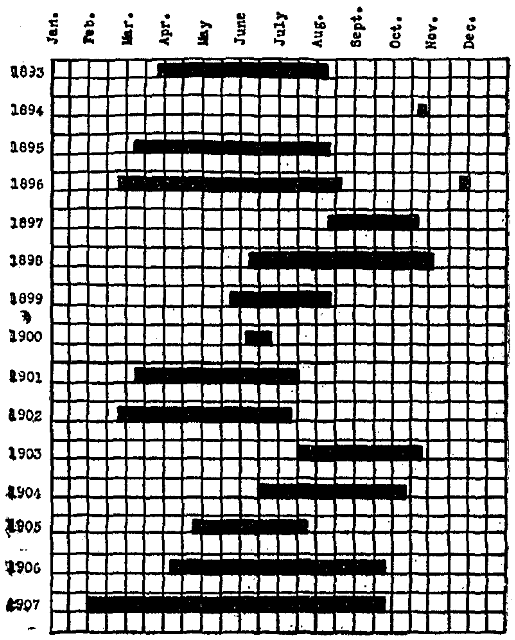

FIG. 74.—Occurrence of Urophycis sp. during successive years, 1893 to 1907

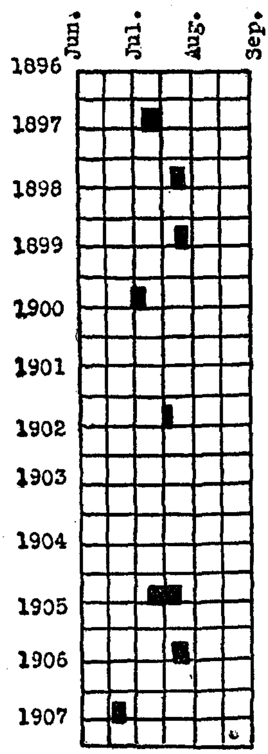

FIG. 75.—Occurrence of *Stenotomus chrysops* during successive years, 1893 to 1907

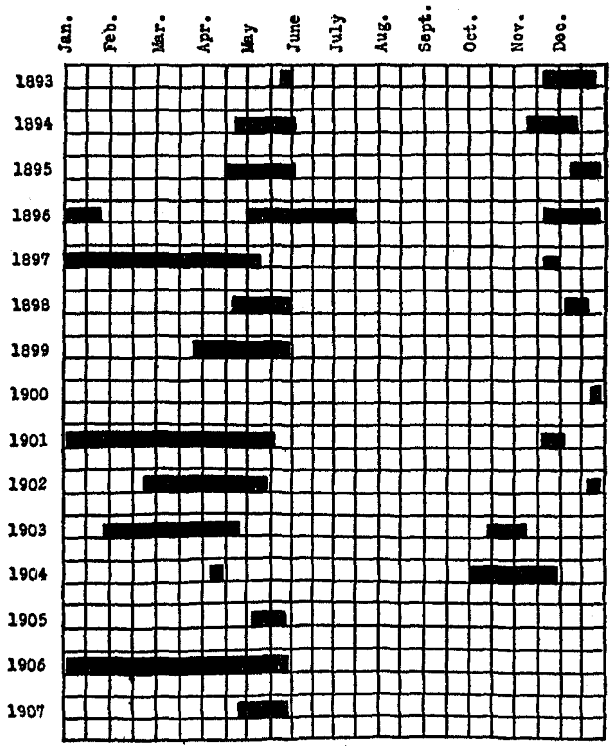

FIG. 76.—Occurrence of *Clupea harengus* during successive years, 1893 to 1907

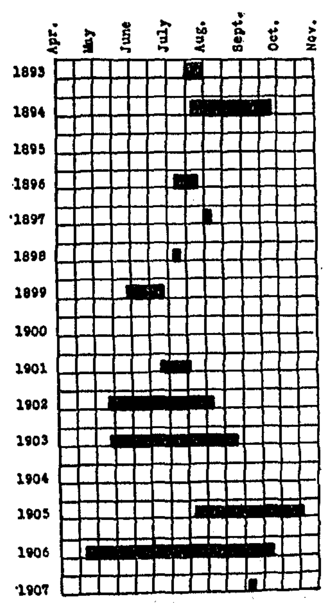

FIG. 77.—Occurrence of *Syngnathus fuscus* during successive years, 1893 to 1907

The following fish were taken in surface collections of 1893 to 1907:

Anguilla rostrata (Lesueur).
Leptocephalus conger (Linnæus).
Clupea harengus Linnæus.
Brevoortia tyrannus (Latrobe).
Anchovia brownii (Gmelin).
Osmerus mordax (Mitchill).
Apeltes quadracus (Mitchill).
Syngnathus fuscus Storer.
Menidia menidia notata (Mitchill).
Ammodytes americanus De Kay.
Poronotus tricanthus (Peck).
Stenotomus chrysops (Linnæus).
Tautogolabrus adspersus (Walbaum).
Tautoga onitis (Linnæus).
Lactophrys trigonis (Linnæus).
Spheroides maculatus (Bloch and Schneider).
Myoxocephalus æneus (Mitchill)?.
Cyclopteras lumpus Linnæus.
Pholis gunnellus (Linnæus).
Cryptacanthodes maculatus Storer.
Anarhichas lupus Linnæus.
Prionotus carolinus (Linnæus).
Pollachius virens (Linnæus).
Microgadus tomcod (Walbaum).
Gadus callarias Linnæus.
Urophycis sp.
Rhinoneumus cimbrius (Linnæus).
Brosmius brosme (Müller).
Lophius piscatorius Linnæus.
Pseudopleuronectes americanus (Walbaum).
Hippoglossoides platessoides (Fabricius).
Lophopsetta maculata (Mitchill).
Pomolobus pseudoharengus (Wilson).
Seriola zonata (Mitchill).
Limanda ferruginea (Storer)?.

GENERAL CONCLUSIONS

I shall not attempt to summarize all the conclusions arrived at during the past year. For the most part these have been taken up under the various subjects and in the discussion on plankton. The following are some of the more general conclusions concerning the nature of the plankton and the physical factors affecting its distribution, resulting from a 2-year study of the Woods Hole pelagic fauna:

1. Woods Hole is an excellent location for the study of the seasonal distribution of plankton.

2. It is impossible to investigate diurnal distribution in Great Harbor. The current rushing through the passage during the flood tide mixes the water so completely that the distribution of plankton remains the same at all times. The entire body of water is affected at the same time, even during periods of sudden heating or rapid cooling of the air.

3. No great amount of fresh water enters Woods Hole. The salinity averages about 31.5. For this reason titrations are of importance in determining the presence of ocean water.

4. As in the case of the benthonic animals, the plankton of this region is made up of a complex of faunas. It forms the northern limit of many southern species, the southern limit of many northern species, and a pocket where oceanic animals blown in by strong southerly winds are deposited.

5. The tropical species appear gradually in Great Harbor in the summer, but stop suddenly in the fall. This is because the temperature of the water in Buzzards Bay rises higher than that of the coastal waters in summer but responds quickly to the falling temperature of the air and by fall becomes much colder. Animals carried into this region in summer survive, but in the fall the lower temperature proves fatal and few live to be carried through the passage back into the deeper waters. However, members of this group may be taken throughout the fall in Vineyard Sound, where the decline in temperature is not so rapid.

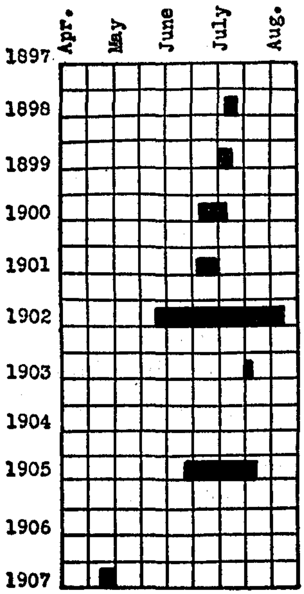

FIG. 78.—Occurrence of *Prionotus carolinus* during successive years, 1893 to 1907

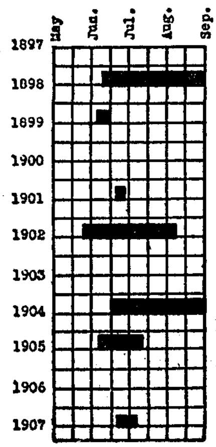

FIG. 80.—Occurrence of *Hippoglossoides platessoides* during successive years, 1893 to 1907

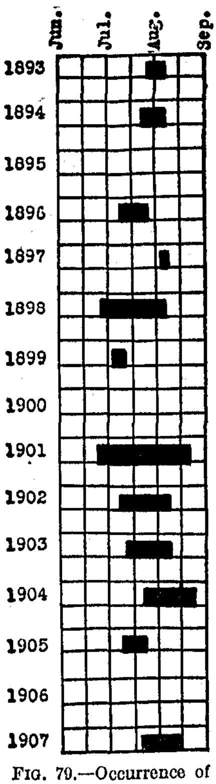

FIG. 79.—Occurrence of *Spheroides maculatus* during successive years, 1893 to 1907

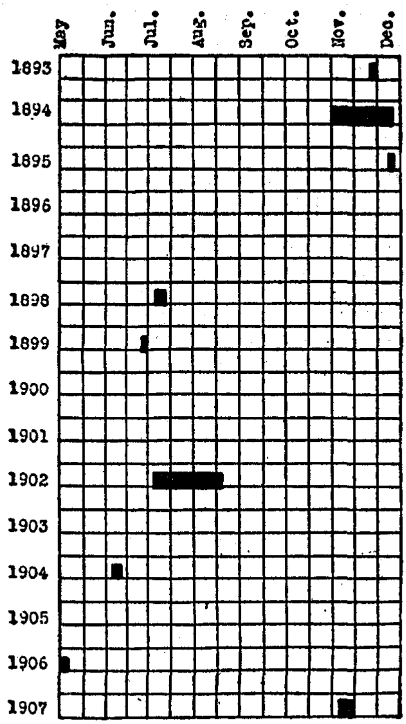

FIG. 81.—Occurrence of *Menidia menidia notata* during successive years, 1893 to 1907

6. The arm of Cape Cod forms a permanent northern barrier for the southern neritic plankton but only a summer barrier for northern pelagic species.

7. The proportion of benthonic animals occurring in the plankton of this region is much greater than that found in normal littoral plankton. After northeast storms Buzzards Bay types predominate; after southerly storms Vineyard Sound types are most plentiful. This is particularly noticeable in the case of amphipods.

8. No correct impression of the relative abundance of the local benthonic fauna can be obtained from surface collections unless the distribution of each of these animals in the bay and sound is completely understood.

9. A distinct periodicity in the occurrence of all the common animals of the region is clearly noticeable. The succession of species remains almost the same each year, the only variation being in the time of their appearance and disappearance.

10. The planktonic animals of the region, with one exception, may be placed in two general groups—the summer community and the winter community. The cœlenterates are the exception. For the most part these have a long spring maximum and a short one in the fall.

11. The pelagic diatoms exert a very great influence on the zooplankton. When the greatest maxima appear most of the zooplanktonic forms disappear. There are possibly two reasons for this. First, the common species having these swarming periods do not form the food of the zooplankton so far as I have been able to determine. During the maxima of the larger diatoms the smaller members of this group which are eaten by pelagic animals disappear, causing a scarcity in the food supply. This may account for the similarity in the time of disappearance of the larger forms and the small diatoms. Second, the great numbers of the diatoms filling the water apparently cause conditions unfavorable for animal life of any sort. The macroplankton seems to be literally choked out. This, however, is hardly probable, and is offered merely as a possible explanation.

12. Conditions favoring the increased production of one species of diatoms are also favorable for many others, provided that one does not become so abundant that almost all others disappear. The summer maximum often exemplifies the latter condition. The winter swarm usually consists of many species in which various forms predominate at different times.

13. My observations on the distribution of pelagic diatoms lead me to disagree with the theory that all production takes place in deeper waters off the coast, the species occurring in the littoral waters being the result of winds and tides. Such factors no doubt account for the distribution of the various species, but the quantitative distribution can not always be explained on that basis.

All evidence points clearly to the fact that great production of floating diatoms takes place at the mouths of rivers where the largest amount of drainage from the land is emptied into the coastal waters. Peck's observations in Buzzards Bay also indicate that the greatest swarms are found where the greatest outwash from the land occurs. Buzzards Bay is a great reservoir in which pelagic diatoms accumulate and multiply, and as a result the swarms carried into Great Harbor are often exceedingly large.

14. Temperature is the dominant factor in governing the seasonal distribution of all local pelagic animals. It also determines whether oceanic species entering the region shall perish at once or live long enough to become an important factor in the local fauna. Three general conditions cause the appearance of the pelagic animals—winds, tides, and the food supply. Salinity forms barriers in some localities, but not at Woods Hole. Once introduced into the region, the organisms remain until the temperature becomes unfavorable or the food supply is exhausted, and then they must leave or perish. Food is also an important factor in causing the disappearance of a species during a period of favorable physical conditions. This is probably the limiting factor of the summer diatom season. Temperature governs the breeding seasons of all planktonic and benthonic animals of this region. The temperature prevailing at the time of the extrusion of the eggs is not often the important factor, for the eggs are usually thrown off as soon as ripe, provided the conditions are not too unfavorable. After the eggs have been deposited in the waters the existing temperature plays a part in determining whether the incubation period will be long or short. The determination of an early or a late breeding season, then, depends upon the temperature at some previous date when a warming or cooling of the water started the development of the sex products. This fact must be considered when interpreting the appearance of certain larvæ in the plankton.

15. Reactions to changes of temperature are for the most part more evident among planktonic animals than among benthonic forms. Bottom dwellers, particularly sessile forms, in order to maintain themselves must be able to withstand a great range of temperature. Unusually low temperatures often kill large numbers, but as a rule both the larvæ and adults are extremely hardy. This is not true in the case of planktonic forms. Certain species, such as *Calanus finmarchicus*, although preferring cold water, are able to stand sudden rising or falling temperatures and appear to survive as well in water of 22° C. as at 0° C. Most pelagic animals, however, particularly the phytoplankton, disappear as soon as the temperature conditions become unfavorable.

16. The annual distribution of the diatom maxima of the American coast is very similar to that of the eastern Atlantic waters in that the seasons of the greatest swarms retreat farther and farther from the warmest months as one approaches the Tropics. A similarity in the seasonal variation in European and American waters of the same latitude is particularly noticeable, conditions at Woods Hole corresponding to those in the Adriatic Sea. The great effect of the arm of Cape Cod on the local plankton is again evident here, for within 20 miles of Massachusetts Bay, with conditions similar to the Norwegian Sea, conditions comparable to those of the Mediterranean and Adriatic Seas are found in Buzzards Bay.

17. The distribution of the plankton of the western Atlantic coast is little understood, and the number of animals new to the region taken during the past year indicates that most of the eastern Atlantic coast pelagic species probably will be found here also.

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