A BIOLOGICAL STUDY OF THE OFFSHORE WATERS OF CHESAPEAKE BAY [1]

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INTRODUCTION

One object of this biological survey of Chesapeake Bay has been to make collections and identifications of various animals and plants found there in order to learn more of their distribution and abundance. An equally important object has been to record at the same time some of the environmental conditions which might determine such distribution and abundance. In addition to this it has been the intention of the survey to continue the work for several years in an effort to ascertain what the usual environmental conditions in the bay are, so that when great mortality of fishes, oysters, crabs, clams, etc., occurs there will be data at hand from which to decide as to what unusual changes may have been the cause of the trouble. Finally, it has been hoped that the information obtained concerning salinity, temperature, and plankton content of the water may help at some time in the future to throw light on the laws which govern the migration of fishes, crabs, and other organisms in Chesapeake Bay.

The survey has been a rather general one, many regions having been visited at intervals, so that no one region has been studied intensively—daily for example—although each region has been visited several times during a year. At certain ones, observations and collections have been made every 1½ hours for a period of 24 hours. The temperature and salinity data obtained during several years of observation have been studied. An attempt has been made to work out the distribution of the plankton diatoms and other forms and also to see how they are related to salinity and temperature; but the rôle played by each of these factors can not be conclusively shown, owing to the difficulty of controlling the numerous factors involved. In order to have a better idea of the general physical characteristics of Chesapeake Bay before taking up the discussion of salinity, temperature, and diatom distribution, the following section on the physical features has been included.

PHYSICAL FEATURES

Chesapeake Bay is a large estuary on the eastern coast of the United States lying between latitude 76° to 76° 30′ and longitude 37° to 39° 30′. It forms a deep indentation into the States of Maryland and Virginia, extending inland about 160 nautical miles, varying from 5 to 20 nautical miles in width, and covering an area of approximately 2,800 square miles.[2]

Sounds, small bays, and many small inlets make the outline very irregular. Several moderate-sized rivers empty their waters into the bay. On the west shore, beginning at the head of the estuary, are the Susquehanna, Patapsco, Severn, Patuxent, Potomac, Rappahannock, York, and James Rivers; on the eastern shore the Elk, Sassafras, Chester, Choptank, Nanticoke, and Pocomoke Rivers are the most important ones. The Susquehanna and Potomac, which are the largest, and the rest of the rivers of the western shore supply by far the greater bulk of the fresh water emptied into the bay.

While Chesapeake Bay extends almost directly north and south, its mouth faces the east. Cape Charles and Cape Henry, which guard the entrance to the north and south, respectively, are about 10 nautical miles apart, a distance which is considerably less than the average width of the southern part of the bay. This narrowed condition, together with the occurrence of a tidal delta cut by channels running parallel with the current, have an effect on the velocity of the current through the mouth.

Chesapeake Bay is rather shallow, and there is not a great deal of difference between the upper and lower parts of the bay. Thirty or forty feet is about the average for deep water. Here and there, especially along the eastern shore, there are very deep holes: 150 feet off Kent Island, 114 feet off Poplar Island, 118 feet off Tilghman Island, 114 feet off Taylors Island, 156 feet off Barren Island, 134 feet off Hooper Island, 122 feet off Point No Point, 139 feet off Smiths Point, and 150 feet off Cape Charles City. All of these are close to the eastern shore except the one off Smiths Point, which is near to the western shore, and those off Taylors Island and Point No Point which are in the middle of the bay.

The deep holes along the eastern shore are connected with one another by regions of greater depth than the average of the bay, so that there is a natural deep channel hugging the eastern shore more or less closely and extending from the head of the bay to Point No Point, from which region it crosses over toward the western shore, becoming lost near Rappahannock Spit (Windmill Point). The deep water then continues nearer the eastern shore almost to Cape Charles. (See fig. 1 and Coast and Geodetic Survey charts, Nos. 77 and 78.)

These deep holes are of special interest on account of their permanence, their comparatively rich and unusual invertebrate fauna, and their relation to fishing grounds. It is at the bottom of the deep-water channel that the most saline and densest water is found. Similar deep pools are known in England—for example, the Sloyne in the Mersey River, Lune Deeps in the Irish Sea, and Lynn Well in the Wash. Wheeler (1893) has pointed out that these deeps are permanent because equilibrium of erosion has been attained, and filling up is prevented by the action of the tides combined with the production of eddies. Most of the deep holes of the Chesapeake are located close to the same shore as the submerged "deeps" of the Susquehanna River, studied by Mathews (1917).

Geologists have generally agreed that Chesapeake Bay, in part at least, is a submerged river (McGee, 1888, Lindenkohl, 1891) and that the deep-water channel under consideration is the old bed of the Susquehanna River before the subsidence of the coastal plain. Probably, then, the deep channel was established in geological

[2] This area has been computed for this survey by the U. S. Coast and Geodetic Survey, and it includes, in addition to Chesapeake Bay proper, Mobjack Bay, Pocomoke Sound, Tangier Sound, Kedges, Holland, and Hopper Straits, Fishing Bay, Honga River, Eastern Bay, Herring Bay, and the entrance to the Choptank River.

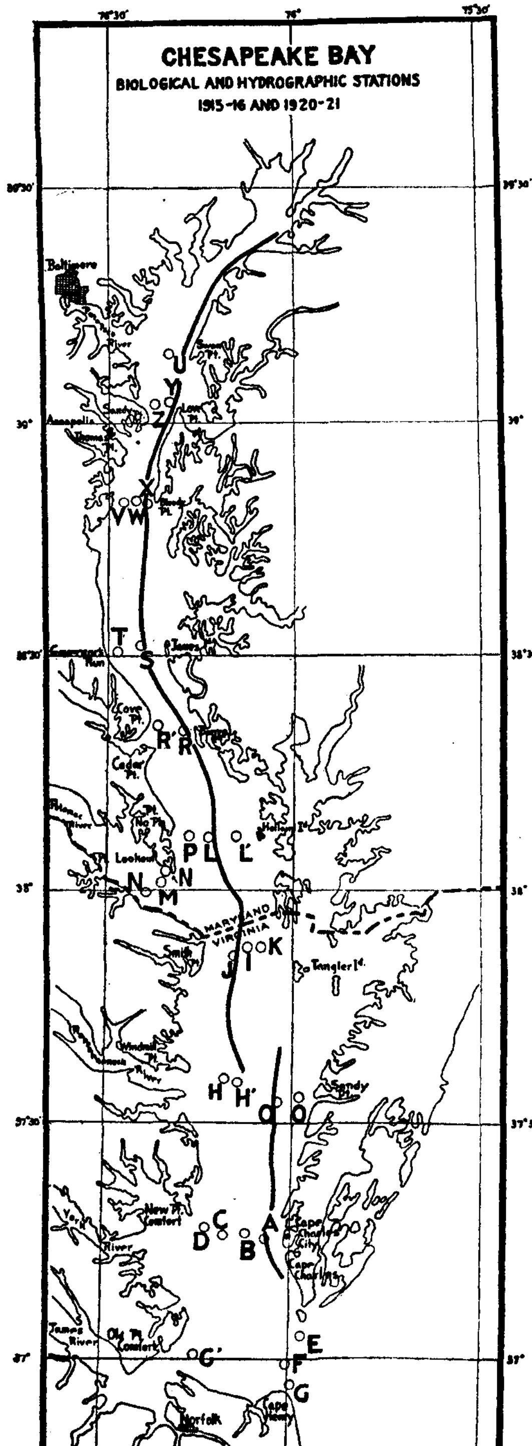
CHESAPEAKE BAY
BIOLOGICAL AND HYDROGRAPHIC STATIONS
1915-16 AND 1920-21
Baltimore
Annapolis
Cove Pt.
Cedar Pt.
Pt. Lookout
MARYLAND
VIRGINIA
Smith Pt.
Tangier Id.
Windmill Pt.
New Pt. Comfort
York River
Cape Charles City
Cape Charles
James River
Old Pt. Comfort
Norfolk
Cape Henry
U
Y
Z
X
V
W
T
S
R'
R
P
L
L'
N
N'
M
K
J
I
H
H'
O'
O
C
A
D
B
E
C'
F
G

FIGURE 1

times when the coastal plain was more elevated than at the present time. While there does not seem to be any good reason for believing that the ebb and flood of the tide during recent times has cut the deep channel, yet it is known that erosion to a marked degree is taking place along the eastern shore of the bay (Hunter, 1914).

Like most estuaries, Chesapeake Bay has, in general, a muddy bottom, resulting in part from the deposition of large amounts of organic matter brought down from the land by the rivers; in part from the settling of the dead bodies of marine, brackish-water, and fresh-water organisms, and in part from the settling of finely divided mineral matter. The latter is commonly called clay. This mixture of clay and organic matter, which assumes a soft, sticky condition when wet, undoubtedly contains some iron sulphide resulting from the action of the sulphates in the sea water on the iron compounds brought from the land. The mixture is characteristic of estuaries, ocean waters near the land, and deeps outside of the 100-fathom line, according to Murray and Irvine (1893). They have given it the name "blue mud" or clay. This "blue mud" varies somewhat in color from a black to a blue-black and to a brown in the Chesapeake, depending, probably, on the amount of organic matter and sulphide of iron present, as pointed out by Murray and Irvine.

The consistency of the blue mud is not the same in all regions. In some places it forms a rather firm, cakelike layer without a soft surface, in others the typical plastic, claylike mud with a soft surface, and in still other localities a soft, puddled mud. Samples of the bottom of Chesapeake Bay show, as a rule, that the blue-mud layer is not very thick except in certain regions, such as the mouths of rivers. Usually a sample cut out of the bottom to a depth of 2 or 3 inches shows a lower layer of sand, clay, or shells, and often the blue mud is more or less mixed with these materials. While the bottom of Chesapeake Bay is largely muddy, the shores are usually sandy, and this latter condition is especially characteristic of the southern half of the bay.

The movements of the water of Chesapeake Bay are complicated. The ebb and flood of the tide, the outflow of many rivers which aid the ebb and hinder the flood, the greater volume of river water entering from the western shore, eddies produced by headlands at the mouths of rivers and inequalities on the bottom, currents moving in more or less opposite directions at surface and bottom in the same locality, variations in rainfall, seasonal changes in temperature, and strong winds are factors which govern the movements of the water in the bay. There are no very strong currents, a condition which has been noted by the Coast and Geodetic Survey (1916), Grave (1912), and the author.

METHODS

Some preliminary investigations of much value were made by Lewis Radcliffe, of the Bureau of Fisheries, in 1915, 1916, and 1917, but this work was discontinued in March, 1917. In January, 1920, the writer continued the investigation under the United States Bureau of Fisheries and was in charge until March, 1922.

During 1916 and 1920, 13 general cruises over the bay were taken on the U. S. S. *Fish Hawk*. In addition to these, 2 preliminary cruises were made in 1915, another on the U. S. S. *Roosevelt* outside of the bay near the entrance in 1916, 4 special cruises in the bay to study hydroids in 1916, 2 special cruises in 1921, and 2 in 1922. The 24 cruises, including dates, station numbers, and other data, are given below:

Cruise

I. October 22–27, 1915, stations 8336 to 8365.

II. December 1–10, 1915, stations 8366 to 8402; 24-hour station 8394.

III. January 15–22, 1916, stations 8403 to 8441.

Cruise
IV. January 27–February 1, 1916. (Outside of Capes Henry and Charles) (on U. S. S. *Roosevelt*.) Stations 8442 to 8457.
V. March 6–12, 1916, stations 8458 to 8496.
VI. April 21–26, 1916, stations 8497 to 8535.
VII. May 22–30, 1916 (for hydroids), stations 8536 to 8549.
VIII. June 2–12, 1916, stations 8550 to 8588.
IX. July 17–31, 1916, stations 8589 to 8627; 24-hour station 8617.
X. August 30–September 2, 1916 (for hydroids), stations 8628 to 8650.
XI. September 8–12, 1916, stations 8651 to 8686.
XII. December 16–17, 1916 (for hydroids), stations 8687 to 8696.
XIIa. March 20–22, 1917, (for hydroids), stations 8697 to 8706.
XIII. January 10–16, 1920, stations 8707 to 8737.
XIV. March 6–12, 1920, stations 8738 to 8769; 24-hour stations 8738 and 8760.
XV. May 1–8, 1920, stations 8771 to 8799.
XVI. July 3–9, 1920, stations 8800 to 8831; 24-hour stations 8800 and 8811.
XVII. August 21–26, 1920, stations 8832 to 8866; 24-hour stations 8855 and 8866 (8832 to 8836 outside of bay).
XVIII. October 15–21, 1920, stations 8867 to 8896; 24-hour stations 8867 and 8877.
XIX. December 4–10, 1920, stations 8897 to 8928; 24-hour stations 8918 and 8928.
XX. January 22–27, 1921, stations 8929 to 8959; 24-hour stations 8948 and 8959.
XXI. March 28–April 2, 1921, stations 8960 to 8988; 24-hour stations 8960 and 8970.
XXII. May 30–June 3, 1921, stations 8989 to 9019; 24-hour stations 9008 and 9019.
XXIII. January 21–25, 1922, stations 9020 to 9047; 24-hour station 9039.
XXIV. March 25–30, 1922, stations 9048 to 9078; 24-hour stations 9067 and 9078.

The general cruises were made at approximately equal intervals, and on each cruise about 30 "areas" or regions were visited; and, for the most part, the same areas were visited on each cruise. These areas, which were circular in outline, were charted as 183 meters (200 yards) in diameter, and their positions were selected in such a way as to make lines across the bay covering all localities of interest from Cape Charles and Cape Henry to Swan Point and North Point. Each area was designated by a capital letter, as may be seen in Figure 1. While they were recorded as measuring 183 meters in diameter, the actual stations made were not spread out much within the area during the time the writer was in charge; that is, the various stations within the area were made according to bearings which were kept the same, usually, from cruise to cruise, so that the positions of the various stations in an area did not vary a great deal.

Water samples for quantitative plankton study and for ascertaining the salinity and temperature of the water were collected, using the Green-Bigelow water bottle and the Negretti-Zambra reversing therometer. About half of each sample of water (approximatley 500 cubic centimeters) was run into a special type of storage bottle with a patent stopper and rubber washer. The collection of these samples was then made a matter of record in the log, and later the samples were shipped to the United States Geological Survey, where, under the supervision of Dr. R. C. Wells, their salinity was determined by titration for chlorine. From the salinity data the densities were calculated.

The other half of the contents of the water bottle was used as a plankton sample. Such samples were later sent to Dr. Bert Cunningham, of Duke University, Durham, N. C., who determined the species, counted the number of organisms per cubic centimeter for each species, and studied the distribution of the species in the bay. These samples gave a fairly good idea of the abundance of most plankton organisms with the exception of copepods and some other of the more active species. While the observations and collections described above were being made the ship was allowed to drift unless the wind or currents were so strong as to carry it out of the 200-yard area. When the latter occurred, the ship was given enough headway to keep within the area.

In order to supplement the information obtained from the plankton samples mentioned above, surface towings were taken with townets made of silk bolting cloth (No. 6 and No. 18 or 20) and a bottom towing with a similar No. 18 townet. The mouth of each surface net measured 30.5 cntimeters (1 foot) in diameter and that of the bottom net one-half meter in diameter. During the towing, which lasted 10 minutes, the speed of the vessel was, as a rule, 2 knots. Samples obtained in this way were shipped to specialists for identification and in some cases for study from the point of view of distribution. The Copepoda, Medusæ, and Sagittæ were studied by Prof. C. B. Wilson, Dr. Henry B. Bigelow, and the author, respectively. Mr. Glassman and the author have undertaken a study of the distribution of the Mysidæ. Most of the Crustaceæ were sent to the United States National Museum, where they have been identified.

A large beam trawl, whose runners were fitted with flat wooden shoes to prevent sinking in the mud, was used for the collection of fishes, sponges, ascidians, hydroids, bryozoans, and echinoderms. The duration of each trawling was 5 minutes; and the speed of the vessel was, as a rule, 3 knots. The fishes have been studied by Messrs. Hildebrand and Schroeder, the echinoderms by Dr. Hubert L. Clark, the ascidians by Dr. William G. Van Name, the bryozoans by Prof. Raymond C. Osburn, the hydroids by Prof. C. W. Hargitt, and the sponges by Prof. H. V. Wilson.

Such animals as mollusks, annelids, holothurians, leeches, and many lower organisms which are found on the bottom or burrowing in the mud or sand, were captured either by the mud bag attached to the beam trawl or by the "orange-peel bucket." The latter is a small commercial dredge that bites to a depth of about 0.5 meter, bringing up about 0.1 cubic meter of the bottom. The mollusks were sent for study to the National Museum, the annelids to Dr. A. L. Treadwell, the holothurians to Dr. Hubert Lyman Clark, and the leeches to Dr. J. P. Moore.

SALINITY

The determination of the salinity of a body of water is one of the necessary procedures in a biological survey because the degree of salinity is believed to be a factor in determining the distribution of some of the animals and plants found in the water and because it is desirable to know how much the salinity varies from time to time. For this reason water samples were collected at each station visited, and their salinity determined by titration for chlorine, from which the salinity was calculated.

The data on surface and bottom salinity and temperature will be discussed first, since many of the organisms collected and counted were taken at those levels. In this same part of the paper the vertical distribution of salinity and temperature will be taken up. After that, under the heading of seasonal distribution, data from intermediate waters will be compared at equivalent depths such as 20 and 30 meters.

SURFACE SALINITY AT MOUTH AND HEAD

The salinity of Chesapeake Bay, like that of other long bays and estuaries, gradually decreases, with very few exceptions, from the mouth to the head; and the bay is known as a brackish body of water, although the failure, as a rule, of the fresh waters from the land and the saline waters of the sea to mix completely, and the variation in the volume of fresh and salt water entering the bay, result in different degrees of brackishness (Cowles, 1920). The surface data at the mouth of the bay show a vari-

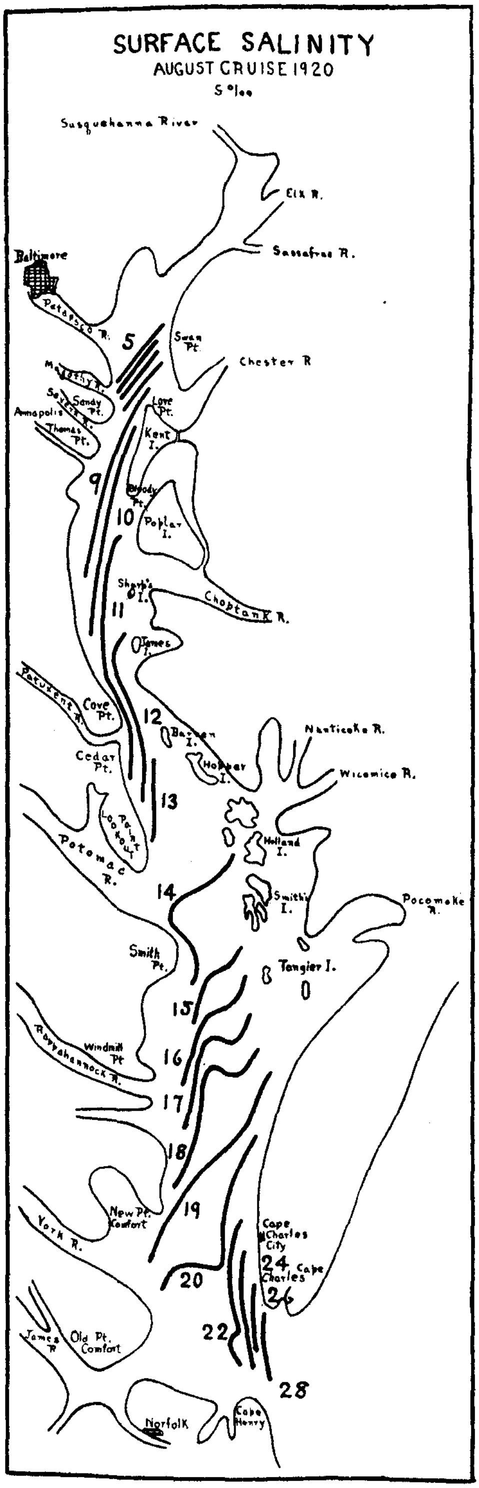
SURFACE SALINITY
AUGUST CRUISE 1920
S °/oo
Susquehanna River
Elk R.
Sassafras R.
Baltimore
Patapsco R.
Swan Pt.
Chester R
Magothy R.
Sandy Pt.
Severn R.
Annapolis
Thomas Pt.
Love Pt.
Kent I.
Bloody Pt.
Poplar I.
Sharp's I.
Choptank R.
James I.
Patuxent R.
Cove Pt.
Barren I.
Hooper I.
Nanticoke R.
Wicomico R.
Cedar Pt.
Point Lookout
Potomac R.
Holland I.
Smith I.
Pocomoke R.
Smith Pt.
Tangier I.
Windmill Pt
Rappahannock R.
New Pt. Comfort
York R.
Cape Charles City
Cape Charles
James R
Old Pt. Comfort
Norfolk
Cape Henry
5
9
10
11
12
13
14
15
16
17
18
19
20
22
24
26
28

FIGURE 2

ation in salinity from about 19.00 to 30.00 grams per liter in the region of areas *G*, *F*, and *E*, while near Balitmore at area *U* there is a variation from about 3.00 to 11.00 grams per liter. So far as our records show (January, March, April, June, July, September, 1916; January, March, May, July, August, October, December, 1920; January, March–April, May–June, 1921; and January, March, 1922), the surface salinity never reached 31.00 at the mouth, but occasionally it was reduced to less than 19.00—for example 18.36 at *G* in March, 1922. On the other hand, at area *U* the surface salinity never reached 12.00 and sometimes dropped below 3.00—for example 2.26 in May, 1920. It will be seen then that the range of surface salinity from head to mouth may be large, for example 2.26 at *U* to 25.40 at *F* in May, 1920.

SURFACE SALINITY FROM MOUTH TO HEAD

A good general idea of the variation of the surface salinity from the mouth to the head of Chesapeake Bay may be obtained from Figure 2, which is a map [3] of the bay showing the surface salinity for a cruise in August, 1920. During this cruise the range of surface salinity was from 28.94 (area *E*) at the mouth to 4.75 (area *U*) at the head. The arrangement of the isohalines [4] shows clearly that the most saline surface water was uniformly on the east side of the bay from head to mouth. Similar maps for other months are shown in Figures 3, 4, 5, and 6.

The greatest decrease per unit of distance in surface salinity took place between *E*, *F*, *G*, and *D*, *C*, *B*, *A* (from 28.94 to about 20.00 in a distance of about 15 miles) near the mouth, and this is indicated by the crowding of the isohalines. (August, 1920). A similar condition was noted in the Baltic Sea by Pettersson (1894). Next in order was that between *Y*, *Z*, and *U* near the head. The decrease from the mouth of the Potomac River to *Y*, *Z*, as well as from *D*, *C*, *B*, *A* to the Potomac River was very gradual. A study of the data from the other cruises shows that while there is considerable variability in the rate of decrease from cruise to cruise in the regions mentioned, the condition during August is an average one. The amount of decrease in salinity per unit of distance from *J*, *I*, *K* into the mouth of the Potomac River at *N*, *M*, *N′* is usually rather high, but it will be noted by referring to the map (fig. 2) for August, 1920, that the isohalines do not show such a condition. This is probably due to the unusual time elapsing between the times of making the observations at *J*, *I*, *K*, and *N*, *M*, *N′*.

VARIATION OF SURFACE SALINITY ACROSS BAY

One of the most striking characteristics of part of Chesapeake Bay is the higher surface salinity on the eastern than on the western side of the bay (Cowles, 1925). Such a distribution of salinity is most marked from the region of James Island to the mouth, although during certain cruises—for example June 1916, January, August, and December, 1920—the surface salinities obtained on the eastern side of the bay were highest from the mouth to the region of Baltimore. A study of the profiles indicates that this condition is due to the fact that the deep-water channel which contains the most saline bottom water lies on this side throughout most of its extent and to the fact that a large volume of fresh water from the rivers of the western shore presses the more saline water toward the eastern shore. Now, taking up in order

[3] No high degree of accuracy can be claimed for such a map, since the water samples could not be collected simultaneously at the stations and since the salinity fluctuates somewhat back and forth at a station with the tide. However, in the opinion of the writer the map presents a good general picture of the distribution of the surface salinity during the period of the cruise.

[4] An isohaline is a line connecting points of the same salinity in a plane.

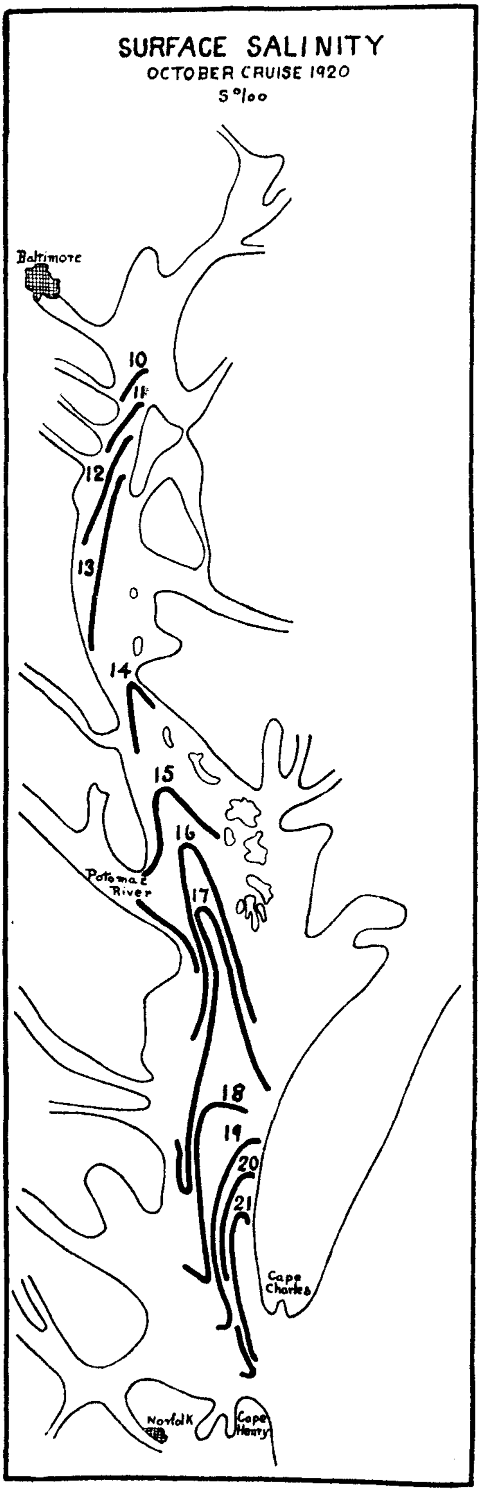

FIGURE 3

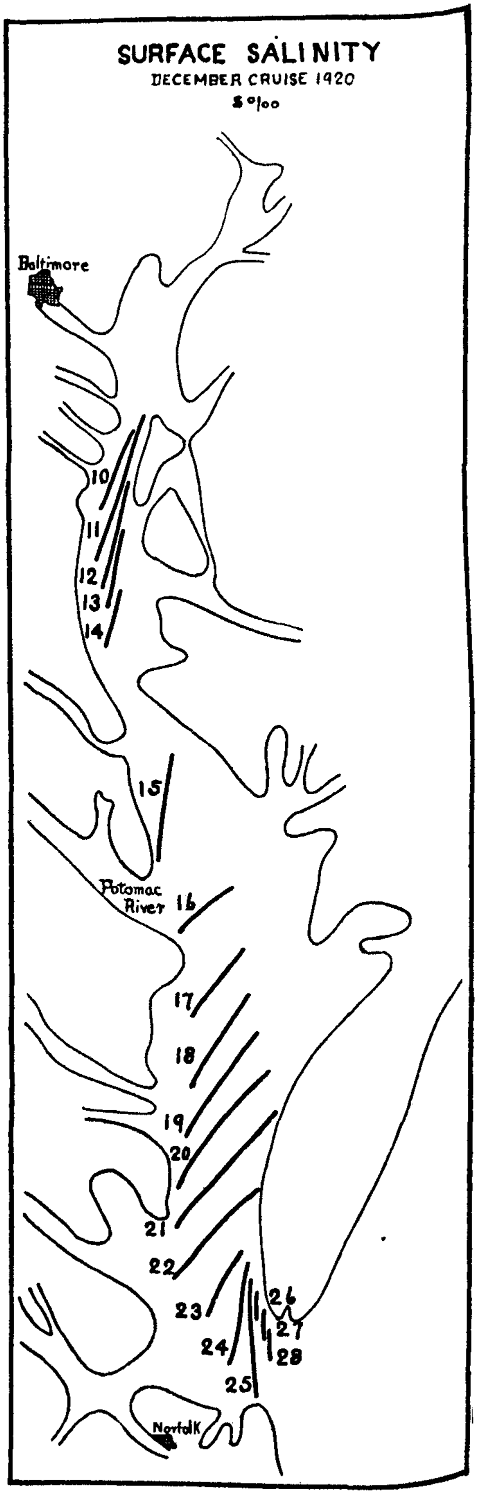

FIGURE 4

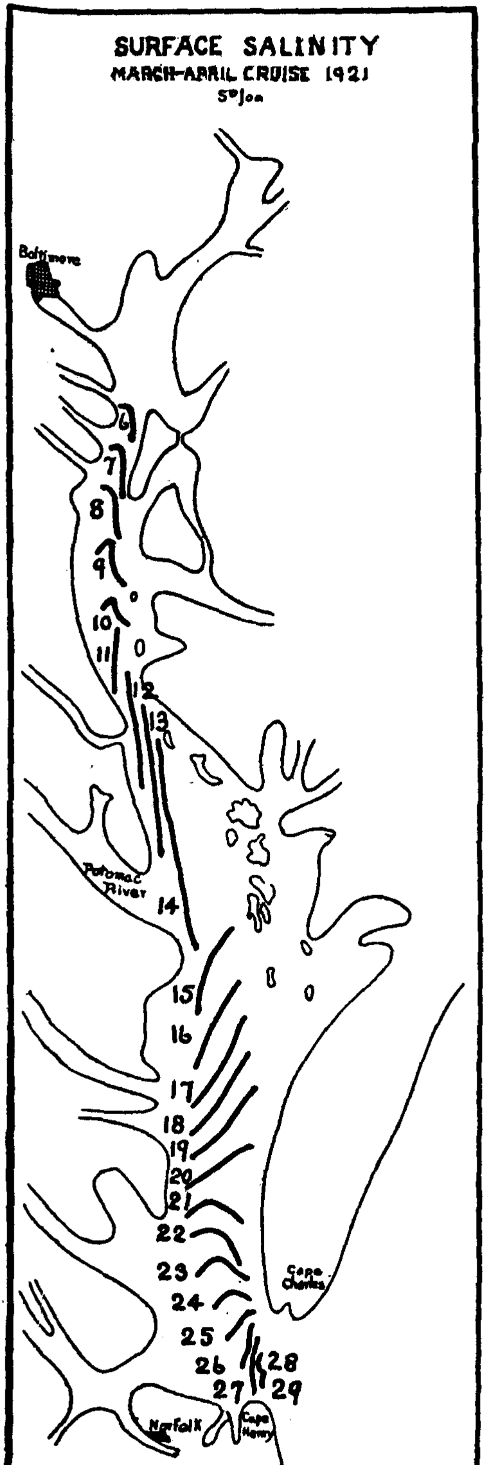

FIGURE 5

FIGURE 6

from the mouth to the head the several lines extending across the bay, we find the following:

Salinity data for the line *G, F, E* during 9 of 11 cruises showed that the surface salinity was higher on the east side [5, 6]; line *D, C, B, A*, 13 of 13 on the east side; line *H, H′, Q, O*, 16 of the 16; line *J, I, K*, 12 of the 13; line *N, M, N′*, 10 of the 12; line *P, L, L′*, 10 of the 11; *R′, R*, 11 of the 11; line *T, S*, 9 of the 11; line *V, W, X*, 8 of the 14; and line *Z, Y*, 9 of the 15[6]. It will be noted that toward the head the condition mentioned gradually changes until along the line *Z, Y* the higher surface salinity occurs on the east side with considerably less frequency.

BOTTOM SALINITY AT MOUTH AND HEAD

In this discussion of the bottom salinities it should be understood that samples from the same area collected on different cruises were not taken at exactly the same depth and that when comparisons are made between bottom salinities in different parts of the bay it is done merely to show under what different conditions of salinity organisms at the bottom may be living.

The bottom salinities recorded on our cruises for the mouth of the bay varied from about 26.00 to a little over 32.00 at area *G*, while in the region of Baltimore at area *U* they varied from about 6.00 to 17.00. These data, which are from the same cruises as those mentioned above, with the exception of July and September, 1916, January, 1920, and January, 1922, when no data were obtained, show that the bottom salinity at area *U* on one occasion was as low as 6.54 (May cruise, 1920) and did not reach, at any time observed, a greater salinity than 17.38 (December cruise, 1920). At area *G* in the mouth the bottom salinity reached the lowest point observed, 25.77, during the May, 1920, cruise. While the maximum salinity observed was 32.57 in January, 1916, at area *G*. The range of bottom salinities, then, from head to mouth, may be very great—for example, 6.54 at *U* to 25.77 at *G* in May, 1920.

It is of interest that the salinities at area *U* closely approach a point where the density is so low that, if continued for a long period of time, it is harmful to oysters (Moore, 1897).

BOTTOM SALINITY FROM MOUTH TO HEAD

A study of the data for the August, 1920, cruise shows that during this cruise the range of bottom salinities was from 31.74 (area *G*) at the mouth to 15.21 (area *U*), as compared with 28.94 (area *E*) at the mouth to 4.75 (area *U*) at the head for surface salinity during the same cruise. As in the case of the surface salinities, the greatest decrease per unit of distance, if one leaves out of consideration the high salinities of deep holes, took place between *E, F, G*, and *D, C, B, A*. At the mouth of the Potomac River, *J, I, K* to *N, M, N′*, the decrease was quite marked; but in the long stretches from the mouth of the Potomac River north to *Y, Z*, and south to *D, C, B, A* changes per unit of distance were small, a condition which holds true for the surface salinity. An examination of the data for the rest of the cruises shows in general similar relative amounts of decrease in bottom salinities per unit of distance for the regions just mentioned.

An interesting exception to the gradual decrease in bottom salinity from the mouth to the head of the bay is seen at *T, V*, and *Z*. These areas, which lie on the west side of the bay from Governors Run to the mouth of the Magothy River, have fairly similar depths—for example, 9.15 meters at *T*, 10 meters at *V*, and 12.81 meters

[5] More accurately on the north side, since this line runs about north and south.

[6] Only cruises for which there were sufficient surface salinity determinations are included in the counts.

at Z (August cruise, 1920). On 10 of the 15 cruises for which we have data during 1916, 1920, 1921, and 1922 the bottom salinity increased, passing from T to Z—that is, toward the head of the bay. While there is not much difference in depth from T to Z, yet it will be seen that the latter is a little deeper than the former and this is probably enough to account for the condition mentioned. At the surface the salinity decreases almost invariably from T to Z.

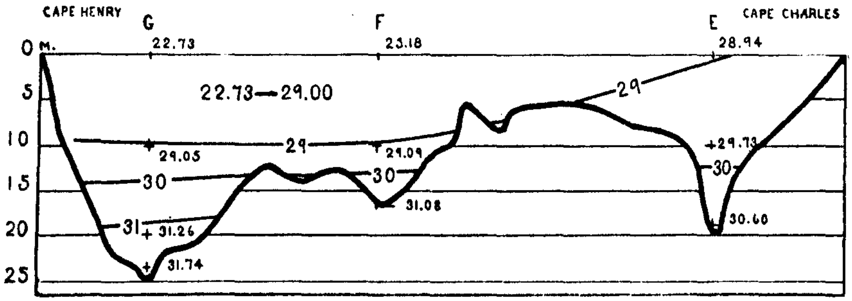

Figure 7.—Salinity profile from Cape Henry to Cape Charles, August 22, 1920

VARIATION OF BOTTOM SALINITY ACROSS BAY

It will be remembered that there seems to be a strong tendency for the most saline surface water to lie near the eastern shore of the bay but that this tendency decreases in the upper part until at Z, Y the saltier water occurs with more nearly an equal frequency on the eastern and western sides. The most saline bottom water, however, as might be expected, owing to its higher density finds its way into the deep-water channel of the bay and may be traced during every cruise along the eastern

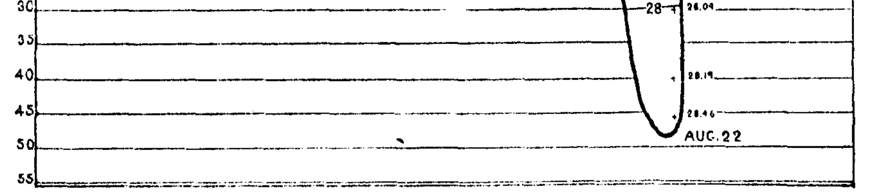

Figure 8.—Salinity profile from New Point Comfort to Cape Charles City, August 22, 1920

shore and almost invariably through Y, X, S, and R, then to the middle of the bay through L, then nearer the western shore through J, again on the eastern shore through Q and A, and finally out through the mouth of the bay at G. (See map showing deep-water channel, fig. 1.)

VERTICAL DISTRIBUTION OF SALINITY

Profiles across the bay show that especially along the deep-water channel, sometimes in the region of the mouths of rivers, and usually at the mouth of the bay, a sharp increase in salinity occurs somewhere between the surface and about the 20-meter level. (Figs. 7, 8, 9.) This phenomenon, which is a well-known one for regions where fresh and salt water meet, is due to the lighter fresh water flowing over the heavier salt water. (See Pettersson, 1894, and Murray and Hjort, 1912.) The sharp increase occurs usually at about 10 meters, but there are exceptions, and at times, depending upon the flow of fresh water from the rivers, the character of the tides, the winds, the temperature, etc., the line of demarcation may be nearer the surface or

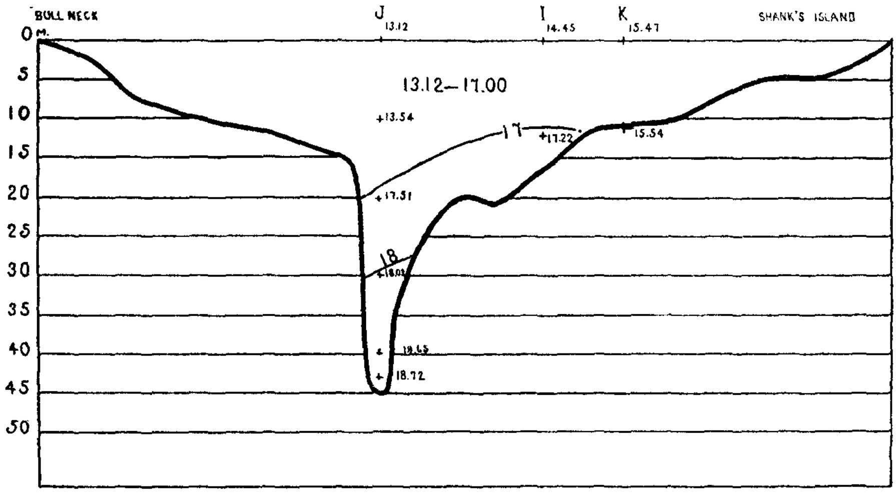

FIGURE 9.—Salinity profile from Bull Neck to Shanks Islands, January 24, 1921

below 10 meters. While the stratification just described was very marked during most of our cruises, there were times in the spring and winter months when the water approached a condition of equal salinity from surface to bottom. (Fig. 10.) A discussion of this phenomenon will be taken up under seasonal distribution of salinity.

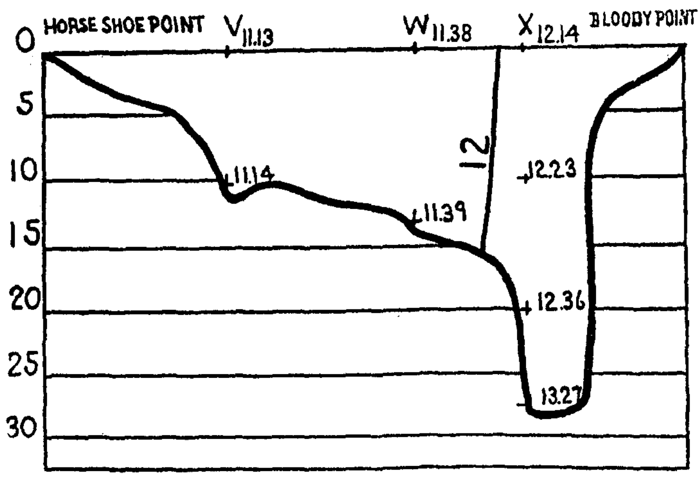

FIGURE 10.—Salinity profile from Horse Shoe Point to Bloody Point, January 27, 1921

In addition, the vertical distribution of salinity as seen in profiles illustrates graphically the conclusions arrived at above from a study of the data for surface and bottom salinities; namely, that the more saline surface water, in general, lies nearer the eastern shore, although in the northern part of the bay it may be found on either side with almost equal frequency, and that the more saline bottom water follows the deep-water channel *Y*, *X*, *S*, *R*, *L*, *J*, *Q*, *A*, and *G*.

An interesting condition, which shows on practically all cruises, is the one along the line *J*, *I*, *K* just below the mouth of the Potomac River. The most saline bottom water is found at area *J*, located on the deep channel near the western shore, while the most saline surface water lies on the eastern side, usually at area *K* or at least at area *I*. The density profiles indicate that the condition mentioned is due to the pressure of the Potomac River water, which, coming from a westerly direction, crowds the more saline surface water overlying the deep channel toward the east. A similar but less marked condition occurs along the line *P*, *L*, *L'*.

SALINITY OF WATER DURING WINTER

It has been pointed out that there is a comparatively large decreasing range of salinities from the mouth of the bay to the head throughout the year. This range varies from time to time, but there is no evidence in our data to show that there is any uniform seasonal fluctuation in the amount of range.

Inspection of the salinity values of the January cruises taken in 1916, 1920, and 1922 shows that they were generally higher than those of the January, 1921, cruise. This condition is probably correlated with the fact that January, 1921, was an exceptionally mild month. (Table 1.) (See section on salinity during the spring.)

TABLE 1.—*Temperatures and salinities at surface, 20 meters, and 30 meters, during January, for various years and areas*

Areas	January, 1916		January, 1921						January, 1922					
	Temperature, °C., surface	Salinity, surface	Temperature, °C.			Salinity			Temperature, °C.			Salinity		
			Surface	20 meters	30 meters	Surface	20 meters	30 meteas	Surface	20 meters	30 meters	Surface	20 meters	30 meters
G	4.1	23.40	5.9	6.0	------	19.22	28.10	------	12.9	5.9	------	23.91	29.15	------
A	3.3	22.74	4.9	4.9	4.8	------	------	------	4.4	4.5	4.1	23.96	25.71	25.89
J	1.4	15.14	3.9	3.9	4.0	13.12	17.51	18.30	3.4	3.2	2.7	------	------	------
L	1.8	14.36	3.1	3.0	3.7	13.64	13.80	16.80	2.6	2.4	2.8	15.46	20.31	20.46
R	1.1	13.66	2.6	3.4	3.7	------	------	------	1.4	2.7	2.5	15.81	19.54	19.86
S	1.1	12.77	2.7	------	------	------	------	------	1.7	------	------	13.17	------	------
X	1.0	11.13	2.0	2.1	------	12.14	12.36	------	.8	3.2	------	13.26	18.95	------
Y	1.2	9.22	1.6	[1] 3.8	------	10.88	[1] 14.46	------	------	------	------	------	------	------
U	.6	6.83	1.1	------	------	6.44	------	------	------	------	------	------	------	------

[1] At 20.13 meters.

Throughout the year the salinity usually increases with the depth (Katohalin). This might be expected in a body of water where there is fresh water from rivers flowing over tidal saline water entering from the ocean, even though currents, river floods, low air temperatures, and winds tend at times to alter that condition. A discontinuity in salinity was frequently seen during the winter cruises and, although the water was at times almost homohaline from the surface to the discontinuity layer, it was seldom that even an approach to complete homohalinity along the deep-water channel was observed. The salinities for January, 1916, are typical: Area *U*, surface 6.83, 4 meters 8.44, 9 meters 12.92, 15 meters 14.31; area *L*, surface 14.36, 5 meters 14.92, 10 meters 15.72, 17 meters 16.87, 25 meters 19.27, 31 meters 19.87; area *G*, surface 23.40, 8 meters 27.20, 17 meters 32.54, 22 meters 32.57. Occasionally, however, as on January 25, 1921, at area *L*, an approach toward an homohaline and homothermous condition was observed. The salinities were as follows at 7.35 p. m.: Surface 14.36, 10 meters 14.26, 20 meters 14.34, 30 meters 14.64, 33.9 meters 14.78. The temperatures were: Surface 3°, 10 meters 3°, 20 meters 2.9°, 30 meters 3°, 33.9 meters 3.3°. The wind, temperature, and direction of the current at this time were favorable for profound changes in the relation of waters of different salinities. There was a moderate breeze blowing from north-northeast at about 15 miles per hour, the sea was rolling, and there was an outgoing current moving slowly almost without exception from surface to bottom throughout 24 hours of observation. These conditions, together with a rapid fall in air temperature two days previous to the time when the water samples were collected and a continued low air temperature of about −4° C., were probably the cause of the almost homothermous and homohaline relations.

SALINITY OF WATER DURING SPRING

The salinity data for 1916 show that the deep-water salinity values found in the bay were considerably less, with very few and unimportant exceptions, during the March cruise than during the January cruise. The same was true for 1920 and 1922. This relation did not hold in the lower half of the bay between the January and March-April cruises of 1921. The exceptional mildness of the month of January, resulting in a flood of fresh water, probably accounts for the difference. The evidence on the whole from the four years indicates, nevertheless, that in the spring there is a decrease in the salinity of Chesapeake Bay. Such a condition would be expected, if for no other reason than that in the spring months the maximum discharge occurs in the larger rivers which empty into Chesapeake Bay. (Table 2.)

TABLE 2.—*Temperatures and salinities at surface, 20 meters, and 30 meters, during March, for various years and areas*

Areas	March, 1916		March-April, 1921						March, 1922					
	Temperature, °C., surface	Salinity, surface	Temperature, °C.			Salinity			Temperature, °C.			Salinity		
			Surface	20 meters	30 meters	Surface	20 meters	30 meters	Surface	20 meters	30 meters	Surface	20 meters	30 meters
G	3.7	28.15	12.1			27.74			8.9			18.36		25.10
A	3.1	20.14	12.1	11.3	11.4	21.56	24.62	28.23	7.3	7.0	6.7	19.33	23.91	18.26
J	2.3	15.17	10.9			14.30			8.1	6.2	6.5	11.62	17.89	17.12
L	1.8	15.25	11.4			14.26			7.2	5.7	5.6	12.21	16.95	
R	1.6	14.94	10.2	10.7		13.94	14.20		7.7	4.9	5.2			
S	1.7	14.61	10.8			10.87			7.3			11.89		
X	1.1	12.92	10.5	9.9	8.4	7.43	10.38	13.53	8.2	4.5		9.84	15.26	
Y	1.2	10.55	12.4			5.26			9.2	5.2		5.65	15.79	
U	1.4	9.25	12.7			3.61			9.0			5.22		

A discontinuity in the vertical distribution of salinity is usual along the deep-water channel for the spring cruises, although the salinity is as a rule lower than at other seasons of the year. At times, however, as in the early part of March, 1920, when one of our cruises was made, the vertical distribution of salinity approached homohalinity at several areas in the northern part of the bay. Only during the winter (fig. 10) and spring cruises has this condition been observed. On the morning of March 6 we began to take samples at area *U* and continued their collection every hour and a half until 11.45 p. m. Throughout the day the salinities were unusually similar from surface to bottom—for example, at 1.15 p. m., surface 10.05, 3 meters 10.11, 6 meters 10.17, and bottom (9 meters) 10.71. At station 8748, between areas *R* and *L*, a similar condition was found: Surface 16.11, 10 meters 16.14, 20 meters 16.14, 30 meters 16.16, 35 meters 16.22. The conditions were favorable for such distribution of salinity. At area *U* the sea was rough, a 15-mile wind blew from the northwest, ice floes were in the bay, there was no dominating flood current, and the air temperatures were exceptionally low. During the night of March 5, 1920, an exceptionally large drop in temperature occurred—from 46° F. (7.8° C.) to 18° F. (−7.8° C.), a drop of 28° F. (15.6° C.), in Baltimore.

SALINITY OF WATER DURING SUMMER

A discontinuity in the vertical distribution of salinity was distinctly seen on the summer cruises. This might be expected, since the time for spring freshets was over and there was less chance of a disturbance in the stability of the layers. The maximum rains in the Chesapeake Bay region usually occur during the summer months. While they may cause a distinct decrease of temperature in the surface layers and while, of course, the surface layers are diluted to some extent, our data, except for the July, 1916, cruise in the upper part of the bay, do not show any appreciable decrease in the salinity at the surface or in the deeper layers during the months of maximum precipitation. (Table 3.) The indications are that the effects of precipitation on the bay itself are not very important in changing the salinity. No tendency toward a homohaline condition was observed during the summer cruises along the deep-water channel, and even in shallow water the range from surface to bottom was usually considerable. Typical summer conditions for *U*, July 3, 1920, were as follows: Surface, 6.80, 5 meters 8.49, 10 meters 12.24, 12.5 meters 13.31, at 11.28 p. m.; and for *L* at 10.19 a. m., July 6, 1920, surface 12.50, 10 meters 14.66, 20 meters 19.72, 30 meters 20.20, 36.6 meters 20.22. That the salinity values of the midsummer and late summer cruises showed an increase over the low salinity values of the spring cruises may be seen from the data given under the section "Salinity at 30 meters and averages of salinities."

SALINITY OF WATER DURING AUTUMN

So far as our records show, the discontinuity in vertical distribution of salinity persists in a striking manner into the autumn. During this season the discharge from rivers is at its minimum and the weather is usually exceptionally mild on Chesapeake Bay. Possibly, but not probably, almost homogeneous vertical distribution of salinity, occurred at times, but our records do not show that such changes have taken place. However, only two cruises have been made during the autumn—one in September, 1916, and the other in October, 1920. During the cruises of the autumn months just mentioned the salinities, like those of the summer, were higher than those of the spring cruises. (Table 4.)

TABLE 3.—*Temperatures and salinities at surface, 20 meters, and 30 meters, during July and August, for various years and areas*

Areas	July, 1916		August, 1920					
	Temperature, °C., surface	Salinity, surface	Temperature, °C.			Salinity		
			Surface	20 meters	30 meters	Surface	20 meters	30 meters
G	23.5	24.90	27.0	17.2	----	22.73	31.26	----
A	24.3	22.54	27.0	22.2	21.3	22.36	27.43	28.00
J	----	----	26.0	26.0	25.2	----	----	----
L	----	----	25.5	25.5	25.0	13.72	13.77	19.76
R	25.2	10.21	24.2	----	----	12.83	----	----
S	26.0	8.46	----	----	----	----	----	----
X	25.2	5.41	23.7	----	----	10.65	----	----
Y	26.0	4.02	23.5	----	----	9.46	----	----
U	----	----	23.5	----	----	4.75	----	----

TABLE 4.—*Temperatures and salinities at surface, 20 meters, and 30 meters, during September, October, and December, for various years and areas*

Areas	September, 1916		October, 1920						December, 1920					
	Temperature °C., surface	Salinity, surface	Temperature, °C.			Salinity			Temperature, °C.			Salinity		
			Surface	20 meters	30 meters	Surface	20 meters	30 meters	Surface	20 meters	30 meters	Surface	20 meters	30 meters
G			20.4			20.28			10.5	11.3		25.20	30.22	
A	23.4	23.59	20.4	20.0	19.4	21.99	26.18	27.02	10.3	10.2	10.2			
J	24.1	14.54	20.0	19.3	19.5	14.87	22.80		9.5	9.7	10.0			
L			19.7	19.5	19.3	15.89	20.20	22.24	8.7	10.1	10.1	15.14	19.51	20.10
R									8.6	9.5	9.9	14.93	18.35	19.68
S	23.9	12.05	20.2			13.72			7.8			14.69		
X	23.9	11.09	19.4			13.70	16.00		7.9	8.8		12.42	12.84	
Y	24.4	9.56	19.2						7.4			10.64		
U			19.8			9.25			7.0			9.13		

SEASONAL SURFACE SALINITIES DURING 1916

I have stated that the salinity values obtained during the different seasons indicate that in the spring the salintiy in Chesapeake Bay decreases markedly, that in the summer it begins to increase again, reaching its highest degree ordinarily in the fall and winter. Inspection of the surface salinity values obtained at areas *G, F, D, C, B, A, H, J, I, M, X,* and *Z* for the cruises of January, March, April, June, July, and September, 1916, tends to support this contention so far as surface water is concerned (Table 5), although in these data, as well as those which have been given above, the water samples were not taken simultaneously at the various areas, so that they were not collected necessarily at the same stage of the tide. However, the rather close uniformity in the seasonal fluctuation of the salinity values for each area indicates strongly that they show, in a comparative way, the salinity conditions in the bay.

TABLE 5.—*Surface salinities during 1916*

Areas	January	March	April	June	July	September	Areas	January	March	April	June	July	September
G	23.40	28.15	21.92	22.92	24.90		H	18.53	17.30	13.21	14.33	15.99	16.31
F	30.48	25.23	18.89	25.14	26.69	27.54	J	15.14	15.17	10.80	12.97	16.31	14.54
D	19.85	18.46	17.18	17.30	21.46		I	13.37	15.79	11.55	13.24	11.78	15.21
C	19.98	18.91	15.84	17.81	21.62	21.55	M	13.73	13.59	11.09	11.76	9.99	13.26
B	21.47	18.93	16.28	21.17	21.62	21.65	X	11.13	12.92	5.88	8.30	5.41	11.09
A	22.74	20.14	18.46	22.11	22.54	23.59	Z	9.29	10.01	3.35	3.10	4.25	10.16

SEASONAL SURFACE AND 30-METER SALINITIES FOR AREA L DURING 24 HOURS

As further evidence supporting the belief that the salinity decreases in the spring and rises again to a maximum in the latter part of the year we have the data from water samples collected usually at 1½-hour intervals through 24 hours. Such data bring out the tidal fluctuation in salinity during that period as well as the changes from cruise to cruise (1920).

The 24-hour observations were not begun at area *L* until the July cruise, but the single surface salinity determinations for area *L* in March and May were 15.87 and 7.30, respectively. The data for the July and October cruises (1920) show an increase over those of the May cruise, while on the cruise during the unseasonably mild month of January, 1921, the salinity values decreased again. (Table 6.)

A similar condition may be seen for the salinity values at the 30-meter depth. The single determination at 30 meters during the March cruise was 16.50, while those of the July and October cruises (1920) were higher and those of the January, 1921, cruise lower.

TABLE 6.—*Surface and 30-meter salinities at area L, taken at frequent intervals during 24 hours, July and October, 1920, and January, 1921*

Period	Surface	30 meters	Period	Surface	30 meters	Period	Surface	30 meters	Period	Surface	30 meters
July 6-7, 1920			*July 6-7, 1920*—Continued			*Oct. 18-19, 1920*—Continued			*Jan. 25-26, 1921*		
10.19 a. m.	12.50	20.20							10.30 a. m.	13.64	16.80
11.49 a. m.	12.56	20.04	4.19 a. m.	12.76	19.18	9.00 p. m.	15.92	21.93	Noon	13.64	15.34
1.19 p. m.	12.57	19.98	5.49 a. m.	12.40	20.01	10.30 p. m.	15.85	21.92	1.30 p. m.	13.97	16.12
2.49 p. m.	12.53	20.10				Midnight	15.38	22.04	3.00 p. m.	14.15	14.87
4.19 p. m.	12.60	20.00	*Oct. 18-19, 1920*			1.30 a. m.	15.79	21.88	4.30 p. m.	14.52	14.87
5.49 p. m.	12.68	20.10	10.30 a. m.	15.90	22.30	3.00 a. m.	15.77	21.82	7.35 p. m.	14.26	14.64
7.19 p. m.	12.68	20.04	Noon	15.89	22.24	4.30 a. m.	15.68	21.75	3.00 a. m.	14.59	14.59
8.49 p. m.	12.66	20.00	1.30 p. m.	15.90	22.34	6.00 a. m.	15.76	21.61	4.30 a. m.	14.38	14.87
10.19 p. m.	12.58	19.68	3.00 p. m.	15.86	22.32	7.30 a. m.	15.71	21.99	9.00 a. m.	14.20	14.34
11.49 p. m.	12.68	19.69	4.30 p. m.	15.95	22.22	9.00 a. m.	15.81	21.87			
1.19 a. m.	12.68	20.06	6.00 p. m.	15.98	21.35						
2.49 a. m.	12.73	20.02	7.30 p. m.	15.92	21.85						

RELATION OF SEASONAL SALINITY TO SALINITY OF COASTAL WATER

The investigations of H. B. Bigelow (1917b) along the eastern coast of the United States in the region of Chesapeake Bay indicate that "the salinity of the coast water, so far as is known, rises during autumn and winter * * *". Water samples collected outside of the mouth of Chesapeake Bay on January 20, 1914, and January 27, 1916, at the depth of 18 meters showed that the salinity was 33.57 and 33.35, respectively. (See Bigelow, 1917b, pp. 54, 55, 60; and 1922, pp. 124, 181, 184.) While no water sample was collected below the surface at this same station in November, 1916, other data indicate that the salinity at 18 meters was about 33.00; at the surface in this same locality the salinity was 32.52. On the other hand, the salinity at 18 meters on August 21, 1916, was 31.02. These data, which were the ones directly concerned with Chesapeake Bay in Bigelow's study, indicate a higher degree of salinity for the coastal water in the winter than in the summer.

The salinity determinations inside of Chesapeake Bay are, on the whole, in accord with Bigelow's tentative statement concerning the rising of the salinity of the coastal water during autumn and winter.

SALINITY AT 30 METERS AND AVERAGES OF SALINITIES

The data that we have for salinities at 30-meter depths, although limited, support the view that the coastal water increases in salinity during the latter part of the year after the floods of the first part of the year. At area *A*, off Cape Charles City, the salinities at 30 meters on the following 1920 cruises were: March, 20.81; August, 28.09; and October, 27.02. Near the middle of the bay at area *L* during the same year and at the same depth they were as follows: March, 16.15; July, 20.26; August, 19.76; October, 22.24; and December, 20.10. Farther up the bay at area *R* the data at 30 meters for two cruises during 1920, were: March, 16.06; and December, 19.68. No samples were collected at 30 meters during the January cruise.

Those areas visited during 1920 also show higher surface salinities during the cruises of the latter part of the year. The following are examples: Area *G*, January, 28.19; March, 20.64; May, 19.26; July, 20.54; August, 22.73; October, 20.28; and December, 25.20. Area *A*, January, 23.32; March, 18.70; July, 21.72; August, 22.36; October, 21.99; and December, 22.78. Area *H*, January, 16.85; March, 16.22; May, 11.95; July, 15.57; August, 16.45; October, 16.74; and December, 18.25. Area *X*, January, 13.57; March, 13.77; May, 5.81; July, 9.40; August, 10.65; October, 13.70; and December, 12.42.

During the year 1922 only 2 cruises were made, 1 in January and 1 in March; and a distinctly lower salinity was found during the latter cruise. At area *A*, near the mouth of the bay, the salinities at 30 meters for January and March were 25.89 and 25.10, and for area *L*, near the mouth of the Potomac River, 20.41 and 17.12. A similar condition was found at the surface and at 20 meters.

Averages of the surface salinities of 12 widely distributed areas (*G*, *F*, *D*, *C*, *B*, *A*, *H*, *J*, *I*, *M*, *X*, *Z*) during the cruises of 1916 show the seasonal condition mentioned above: January, 18.26; March, 17.88; April, 13.70; June, 15.85; and July, 16.88. Surface salinities for the September cruise were markedly higher than those of the summer and spring cruises, but, owing to the fact that the data for areas *G* and *D* are lacking, no average is given for that cruise. Also the data at each area for each cruise show a similar relation: Area *A*, January, 22.74; March, 20.14; April, 18.46; June, 22.11; July, 22.54; and September, 23.59. Area *H*, January, 18.53; March, 17.30; April, 13.21; June, 14.33; July, 15.99; and September, 16.31. And area *X*, January 11.13; March, 12.92; April, 5.88; June, 8.30; July, 5.41; and September, 11.09.

The data show that there was a minimum degree of salinity in Chesapeake Bay during those cruises taken in the spring months of 1916 and 1920, and that, in general, higher salinities occurred during the summer, fall, and winter cruises. Also in 1922 the data show that salinities of the March cruise were distinctly lower than those of the January cruise, but in the winter and spring of 1921 this relation was disturbed in the lower part of the bay. It has been pointed out that the winter months, December, 1920, and January and February, 1921, were unusually mild in Maryland and that probably that accounts for the low salinities during that time.

A study, then, of the salinities of the various cruises taken on Chesapeake Bay favors the view that a decided decrease in salinity occurs during the early part of the year and that later in the year there is a tendency for it to increase again. Such a view is in keeping with the time of occurrence of the maximum discharge of the water from the large rivers entering the bay, and, as we shall see in the next section, with the tendency for the more saline deep water of partly marine origin to make its way up into the bay during the latter part of the year.

RELATION OF DIRECTION AND VELOCITY OF CURRENT AT 24-HOUR STATIONS TO SEASONAL SALINITY

It is evident that the degree of salinity depends on (1) the amount of fresh water brought in by rivers or by local precipitation, (2) on the amount of saline water brought in by the sea combined with (3) the mixing of these waters, and (4) the amount of evaporation of the water. The records of the water-supply department of the United States Geological Survey show that the maximum discharges of such large rivers as the Potomac and Susquehanna at points somewhat above their entrance into the Chesapeake occur during the spring months, March, April, or May, and that the minimum discharges are in August, September, or October. These conditions alone would tend to establish a low salinity in the bay during the spring and a higher one during the summer, fall, and winter.

On the other hand, Chesapeake Bay is a tidal estuary, although the tidal currents are weak compared to those of many other estuaries. A clearly defined ebb and flood of the water were made out at the areas mentioned below during the spring and summer cruises, but the current velocities, according to current-meter records, were quite low. During the fall and winter cruises, however, when the current velocities were a little higher, the alternating incoming and outgoing currents characteristic of tides were usually not so evident, judging from our data obtained during 24-hour observations at area *U*, near Baltimore, and at areas *R*, *L*, and *Q*, lower down in the bay. These results are of interest in connection with the observations made by Canadian observers. (See Dawson, 1897.) Changes due to local precipitation and evaporation can not be made out, as a rule, from our data. Other changes due to more dominant causes mask them.

The fact that the water at 30 meters as far north as a little below Baltimore (area *R*) may have a salinity of 20.00 shows, of course, that water of partly marine origin makes its way up in the bay. It is difficult to ascertain what factors bring this condition about and whether the higher salinities sometime after the spring freshets are due to decreased pressure from the fresh water, to reaction currents resulting from outflow of surface fresh water, to the pressure of oceanic water resulting from the northerly drift of the highly saline water of equatorial regions, to a combination of these factors, or to other factors. Irregularities in tidal flow due to hydrological conditions in the upper part of the bay, the occurrence of spring and neap tides, and probably many other factors which add complexity make it difficult to analyze the movements of the waters of Chesapeake Bay.

Current records, however, at 24-hour stations do show at times what appears to be a persistent, although not continuous, tendency for the rather highly saline waters of the lower layers to move slowly into the bay. Areas *L* and *R* are both deep-water areas situated in the deep channel where the movements of the more saline water may be observed. The records indicated that with the approach of autumn and during the winter months there was at times a persistent tendency for the highly saline water of the lower layers to push its way slowly inwards, thus masking the tidal movements, and that during the spring and summer cruises this tendency was not so evident, with the result that the tidal currents were more clearly seen. A similar condition has been observed in Christiana Fiord by Hjort and Gran (1900). The movement inward during the autumn and winter cruises did not seem to be dependent on the conformation of the bottom, nor could it be related clearly to the occurrence of spring and neap tides. Undoubtedly, however, a nontidal factor (see Marmer, 1925, and Zeskind and LeLacheur, 1926) was responsible for this ingoing current. The wind, as an example, blows more frequently from a northerly direction during the winter, while during the summer the more common direction is southerly, according to Spencer. This would tend to move the fresher surface water oceanward in the winter and as a result produce the so-called "reaction stream" of Ekman (1876); the "reaction current" of Helland-Hansen and Nansen (1909); "compensatory bottom current," Johnstone (1923); "induction current," Cornish (1898); "undercurrent," Dawson (1896), in which the deeper more saline water moves inward from the sea. In summer, on the other hand, with the wind from the opposite direction such a tendency would not exist.

The discharge from rivers (another nontidal factor) would also bring about conditions such as those just described, but it is not clear why the undercurrent moving in an ingoing direction is so marked during the winter months, when the discharge from the rivers is not ordinarily at is height.

Finally, it may be mentioned that so far as the time of the occurrence (autumn and winter) of a strong tendency toward an incoming current in the lower layers is concerned, it would be permissible to relate that phenomenon to the influence of the North Equatorial Stream and the Atlantic gyral (Gulf Stream eddy) of which it is a part. It is known (Johnstone, 1923) that the axis of this stream or drift and also the rest of the Atlantic gyral shifts in a northerly direction during the summer, reaching its northermost position in the autumn; and that in such regions as the North Sea, Irish Sea, and Baltic Sea the culminating effect of this moving water occurs in March or in some regions later. Chesapeake Bay might be expected to show the effect of this movement of saline water during the autumn and winter, but while the data on salinity, temperature, current velocity, and current direction show that there is at times an unusual inflow of saline water into the bay during the autumn and winter, there is no conclusive evidence to support the theory that this condition is brought about by the northerly shift of the Atlantic Stream gyral alone or even in part.

TEMPERATURE OF WATER

It is well known that certain organisms are adapted to one range of temperatures and that others flourish under a different range. Also, it is known that there are some which are very hardy, being able to live between widely separated extremes, and that others are sensitive and can exist only within a small range of temperatures. Such a dependence on temperature must necessarily be an important factor in determining the latitudinal, seasonal, and vertical distribution of aquatic animals and plants. Furthermore, the degree of temperature undoubtedly is often an important factor in regulating the rate of reproduction, and extreme temperatures may at times cause great mortality. Finally, it is believed that temperature is a factor which has an influence on the migration of some fishes. For these reasons water temperature data have been recorded. A discussion of the data follows.

SURFACE TEMPERATURE AT MOUTH AND HEAD

The temperature data for the surface water collected at the mouth of Chesapeake Bay on the various cruises showed a variation from about 4° C. to 27° C. at area *G*, while at the head (area *U*) near Baltimore temperatures ranging from about 0.0° C. to 25° C. were found. The data for January, March, April, June, July, September, 1916; August, October, December, 1920; January, March–April, May–June, 1921; and January, March, 1922, show a maximum surface temperature of 27° C. at area *G* in August, 1920, and only on one cruise a temperature as low as 3.7° C. (at area *G* in March, 1916).

At area *U*, near Baltimore, the highest surface-water temperature recorded on our cruises was in August, 1920, 24.8° C., and the lowest, 0.3° C. in January, 1921. The maximum surface temperature seems to have been about the same for the mouth and the head; but the minimum was lower at the head than at the mouth, due undoubtedly to the presence of ice floes and to slightly lower air temperatures during the winter.

Temperature data were collected also during January, March, May, and July, 1920. The thermometers used during this period were tested for accuracy and the necessary corrections were determined; but since they were not of the reversing type, and hence not suitable for work at depths, it is considered best to disregard the results. However, the surface readings for the latter part of the first week in March, 1920, were frequently below 0.0° C.; and it is the writer's belief that the temperature of the surface water in the upper part of the bay reached temperatures below 0.0° C.—for example −0.2° C. (salinity 13.67) on March 7, 1920, at area *W*.

SURFACE TEMPERATURE FROM MOUTH TO HEAD

Leaving out of consideration, for the moment, the surface temperature conditions along the line *E*, *F*, *G*, which extends across the mouth of the bay, an examination of the surface temperatures observed during the cruises of the coldest months of the year suggest that, in general, there is a decrease from a region near the mouth (line *D*, *C*, *B*, *A*) to the head. The data consistently show a graded decrease; and such a condition would be expected, but it must be remembered that our observations were not made simultaneously at the thirty-some areas distributed over the bay and that, in fact, it took several days to complete the collection of the data. It is hardly necessary to state that there was some change in the temperature conditions from day to day so that a map showing isotherms for a cruise can give only a general idea of the conditions over the whole bay. Such a map for the January, 1921, cruise is shown in Figure 13. The decreasing range of surface temperatures for January, 1916, 1921, and 1922 may be seen well in Table 1 where series are given for areas from the mouth to head.

During the cruises of the spring, summer, and fall the surface temperature values with one exception did not show the decreasing range from the mouth to the head. Although not taken simultaneously, they indicate a more variable condition and smaller range during those seasons. The exception mentioned above was found during the August, 1920, cruise, when, as may be seen from Table 3 and Figure 11, the data showed a decreasing range of surface temperatures from the mouth to the head. These figures were rather surprising until it was seen by reference to the weather map of the United States Weather Bureau that shortly before the observations were made at areas *D*, *C*, *B*, and *A* (August 21) the air temperature at Norfolk reached 90° F. (32.2° C.) and at Baltimore only 70° F. (21.1° C.).

Much variability in temperature distribution is to be expected, especially at the surface, in a shallow body of water where a difference of 20° F. in the temperature of the air over two different areas may occur at the same time so that maps showing isotherms can give only approximate pictures of conditions. The map for the cruise of August, 1920 (fig. 11), shows a range of surface temperatures from 23° near the head to 27° near the mouth, an unusual condition for which an explanation has just been offered. The 27° isotherm is of special interest in this connection. A more usual condition for the warmer months is shown on the map for June, 1916. (Fig. 15.)

The greatest differences in surface temperatures per unit of distance from mouth to head were found, as in the case of salinity, near the mouth of the bay. They occurred during the cruises of the warmer months, when the heated waters of the rivers and bay meet the colder waters of the ocean. As examples, in August, 1920, there was a difference of almost 5° C. between *E* and *A*; in June, 1916, there was almost 4° C. difference between the two areas. During the cruises of the colder months, however, such a rapid change in passing from the line *G*, *F*, *E* to the line *D*, *C*, *B*, *A* was not observed. (Figs. 11, 12, 13, 14, and 15.)

The range of surface temperatures passing from *D*, *C*, *B*, *A* out through the mouth of the bay by way of areas *G*, *F*, *E* showed almost invariably a decrease in temperature during the cruises of the warmest months, and an increase in temperature during those of the coldest months.

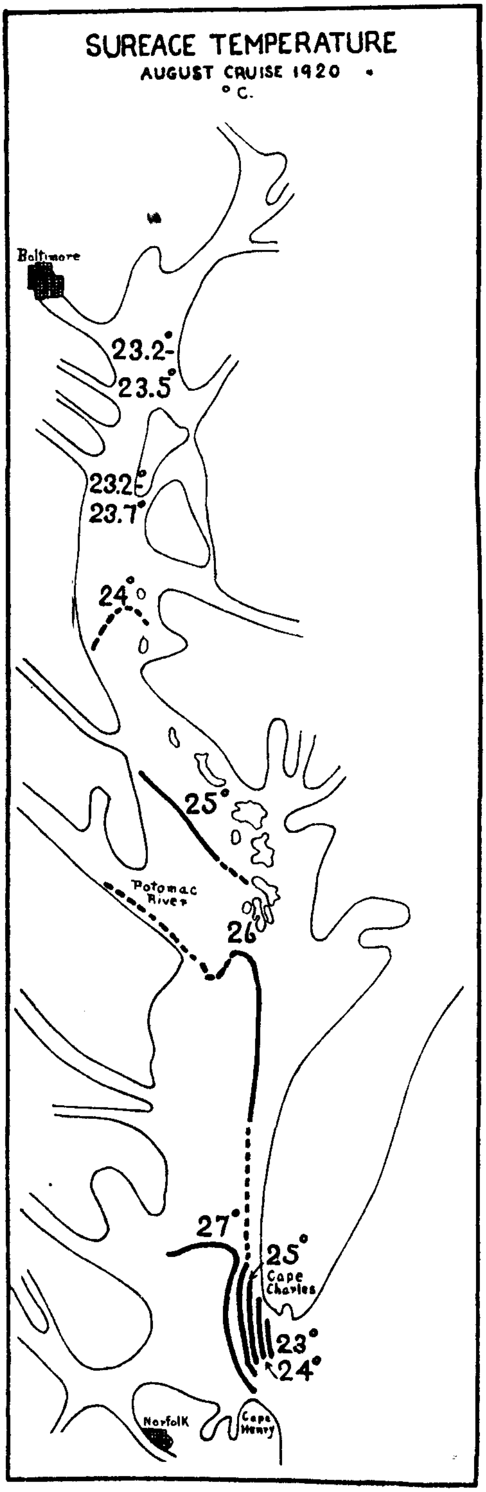

FIGURE 11

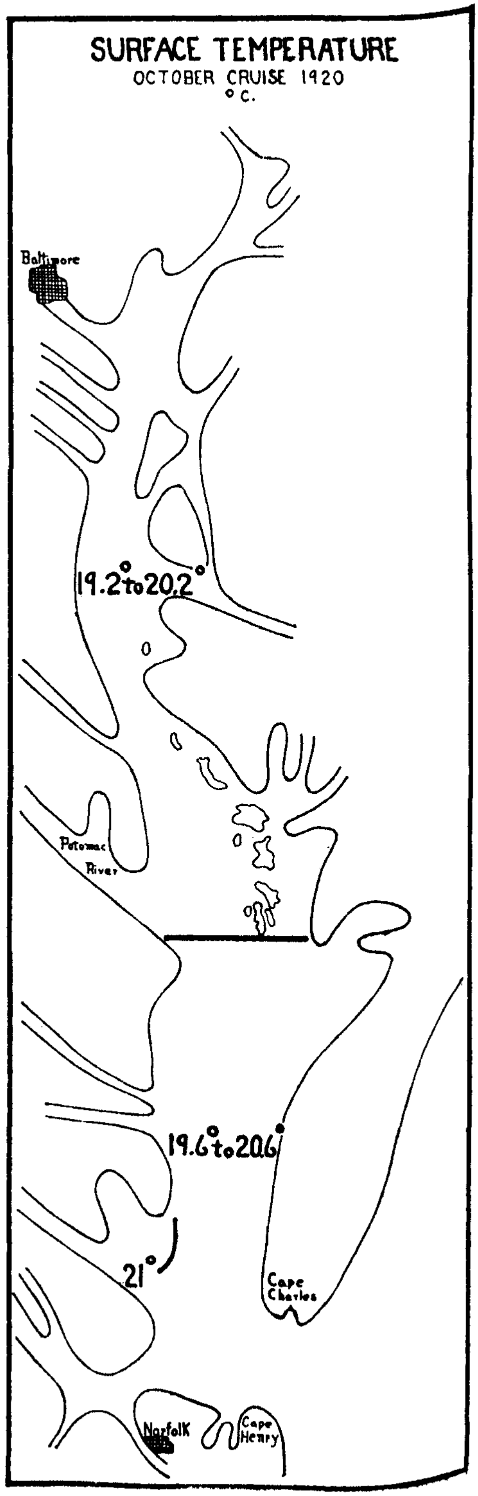

FIGURE 12

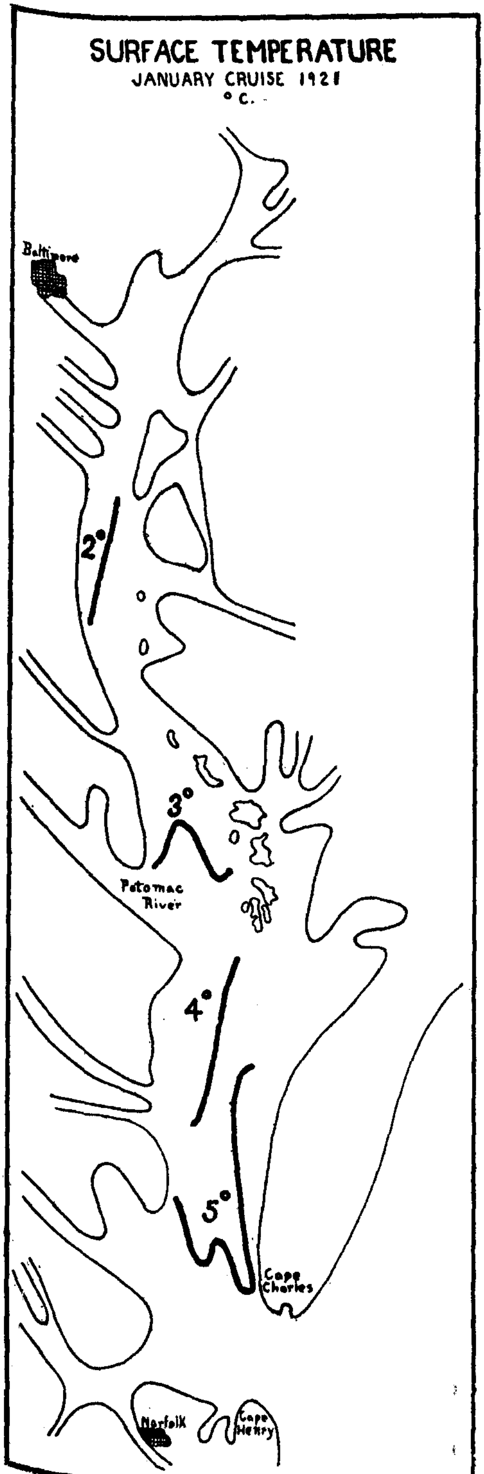

FIGURE 13

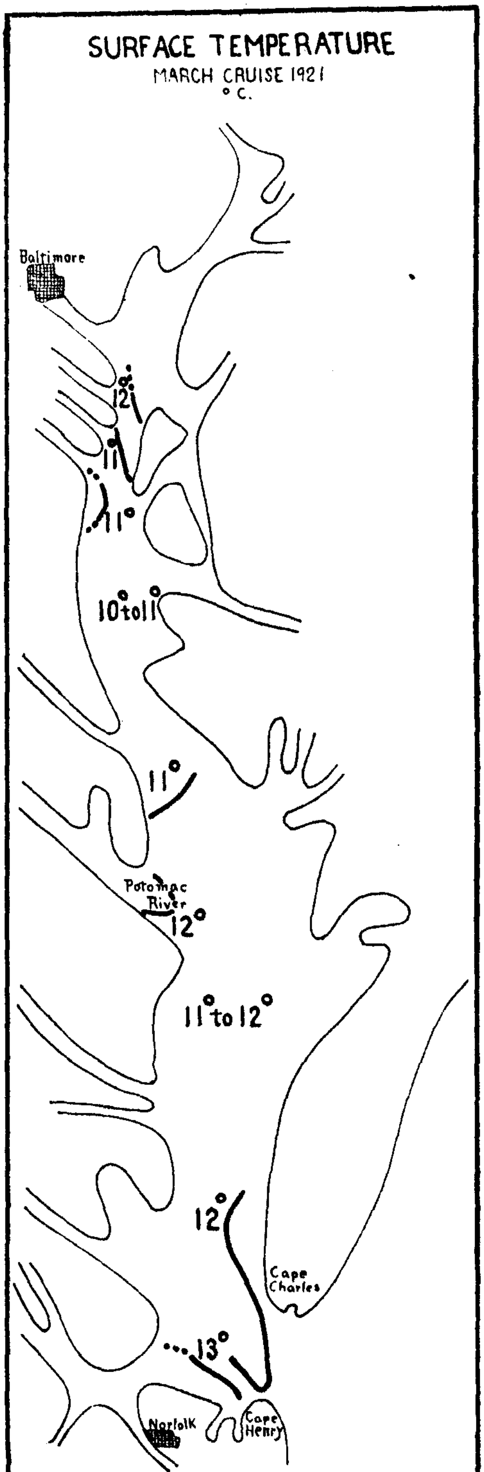

FIGURE 14

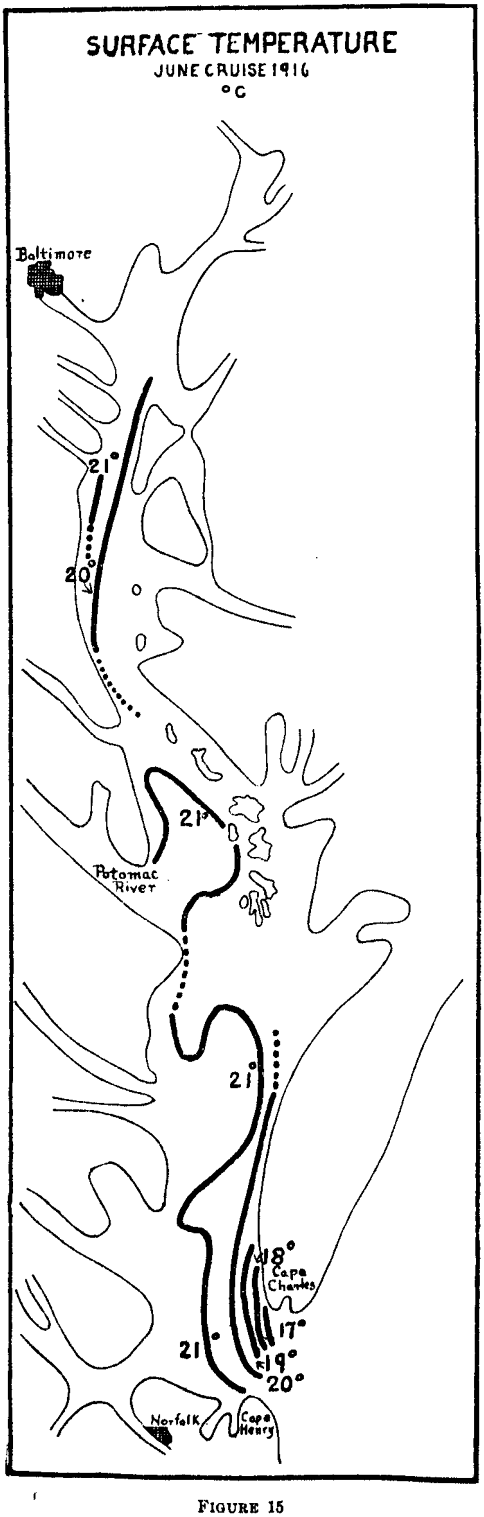
SURFACE TEMPERATURE
JUNE CRUISE 1916
°C
Baltimore
21°
20°
21°
Potomac River
21°
18°
Cape Charles
17°
21°
19°
20°
Norfolk
Cape Henry

FIGURE 15

VARIATION OF SURFACE TEMPERATURE ACROSS BAY

Referring to the map showing the surface temperatures for June, 1916 (fig. 15), one sees at once that the isotherms are arranged quite differently from those of August, 1920. Here we see a condition which is more characteristic of the warmer months. The isotherms, during this cruise at least, run, more or less, up and down the bay. This condition results from the warmer water being on the western side of the bay, except along the line *J*, *I*, *K*, and also from the fact that temperatures from north to south are close to uniformity.

After a study of the data for all the cruises it seems to be difficult to formulate any very definite rule for the distrubution of surface temperature with reference to the east and west sides of the bay. However, it may be stated that, judging from data collected during winter and summer cruises, warmer water lies decidedly more often at area *G* than at area *E*. These areas mark the line across the mouth of the bay.

BOTTOM TEMPERATURE AT MOUTH AND HEAD

The highest and lowest bottom temperatures for area *G* at the mouth of Chesapeake Bay, as recorded on our cruises, were 21.0° C. in July, 1916, and 3.6° C. in March, 1916, while at the head of the bay the highest and lowest temperatures at *U* were 24.4° C. in August, 1920, and 0.9° C. in January, 1921. It will be noted that the range was considerably less for the bottom water than for the surface water both at area *G* and at area *U* (surface 27.0° C. to 3.7° C. at *G* and 24.8° C. to 0.3° C. at *U*). A smaller range would be expected at the bottom, since that water is not subject so much to the effect of great changes in air temperatures.

DEEP-WATER TEMPERATURE FROM MOUTH TO HEAD

The decrease in water-temperature values passing from the line *D*, *C*, *B*, *A* just inside of the mouth of the bay to the region near Baltimore (this leaves out of consideration for the moment the region between *D*, *C*, *B*, *A* and *G*, *F*, *E*) was as marked for the deep water during the cruises of the colder months as for the surface water. This relation can be seen by inspection of the data for 20 and 30 meters. (See Tables 1, 2, and 4.) As in the case of the salinity, the data could not be collected simultaneously at all areas, but notwithstanding this they show consistently a decreasing range.

The greatest differences in deep-water temperature per unit of distance from mouth to head were found near the mouth of the bay between *D*, *C*, *B*, *A* and *G*, *F*, *E*, as in the case of the surface water. It was during the cruises of the warmest months of the year that the greatest range occurred. As examples, the difference in the bottom temperatures between *G* and *A* (21.0° C., 24.2° C.) or *G* and *D* (21.0° C., 25.5° C.) in July, 1916, *G* and *A* (15.5° C., 21.3° C.) or *G* and *D* (15.5° C., 24.0° C.) in August, 1920, and *G* and *A* (15.2° C., 17.1° C.) or *G* and *D* (15.2° C., 19.1° C.) in May, 1921, are of interest, especially those between *G* (the area through which most of the oceanic water enters) and *A*, where the bottom temperatures for *G*, at about 20 meters, are much lower even than those for *A* (about 43 meters). This condition supports the statement that the bottom water, as well as the surface water, entering the bay during the warmer months has a lower temperature than that inside of the bay.

Deep-water temperatures, as in the case of the surface temperatures, show almost invariably a decreasing range in the warmest months passing from *D*, *C*, *B*, *A* through *G*, *F*, *E* and an increasing range during the coldest months.

VARIATION OF BOTTOM TEMPERATURE ACROSS BAY

The temperature of the bottom water depends upon several factors, the most important of which are depth, presence of ice, inflow of water from the ocean, seasonal changes, and to some extent sudden changes in air temperatures. Our records show that on the summer cruises the coldest bottom water was found along the deep-water channel *G, A, H, J, L, R, S, X,* and *Y* and that on the winter cruises the bottom water of this channel was the warmest. Locally, at times during the autumn or winter and occasionally during the spring the temperature relations just mentioned were not so marked. The bottom temperatures along a line across the bay cutting the deep channel may show an approach to uniformity, notwithstanding large differences in depths. As examples, in the spring, during the March cruise, 1916, the bottom temperatures for *D* (5.5 meters), *C* (11 meters), *B* (12 meters), and *A* (40 meters) were 3.3° C., 3.3° C., 3.3° C., and 3.4° C., respectively, while in January, 1916, for the same areas the temperatures were 3.3° C., 3.9° C., 3.8° C., and 4.3° C. During the summer cruises, July, 1916, the bottom temperatures for *D* (6 meters), *C* (10 meters), *B* (12 meters), and *A* (42 meters) were 25.5° C., 24.9° C., 24.4° C., and 24.2° C.

VERTICAL DISTRIBUTION OF TEMPERATURE

The vertical distribution of temperature depends on many factors among which are: Seasonal, diurnal, and sudden local changes in air temperature sometimes accompanied by vertical circulation; strength and direction of the wind; relative thickness of fresh-water layers coming from the rivers and the more saline layers derived from the ocean; the relative temperatures of the fresh water and saline water layers; the cooling effect of the rain on both air and surface water (Krümmel, 1911); the decrease in temperature due to ice floes; and the depth of the water.

As might be expected, the greatest range in temperature from surface to bottom was found in the deep channel. Area *G*, at the mouth, showed the most extensive range—for example, in August, 1920, surface 27.0° C., bottom (23.6 meters) 15.5° C.; and in June, 1916, surface 20.5 ° C., bottom (22 meters) 10.7° C., a difference of 11.5° C. and 9.8° C., respectively.

An examination of the vertical temperature series shows that sudden breaks in temperature occur in the region of 10 to 20 meter depths. These changes are most clearly marked in the deeper parts of the bay and are most commonly observed when the water is stable or "harder" as Sandström (1919) describes it. Water in this condition shows layers of increasing density and usually increasing salinity passing from the surface to the bottom, and such a condition is characteristic of the warmer months of the year. A rather common summer condition for temperature, at least during the warmer part of the day, is that obersved at area *R* during June, 1921 (surface 20.0° C., 10 meters 20.0° C., 20 meters 15.5° C., 30 meters 15.3° C., 40 meters 15.3° C., 47.6 meters 15.1° C.). The layer showing the sudden decrease in temperature between 10 and 20 meters, which is evident in the series, is what is called the "Sprungschicht" by Richter (1891) and Krümmel (1911), "discontinuity layer" by Murray and Hjort (1912), "thermocline" by Birge (1898), and "transition zone" by Whippel (1914). This decline in temperature corresponds very definitely in depth with an increase in salinity. (Surface 11.20, 10 meters 11.68, 20 meters 19.42, 30 meters 19.66, 40 meters 19.80, 47.6 meters 19.78.) A similar relation between temperatures is often seen during the warmer months but frequently the correspondence in depth with the salinity increase is not so definite as in the case mentioned. Indeed, there is evidence indicating that the discontinuity in temperature may be disturbed by a drop in temperature due to rain, cloudiness, or other factors. As an example, in July, 1916, the surface temperatures at practically all stations on the bay were lower than those a few meters below, a condition which was not found usually during continued fair weather on the cruises of the summer months. At area *R* the temperatures were as follows: Surface 25.2° C., 8 meters 25.6° C., 16 meters 25.3° C., 26 meters 24.5° C., 36 meters 25.0° C., 46 meters 25.2° C. During June of the same year at area *R* a summer condition was found—for example, surface 20.3° C., 9 meters 19.3° C., 18 meters 17.7° C., 21 meters 17.6° C., 27 meters 17.2° C., 31 meters 17.0° C., and 41 meters 17.2° C. The records of the United States Weather Bureau show that during the July cruise there were heavy rains in regions about and on Chesapeake Bay. It seems highly probable that they account for the low surface temperatures. (See Krümmel, 1911.) An equally interesting cruise is that of August, 1920. Areas *G*, *F*, *A*, and *B*, near the mouth of the bay, were visited on August 22 and showed a very marked thermocline—for example, at *G*, surface 27.0° C., 10 meters 20.2° C., 20 meters 17.2° C., and 23.6 meters 15.5° C. Similar exceptionally high surface temperatures, even for summer months, were found at areas *F*, *A*, and *B*. This condition seems to be traceable to high air temperatures in that region. (Maximum at Norfolk 90° F. (32.2° C.) and minimum 68° F. (20.0° C.) on August 20.) Farther up the bay the air temperatures and the surface-water temperatures were much lower. (Maximum air temperature at Baltimore 70° F. (21.1° C.) and minimum 68° F. (20.0° C.) on August 20.) The thermocline was obliterated at practically every station and frequently the surface temperatures were lower than those a few meters below. Observations made at area *U*, near Baltimore, on August 26, showed, as an example, surface 23.5° C., 5 meters 24.4° C., 11 meters 24.2° C., at 12 noon. The night before these data were obtained the temperature at Baltimore had dropped to as low as 64° F. (17.8° C.) with a daytime maximum of 74° F. (23.3° C.), according to the records of the United States Weather Bureau. Several days of rainy weather in the region of Baltimore and Washington had preceded August 20, so it seems probable that the rain was also a factor in bringing about the lowered temperatures at the surface.

Ice floes have an effect on the distribution of temperature in the Chesapeake Bay. This was evident at area *U* during January, 1921. Observations were made of temperature and salinity at 1½-hour intervals for a good part of 24 hours, but toward the end of that period observations were discontinued on account of the floating ice which interfered with the instruments. Before the ice disturbed the work, the typical distribution of winter temperature was observed hour after hour—for example, at 4.05 a. m., surface 2.1° C., 5 meters 2.9° C., 11.9 meters 3.5° C. When the ice floes appeared at 5.35 a. m., however, a mesothermous distribution occurred as follows: Surface 0.3° C., 5 meters 1.6° C., 11.9 meters 0.9° C.

SEASONAL DISTRIBUTION OF WATER TEMPERATURE AND SALINITY

TEMPERATURE OF WATER DURING WINTER AND INFLUENCE OF OCEANIC WATER

The range of temperature values observed from the mouth of the bay toward the head varied with the season. A study of the winter data at the surface and at the 20 and 30 meter depths along the deep-water channel, areas *A*, *J*, *L*, *R*, *S*, *X*, *Y*, and *U*, shows a decreasing range with some irregularities from the mouth toward the head, as shown in Tables 1 and 4. The largest irregularities in the decreasing range of the 30-meter temperatures occur at areas *J* and *L*, which are close to the mouth of the

Potomac River. The reduced temperatures at these two areas are probably due to the large volume of colder, fresh water forcing its way in from the Potomac River, as seen in density profiles. Ordinary daily variations in air temperature should not cause the irregularities mentioned at 30 meters, but the surface water temperature would, of course, be affected by them.

Data for area *G*, which marks the main entrance into the bay, are included in the following discussion in order to show the influence of the oceanic water, although the depth at this area does not equal 30 meters (22 meters in January, 1916, 22.9 meters in January, 1921, and 23.8 meters in January, 1922). The data for area *S* in 1916 were obtained from a station near area *S*.

The decreasing range of temperature values from mouth to head shown in Table 1 may be ascribed to a difference in latitude, but there is evidence which indicates that the higher temperature at *G*, the deepest area in the mouth of the bay, is due, in part, to the entrance of warmer water from the ocean. The bottom reading at *G* during the January, 1916, cruise was 6.1° C. (22 meters), a temperature higher than that observed at any area or any depth in the bay during that cruise—considerably warmer even, than those at area *G′*, near Norfolk. The temperatures inside of the bay, then, show that the comparatively high bottom temperature at area *G*, in the mouth of the bay, has its origin from some other source. The data from the cruise of the U. S. S. *Roosevelt* off the mouth of Chesapeake Bay during January and February, 1916, (see Bigelow, 1917 b), show that the temperatures out to about the 20-meter contour were between 6° C. and 7° C. from the surface to the bottom, and that at the 200-meter contour they were considerably higher than nearer shore. These observations, however, were made about two weeks after the time the observations were made at *G*, but it is very probable that similar relations existed two weeks earlier. Temperatures of 10° C. and 12° C. were found over the continental slope—for example, in the region of the 200-meter contour. It is evident that there was a gradual increase in temperature at the surface and at depths from the shore outward; and it is practically certain that the warmer water at *G* had a higher temperature, owing to the fact that its origin was largely oceanic. It is through this area that the bulk of the salt water usually finds its way into the bay. At the time the temperature observations were made at *G*, the salinity at 22 meters was 32.57, the highest found on that cruise in the mouth or anywhere else in the bay. During January, 1921 and 1922, the highest bottom temperatures for the whole bay were found again at *G*, with the exception that in the latter year the temperatures at *F* equalled those at *G*. It is quite probable that the comparatively warm water of the ocean during the colder months of the year has a tendency to raise the temperature of the water of Chesapeake Bay. The temperature conditions at area *G*, the occurrence of water of fairly high salinity in the northern part of the bay, and the distribution of certain marine organisms are in keeping with this theory.

The vertical distribution of temperature during the winter cruises was found to be characterized by a low temperature at the surface and an increasing range from the surface downward (Katothermous, following Krümmel, 1911), as at area *G* in January, 1916, surface 4.1, 8 meters 4.9, 9 meters 5.6, 17 meters 5.8, 18 meters 5.9, 22 meters 6.1; and at area *R* during the same cruise, surface 1.1, 5 meters 1.2, 9 meters 2.2, 18 meters 3.4, 27 meters 3.6, 36 meters 3.8. A similar condition may be seen at area *G* in December, 1920, surface 10.5, 10 meters 10.8, 20 meters 11.3, 22.9 meters 11.6, and at many other areas. But there are times during the winter when close approaches to uniformity of water temperatures from surface to bottom occur. Such temperatures were observed during the month of January, 1921, which was an exceptionally mild month in Maryland at least. Ice floes were so common during the cruise in the upper part of the bay that they interfered with the instruments. The 24-hour current meter records at area *L* near the mouth of the Potomac River showed a dominating outgoing current from surface to bottom, which, however, was as usual of low velocity. The salinities were remarkably low at all depths for that time of the year, and at many areas there was, for such a body of water as Chesapeake Bay with its highly variable temperatures, a rather close approach to uniformity from the surface to the bottom. So there is much evidence to show that the bay had been flooded, probably gradually, with almost homothermous water of low salinity similar to that of the spring freshets. This condition combined with the freezing air temperatures, which occurred at the lower end of the bay during the January cruise (see U. S. Weather Bureau records for Norfolk, two days before our observations were made) and which chilled the upper layers, was undoubtedly largely responsible for the almost homothermous gradient from surface to bottom.

TEMPERATURE OF WATER DURING SPRING

The data collected on the spring cruise, as for the winter cruise, range decreasingly for the most part from the mouth toward the head. This is shown in Table 2, although it will be seen that there are some irregularities—for example, high surface temperatures at the upper end of the bay during March, 1922, and March-April, 1921, cruises. The temperature values for the bay were somewhat higher during three of the spring cruises, but in March, 1916, the readings, especially at the bottom, ran lower than during any of the winter cruises. According to the United States Weather Bureau this was an exceptionally cold March for Maryland. There was a remarkable unbroken period of low daily air temperatures recorded. The temperature observations made at *G* during the March cruise, 1916, were the highest observed in the whole bay, as was the case during the winter cruises, but in the data for the April, 1916, March, 1922, and March-April, 1921, cruises this relation was not so evident. Apparently during those months the change was taking place from the winter condition to that found during the summer cruises in which the bottom water temperatures at *G* were cooler than those observed at other areas in the bay.

The vertical distribution during the spring cruises varied like that of the winter season. On the March cruise of 1916—the exceptionally cold March—the temperatures showed a close approach to uniformity (homothermous), as at area *G* where the following readings were made: Surface 3.7, 5 meters 3.8, 10 meters 3.7, 20 meters 3.5, 22 meters 3.6. Occasionally the surface water was a little warmer than the intermediate layers, and below the latter the temperatures increased again (dictothermous), as during the March-April cruise, of 1921, at area *A:* Surface 12.1, 10 meters 11.2, 20 meters 11.3, 30 meters 11.4, and 42.5 meters 11.5—or as during the March cruise of 1922 at area *J:* Surface 8.1, 10 meters 6.2, 20 meters 6.2, 30 meters 6.5, 40 meters 6.2, 43 meters 6.6. Often on the March cruise and more often on the March-April cruise, however, the surface water was the warmest, and there was a decrease in temperatures passing downward (anothermous). In March, 1922, at area *G*, as an example, the temperatures were as follows: Surface 8.9, 10 meters 6.6, 24 meters 6.5; and at area *X*, surface 8.2, 10 meters 7.2, 20 meters 4.5, 26.5 meters 4.0.

1988—30——3

TEMPERATURE OF WATER DURING SUMMER

It has been pointed out, under the section devoted to the surface temperature from mouth to head, that the distribution of the surface temperatures during the summer cruises was quite variable. There are indications that the surface temperatures may be much warmer at the southern end than at the northern, as when on August 21, 1920, the air temperatures were high at the lower end of the bay and low temperatures and rainy weather prevailed at the upper end, or warmer at the northern end than at the southern, as during the cruise of July, 1916. At the bottom there was evidence to show that the winter condition had been reversed, so that the coldest water was at the mouth of the bay. These conditions at 20 and 30 meters are illustrated in Table 3. It is clear that there was an increasing range of deep-water temperatures (as an example, at 20 meters) passing from *G* to *A*. On these cruises the lowest temperature observed in the whole bay was that at the bottom of area *G*, just the reverse of the condition existing in the winter, when the highest temperatures observed in the whole bay were at the bottom of the same area. Observations made outside of the bay at the beginning of the August cruise show that as far as the 200-meter contour, the temperatures (from 8° C. to 10° C. at all depths) were considerably lower than those of the bay and in a decreasing range as far as the 80-meter contour. Also, the temperatures at the surface were somewhat less than those of the surface of the bay.

During the summer cruises the surface water was found to be almost always the warmest, during the warmer part of the day at least, the temperature decreasing with the depth (anothermous), as in August, 1920, at *G*, surface 27.0, 10 meters 20.2, 20 meters 17.2, 23.6 meters 15.5; and at *R*, surface 24.2, 45.8 meters 23.9; or as in May, 1921, at *G*, surface 19.0, 10 meters 17.4, 22.8 meters 15.2, and at *R*, surface 20.0, 10 meters 20.0, 20 meters 15.5, 30 meters 15.3, 40 meters 15.3, 47.6 meters 15.1. The cruise of July, 1916, was made during a time when there was much rain and cloudy weather, and it had a marked effect on the vertical distribution of the temperature. At *A* the temperatures were as follows at 9 a. m.: Surface 24.3, 5 meters 24.9, 10 meters 24.6, 20 meters 24.1, 30 meters 23.9, 40 meters 24.1; and at *R*, surface 25.2, 5 meters 25.5, 10 meters 25.5, 20 meters 25.0, 30 meters 24.6, 40 meters 24.9, 46 meters 25.2 at 1.35 p. m. In general, all over the bay the surface temperatures were somewhat lower than those of the water a few meters below, and this condition was independent of the time of day.

TEMPERATURE OF WATER DURING FALL

During the cruise of September, 1916, the temperature values observed at the bottom (no data at 20 and 30 meters are available) showed an increasing range from the mouth northward as during the summer. No data were obtained at area *G* during that cruise, but at both *F* and *E*, which are areas in the mouth of the bay, the bottom temperatures were 22.8 at 13 meters and 22.2 at 16 meters, while the bottom temperatures for the following areas, marking regions of considerably greater depth even than those of *F* and *E*, were higher: *A* 23.4, *J* 24.6, *S* 24.8, *X* 24.8, and *Y* 24.8. During the cruise of October, 1920, the range of temperature values for 20 and 30 meter depths indicated that the summer condition was changing into that of the winter, while the data for the December, 1920, cruise indicated that this latter condition was established, the temperatures decreasing in range again from the mouth toward the head with the highest temperature in the whole bay at *D*. (Table 4.)

The cooler weather of fall brings with it a lowering of the temperature of the upper layers of Chesapeake waters, while those below, as pointed out by Hjort (1896) for Norwegian fjords, often retain their summer condition, thus resulting in a warmer layer being found between upper and lower cooler ones (mesothermous). Such a vertical range of temperatures was widespread over the bay during the cruise of September, 1916. This condition is well illustrated at area *A:* Surface 23.4, 7 meters 24.4, 14 meters 23.9, 22 meters 24.1, 32 meters 23.6, 42 meters 23.4; at area *J*, surface 24.1, 5 meters 25.0, 10 meters 24.7, 17 meters 24.6, 27 meters 24.6, 37 meters 24.6; and at area *X*, surface 23.9, 7 meters 24.9, 14 meters 25.0, 24 meters 24.8, 34 meters 24.8. According to the United States Weather Bureau, this was a decidedly cool September except during the first week. In fact, on the day the cruise was begun (September 8) the air temperatures at Baltimore, Washington, and Norfolk reached 94° F., 93° F., and 90° F. (34.4° C., 33.9° C., 32.2° C.), respectively, but a drop of 12, 5, and 4 degrees, respectively, occurred the next day and decreases in temperature continued for several days after that. On the other hand, October, 1920, was a warm month, and at the same areas the following readings were obtained: At area *A*, surface 20.4, 10 meters 20.1, 20 meters 20.0, 30 meters 19.4, 40 meters 19. 3, 44.8 meters 19.3; at area *J*, surface 20.0, 10 meters 19.8, 20 meters 19. 3, 30 meters 19.5, 40 meters 19.1, 43.0 meters 19.2; and at area *X*, surface 19.4, 10 meters 19.9, 27.5 meters 20.2. The lower bay, in general, showed a decreasing range of temperatures from the surface downward which would be in keeping with the high air temperatures. The surface temperatures, however, at *X* and at a few other areas, especially in the northern part of the bay, were found to be a little lower than those of the layers immediately below.

During the December cruise of this same year (1920) the autumnal condition had taken on the winter condition (katothermous), with a few exceptions.

SEASONAL DISCONTINUITY OF VERTICAL DISTRIBUTION OF TEMPERATURE

Under the section in which the vertical distribution of temperature from the surface to the bottom is discussed, it has been pointed out that the thermocline (discontinuity layer, Sprungschicht) is frequently seen in Chesapeake Bay and that at times its position coincides with a similar discontinuity in salinity. Such a condition has been noted in the Norwegian fjords, the Baltic Sea, and other localities. (See Krümmel, 1907, p. 395.) The thermocline is most marked during the warmer months, since it is the heat of the summer sun's rays that brings about the increase in temperature of the upper layer, thus separating it from the cooler mass of water below. During the cruises of April and June, 1916, the thermocline was evident at many areas on the bay. But such a condition is not necessarily limited to the warmest months, for during the cruise of March, 1922, when the waters were still cold, a distinct thermocline was noted. The data for areas *U, L,* and *G* are given in Table 7. At area *U* observations were made during the night as well as during the day and the temperatures were almost invariably higher at the surface than at 5 meters.

TABLE 7.—*Temperatures and salinities at various depths on March, 1922, cruise*

Date	Area	Temperature, ° C.	Salinity	Depth, meters	Date	Area	Temperature, ° C.	Salinity	Depth, meters
Mar. 29, 1922	U	9.0	5.22	0	Mar. 27, 1922	L	5.6	17.12	30
		6.4	8.22	5			5.4	17.22	40
		5.0	10.33	11	Mar. 25, 1922	G	8.9	18.36	0
Mar. 27, 1922	L	7.2	12.21	0			6.6	30.65	10
		5.8	14.54	10			6.5	31.10	24
		5.7	16.95	20					

On the other hand, during some of the midsummer cruises, such as July, 1916, and August, 1920, the thermocline was practically obliterated in the bay, owing to rain in the first case and cool weather in the second, aided probably by wind and currents. The records show, as would be expected, that the temperature of the upper layers drops during the night and rises during the day; but, independently of this, discontinuity layers occur corresponding to the warm and cold parts of the year and often in accordance with the origin of the upper and lower layers of water. On the August cruise the temperature and salinity data were as shown in Table 8.

TABLE 8.—*Temperatures and salinities at various depths on August, 1920, cruise*

Date	Area	Tempera-ture, ° C.	Salinity	Depth, meters	Date	Area	Tempera-ture, ° C.	Salinity	Depth, meters
August, 1920	U	23.5	4.75	0	August, 1920	L	25.0	19.76	30
		24.4	14.21	5			24.8	20.50	37
		24.2	15.21	11	Do	G	27.0	22.73	0
Do	L	25.5	13.72	0			20.2	29.05	10
		25.5	13.72	10			17.2	31.26	20
		25.5	13.77	20			15.5	31.74	23

It will be noted that the thermocline is conspicuous at *G*, the result of high air temperature in that region. Farther north, where the thermocline was not so evident or lacking, the air temperature was about 10° C. lower than in the region of *G*.

While the thermocline is more or less characteristic of the waters of Chesapeake Bay during the warmer months, a discontinuity in the degree of temperature and salinity often occurs during the winter. This condition is the reverse of that during the summer because there is an upper layer of water which is distinctly colder than the water below. This is most conspicuous along the deep-water channel. The fresher and lighter, although colder, water from the rivers lies over the much warmer but much heavier saline water having its origin from the ocean. Excellent examples of the discontinuity just mentioned occurred when the cruise of December, 1920, was made. Data for areas *U*, *L*, and *G* are shown in Table 9.

TABLE 9.—*Temperatures and salinities at various depths on December, 1920, cruise*

Date	Area	Tempera-ture, ° C.	Salinity	Depth, meters	Date	Area	Tempera-ture, ° C.	Salinity	Depth, meters
December, 1920	U	5.8	5.70	0	December, 1920	G	10.5	25.20	0
		5.9	6.02	5			10.8	28.76	10
		9.0	14.02	11			11.3	30.22	20
Do	L	8.7	15.03	0			11.6	30.96	22
		8.6	15.21	10					
		10.0	20.01	20					
		10.1	20.13	30					
		10.1	20.21	37					

DELAY IN SEASONAL CHANGE OF TEMPERATURE

The "Phasenverzug," a condition described by Krümmel (1907) in which there is a delay in the change of temperature of the bottom water, so that it does not reach its maximum temperature in midsummer but in the fall and does not reach its minimum temperature in the midwinter but in the spring, can not be said to be a fixed condition in Chesapeake Bay, such as it is in the English Channel according to Dickson (1893). The time of occurrence of maximum and minimum temperatures varies somewhat with the year. There are indications from the data obtained on our cruises that the minimum bottom temperature occurs sometimes in midwinter and sometimes in the early spring and that the maximum bottom temperature is attained at times in the late summer and at times in the autumn.

BACILLARIOPHYTA

DIATOMS

The indentifications of the diatoms found in the plankton of Chesapeake Bay have been made by Dr. J. J. Wolfe, and the original list may be found in a paper by Wolfe and Cunningham (1926). A considerable number of bottom diatoms stirred up by currents and semibottom diatoms are included. The discussion which follows is based on data tabulated by Doctor Cunningham.

GEOGRAPHICAL DISTRIBUTION

An examination of the list of diatoms with reference to the recorded distribution in other parts of the world shows that the various species mentioned may be classed as fresh water, brackish water, and marine diatoms. It is evident, judging from what is known of the distribution of marine diatoms in other regions, that those found in the bay include some neritic species (bottom or semibottom forms) which are not placed among the true planktonic forms, some which are considered to be true planktonic forms inhabiting coastal regions (neritic), and still others, also planktonic, which are spoken of as oceanic forms since they are ordinarily found outside of the coastal regions in the great ocean currents where the salinity is high. Furthermore, a glance at the list of neritic and oceanic species of diatoms shows that if we follow Cleve's (1897, 1901–02) grouping into arctic, temperate, and tropical forms all three groups are represented in Chesapeake Bay, although naturally the temperate forms are much in excess of the others. The grouping in the list given below is based on that of Cleve, but it has been modified to some extent in the light of the more recent work of Gran, Ostenfeld, Lemmermann, Karsten, Johnstone, Bigelow, and Fish. Unfortunately, our knowledge of the distribution of the various species of diatoms, even in the Atlantic Ocean, is still imperfect and the different groupings overlap one another to a considerable extent, so that the distribution given must be looked upon as tentative.

The following marine planktonic diatoms have been found in Chesapeake Bay. Species of Coscinodiscus and other species, concerning which there is confusion as to identification, have been left out. Those listed have been arranged according to their usually accepted distribution with reference to the arctic, temperate, and tropical regions of the Atlantic Ocean.

Neritic, Arctic: *Biddulphia aurita* (Lyngb.) Breb.

Neritic, Northerly Temperate: *Chaetoceras teres* Cl., *Leptocylindrus danicus* Cl., *Rhizosolenia setigera* Brightw., *Skeletonema costatum* (Grev.), *Thalassiothrix nitzschioides* Grun. Another form which may be included in this group but whose position is somewhat uncertain is *Nitzschia longissima* (Breb.) Ralfs.

Neritic, Southerly Temperate: *Biddulphia mobiliensis* (Bail), *Cerataulina bergonii* Perag., *Ditylium brightwellii* (West) Grun., *Eucampia zodiacus* Ehr., *Guinardia flaccida* (Castrac.) Perag. The following may be placed in this group, but their distribution is still uncertain: *Bacteriastrum varians* Lauder, *Bellerochea malleus* (Brightw.), *Lithodesmium undulatum* Ehr., *Rhizosolenia calcar avis* Schultze, *Rhizosolenia stolterfothii* Perag.

Neritic, Tropical: None.

Oceanic, Boreal Arctic: *Rhizsolenia semispina* Hensen,[7] *Chaetoceras decipiens* Cleve.

Oceanic, Temperate: *Rhizosolenia alata* Brightw., *R. styliformis* Brightw. The inclusion of the following species in this group is not as yet fully established: *Thalassiothrix frauenfeldii* Grun.

Oceanic, Tropical: *Planktoniella sol* (Brightw.) Schuett.

In addition to the true marine planktonic diatoms the following marine, bottom, or semibottom (tycopelagic) diatoms (Ostenfeld., 1913) occurred abundantly at times: *Actinoptychus undulatus* (Kuetz) Ralfs., *A. splendens* (Bail) Ralfs., *Donkinia recta* (Donk.) Grun., *Hyalodiscus stelliger* Bail., *Melosira sulcata* (Ehr.)[8] Kutz., *N. bombus* (Ehr.) Kutz., *N. cancellata* Donk., *N. humerosa* Breb., *N. smithii* Breb., *Pleurosigma affine* Grun., *P. fasciola* (Ehr.) W. Sm.

A few fresh-water or so-called brackish water forms were found and are here listed:

Asterionella formosa (Hass.), *Bacillaria paradoxa* Gmel., *Campylodiscus echeneis* Ehr., *Navicula borealis* (Ehr.) Kutz., *Nitzschia plana* W. Sm., *N. sigma* (Kutz) W. Sm., *Pleurosigma balticum* W. Sm., *Raphoneis amphiceros* Ehr.

Referring to the above list of those neritic species of marine, planktonic diatoms whose distribution in other regions is well established, we find the arctic, temperate, and tropical groups represented in Chesapeake Bay as follows: Arctic neritic, 1; northerly temperate neritic, 5; southerly temperate neritic, 5; tropical neritic, 0. Practically all the neritic diatoms belong to the temperate group. True tropical neritic diatoms have not been found, and only individuals of one species ordinarily classed as an Arctic form have been taken. This diatom, *Biddulphia aurita* (Lyngb.) Breb. was collected once in Chesapeake Bay during March, 1916, at area *A* in a surface sample. It was found to be common, according to Mann (1894), in deep-water dredgings off the mouth of Delaware Bay; it has occurred as an occasional species in Massachusetts Bay (April, 1913) according to Bigelow, and was common throughout most of the year 1916 (possibly 1915) in the Bay of Fundy according to Bailey (1917). Gran (1919) has found it a little farther north in the Gulf of St. Lawrence, and finally Cleve (1897) mentions it as occurring rarely in a few samples in Baffins Bay and Davis Straits.

The oceanic diatoms are distributed in regard to number of species in the different geographic groups as follows: Boreal, arctic oceanic, 2; temperate oceanic, 2; and tropical oceanic, 1.

Albert Mann (1894) has studied the diatoms dredged by the U. S. S. *Albatross* in 813 fathoms (1,487 meters) of water off the mouth of Delaware Bay, and has found a large number of species many of which are fresh-water forms characteristic of rivers in that latitude. He believes that they have been supplied largely by the Delaware River. In addition to these fresh-water forms, however, there are many marine forms, a few of which, as Mann says, may have been deposited there by the Gulf Stream. Those diatoms common to both regions are the following: *Navicula borealis* Ehrb., *Raphoneis amphiceros* E., *Actinoptychus undulatus* Ehrb., *A. splendens* Ralfs., *Melosira sulcata* Kz., *Navicula humerosa* Breb., *N. smithii* Breb., *Pleurosigma affine* Grun., *Biddulphia aurita* Lyngb., *Ditylum brightwellii* West., and *Rhizosolenia styliformis* Bright.

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[7] *Rhizosolenia hebetata* var. *semispina* (Hensen).

[8] *Paralia sulcata* (Ehr.).

It is interesting to compare the species collected during 1915 and 1916 in Chesapeake Bay with the species observed by Fish (1925) at Woods Hole during 1923, although in comparing the two it must be remembered that collections at Woods Hole were made largely at the surface. However, Fish has found that the water at Woods Hole is thoroughly mixed owing to currents. Those marine planktonic species in common for the two regions, following Fish's grouping, are these:

Fresh and brackish water forms: None.

Semibottom forms: *Actinoptychus undulatus, Hyalodiscus stelliger.*

Neritic, Arctic: None.

Neritic, Northerly Temperate: *Chaetoceras teres, Leptocylindrus danicus, Nitzschia longissima, Rhizosolenia setigera, Skeletonema costatum, Thalassiothrix nitzschioides.*

Neritic, Southerly Temperate: *Bacteriastrum varians, Ceratulina bergonii, Ditylium brightwellii, Guinardia flaccida, Rhizosolenia calcar avis.*

Neritic, Tropical: *Bellerochea malleus.*

Oceanic, Boreal Arctic: *Chaetoceras decipiens, Rhizosolenia hebetata ver. semispina.*

Oceanic, Temperate: *Rhizosolenia alata f. genuina* (?), *Rhizosolenia styliformis, Thalassiothrix frauenfeldii.*

Oceanic, Tropical: None.

Here again, as in the case of the Chesapeake diatoms, a survey of the complete list of species as given in Fish's paper, with reference to the geographic groups in which they are usually placed, shows more temperate neritic forms than boreal arctic or tropical, and of these temperate forms the larger number belong to the southerly temperate neritic. The oceanic forms are much fewer in number than the neritic forms, a condition which is true of the Chesapeake collections. It should be noted, however, that the proportion of boreal arctic oceanic forms shows a considerable increase over what is found in Chesapeake Bay, and this is what should be expected. It is also in keeping with the fact that the colder currents from the northern regions which carry boreal arctic forms are of more importance in the latitude of Woods Hole than they are in the latitude of the mouth of Chesapeake Bay, where such currents have probably dipped below the Gulf Stream.

A study of Bigelow's (1914a, 1914b, 1915, 1917a) preliminary work on collections made in the Gulf of Maine, Massachusetts Bay, and the coastal waters between Maine and the mouth of the Chesapeake Bay show the preponderance of temperate neritic forms as is the case for Chesapeake Bay and Woods Hole, while the boreal arctic forms have assumed considerable importance among the oceanic diatoms as at Woods Hole.

Although Bailey's (1917) collections in the Bay of Fundy were made at a little higher latitude than those of Bigelow, not so many boreal arctic forms were found, although they were fairly well represented. His records cover collections made from January to October, inclusive, 1916 (?).

Still farther north the work of Gran (1919) in the Gulf of St. Lawrence and the oceanic regions outside of it shows the northerly forms replacing almost, if not entirely, the southerly forms. With the exception of four species which I have not been able to place with the literature at hand, the various species are grouped as follows: Arctic neritic, 9; boreal arctic neritic, 5; northerly temperate neritic, 3; arctic oceanic, 1 (?); boreal arctic oceanic, 5. Gran's collections were made during May, June and August, 1915.

SPRING AND FALL MAXIMA

It is evident from the study of the diatom counts of Wolfe and Cunningham that they were high during the April cruise of 1916 and the March cruise of 1920 in Chesapeake Bay. While this conclusion is not reached from counts made daily in any one locality, it is based on many samples collected on each cruise in 1915–16 and 1920–21. During 1915 the cruises were taken in October and December; during 1916 in January, March, April, June, July, and September; during 1920 in January, March, May, July, August, October, and December; during 1921 in January. The diatom counts were made on water samples collected at the surface and at or near the bottom. In addition, during 1915–16 counts were made of the individuals of each species at various depths. The results are expressed in the number of diatoms per liter of water.

As an example, the diatom counts for area *A* at the surface were as follows: Year 1915, October, 4,300, December ——; year 1916, January 13,600, March 17,000, April 558,300, June 9,200, July 6,200, September 92,800. The counts at 27 meters were these: October 99,400, December ——, January 39,800, March 26,500, April 359,100, June 19,500. The maximum spring count was that of the April cruise both at the surface and at 27 meters, and there was a less marked rise in surface counts during the autumnal cruise. Autumnal records for 27 meters are lacking.

A similar surface series at area *A* for 1920 is the following: January 16,500, March 262,600, May ——, July 8,300, August 14,400, October 21,300, December 418,400. At the bottom these counts were found: January 19,700, March 229,400, May ——, July 27,000, August 32,800, October 3,100, December 43,600. Here again there was a markedly high count during the spring cruise of March and a fairly well-marked autumnal rise, which seems to have persisted into the winter months. The results of surface counts from area *A* are graphically shown in Figure 16.

High counts were found in all regions (although not at all areas) over the bay in March, 1920, and there were fairly widespread evidences of similar conditions during the April, 1916, cruise. An autumnal rise probably occurred all over the bay but not so markedly in the upper part. The records of the different cruises often show successive increases from early fall into midwinter, and the suspicion arises in one's mind as to whether the so-called autumnal rise is not the beginning of the spring maximum of the following year. As a matter of fact, data for 1915–16 and 1920–21 indicate that the autumnal maximum did not occur until very late and that there may have been a close approach of the two maxima to one another. The results in the Chesapeake are very similar to those observed by Steuer (1910) for the Adriatic Sea and by Fish (1925) for Vineyard Sound, etc.

SUMMER MINIMUM

The decrease in the number of diatoms during the summer cruises was about as marked as the increase for the vernal cruises; but occasionally, as has been observed by Gran in the Gulf of St. Lawrence, Fish at Woods Hole, Bigelow off Marthas Vineyard and others, rather large numbers occur locally in the summer months. A slight but distinct increase in diatom counts was found in the upper part of the bay during July, 1920. If these increases were due to specially favorable conditions of food supply in the bay, resulting from exceptional outflow from rivers, it is of interest to note that during the month previous the rainfall in Maryland and Delaware was one and one-third times the normal and that the summer was cool and wet, the wettest on record over southern Baltimore County.

DIATOM COUNTS AND MAXIMUM AND MINIMUM SALINITY

During 1916 and 1920 the salinity was high on the midwinter cruise—that is, January. The diatom counts for the same period were low. On the spring cruises, for example, April, 1916, and March, 1920, the salinity was much lower than in January. The diatom counts for these same periods reached the maximum for the year so far as our records show. During the summer cruises the salinity was a little higher and the diatom counts were markedly lower as a rule. In the autumn the data did not show clearly a correlation between lower salinities and the increased

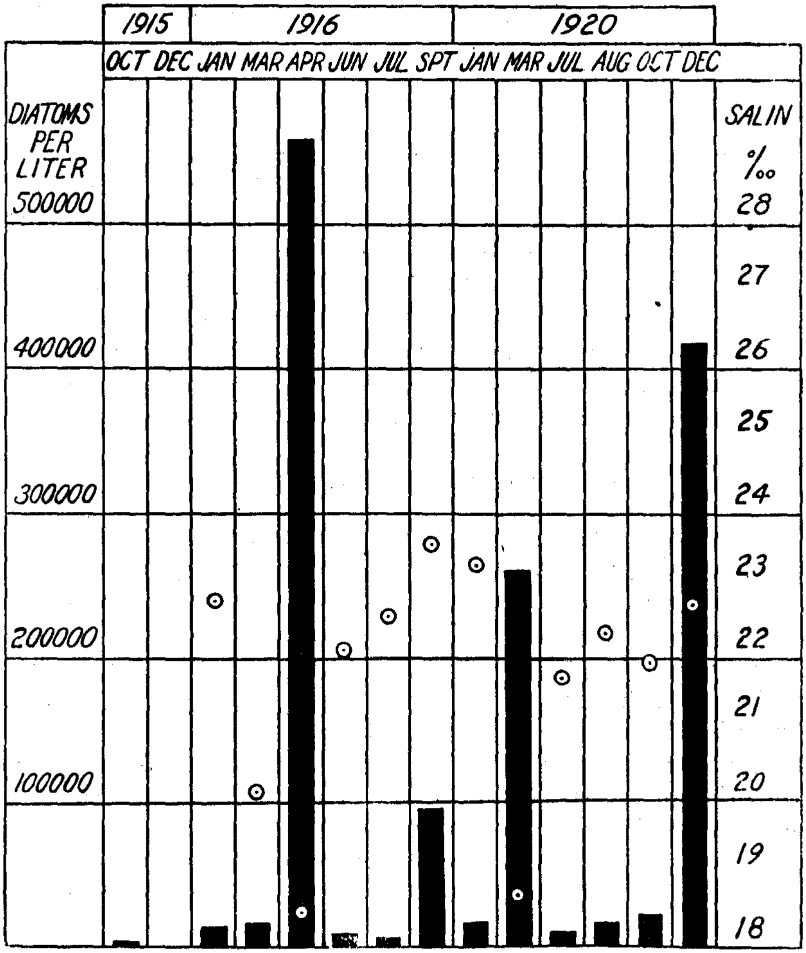

FIGURE 16.—Diatoms per liter of surface water at area A indicated by black columns. Salinity of water from which diatom samples were taken indicated by circles

diatom counts known as the autumnal maximum. These relations may be seen in Figure 16, in which the diatom counts and salinities for surface water are shown graphically for area *A* during the cruises of 1915–16 and 1920. Similar conditions occurred at many areas, although often not as marked, especially in the upper part of the bay. Usually, however, the spring diatom maximum and the decrease in salinity at that time showed clearly. During the cruises of most of the year the numbers of diatoms were usually greater in the deep layers than at the surfaces, but at the time of the maxima, and especially the spring maximum, large numbers were found both at the surface and at the bottom and probably were present at intermediate depths. The larger number was sometimes at the surface and sometimes at the bottom.

It will be seen from Figure 16 that the highest counts for the spring cruises of 1916 were found in April and those for 1920 in March, but it must be noted that no samples were collected during April, 1920. Possibly, then, the maximum occurred in April, although we have no data to show it.

The records indicate clearly, so far as the surface and bottom samples are concerned, that the high diatom counts, especially those of the spring cruises, occurred generally at the time of low salinity, but it does not follow that the low salinity caused the large increase in diatoms.

DIATOM COUNTS AND HOMOHALINITY

An interesting relation is that between the vertical distribution of salinity and diatom counts. In many cases during 1920 when high diatom counts occurred there were unusually close approaches toward homohalinity from surface to bottom. Such a condition has been observed by Nathansohn (1909) for certain regions in the sea, by Gran (1912) for the waters southwest of Ireland, and by others more recently. This relation existed quite frequently during the spring cruise of March, 1920, but in 1916 this same condition was not so marked; in fact, usually the highest diatom counts were obtained on the April cruise while the nearest approach to homohalinity from the surface to the bottom, so far as we have records, occurred generally during the March cruise.

DIATOM COUNTS AT RIVER MOUTHS

The data which the survey has collected on the number of diatoms as a whole, not on separate species, do not supply any very convincing evidence for the theory that diatoms occur in greater abundance in the neighborhood of the mouths of rivers than at other places. Owing to the fact that quite a number of the diatom counts for the different areas along the western side of the bay were not made, a comparative study of the counts with reference to the river mouths on that side does not yield very satisfactory results. However, it may be seen from the surface data in Table 10 that, so far as our data go, the numbers were usually comparatively large at one or the other of the areas *P*, *J*, or *H*. These areas in the case of *P* and *J* are close to the mouth of the Potomac River and area *H* is near the entrance to the Rappahannock River. On the other hand, during the March cruise while the counts were high at area *P* near the mouth of the Potomac River they were even higher farther up the bay.

TABLE 10.—*Diatom counts in surface samples on west side of bay, per liter*

Area	1920							1921
	January	March	May	July	August	October	December	January
D	14,700	(1)	(2)	7,400	900	5,700	28,300	(2)
H	7,400	86,300	269,100	7,800	3,700	3,200	31,300	36,300
J	243,100	(2)	593,700	3,400	3,900	10,600	13,400	29,000
P	11,100	465,400	507,300	105,800	4,900	(2)	5,700	11,800
R'	(2)	690,100	(2)	14,100	(2)	3,900	(2)	(2)
T	4,600	769,200	(2)	9,900	1,000	(2)	(2)	12,200

[1] No sample. [2] No count.

The highest diatom count for all of the cruises of the year 1920 was 1,563,000, and this was found in March, 1920, at area *L* close to the mouth of the Potomac and at the bottom. On the other hand, the second largest count, 1,055,400, was found at area *B* in a sample taken at the bottom in March, 1920. This area is situated close to one of the deepest holes in the bay and near Cape Charles City, which is located on the shore of the bay within a few hundred yards of the area.

The evidence in support of the theory that the highest diatom counts are to be found in the neighborhood of the mouths of rivers is not conclusive, and yet there are indications that there may be such a relation. Undoubtedly a study of the distribution of each species of diatom rather than a mixture of fresh-water, semi-bottom, and marine diatoms, such as is found in total diatom counts, would be more satisfactory. Some of the evidence we have from this source will now be mentioned. It will be discussed later.

The data concerning the abundance of the different species of diatoms at surface, bottom, and uniform intermediate depths are limited to the cruise taken in October, 1925. One species, *Skeletonema costatum*, which lives as a littoral-bottom form to some extent but which also exists as a widely distributed plankton form in Chesapeake Bay, is of interest in this connection. It will be shown later under the section in which the distribution of *S. costatum* with reference to hydrographic data is discussed that this diatom during the cruise of October, 1915, was more abundant, except at 27 meters, in the region of the mouth of the Potomac River than at any areas investigated.

DIATOM SCARCITY AT MOUTH OF BAY

The diatom counts in the mouth of the bay were usually comparatively small. Such a condition might be expected, since it is a shallow region with a shifting bottom which at times is scoured by rather rapid currents. It is a well-established fact that such places are not favorable for the development of diatoms. The highest count recorded in the mouth of the bay during the years 1916 and 1920 was a surface count of 438,800. This number was found at area *F* during April, 1916, along the line *E*, *F*, *G*, which extends across the mouth of the bay. Even at this time, which was during the spring maximum, there were higher counts along the line *A*, *B*, *C*, *D*, which runs from Cape Charles City to New Point Comfort. The records show 558,300 (surface) at *A* and 3,157,200 (bottom) at *D*.

RELATION OF DISTRIBUTION OF DIATOMS TO SALINITY

It is well established from a study of geographical distribution that certain diatoms (oceanic) are characteristic of waters of high salinity, such as that of the open ocean; that others (neritic) are characteristic of waters of lower salinity found along the sea coast and in estuaries; and that still different ones frequent the fresh waters or rivers emptying into the ocean. But, also, it is well known that many of these diatoms are able to stand a large range of salinities and that oceanic as well as neritic diatoms are often found in estuaries where the salinity is very low. The assumption is that the oceanic forms as well as neritic forms are brought in with the currents from the ocean, but it is known that resting spores are formed in the latter type. It is believed by many investigators, especially by Gran, that these spores settle to the bottom of the estuaries and periodically assume the floating condition, so that there are supplies from year to year of certain neritic species which arise locally.

The degree of dependence of diatoms on the salinity of the water has long been an unsettled question. Naturally, one would seek for light on the subject in regions where there is a distinct stratification with reference to salinity—that is, where there are considerably fresher layers overlying much more saline layers. The Baltic Sea, which is flooded now and then by saline water from the ocean and by fresh water from rivers; the Arctic and Antarctic Oceans, which have a surface layer of fresher water arising from the melting polar ice; estuaries such as are found in England; the fjords of Norway and Sweden; and finally the mouths of large rivers where fresh water and saline water meet one another, have been investigated by ascertaining the salinity at various depths from surface to bottom, together with the diatom counts at the same depths. If there is a horizontal distribution of diatoms with reference to salinity as indicated by geographical studies, one would expect a vertical distribution correlated to some extent with the salinity gradient from surface to bottom. But the problem is complicated by other possible factors—differences in temperature, light intensity, and amount of nutriment at various levels, with the accompanying reactions to these differences. Also water currents produced in various ways often tend to disturb the relation which the diatoms might usually bear toward salinity.

However, some investigators have found the number varying with the salinity in regions where the temperature and light did not seem to be controlling factors. Apstein (1906), in his studies of the waters of the Baltic Sea, discovered that many Chaetoceras, Rhizosolenia, Cerataulina, and Guinardia species of diatoms occurred only on the western side of the Baltic where the salinity was more than 15 per mille while *Chaetoceras danicum* and *bottnicum* were confined mainly to the east side, where the salinity was much weaker. Büse (1915) found the currents entering Kiel Bay from the west generally richer in diatoms and of a higher salinity than those coming from the east.

One would look for such relations near the mouth of Chesapeake Bay, as, for example, along the line made by areas *A, B, C, D*. At *D* on the west side of the bay, the fresher water is found, while at area *A* on the east side, where the depth is much greater, the more saline water of the ocean finds its way. The numbers of individuals of different neritic and oceanic species should be compared with the salinities at these areas. Unfortunately, the data on separate species are insufficient for such a comparison. Total diatom counts, however, at the surface for these two areas as compared with the salinities are of interest.

TABLE 11.—*Surface diatom counts and salinity for 1920*

Area	January		July		August		October		December	
	Diatoms	Salinity	Diatoms	Salinity	Diatoms	Salinity	Diatoms	Salinity	Diatoms	Salinity
A	16, 500	23. 32	8, 300	21. 72	14, 400	22. 36	21, 300	21. 99	418, 400	22. 78
D	14, 700	19. 74	7, 400	17. 28	900	19. 48	5, 700	17. 31	28, 300	21. 64

It is clear from data obtained for the cruises of January, July, August, October, and December during 1920 that the more saline surface water along the line *A, B, C, D* was found on the eastern side of the bay—that is, at area *A*. The total surface diatom counts were higher, on each cruise, at area *A* than at area *D*, which is on the west side of the bay. While the various species making up these total counts have not been identified, it is safe to say that the counts include fresh-water, neritic, oceanic, and semibottom diatoms. We have no data to show that the higher counts at area *A*, where the water was most saline, were due mainly to neritic and oceanic diatoms carried in at the time from the ocean and consequently adapted to a sea water of higher salinity. It is possible also that some of the neritic forms were produced locally from resting spores. Furthermore, the differences may be due to differences in nutritive value of the water or to other factors. Occasional surface counts made at areas *B* and *C*, especially during the spring maximum, did not always support the relation pointed out above. Deep-water counts were not made at equivalent depths on the east and west sides of the bay, so they are useless in this connection.

COMPARISON OF DIATOM COUNTS AT MOUTH AND INSIDE THE BAY

A comparison of the diatom counts found along the line *E*, *F*, *G*, in the mouth of the bay, with those along the line *A*, *B*, *C*, *D*, which runs from Cape Charles City to New Point Comfort, farther inside the bay, would be of interest in order to see if the numbers are higher in the mouth of the bay during the autumn and winter cruises when, as a rule, the salinities are higher, the incoming current is more dominant, and the Gulf Stream Eddy (Atlantic gyral) is shifting in a northerly direction. At such a time one might expect larger numbers at the mouth, if the bay receives any considerable supply of diatoms from the outside. Only during March, 1916, and January, 1920 which were months of high salinity, have higher counts been found along the line *E*, *F*, *G*, than along *A*, *B*, *C*, *D*. The differences were small and the data too meager for a satisfactory comparison. It is true that the oceanic diatoms (see the section on the relation of distribution of species to the hydrographic data) which can be taken as an indication of the influx of oceanic water have been found almost exclusively during the months when water of higher salinity was making its way into the bay, yet the lack of diatom counts for some of the areas along the lines *E*, *F*, *G* and *A*, *B*, *C*, *D* on every cruise, the absence of data on the species found, and the rather limited current data from 24-hour stations make further work necessary before any definite conclusions may be reached.

The Atlantic water that enters the bay, judging from our salinity data, is not pure oceanic water. Salpa, which is commonly found in the oceanic water of the Gulf Stream off the mouth of Chesapeake Bay, has not been found in the bay, and true oceanic diatoms during 1916 at least were scarce.

RELATION OF DISTRIBUTION OF SPECIES TO HYDROGRAPHIC DATA

The data on the number of individuals of each species are limited to the cruises of October and December, 1915, and January, March, April, June, July, and September, 1916. During October, 1915, counts were made for each species of diatom from the surface to the bottom at 9-meter intervals for areas *A*, *J*, *L*, and *R*. Counts were made also at many other areas during the cruises for 1916, but there was considerable irregularity in the choice of areas and the number of samples. However, the depths at which samples were taken were practically without exception at 0, 9, 18, or 27 meters, thus corresponding with those for October, 1915. Almost invariably only two counts were made for each species at each area during 1916—a surface count and one at 9, 18, or 27 meters, depending on the depth at the area.

The fresh-water diatoms in the plankton were not abundant at the areas visited in Chesapeake Bay. This was expected, since usually the water at all these areas was brackish in character. *Asterionella formosa* (Hass.), the tests of which occurred so commonly in oceanic bottom deposits off the mouth of the Delaware River according to Mann (1894), were found only here and there in small numbers but widely distributed over Chesapeake Bay. The highest counts were obtained during the colder months and at areas near the mouth of the bay. *Navicula borealis* (Ehr.) Kutz, also mentioned by Mann, and *Bacillaria paradoxa* Gmel. (now called *Nitzschia paradoxa* Gmel.) occurred about as abundantly as *A. formosa*, but they were less widely distributed. *Campylodiscus echeneis* Ehr. was taken in very small numbers in the lower half of the bay. Most, if not all, of these forms are littoral also (Gran, 1908).

The so-called brackish water diatoms were represented in largest number by *Raphoneis amphiceros* Ehr.—a form found frequently in deposits off the mouth of the Delaware River by Mann. It was taken only in the southern half of the bay. Another brackish-water form, *Nitzschia sigma* (Kutz) W. Sm., designated by Mann as "frequent" was found widely distributed over Chesapeake Bay but in every small numbers. *Nitzschia plana* W. Sm. and *Pleurosigma balticum* W. Sm. were very scarce, the former occurring only in the lower half of the bay and the latter only at area *A* near the mouth.

The bottom and semibottom (tychopelagic) diatoms are abundantly represented in Chesapeake Bay. A form which is closely related to the tychopelagic group (classed above in the neritic northerly temperate group) is *Skeletonema costatum* (Greve) which according to Ostenfeld (1913) is found all the year round as a littoral-bottom form in European waters. It was very abundant and very widely distributed in Chesapeake Bay during the cruises of 1915 and 1916. It is known to be largely independent of the degree of salinity, and so its occurrence in considerable numbers at area *X*, almost as far north as Annapolis, is not surprising. As we shall see, its behavior is not that of a bottom form, for the highest counts, judging from the data for the cruise of October, 1915, are not at the bottom. The condition just mentioned is in keeping with Ostenfeld's statement that this species multiplies to an important degree in the plankton. *Skeletonema costatum* was found in the plankton samples during all the cruises from October, 1915, to September, 1916.

The highest counts were obtained during the October and January cruises, the numbers decreasing during the spring cruises until April, when the maximum was reached. This and similar conclusions for other forms as to the maximum and minimum occurrence is based mainly on a surface and a deep-water count for each area, but such counts were made at nine widely distributed areas on each cruise.

Ostenfeld and others have pointed out that *Skeletonema costatum* is extremely euryhaline—that is, adapted to a great range of salinity. In Chesapeake Bay it has been found in waters from 11.13 to 32.00 per mille. The range of temperatures, 1.0° to 26.1° C. is about as extreme as that of the salinities.

During the cruise of October, 1915, when the largest numbers were found for *Skeletonema costatum*, there was evidence to show that the highest counts were near the mouth of the Potomac River. The surface counts were as follows: Area *A*, 900; *J*, 4,300; *M*, 1,800; an unlettered area near the middle of the Maryland and Virginia line directly in front of the mouth of the Potomac River, 35,800; *L*, 4,200; *P*, 28,500; and *R*, 25,800. At 9 meters the counts for the same areas were these: Area *A*, 200; *J*, 6,700; *M*, no count; the unlettered area, 26,600; *L*, 10,500; *P*, 33,300; and *R*, 5,700. At 18 meters the following counts were obtained: Area *A*, 1,400; *J*, 13,200; *M*, 34,100; the unlettered area, no count, not 18 meters deep; *L*, 2,100; *P*, too shallow; and *R*, 2,600. It will be seen that at 0, 9, and 18 meter depths the highest counts were close to the mouth of the Potomac River. On the other hand, at 27 meters the highest was at area, *A*; but at 36 meters, again, the highest count was near the entrance of the Potomac: Area *A*, 700; *J*, 9,500; *M*, too shallow; the unlettered area, too shallow; *L*, 7,500; *P*, too shallow; *R*, 900. The largest count for any area at any depth during the October cruise was 35,800, a surface count directly in front of the mouth of the Potomac; and the second largest count, 34,100, was one at 18 meters on area M in the middle of the mouth of the Potomac. Again in December, 1915, the highest surface count, 15,100, was at area *J* and the largest deep-water count, 22,800, was at area *P*. Both of these areas are very close to the mouth of the Potomac River. It must be mentioned, however, that the counts for December are much fewer in number than those for October. The data for the rest of the cruises are insufficient for purposes of comparison.

The vertical distribution of *Skeletonema costatum* during October, 1915, seems to have been largely independent of the degree of salinity, although, as a general rule, the highest counts were below the surface and above the bottom. A very interesting comparison of the vertical distribution of this diatom at areas *A*, *J*, *L*, and *R* during October may be seen in Table 12. The samples for *A* (near Cape Charles City) were collected on October 22 from 3 to 4 p. m.; those for *J* (a little south of the mouth of the Potomac) on October 24 from 10.30 to 12 noon; those for *L* (a short distance north of the mouth of the Potomac) on October 25 from 9.49 to 10.38 a. m.; and those for *R* (about half way up the bay) on the same date from 1.50 to 3.08 p. m. It will be seen that the highest count for area *A* was in deep water, 27 meters; for *J* at shallower depth, 18 meters; for *L*, at 9 meters; and for *R* at the surface.

TABLE 12.—*Skeletonema costatum, October, 1915*

Meters	A	J	L	R	Meters	A	J	L	R
0	900	4,300	4,200	25,800	27	10,400	100	4,400	700
9	200	6,700	10,500	5,700	36	700	9,500	7,500	900
18	1,400	13,200	2,100	2,600	46	800			1,300

A similar condition, although not so marked, was seen for some other neritic diatoms collected at the same time. The true bottom forms, on the other hand, which do not multiply to any extent in the plankton, did not show the vertical distribution just mentioned. It is not permissible to draw any definite conclusions as to the factors involved in bringing about the vertical distribution of *Skeletonema costatum* during the October cruise, especially since no counts approaching these in completeness were made during any other cruises, but it may be mentioned that during the time from October 21 to 25 the air temperature at Baltimore and Washington, according to the United States Weather Bureau, dropped from 64° F. (17.8° C.) to 42° F. (5.6° C.) and 37° F. (2.8° C.), respectively. One might suspect that there had been an increase in the viscosity of the water in the northern part of the bay due to the large drop in air temperature, which resulted in a greater buoyancy of the water and an upward movement of the diatoms. If such a movement toward the surface actually occurred at area *R*, and to a lesser degree at *L* and *J*, we have no evidence to show that it was in response to differences in the turbidity of the water, to differences in food conditions, nor to differences in the intensity of the sunlight shining on the surface. Concerning the last possible factor, however, the ship's log showed that the sky was clear when the samples were taken at areas *J*, *L*, and *R*. Whatever conditions gave rise to the vertical distribution mentioned during the October cruise of 1915, it seems probable that they were peculiar to that cruise, for such a distribution is not even suggested from an examination of the data from other cruises.

Paralia sulcata (Ehr.), a tychopelagic diatom listed by Wolfe and Cunningham as *Melosira sulcata* (Ehr.) Kutz, was widely distributed in Chesapeake Bay during 1916 and was present at least as late as September in considerable numbers. It was found even as far north as area *X* during every cruise except September in 1916, and it was present in waters of a great range of salinities and temperatures.

The highest counts obtained both at the surface and in deep water were during the March and April cruises. As examples, the surface counts at area *A* were as follows: January, 2,600; March, 4,200; April, *7,700*, June, 0; July, 100; and September, 1,000. At 27 meters the counts were: January, 4,900; March, *6,700;* April, 4,800; June, 2,400; July, no count; and September, no count. For area *J* the surface counts were the following: January, 500; March, *2,400*; April, 1,100; June, 500; July, 200; and September, 200. At 27 meters: January, 3,900, March, no count; April, *15,200*; June, 500; July, no count; September, 400.

Again, as in the case of *Skeletonema costatum*, the highest counts were found close to the mouth of the Potomac River, 15,200 at 27 meters and 15,800 at 26 meters for areas *J* and *L*, respectively, during April. These counts are about double those of any other counts during the year for this species.

This diatom, which has a comparatively heavy test, has the vertical distribution of a typical bottom form. The counts of *Paralia sulcata* showed the highest numbers, with one exception, at the bottom; the numbers gradually decreasing toward the surface. Data from other cruises, although limited to a surface and a deep-water count, showed the highest numbers in deep water with only a few exceptions—namely, in very shallow regions and during the spring maximum, when the water is in an unstable condition.

Table 13 gives the counts for *Paralia sulcata* found in the same samples from which the counts for *Skeletonema costatum* tabulated above were made, so the salinity, temperature, and other environmental conditions were the same for both.

TABLE 13.—*Paralia sulcata, October, 1915*

Meters	A	J	L	R	Meters	A	J	L	R
0		700	500	700	27	800	1,200	1,600	3,400
9	500		300		36	1,400	2,100	4,700	1,400
18	700	3,600	600	2,600	46	4,800			4,800

Another common diatom in Chesapeake Bay during 1916 which is not a true plankton form is *Pleurosigma affine* Grun. It was widely distributed through the bay from the mouth to the region of Annapolis and occurred in the plankton during all the cruises—that is, January, March, April, June, July, and September. In addition to this it was present during October and December in 1915. The highest counts were found during October, January, and April, and most of these were from areas near the mouth of the Potomac River. The highest count for all cruises was at area *M*, in the mouth of the Potomac at 18 meters. The numbers of this diatom usually increase from the surface to the bottom. It seems to be a bottom form which is easily disturbed from its resting place.

The following tychopelagic forms were widely distributed in the bay but the counts made were not large: *Actinoptychus undulatus* (Kuetz) Ralfs., *Hyalodiscus stelliger* Bail., *Navicula bombus* (Ehr.) Kutz., *N. cancellata* Donk. Other tychopelagic forms occurred in very small numbers and had a very limited distribution in the plankton so far as the data for 1916 show. *Actinoptychus splendens* (Bail.) Ralfs. was found near the mouth of the bay only at areas *A*, *G*, and *F* and *Donkinia recta* at area *G* only.

The neritic arctic group is represented by one species, *Biddulphia aurita* (Lyngb.) Breb. While it was found to be common in bottom samples off the mouth of the Delaware River by Mann, it was collected from the plankton on one occasion only in Chesapeake Bay during the year 1916. It was in a surface sample at area *A* near the mouth of the bay. The sample was taken during the month of March in water of 3.1° C. temperature and 24.14 salinity.

Of those diatoms which have been included under the neritic north temperate group only two species, *Rhizosolenia setigera* Brightw. and *Skeletonema costatum* (Grev.), were widely distributed in Chesapeake Bay. The records for *R. setigera* show that it occurred most abundantly from the mouth of the Potomac River to the mouth of the bay, and that the highest counts were obtained during the autumn and spring cruises (October, 1915, and April, 1916), indicating autumn and spring maxima. The counts in the region of the mouth of the Potomac were not any larger than those lower down the bay at area *A*. The distribution of this species in the Chesapeake shows that it can stand considerable variation in salinity and temperature, but it is of interest to note that above the mouth of the Potomac it was not recorded as having occurred in the surface layer. The data are not complete enough to admit of any conclusions as to the vertical distribution. A discussion of the distribution of *S. costatum* has been taken up above. Other species included in the neritic northerly temperate group—namely, *Thalassiothrix nitzschioides* Grun., *Nitzschia longissima* (Breb.) Ralfs., *Chaetoceras teres* Cl. and *Leptocylindrus danicus* Cl.—were not represented by large numbers in the bay, although *T. nitzschioides* was found as far north as area *R* in October (16.49 per mille, 17.3° C.) and *N. longissima* as far north as the same area in June (approximately 17.00 per mille, 17.2° C.).

The most abundant diatom of the neritic southerly temperate group during the 1915 and 1916 cruises was *Cerataulina bergonii* Perag. The high counts of the April, 1916, cruise at areas *A*, *J*, *L*, and *X* as compared with the numbers found on other cruises indicate a marked spring maximum. The minimum occurred in the summer, judging from the surface records of the July cruise. At area *A* during the April cruise the surface count was 407,200 (18.46 per mille, 11.4° C.), at *J*, 65,400 (10.81 per mille, 12.1° C.); at *L*, 40,400 (12.05 per mille, 11.0° C.); and at *X*, 5,200 (5.88 per mille, 9.4° C.). The deep-water count for *A* at 27 meters was 300,800 (no salinity record, 10.5° C.); for *J* at 27 meters, 353,800 (no salinity record, 8.8° C.); and for *L* at 26 meters, 173,200 (17.63 per mille, 8.9° C.). No deep-water count was made at *X*. It is evident from the records that the largest numbers of *C. bergonii* were found in samples from the lower half of the bay, especially at area *A* and the areas near the mouth of the Potomac River. The records for this diatom and those which follow are insufficient for a consideration of the vertical distribution. *Rhizosolenia calcar avis* Schultze, which I have placed provisionally in the neritic southerly temperate group but which is sometimes included among the neritic tropical forms, does not seem to have been taken at all by Bailey, Fritz, Gran, Mann, or Cleve in more northern waters. It occurred in fairly large numbers in Chesapeake Bay during the year 1916 and was widely distributed over the bay. At area *A*, near the mouth of the bay, it was taken on the cruises of October, 1915, January, March, April, June, July, and September, 1916; in other words during all the cruises except December, 1915. Farther up the bay it was recorded also during December. The highest counts were obtained during the April cruise and the smallest during the July cruise. The two largest counts were those of area *J*, 6,400 at 27 meters (estimated at 18.00 per mille, 8.8° C.), and of area *L*, 6,500 at 26 meters (17.63 per mille, 8.9° C.), during the April cruise. It will be noted that both areas mentioned are close to the mouth of the Potomac River. This form was found as far north as area *X* on the cruises of December, 1915, January, March, and September, 1916, when the salinity was comparatively high for that region. During the January cruise the surface count was 100 (11.13 per mille, 1.0° C.), and that at 28 meters, 3,000 (17.00 per mille, 3.6° C.). The wide distribution of this diatom in Chesapeake Bay, its occurrence there during a large part of the year, and the fairly large numbers during the spring maximum in the region of the mouth of the Potomac River are conditions which favor its inclusion under the neritic group, where Cleve, Ostenfeld, and Fish have placed it, rather than under the oceanic group to which it has been assigned by Gran (1908).

Rhizosolenia stolterfothii was found as far north as area *X*, in very small numbers on the cruise of June, 1916. During the winter cruises (December, 1915, January, 1916) and even on the March cruise this form was almost absent from the plankton; but in April it was very abundant at two areas under the following conditions: Area *G*, surface 126,000 (21.92 per mille, 11.1° C.), 18 meters 52,000 (29.78 per mille, 7.0° C.); area *P*, surface 49,800 (11.98 per mille, 10.3° C.), 11 meters 11,400 (12.12 per mille, 10.6° C.). At other areas there were no records of its occurrence in April. During the summer cruises (June and July) the counts were small, but in September large numbers were found at area *F*, surface 35,900 (27.54 per mille, 22.5° C.) and area *A*, surface 79,000 (23.59 per mille, 23.4° C.). This species was evidently widely distributed over the bay but in small numbers except in the lower half, where it was most abundant near the mouth (areas *A*, *F*, *G*). As in the case of *Skeletonema costatum*, the largest counts were obtained at 27 meters for area *A*, at 9 meters for area *L* and at the surface for area *R* during the October cruise of 1915. The records for the remaining diatoms included in the neritic southerly temperate group indicate that they did not flourish in Chesapeake Bay, at least during the year 1916, that they occurred in largest numbers near the mouth of the bay, and that the counts near the mouth of the Potomac River were not conspicuously large. There is some indication that *Guinardia flaccida* (Castrac.) Perg., *Biddulphia mobiliensis* (Bail.), and *Bellerochea malleus* (Brightw.) have maxima in the autumn and the spring. The data for *Ditylium brightwellii* (West) Grun., *Eucampia zodiacus* Ehr., *Lithodesmium undulatum* Ehr., and *Bacteriastrum varians* Lauder are so meager that it is unjustifiable to discuss them in detail.

No neritic tropical forms were found in Chesapeake Bay unless *Bellerochea malleus* and *Rhizosolenia calcar avis*, which I have included provisionally in the neritic south temperate group, are considered as tropical forms.

The oceanic diatoms were not abundantly represented in Chesapeake Bay during 1916—a condition which should be expected, since pure oceanic water, so far as our records show, did not have access to it. There was no marked maximum for these forms during April such as was characteristic for many neritic forms, and in most cases their occurrence was confined to the late summer, fall, winter, and early spring, when the salinity was highest near the mouth of the bay. Whether such a condition can be related without question to the shifting of the highly saline North Equatorial Stream (Johnstone, 1923) toward the north during late summer and early fall must remain a subject for further investigation.

Two species belonging to the oceanic, boreal, Arctic group have been found: *Chaetoceras decipiens* Cleve and *Rhizosolenia semispina* Hensen. The former, which is such a common form in the North Atlantic Ocean, but which was only fairly numerous at Woods Hole according to Fish was taken in small numbers near the mouth of the bay at areas *G* and *A*. It occurred there during the months of June, July, and September, which is about the same time it was found commonly in the southern part of the North Sea, as pointed out by Ostenfeld. The specimens occurred in the surface layers where the salinities and temperatures ranged from 22.11 to 23.59 per mille, and 19.9° to 24.3° C., respectively. It is necessary to state, however, that the counts were not only small but included both dead and living specimens. *R. semispina*, a common summer form according to Bigelow and Fish during the summers of 1914 and 1922 in the region of Woods Hole, occurred sporadically during 1916 in the Chesapeake. A few specimens, only in one sample, taken at area *J* during January were found.

By far the most abundant oceanic temperate diatom found in Chesapeake Bay during the year 1916 was *Rhizosolenia alata* Brightw., possibly *f. gracillima*, although Wolfe has not mentioned this form of *R. alata* in his list. Ostenfeld has pointed out that this form is better able to stand neritic conditions and that it has been found in the lower layers of the Baltic Sea. During 1916 in Chesapeake Bay there was no indication of a maximum in April such as was characteristic for many of the neritic diatoms, nor were there any high counts in the region of the mouth of the Potomac River. It occurred in largest numbers in and near the mouth of the bay. At area *G*, during January, the counts at the surface and 18 meters were 200 (salinity 23.40 per mille, temperature 4.1° C.) and 12,700 (32.5 per mille, 5.9° C.); during March at the same depths the counts were 600 (28.15 per mille, 3.7° C.) and 2,700 (30.5 per mille, 3.4° C.); and during April the counts at those depths were almost negligible. *Rhizosolenia styliformis* Brightw., which is such an important oceanic diatom, was found in small numbers in the lower part of the bay during December, 1915, January, March, and September, 1916. The highest count was at area *F*, in the mouth of the bay, during the September cruise. Its occurrence in largest numbers during that cruise indicates that its seasonal distribution is similar to that in European waters. *Thalassiothrix frauenfeldii* Grun. was taken in very small numbers. It was found in the lower part of the bay, in the fall only.

The oceanic tropical diatoms were represented in 1916 by *Planktoniella sol* (Brightw.). Like other oceanic diatoms, it was found in very small numbers and almost invariably only in the fall and winter—that is, during the time of high salinities.

The factors governing the distribution and abundance of diatoms have been for many years and still are subjects of investigation. Currents, light intensity, temperature, salinity, and the chemical composition of the sea water have been recognized as important factors which have to be taken into consideration. All of these have received attention in a general way during the last 50 years, but within the last 5 years there has been a widespread tendency to regard the amounts of certain chemical compounds in the sea water as very important, if not the most important, factors determining distribution and abundance.

The early analysis of sea water for nitrates by Brandt (1899, 1902, 1920) and for phosphates by Raben (1905, 1910, 1914, 1920) which resulted in their emphasizing the importance of these compounds for the growth of the phytoplankton; the observations of Nathansohn (1906) stressing the importance of the sinking nutrient material in the Mediterranean; the observations of the same author (1911) at Monaco, where a diatom increase was found following wet weather; Mathews' (1918) analyses for phosphorus in the surface water of Plymouth Sound; the work of Allen and Nelson (1910) and Allen (1914) pointing out the importance of nitrates and phosphates for the growth of diatoms and the necessity of culture experiments in determining the number of diatoms in a certain quantity of water—all indicate an important relationship between the chemical compounds in the water and the distribution and abundance of diatoms.

Recently, using newer and more accurate methods for the analysis of nitrates and phosphates, Atkins (1923, 1926) and Harvey (1926) have again found a close relation between diatom increase and dissolved phosphates and nitrates in English sea waters. Gaarder and Gran's (1927) cultural work in Oslo Fjord on the growth of diatoms under variations in temperature, illumination, and nutrient salts and Gran's (1929) investigation of the sea outside of Romasdalsfjord indicate the importance of these factors.

The problem as to the factors that govern the distribution and abundance of diatoms is many sided and one in which it is difficult to study a single factor with the others under control. The efforts of Schreiber (1928) to devise such a procedure are worthy of special mention. Using single diatoms which had been rinsed by a special method so as to be free from all other organisms except supposedly a few bacteria, he determined the degree of intensity of light necessary for optimum reproduction, the quantity of nutrient materials and the temperature being kept constant. Such an approach as Schreiber has made, provided it is preceeded by a study of the organisms under natural conditions, it seems to me is very desirable.

PROTOZOA

The Protozoa occuring in the plankton samples of Chesapeake Bay were identified, counted, and tabulated by Cunningham. They are listed and their distribution is discussed from certain points of view by Cunningham in the paper by Wolfe and Cunningham (1926).

The fresh-water rhizopods were represented in the plankton by one or more species of Difflugia during the year 1916. Individuals of this form were present on all the cruises taken, and they were widely distributed. Difflugia is a bottom form, but one specie at least is known to form a gas vacuole and then to take on a tychopelagic existence (Steuer, 1910). Such a condition may account for their abundance in the plankton. Specimens of this rhizopod were taken in greatest numbers during the summer and fall cruises (July and September). The winter cruises yielded the smallest numbers.

Another rhizopod found in the bay, but on one occasion only, was the oceanic plankton form Globigerina.

Among the Silicoflagellata identified by Cunningham are two well-known species *Dictyocha fibula* Ehr. and *Distephanus speculum* Haeck., both of which have been found in the waters about Woods Hole by Fish.

During the October 1915 cruise, *Dictyocha fibula* was taken in comparatively large numbers for that species at area *A* (surface 160, 9 meters 360, 18 meters 80, 27 meters 40, 36 meters 160, 46 meters 640), and somewhat less abundantly at area *J* close to the mouth of the Potomac River. North of that area it was found in very small numbers. During the winter, spring, and summer cruises of 1916 (January, March, April, June, and July) specimens of this species were very scarce in the samples; but in September of the same year there was an indication at area *F* of increasing numbers, and the counts for the October 1915 cruise were the largest obtained on any cruise. The data, although meager, indicate that this form has an autumnal maximum in Chesapeake Bay.

The occurrence of *Dictyocha fibula* in considerable numbers at area *A* (salinity, approximately 25 to 27 per mille, temperature approximately 19° to 20° C.) and at area *J* (salinity, approximately 16 to 23 per mille, temperature approximately 18° to 19° C.) suggests that it is a neretic form as stated by Cleve (1897), although Gran has found it in mid-Atlantic ocean.

Ceratium tripos (Müller), which is such an important element in the marine plankton and which has been found in abundance by Fish at Woods Hole and by Bigelow (1926) in the Gulf of Maine, has not been reported by Cunningham (1925) for the samples taken from Chesapeake Bay. The most abundant species listed for Chesapeake Bay was *Ceratium furca* Ehr., while *C. fusus* Ehr. occurred in much smaller numbers. The data from the 1915–16 cruises of October, December, January, March, April, June, July, and September show the larger numbers during the latter half of the year and, as observed by investigators in other regions for Peridinians, after the spring maximum of the diatoms. During the cruise of July the highest counts for *C. furca* were obtained, while during the cruises of the spring and early summer the numbers were small. The surface counts for area *J*, at the mouth of the Potomac River (and many other areas), show this relation clearly: October, 208; December, 1,320; January, 320; March, none; April, 80; June, 840; July, 23,400; and September, 200.

As is the case of many diatoms the counts for the peridinian, *Ceratium furca* in the neighborhood of the Potomac River were the highest obtained in the bay. As an example, during the July, 1916 cruise, the surface counts at areas distributed along the deep-water channel from the mouth of the bay to near Baltimore were the following: *G*, 800; *A*, 4,280; *J*, 23,400; *L*, 15,320; *R*, 1,360; and *X*, 120. Of these areas, *J* and *L* are close to the mouth of the Potomac River.

While *Ceratium furca* is known as a temperate oceanic form, widely distributed over the Atlantic Ocean and occurring sparingly in the Florida current according to Cleve (1898), it has been recorded in the Baltic, where the salinity was approximately from 15 to 17 per mille by Apstein (1906), in the saline bottom water (approximately 17 to 20 per mille) entering Kieler Förde by Lohmann (1913), and in Fehmarn Belt, where the salinity was higher, by Büse (1915). Its presence in Chesapeake Bay then in comparatively large numbers near the mouth of the Potomac River is not surprising even though the surface salinity was low, approximately 16 per mille at area *J*.

Several species of the genus Peridinium were taken in Chesapeake Bay during the cruise of 1915 and 1916, but no attempt to identify them was made. Rather large numbers of individuals were found on every cruise, and they were widely distributed over the bay. The counts obtained during the June, July, and September cruises were in general the highest, while on the spring cruises, March and April, the lowest numbers were found. In other words, the data point to a summer maximum following the spring diatom maximum. A marked tendency for the highest numbers to be at or near the surface may be seen from the data, a condition which was found by Apstein (1906) in the North Sea. (See Steuer, 1910.)

The data do not show that the highest counts were found usually in the neighborhood of the mouth of the Potomac River, although such was the case especially during the July and September cruises.

Many specimens belonging to the genus Prorocentrum (two forms of *P. micans* according to Cunningham) were collected during the 1915 and 1916 cruises. By far the largest numbers were found at the time of the summer and fall cruises, and the smallest during the midwinter and spring cruises. At area *J* the surface counts were these: October (year 1915), 1,560; December, 320; January (year 1916), 360; March 40; April, 200; June, 480; July, 8,440; September, 4,200. At 27 meters the counts at the same area were: October, 448; December, 120; January, 120; March, no count; April, 280; June, 120; July, no count; September, 4,480. The numbers found in the surface samples during the cruises of July and September were highest in the region of the mouth of the Potomac River, but during other months this relation did not hold. In fact the two largest counts taken in the bay were 15,320 at area *R* in October and 92,800 at area *X* in June—both surface samples collected far northward in the bay. The time of occurrence of the maximum counts for this genus and for other Dinoflagellata mentioned above supports Kofoid's suggestion (1921) that the increase in numbers may be related to the decay of phytoplankton, but it is also true that the increase in number took place when the temperature was highest and the light strongest.

Noctiluca miliaris Surivay, a protozoan belonging to the group Cystoflagellata was found on nearly every cruise in 1915 and 1916. This form, according to Ostenfeld's résumé (1913), occurs only in coastal waters, not in the open ocean and not in water of too low salinity like that of the Baltic Sea. Bigelow (1926) has not taken it in the Gulf of Maine, and Fish (1925) did not report it from Woods Hole. Its decidedly irregular distribution in Chesapeake Bay bears out the statement of Ostenfeld that individuals may appear in large numbers in a certain place, stay for several weeks, and disappear then, while a short distance away they never become numerous. A few specimens of Noctiluca made their way north as far as area *X* in Chesapeake Bay during 1915 and 1916, but it was only in the lower end of the bay that they occurred in considerable numbers. The data show the highest numbers at the surface and the largest count (2,400) was that in a surface sample taken at area *F* during September, 1916. While the distribution in the bay was quite irregular, the data point to a maximum in the fall with considerable numbers in the spring and early summer. During the cruises of January and March almost no specimens were recorded, while during the cruise of July the numbers were low. No conclusion can be reached as to the distribution with reference to the mouth of the Potomac River except that the outstanding high counts were not there but in the region of the mouth of the bay.

A rather large number of genera belonging to the Infusoria were represented in the plankton samples, and they have been listed and the numbers tabulated by Cunningham in the paper of Wolfe and Cunningham (1926). Of these only one genus, Cyttarocylis, belonging to the Tintinnidae has been studied sufficiently to make it possible to draw any conclusions as to distribution. Specimens were found on every cruise during the year 1916 (January, March, April, June, July, and September). The highest counts were obtained from samples taken during the March cruise, and the numbers were more abundant in the samples from the lower part of the bay.

COELENTERATA

PORIFERA

Practically all of the collecting done on the survey was in the offshore waters, so that the sponges of the shallower water have not been investigated. Dredging with the beam trawl and with the mud bag at the shallow stations have brought to light, however, four species of sponges, one of which is new, and a new variety. These have been identified by H. V. Wilson, and I am indebted to him for the following list: *Tetilla laminaris* George and Wilson, *T. laminaris* var. symmetrica n. var., *Suberites paradoxus* Wilson, *Halichondria panicea* Johnston, and *Microciona prolifera* Verrill.

Tetilla laminaris was dredged on one occasion only at 10 meters at area *K*. This area is located on the eastern side of the bay opposite the mouth of the Potomac River. The specimen was taken during July, 1920, in water of 14.79 per mille salinity and 24.4° C. temperature. The bottom in this region was partly sandy and partly muddy (depth 10 meters). *T. laminaris* George and Wilson, var. symmetrica was found growing at area *D*, off New Point Comfort (depth of 8 meters) on a sandy bottom. Three specimens were brought up during the April, 1920, cruise from water of 21.23 per mille salinity and 11.1° C. temperature. A new species, *Suberites paradoxus* was dredged during the July, 1920, cruise at area *C*, off New Point Comfort (depth about 13 meters). The bottom in this region was variable in character, and the temperature and salinity of the water from which the specimen was taken were 22.0° C. and 22.49 per mille. During the January, 1921, cruise numerous fragments of *Halichondria panicea* were found at area *Q* (depth about 14 meters) off Sandy Point and at area *A* (depth about 46 meters) near Cape Charles City. In the first case they were taken from water of 21.59 per mille salinity and 4.2° C. temperature, while in the second case the salinity and temperature were about 26.00 per mille and 4.9° C. *Microciona prolifera* was dredged during the July, 1920, cruise at area *P* (depth about 13 meters) off Point No Point and area *I* (depth about 13 meters) just south of the Maryland and Virginia line. The salinities were 17.27 per mille and 15.47 per mille, the temperatures 23.5° C. and 25.2° C., respectively.

Undoubtedly the ideal home for sponges is in a region where there are plenty of solid objects for attachment, so one finds them living well among rocks, stones, shells, corals, etc. They are known not to do so well in regions where the bottom is made of soft mud or fine sand. For example, in the deeper part of the fjords (Appellöf, 1912) of Norway, where the bottom is muddy, the sponges are absent. It is not surprising, then, that many specimens or species of sponges were not found during the offshore dredging in Chesapeake Bay, since much of the bottom in the deeper parts of the bay is muddy. It is of interest to note that all of the specimens collected, with the exception of one, were taken from regions where the depth ranged from 8 to about 14 meters—in other words from the shallower areas of the bay. No sponges were dredged from the mouth of the bay, which is largely a region of shifting sand. All the specimens found come from the lower half of the bay, below area *P*, near the mouth of the Potomac River, and none were taken in water of a lower salinity than 14.79 per mille.

CNIDARIA

HYDROZOA

The hydroids collected in the deep waters of Chesapeake Bay have been studied by Charles W. Hargitt. He has identified 14 species and listed those identified and described for Chesapeake Bay by C. C. Nutting (1901) and S. F. Clarke (1882). By far the most abundant hydroids collected by our survey belong to the genus Thuiaria. Three species, one of which at least is of commercial importance, have been reported from the bay and its tributaries by Nutting. They are *Thuiaria argentea* Linn., *T. cupressina* Linn., and *T. plumulifera* Allman. Hargitt in working over the collections of the year 1920 found *T. argentea* at many stations and speaks of it as "by all odds the most common species taken." The beam trawl hauls show that Thuiaria was found widely distributed over the deeper parts of the bay; but the indications are, as has been pointed out by Radcliffe in the log for the 1916 cruises and by Hargitt, that some of the material taken was unattached to the substratum, although not floating at the surface. Ordinarily roots were not found on the specimens. Floating hydroids have been observed by Bigelow (1915) on Georges Bank off Cape Cod and their occurrence is discussed by C. McLean Fraser in Bigelow's paper (1915). R. C. Osburn, who has studied the Bryozoa collected in the Chesapeake by this survey, has commented on the large amount of dead hydroid material received by him with Bryozoa attached, and suggests that they were brought into the bay by tides and currents from near the mouth, where they grow. The observations of Radcliffe (1916) showed that Thuiaria had increased in abundance during the March and April cruises as compared with the supply during the previous winter. The indications are that the Thuiaria species can withstand a large range of salinities and of temperatures.

The following hydroids are known to occur in the region of Fort Wool, Va.: *Calyptospadix cerulea* Clarke, *Eudendrium carneum* Clarke, *Stylactis arge* Clarke, *Lovenella gracilis* Clarke, *Bougainvillia rugosa* Clarke, and *Hydractinia echinata* Fleming. Several other hydroids have been collected from Chesapeake Bay, and they are now in the United States National Museum. The following list is available owing to the courtesy of Waldo S. Schmitt, curator of invertebrates: *Campanularia* sp., *Thuiaria argentea* (L) from Jerome Creek, Md., *T. cupressina* (L) off Virginia, *T. plumulifera* Allman, *Aglaophenia rigida* Allman, *Cladocarpus flexilis* Verrill off Virginia, *Antennularia americana* Nutting, *A. antennena* (L), *A. simplex* Allman, *Plumularia floridana* Nutting, and *Plumularia*, near *alternata*. Two of these species, *A. antennena* and *P.* "near *alternata*," were determined by Verrill and the rest by Nutting.

HYDROMEDUSÆ

The hydromedusæ collected during the July, August, October, and December cruises of 1920 and the January and March cruises of 1921 have been examined and identified by H. B. Bigelow. I am indebted to him for the information that the collection contains no new species and that no extensions of any importance to the geographic ranges were found. He points out that there are very few species, and that the well-known form *Nemopsis bachei* greatly predominates in the collection. This form, which occurs very abundantly along the Atlantic coast near the mouths of large bays into which pure ocean water has free access (Mayer, 1910), was found widely distributed in Chesapeake Bay during the cruise of December, 1920. It was taken frequently in the surface nets as well as in the bottom net, and the records show its occurrence as far north in the bay as area W, off Bloody Point. The records also show that this form was present in the bay during the cruises of July, August, October, 1920, and January and March, 1921. A few other hydromedusæ were collected, some of which were identified provisionally. The complete list is as follows: *Bougainvillia carolinensis* McCrady, *B. ramosa* Van Beneden (provisional identification), *Nemopsis bachei* L. Agassiz, *Blackfordia virginiana* Mayer, *Liriope scutigera* McCrady (provisional identification), and *Aglantha digitale* Fabricius (too fragmentary to throw light on varietal relationships).

SCYPHOMEDUSÆ

By far the most common jellyfish (or sea nettle, as it is called), in the region of Chesapeake Bay is *Dactylometra quinquecirrha* L. Agassiz. It occurs there usually in the "Chrysaora" stage, characteristic of the brackish water—that is, with 32 marginal lappets and 24 tentacles and mature gonads instead of with 48 marginal lappets and 40 tentacles (R. P. Bigelow, 1890; Mayer, 1910). Mayer reports (p. 588) that *D. quinquecirrha* in the 40-tentacle condition develops at the mouth of Chesapeake Bay "in the purer ocean water * * *" The unpublished observations of Radcliffe on cruises during October and December, 1915; January, March, April, June, July, August, and September, 1916, give a good idea of the seasonal abundance of older specimens of Dactylometra in the bay. During the October cruise this form was reported at practically every station from the mouth to Sandy Point, near Baltimore; on the December cruise it was seen very infrequently; during the cruises of January, March, April, and June it was not reported, although, of course, it may not have been entirely absent; on the July cruise it was very abundant, especially at the mouth of the bay and was found as far north as area *X*; finally, during the September cruise it was still abundant at many stations. The records indicate that Dactylometra became abundant in the Chesapeake during July, 1916, and according to Radcliffe one fisherman, at least, in the southern part of the bay, anticipates a "run" during that time of the year and takes up his nets to prevent their "burning." Midsummer and early fall apparently was the time of abundance of this form in Chesapeake Bay during 1916, a conclusion which agrees with observations made along the New England Coast and at Tampa, Fla. Dactylometra in the "Chrysaora" stage has been found in considerable numbers by the writer in the Severn and Magothy Rivers during October, and Mayer reports it from St. Marys River, Md., early in November, 1904 and 1905. E. A. Andrews has found it in the fall, 10 miles up the Severn River and about the docks in Baltimore Harbor. Undoubtedly it is the common form during the fall in the rivers emptying into Chesapeake Bay. *Dactylometra quinquecirrha*, according to the observations of H. B. Bigelow for the New England region, is strictly a coastal form and does not occur north of the Cape Cod region. In its "Chrysaora" stage it is able to survive through a large range of salinities, judging from observations made in the Chesapeake; but its geographical distribution indicates that it is a warm-water form.

It is not improbable that Dactylometra breeds in Chesapeake Bay and that the planulæ, scyphostomæ, and ephyræ are present in the summer, winter, and spring, respectively, but the records on which the above discussion is based deal only with the older and easily seen specimens. However, the ephyræ of *Dactylometra quinquecirrha* have been seen by W. K. Brooks at Fort Wool, in the southern part of the bay, and figures made from them have been published by Mayer (1910).

The common jellyfish of the Atlantic coast, Aurelia, was not found in large numbers during 1916, but during the March cruise it was taken in considerable numbers in the southern half of the bay. The reddish-colored jellyfish Cyanea, which, according to Damas (1909) and also Bigelow, is characteristic of coast or bank water, appears in Chesapeake Bay at times. It was abundant during the April cruise of 1916 and was found at almost every station from area *J*, at the mouth of the Potomac River, to area *X*, near Baltimore. During the August cruise of 1920 a few large specimens were seen in the region of the Potomac. E. A. Andrews reports having seen small specimens in the waters of the eastern side of the bay near Love Point, which is only a few miles from Baltimore.

ANTHOZOA

Slender branches of a gorgonian have been collected on many cruises during 1916, 1920, 1921, and 1922. These whiplike branches, which may be as much as 60 or 70 centimeters long, measure scarcely over 1 millimeter in diameter. Some are yellow and others reddish in color. They have been taken in the beam trawl and the bottom townet at stations near the mouth of the bay ordinarily, but not infrequently specimens have been found in the region of the mouth of the Potomac River. During June, 1921, a few fragments were collected as far north as area *R*, off Barren Island near the mouth of the Patuxent River. None of the specimens was attached to stones, shells or other objects, and so there was no evidence to show that they were growing on bottom materials. During the May–June cruise of 1921 specimens were brought up from the following areas: *G′* off Old Point Comfort; *H* at the mouth of the Rappahannock River; *I* near the mouth of the Potomac River; *N* in the mouth of the same river; *L′* off Holland Island; and *R* off Barren Island. On no other cruise was such an extensive distribution noted—that is, over more than the lower half of the bay—but in March, 1922, it was found as far north as the mouth of the Potomac River. The records indicate that this gorgonian may be found in the bay at any season, in shallow or deep water, but that it does not reach the upper parts of the bay. An attempt to identify this species from descriptions made by Verrill lead me to believe that it is identical with or closely related to *Leptogorgia virgulata* (Lmk.), but the fragmentary character of the specimens and the lack of confirmation of such an identification by specialists make it necessary to consider the conclusions as tentative. A. Knyvett Totten, who is working on the gorgonians of the British Museum, has examined specimens of the species found in the Cheaspeake, and although he has not had access to Verrill's material is of the opinion that our species is *L. virgulata*.

Only one species of sea anemone has been collected in Chesapeake Bay during the cruises of 1916, 1920, 1921, and 1922, but these cruises were limited to operations in offshore waters. This unidentified species had a surprising distribution, judging from our dredging collections, being found at area *Z* on the following cruises: 1920, August, October, and December; 1921, June; 1922, March; area *W*, 1920, December; 1921, June; area *V*, 1921, June; area *T*, 1920, July; area *R′*, 1921, March; area *P*, 1921, June; and area *I*, 1920, July. In other words, it was not found below the mouth of the Potomac River, and it was taken most often at area *Z*, off Sandy Point, not far from Baltimore. It was always brought up attached to rocks, shells, slag, or other hard objects. This form was never taken in the deep-water channel, possibly because of a lack of shells and stones for attachment. It was found only in water from 7 to 12 meters deep, but probably it may be found, by shore collecting, in shallower water; in fact,

E. A. Andrews reports the occurrence of an anemone (probably of the same species) from the Severn several miles above Annapolis. It seems to be adapted to water of a rather low salinity but to an extensive range of temperatures. However, it must not be forgotten that another factor affecting the distribution is the presence of hard objects for attachment. The 12 samples mentioned above were taken in water which varied in salinity from 11.46 to 18.47 per mille, and in temperature from 5.3 to 24.1° C.

Fragments of a coral which were probably the calcereous portions of *Astrangia danæ* Agassiz were brought up on 9 different occasions by the beam trawl or the mud bag. These were all found near the mouth of the bay—4 times at area *G*; 5 times at area *E*; once near Cape Henry (all three of which localities are directly in the mouth of the bay); and once at area *A* off Cape Charles City. In addition to this, Radcliffe reports finding "white corals, many growing on stones" at station 8592 near Cape Henry in about 18 meters of water.

CTENOPHORA

The ctenophores are a conspicuous element in the plankton of Chesapeake Bay at certain times of the year. They were so abundant during some of the cruises of 1920, 1921, and 1922 that they interferred with the proper working of the townets. No attempt was made to study the ctenophores intensively, and whatever records we have are the result of general observations on their relative abundance made when the nets were brought in. *Beroë ovata* Chamisso and Eysenhardt is known to occur in the bay. It was collected by Mayer (1912) from St. Marys River, Md., in November, 1905, and has been figured in his monograph on the ctenophores. *Beroë forskalli* was reported by Bigelow (1922) as being present in the mouth of the bay and outside in July, 1913. Radcliffe, in the unpublished log, reports the presence of a "Pleurobrachialike" ctenophore at stations near the mouth of the bay—for example, at areas *G* and *A* in March, 1916, and again at areas in the same general region in April, 1916. Very probably the species was *Pleurobrachia pileus* or possibly the nearly related species *P. brunnea*, if the latter is a valid species. It is also probable that *Mnemiopsis gardeni*, which is known to frequent brackish-water bays and estuaries from Chesapeake Bay to northern Florida, was common in the bay. During the January cruise, 1916, ctenophores were abundant in several localities, but on the March and April cruises they were scarce except at stations near the mouth of the bay. They were abundant in the southern half of the bay during the June cruise and all over the bay on the July cruise, although in greater numbers in the upper half. The ctenophores were still very abundant in the upper waters of the bay and extremely abundant near the mouth of the Potomac River during the September cruise. Similar conditions were found in 1920. During the January, 1920, cruise they were numerous all over the bay, but in March they were found only at areas *E*, *F*, and *G*, which are in the mouth of the bay. On the May cruise they were still scarce; but on the July, October, and December cruises they were again numerous all over the bay, and especially so near the mouth of the Potomac in December.

The ctenophores were still widely distributed over the bay during the January cruise of 1921, but again as in 1916 and 1920 the hauls so far as made on the March cruise showed a scarcity. It must be stated, however, that at many areas during this cruise the nets were not used. On the May-June cruise the ctenophores were more numerous. Finally, again during the January and March cruises of 1922, they showed conditions similar to other years—that is, a wide distribution during the

January cruise and a great scarcity in March. While the discussion just given is not based on a careful quantitative study of the abundance of the ctenophores, the fact that there is close agreement between the observations made by Radcliffe in 1916 and by the author in 1920, 1921, and 1922 as to relative abundance makes the conclusions of considerable value. The evidence all supports the view that a scarcity of full-grown specimens, at least, occurs during the spring months (for example, March, 1916, 1920, 1921, and 1922), that the numbers increase in early summer, that they reach a maximum in the late summer and fall, and that during part of the winter they are still present, widely distributed. In the late fall and early winter the writer has found them several miles up the Severn River.

Our observations on the seasonal occurrence of ctenophores in Chesapeake Bay are in rather close agreement with those made by Nelson (1925) for the inland coastal waters of New Jersey.

VERMES

NEMATHELMINTHES

NEMATODA

The collection of nematodes, which is large, is now in the hands of Dr. N. A. Cobb, senior nematologist of the Department of Agriculture. He has been working on them for some time and finds that the five hundred and odd specimens comprise at least a dozen genera (Oncholaimus, Chromodora, Euchromodora, Enoplus, Anticoma, Spilophora, Monhystera, etc.). The number of species he states are "upward of 20, some of them doubtless new." No further discussion of this group can be made at the present time.

CHAETOGNATHA

The occurrence of sagittas, ordinarily thought of as marine planktonic forms, in the waters of Chesapeake Bay is not surprising when it is known that one species at least has been found in the Baltic Sea (Apstein, 1911, p. 174; Ritter-Záhony, 1911, p. 19) and since the investigations of Huntsman and Reid (1921, pp. 10–14) have shown that *Sagitta elegans* was found in brackish water estuaries where the salinity was probably as low as 20 per mille. Three species *Sagitta elegans* Verrill, *Sagitta serratodentata* Krohn, and *Sagitta enflata* Grassi represent the sagittas collected during the cruises of July, August, October, December (1920), and January, March–April (1921). The writer made the identifications following the classifications of Ritter-Záhony (1911) and Huntsman (1919), although no attempt was made to distinguish subspecies. Of the three species mentioned, specimens of *Sagitta elegans* were by far the most abundant, and specimens of *S. serrotodentata* barely made their appearance inside of the bay.

The studies of Huntsman (1919), Bigelow (1922, 1926), and myself all lead to the conclusion that *Sagitta elegans* is primarily a neritic form. This species, however, was all but absent from Chesapeake Bay during the July and August cruises, judging from numerous surface (over 100), and bottom towings (over 40), and vertical hauls (30) made at widely distributed areas. Only at areas *G* in the mouth and *B* near by were any specimens captured. All of these were small forms varying from about 4 millimeters to 10 millimeters in length, and only one specimen was taken in the surface nets. Additional evidence indicating a scarcity during the summer is afforded by the records in the log for the May–June cruise of 1921, which show that no sagittas were seen in any of the unpreserved samples as they came to the surface. Such a condition suggests that the sagittas are really immigrants into the bay. It is of much interest to find that the towings of the October cruise revealed considerably larger numbers of *S. elegans* in Chesapeake Bay than those of the summer cruises, and also to recall that this cruise took place during the time of year when there was a strong tendency for the deeper and more saline layers to move into the bay. The records, which deal with the usual large number of surface and bottom towings, show that all the specimens were small, about 4 to 10 millimeters in length, and that they were distributed as far north in the bay as area *X*. While there were many surface towings made, all of the specimens came from the bottom net (which, however, was not a closing net), indicating that *S. elegans* was confined largely to the deeper and more saline waters in the daytime, at least when all the samples were taken. By far the largest catches were in the mouth of the bay, and the numbers showed a fairly uniform decreasing range for the successive areas passing toward the head. The following data for the bottom net (10 minutes towing) illustrate this: Area *G*, 927 specimens, largest 6 to 7 millimeters long; area *F*, 805 specimens of about the same size as those for area *G*; area *A*, 5 specimens 4 to 7 millimeters long; area *B*, 33 specimens mostly about 8 to 10 millimeters long; area *C*, 16 specimens about 8 to 10 millimeters long; area *Q*, 42 specimens ranging up to 10 millimeters long; area *H'*, 5 specimens 4 to 7 millimeters long; area *I*, 3 specimens about 6 to10 millimeters long; and area *X*, 1 specimen about 9 millimeters long. No large specimens were found.

While it is probable that *Sagitta elegans* breeds to some extent in the bay, the absence of large specimens during the October cruise, the large number of young specimens in the waters of the mouth of the bay with a decreasing number farther in, the autumnal hydrographic conditions, and at the time of the July and August cruises an almost complete absence of it from the hauls, indicate that the bulk of the specimens found during the October cruise were being transported gradually from their breeding place, probably just outside of the capes, into Chesapeake Bay.

The towings of the December cruise showed no large numbers of *Sagitta elegans*, nor was the distribution over the bay extensive. In fact, practically all of the specimens were taken in the mouth of the bay and close by. Only small individuals, from 3 to 11 millimeters in length, were captured, although the usual number of towings was made.

During the January (1921) cruise, the usual, numerous towings all over the bay brought in rather large numbers in the lower half of the bay—that is, from area *J* to the mouth—but north of area *J* no specimens were captured, although many surface and bottom towings were made. At this time specimens of *Sagitta elegans* of rather large size, as much as 25 millimeters long, were taken, but in addition there were many smaller individuals which graded down to 4 millimeters in length. A good idea of the character of the catches may be had from the following data for the bottom net (10-minute towings): Area *F*, 106 specimens (seven 20 to 25 millimeters long, 79 larger than any captured in earlier cruises but none 20 to 25 millimeters long, and the rest of the 106 graded from 6 to 10 millimeters long); area *E*, 17 specimens (six 15 to 21 millimeters long and eleven 4 to 10 millimeters long); area *B*, 60 specimens grading from 5 to 24 millimeters long; area *C*, 1 specimen 17 millimeters long; area *Q*, 1 specimen 25 millimeters long; area *H*, 4 specimens, the largest 17 millimeters long; and area *J*, 3 specimens 20 to 22 millimeters long. Only four of the large number of surface towings yielded any specimens. These, only 10 specimens in all, were mostly small.

The towings from the March–April cruise possibly show the culminating effect of the inflowing bottom current characteristic of the fall and winter months, by the very large catches of *Sagitta elegans;* although the large numbers of small specimens, some of them only 1 or 2 millimeters long, in addition to many large specimens, even in the upper part of the bay indicate that the great abundance was due in part to breeding taking place in the bay. A large number of the specimens collected during the March–April cruise were in good condition but some of the larger specimens were shrunken. Whether this condition indicated the passing of the breeding season for those individuals, or whether it was the result of the effect of low salinity, I am not prepared to say. The following data for the bottom net (10-minute towings) which must be considered as covering only the upper half of the bay since no surface or bottom towings were made south of the mouth of the Potomac River or more precisely south of areas *R′* and *R* off Barren Island, show that the catches (given in round numbers) were much larger in that region than those of any other cruise: Area *R′*, 70 specimens, the largest of medium size and grading down to 2 millimeters in length; area *R*, 2 specimens; area *T*, 120 specimens of medium size; area *S*, 1,850 specimens (nine 26 to 28 millimeters long, 1,841 grading down to 1 to 2 millimeters in length); area *V*, 26 specimens in poor condition (salinity not over 9.16 per mille, shallow area, 9 meters in depth); area *Ẑ*, 7 specimens, one 22 millimeters long; area *Y*, 1,650 specimens, the largest 31 millimeters long and grading down to 2 millimeters in length. This surprisingly large catch at area *Y*, which is off Love Point, not far from Baltimore, was made in water the salinity of which was not higher than 12.99 per mille. On the same day about two hours earlier one of the two largest catches of Copepods for all the cruises was made at area *Z* close by.

The catches of *Sagitta elegans* taken in Chesapeake Bay are of interest because of the large numbers of small specimens and the small numbers of large specimens, the latter being limited to the January and March–April cruises. The capture of only one specimen reaching 31 millimeters in length indicates that this species does not grow as large in the Chesapeake Bay region as farther north, where it is colder, and supports the conclusions of Huntsman (1919, p. 447) and Bigelow (1926, p. 320) that the size of *S. elegans* is dependent upon the temperature. Another point of interest is the occurrence of some very small specimens of *S. elegans*, at least during all of the cruises (July, August, October, December, 1920, and January, March–April, 1921), even though limited to the mouth of the bay. Such a condition indicates that *S. elegans* breeds continuously during those months, outside or inside of the bay, and leads to the suspicion that it may breed to some extent throughout the summer off Chesapeake Bay, as Bigelow (1926, p. 314) has found to be the case on the Georges Bank.

Owing to the fact that the so-called "bottom net" used on our cruises was not of the closing variety, no definite information can be had as to the vertical distribution or as to the precise salinity in which specimens brought up in that net lived. The scarcity of specimens in the surface nets during all cruises shows clearly, however, that *Sagitta elegans* was almost confined to lower layers during the daytime, at least. All of the towings in the bay were made in the daytime. The studies of Huntsman and Reid (1921, p. 12) in the estuary known as the Magagnadavic River show that there was a tendency for *S. elegans* to remain near the bottom, at least during the bright half of the day. As might be expected, we found *S. elegans* in water of 29 to 30 per mille salinity outside of the capes, but large numbers of small specimens grading up to specimens over 30 millimeters long were found in good condition at area *Y* in water of not more than 13 per mille salinity. (Surface salinity at this area, 5.26 per mille; bottom salinity, 18 meters, 12.99 per mille.) This haul was made in March, 1921; and undoubtedly it was not an unusual condition for that time of the year, because the log in which were recorded the conspicuous organisms in the hauls at the time they were brought to the surface shows that in March, 1920, and March, 1922, sagittas were present in the same region, close to area *Y* (surface) and at area *X*, respectively. The salinity of the water in which the specimens were found at the former area was 11.63 per mille and at the latter area not more than 16.79 per mille. The great abundance of *S. elegans* in Chesapeake Bay even at the time of low salinities and the small numbers of *S. serrotodentata*, *S. enflata* and other sagittas, in so far as our records show, indicate that *S. elegans* is adapted to a large range of salinities, while the other species are not. However, it does not follow that the degree of salinity of the water is the only factor which accounts for the horizontal distribution found in Chesapeake Bay. The specimens caught at the surface were too meager in number to make any comparison of the relative numbers at the mouths of rivers as compared with other regions or to study differences on the east and west sides of the bay which might possibly be due to differences in salinity.

It is generally believed that the temperature of the water is another factor governing the horizontal distribution of *Sagitta elegans*. The scarcity of specimens in the bay during the summer cruises, when the comparatively shallow waters are heated to as much as 24° C. at the bottom and 27° C. at the surface, and their abundance during the coldest season, when the temperature drops to near 0.0° C. at the surface and a degree or so higher at the bottom, suggests the importance of temperature in determing the distribution. But other factors, such as an abundance of food, must be be considered; and in this connection it is of special interest to note that during the March–April cruise (1921), when *S. elegans* was so abundant in the upper bay, at least, C. B. Wilson found the copepod *Acartia clausii* in maximum numbers in the same region. It is known that copepods are an important food of sagittas, and Bigelow (1926, p. 320) has pointed out the probable dependence of the distribution of *S. elegans* on the calanoid copepod plankton. In the case of vertical distribution the intensity of light should not be neglected. Finally, dominating fall and winter in-going bottom currents must be considered as probable factors affecting the seasonal and horizontal distribution of *S. elegans* in Chesapeake Bay.

Our records show that *Sagitta enflata* was scarce in Chesapeake Bay during all the cruises. It was taken almost as seldom as *S. serratodentata*. *S. enflata* is recognized as a tropical form, characteristic of the surface waters of the Gulf Stream (Huntsman, 1919, pp. 425, 426; Ritter-Záhony 1911, p. 17; Bigelow 1917, p. 298; Bigelow 1926, p. 334). Huntsman has found it as far north as 43° 30′ N, off Nova Scotia; while Bigelow has taken it off Marthas Vineyard, off the coast of New Jersey, and as far south as the region of Chesapeake Bay. Fish (1925) does not report it from Woods Hole. No specimens were captured in the Chesapeake Bay during our July and August cruises (1920), although a few were found outside; but on the October cruise 4 specimens were taken at area *Q*, 2 at area *A*, and 10 at area *B*. The two latter areas are near the mouth of the bay while the former one is a little farther north abreast of the mouth of the Rappahannock River. It was somewhat surprising to find specimens of *S. enflata* at area *Q*, but the sausage-shaped ovaries with large eggs and short tail convinced me of the identity of the specimens. Furthermore, they were compared with some of Conant's preparations and were in perfect agreement. During the December cruise five specimens were found in the mouth of the bay at areas *G*, *F*, and *E*; while on the January (1921) cruise only one specimen, badly distorted, was caught. It was taken in the mouth of the bay at area *C*. No specimens were obtained during the March (1921) cruise. The scarcity of this sagitta in the bay and its practical absence after the December cruise indicate that it is an oceanic tropical form.

The only other sagitta which has been captured by our nets in Chesapeake Bay is *Sagitta serratodentata*, another tropical form which is characteristic of the Gulf Stream (Bigelow 1926, p. 58) but which may spread shoreward during warm summers. Bigelow (1915, pp. 299 and 300) found it well in toward the mouth of Chesapeake Bay in July, 1913, and Huntsman (1919, p. 442) speaks of it as being a cosmopolitan and epiplanktonic, warm-water form whose distribution in the Gulf of St. Lawrence region extends farther inshore than any other sagitta, being able to withstand the lower temperature and salinity better. While *S. serratodentata* was found outside of Chesapeake Bay in considerable numbers during our August cruise, only five specimens were discovered inside the bay. One was taken at area *G* in August, 1920, another at area *F* in January, 1921, and three specimens at area *E* during the same cruise. All of these areas are in the mouth of the bay. During the July, October, December, and March–April cruises no specimens were found. The specimens captured were all small, varying from 9 millimeters to 15 millimeters in length.

During the August cruise, surface towings were made outside of the bay at three stations (8832, 8833, 8835) where the depths were 118 fathoms (214.5 meters), 67 fathoms (121.8 meters), and 20 fathoms (36.4 meters), respectively. A few specimens of *Sagitta elegans* (35, 1, and 32 after 30 minutes towing), all not more than 10 millimeters in length, were taken in each haul. These three towings were made during the following periods of time: 5.13 p. m. to 6.16 p. m., 7 p. m. to 7.55 p. m., and 11.05 p. m. to 11.45 p. m., respectively, and throughout the work the sky was partly cloudy and the atmosphere hazy. Four specimens of *S. enflata*, three of them over 25 millimeters long, were taken in these surface towings, all four at station 8832, but no specimens of *S. serratodentata*. Towings with a nonclosing bottom net for 30 minutes at each of the three stations—8832, 8834 (43 fathoms or 78.2 meters depth), and 8835—yielded 43 specimens of *S. elegans* of various sizes up to 14.5 millimeters in length at station 8834; 15 specimens, some as large as 12 millimeters in length, at station 8835; and no specimens at station 8832. On the other hand, the same bottom towing sample at station 8832, which it will be remembered was the farthest out in the Atlantic Ocean (depth 118 fathoms or 214.5 meters), and which I have just said yielded no *S. elegans*, brought up 133 specimens of *S. serratodentata*. The bottom towing sample at station 8834 nearer the mouth of the bay (43 fathoms or 78.2 meters depth) which brought up 43 specimens of *S. elegans*, captured 40 specimens of *S. serratodentata*. The individuals of the latter species were all small, varying from about 7 to 17 millimeters in length. Finally, the bottom towing sample at station 8835, close to the mouth of Chesapeake Bay (depth 20 fathoms or 36.4 meters) with its 15 specimens of *S. elegans* brought to light only 2 specimens, both about 12 millimeters long, of *S. serratodentata*. Specimens of *S. enflata* were extremely rare in all of the bottom towings just mentioned. Two, one of which was 21 millimeters long, were taken at station 8832 and one at station 8834. While the use of a nonclosing bottom net and the limited number of samples makes it impossible to draw any conclusions of unquestionable trustworthiness concerning the precise vertical distribution of *S. elegans* and *S. serratodentata*, the indications are that during the August cruise the latter species was more abundant in the deeper layers, since practically no specimens (only 3 specimens at station 8834 and 1 at station 8837) were found in the surface hauls. The gradually decreasing numbers of specimens of *S. serratodentata* from the 100-fathom line to the mouth of Chesapeake Bay, as seen in surface and bottom towings, and the practical absence of this species in the bay throughout our cruises are in keeping with Bigelow's (1922, p. 153) statement that it is the "more oceanic" of the two species under consideration.

BRYOZOA

The offshore waters of Chesapeake Bay have yielded 17 species of Bryozoa. These have been identified by R. C. Osburn. He calls attention to the fact that the number is small for such a large area, but it should be mentioned that the survey covered only the deeper waters and that no special efforts were made to investigate one region more than another in order to find a larger number of species of this group.

The list of species follows: *Barentsia discreta* (Busk), *Crisia eburnea* (Linnaeus), *Bugula gracilis* var. *uncinata* Hincks, *Bugula turrita* (Desor), *Electra pilosa* (Linnaeus), *Membranipora membranacea* (Linnaeus), *Hemiseptella denticulata* (Busk), *Hippothoa hyalina* (Linnaeus), *Schizopodrella unicornis* (Johnston), *Microporella ciliata* (Pallas), *Alcyonidium verrilli* Osburn, *Alcyonidium parasiticum* (Fleming), *Anguinella palmata* Van Beneden, *Bowerbankia gracilis* var. *caudata* (Hincks), ?*Amathia alternata* Lamouroux, ?*Victorella pavida* Saville Kent, and *Triticella elongata* (Osburn).

Most of the specimens collected were taken from the shallower areas of the offshore waters. Only a few specimens came from the deep holes such as areas *A*, *J*, *R*, and *S*. *Amathia alternata* which Osburn found in abundance on the beach at Beaufort, N. C., was dredged from area *G* in the mouth of the bay; area *G'*, nearby, off Old Point Comfort; and areas *A*, *B*, and *C*, which mark a line across the bay from Cape Charles City to New Point Comfort. Its distribution in Chesapeake Bay seems to be limited to the extreme lower end of the bay, as has been pointed out by Osburn, and it was found only in water of a bottom salinity ranging from about 22 to 31 per mille.

Eight other species, *Barentsia discreta* at area *A* (23.96 per mille), *Bugula gracilis* var. *uncinata* at area *A* (27.06 per mille), *Electra pilosa* at area *F* (31.08 per mille), *Hippothoa hyalina* at area *E*, *Schizopodrella unicornis* at area *B* (24.33 per mille), *Microporella ciliata* at area *E*, *Alcyonidium parasiticum* at area *F* (31.08 per mille), and *Bugula turrita* at area *E* were taken only once and at the areas mentioned. While all of these localities are at the extreme lower end of the bay, the number of specimens collected is so small that little should be said of the distribution.

One of the most abundant bryozoans found in the bay was the large, fleshy *Alcyonidium verrilli*, which has been recorded before only from southern New England and New Jersey. Osburn has stated that it was found at areas all over the southern half of the Chesapeake Bay but no farther north than at area *L*, which is close to the mouth of the Potomac River. Its frequent capture in the region mentioned during all cruises and the entire lack of specimens from area *L* to area *U*, near Baltimore, during the same cruises constitute convincing evidence that its distribu-

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tion was limited as just described. It occurred in water of a salinity ranging from about 13.00 to 26.00, or more.

Two species, *Bowerbankia gracilis* var. *caudata* and ?*Victorella pavida,* have a greater range from north to south, according to the data at hand, than any other species collected. The former was found at areas *B, I, L, P,* and *S* in water of salinities ranging from 23.87 to 15.71 per mille, while the latter, which, as Osburn has pointed out, is supposed to frequent waters of only slight salinity, was dredged at areas *A, C, K,* and *S,* which range from Cape Charles City to the region of James Island. The salinities ran from 27.06 to 17.44 per mille.

The distribution of *Anguinella palmata* is of interest since it was found only well within the bay—a distribution which appears to be characteristic of the species, according to Osburn. It was collected almost exclusively from the region close to the mouth of the Potomac River. During the cruises of July, August, and December, 1920, and January and March, 1921, it was dredged at area *I;* in December at areas *J* and *L;* in January at area *N*, and in December at area *H*. Areas *I, J,* and *L* lie close to the mouth of the Potomac, *N* just inside the mouth, and *H* a little farther south at the entrance of the Rappahannock River. The salinities of the water ranged from 13.19 per mille at area *N* to 21.10 per mille at area *J*.

Hemiseptella denticulata was found at many areas in the lower half of the bay but not north of area *L*. It was collected from water ranging in salinity from 14.72 to 26.44 per mille.

Undoubtedly the presence of solid objects upon which the Bryozoa may attach themselves constitutes an important factor affecting the distribution; but the apparent confinement of one species, at least, to the region of the mouth of the bay, the taking of one only from the waters around the mouth of the Potomac River with the reports of a slightly brackish habitat for this species in other regions of the Atlantic coast, and the total lack of specimens in our collection of over 70 colonies from above area *S* indicate that the degree of salinity is a factor in determining the distribution. At least, as Osburn has stated, no specimens were taken in waters of a salinity lower than one-third of the salinity of pure sea water. Not much can be said concerning the influence of temperature, but several of the species seem to be able to withstand the winter and summer extremes of temperature found in the offshore waters at the bottom (about 2° to 25° C.).

The salinities given in this section on the Bryozoa are those determined from bottom samples; and they are probably the ones in which the various specimens were growing; but in some cases the specimens were taken on old hydroid stems which may have been unattached to the bottom but probably drifting about very close to it.

ANNELIDA

The collection of polychaetous annelids is rather small, but this is largely due to the fact that all of the material was dredged and to the fact that only the offshore waters of the bay were studied.

The species listed below were collected during the August, October, December (1920), and January, March–April (1921) cruises. All of the identifications were made by Dr. A. L. Treadwell. The following species have been identified by him (three of the species are new): *Lepidonotus squamatus* Linnaeus, *L. variabilis* Webster, *Harmothoe aculeata* Andrews, *Paranaitis speciosa* Webster, *Nephthys ingens* Stimpson, *N. phyllocirra* Ehlers, *N. verrilli* McIntosh, *Sphaerosyllis fortuita* Webster, *Pionosyllis manca*[9] Treadwell, *Myriana cirrata*[9] Treadwell, *Autolytus hesperidium* Claparède, *A. solitarius* Webster and Benedict, *Nereis dumerilii* Audouin et Milne Edwards, *N. limbata* Ehlers, *Lumbrinereis tenuis* Verrill, *Arabella opalina* Verrill, *Diopatra cuprea* Claparède, *Chaetopterus variopedatus* Renieri, *Streblospio benedicti* Webster, *Scolecolepis viridis* Verrill, *S. tenuis* Verrill, *Polydora ligni* Webster, *P. commensalis* Andrews, *Prinospio plumosa*[9] Treadwell, *Ammotrypane maculata* Webster, *Glycera americana* Leidy, *G. dibranchiata* Ehlers, *Goniada oculata* Treadwell, *G. solitaria* Webster, *Anthostoma fragile* Verrill, *Pectinaria gouldii* Verrill, *Maldane elongata* Verrill, *Praxiothea torquata* Leidy, *Eupomatus dianthus* Verrill, *Terebella ornata* Leidy, and *Loima turgida* Andrews.

The European species, *Lepidonotus squamatus*, is widely distributed along the eastern coast of North America—from Canada to Virginia at least. In Chesapeake Bay it was found no farther north than the mouth of the Potomac River and in water of not less than 20.00 per mille salinity at the bottom.[10] This species which was most prevalent on sandy, shell, and gravel bottoms at Woods Hole (Sumner, Osburn, and Cole, 1913, p. 120) was found in regions of sand, shells, and mud in the Chesapeake and at depths ranging from 13 to 37 meters. It was collected on the July, December (1920) and January (1921) cruises in water whose temperature varied from 22.0° C. to 4.2° C.

Lepidonotus variabilis seems to be less widely distributed so far as reports go, than *L. squamatus*. Apparently it has a more southerly range, having been reported, so far, from Virginia and North Carolina. In Chesapeake Bay it was found in several regions (depths 11 to 46 meters) from the mouth of the bay to the mouth of the Magothy River, near Baltimore. The salinities varied from 16.50 to 25.23 per mille. Some of our specimens were collected in muddy regions, but the observations of Andrews (1891) show that this species frequents shells, sponges, hydroids, etc., at Beaufort, N. C. This species was taken during the July, December (1920) and March–April (1921) cruises at water temperatures ranging from 21.9° to 10.3° C.

The "scale-annelid," *Harmothoe aculeata* which has been found in Beaufort, N. C., under stones and in sponges, by Andrews (1891) was taken in the lower part of Chesapeake Bay on several occasions, and once outside of the bay, in regions of sand or mainly sand and shells. The salinities ranged from 17.70 to 31.08 per mille. Specimens were captured during the July, August, and December cruises of 1920 in water whose temperature varied from 24.8° to 10.1° C. They were taken in depths from 8 to 28 meters and more.

Paranaitis speciosa (*Anaitis speciosa*) has been reported from Massachusetts and New Jersey, where it was found on Mytilus beds and Diopatra tubes. Our dredging records show that it is common in Chesapeake Bay, in regions where the bottom is firm. It was collected from a region extending from Baltimore to the mouth of the Rappahannock River, and was found frequenting shallow waters, ranging from 9 to 22 meters in depth. It was taken during the July, October (1920), and January, March–April (1921) cruises in water of various temperatures, ranging from 23.5° C. to 1.3° C.

The genus Nephthys is represented in Chesapeake Bay by three species, *Nephthys ingens*, *N. phyllocirra*, and *N. verrilli* (the two latter European forms). Evidently they are not common species in the region investigated, since only one or two specimens of each were collected.

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[9] Named and described by Treadwell but still unpublished.

[10] The salinities mentioned in this section on the Annelida are those at the bottom.

Sphaerosyllis fortuita and *Pionosyllis manca* (a new species) are represented by single specimens taken just outside of the bay.

A new species, *Myriana cirrata*, was taken frequently in the extreme southern part of the bay (areas *A*, *E*, *F*, and *G*) during the July, August (1920), and the March-April (1921) cruises. It occurred in water that varied in salinity and temperature from 25.23 to 30.39 per mille and 11.5° C. to 21.9° C. It was found at various depths from 16 to 46 meters. The bottom in this region was largely of sand and mud, with some shells.

The two species of Autolytus were not found abundantly. Of these, *Autolytus hesperidium*, which has been reported previously from New Jersey and Virginia living on seaweed and shells, was collected on one occasion only. It was taken from area *D*, off New Point Comfort, during the January 1921 cruise. The depth was 10 meters, and the salinity and temperature of the water were 23.39 per mille and 4.8° C. The other species *A. solitarius*, has been reported heretofore only from Maine. In the Chesapeake it was dredged in the mouth of the bay and off Barren Island, which is about midway between the head and the mouth of the bay. Evidently it is able to live in waters of widely differing salinities and temperatures. It was collected during the October 1920 cruise at depths ranging from 23 to 48 meters.

Nereis dumerilii, a European form, which has been collected along the Atlantic coast of America from the coast of Virginia and from the region of Woods Hole, was found in the lower half of Chesapeake Bay. It was collected from these localities (areas *O*, *F*, and *B*) during the July, August, and October (1920) cruises. The records show that the specimens collected were living in water the salinity and temperature of which ranged from 17.70 to 31.08 per mille and 17.3° C. to 24.8° C. They were dredged from depths of 8 to 48 meters.

Nereis limbata, which is generally considered as a littoral form frequenting foul and brackish waters (Sumner, Osburn, and Cole, 1913, p. 124), was the most common annelid in the Chesapeake collection according to Treadwell. It has been reported from various places from South Carolina to Maine. Webster (1879, p. 36) considers it as the only annelid that can live in the soft mud of brackish-water regions. In the Chesapeake it was taken many times at areas which were in the upper half of the bay. Only in a few cases were specimens captured near the mouth of the bay. Apparently this species thrives in muddy regions in Chesapeake Bay, but it has been taken also from some areas where the bottom was sandy or shelly. Almost invariably the specimens were found in water the salinity of which was not more than 20.00 per mille (9.00 to 20.00 per mille) but in a few cases the salinity was higher. *N. limbata* was taken many times during each of the cruises (July, August, October, December, 1920, and January, March–April, 1921) in water varying from 1.9° C. to 25.2° C. Most of the specimens were found in shallow water, seldom deeper than 15 meters, but the whole series of depths ranges between 7 and 38 meters.

Lumbrineries tenuis is an inhabitant of compact mixtures of mud and sand according to Verrill (1873, p. 342), who found it abundant in the region of Vineyard Sound. It has been reported from several localities (Virginia to Massachusetts), but in small numbers. No specimens were dredged inside of the bay, but just outside on the 20-fathom line one specimen was taken in August, 1920, in water of 33.58 per mille salinity and 8.9° C. temperature.

Arabella opalina, which has been found commonly along the Atlantic coast of the United States and in great numbers in quiet bays and creeks (Andrews, 1891), was dredged once only in Chesapeake Bay, and then at area *G* in the mouth of the bay. It was found at a depth of 23 meters in a region of black mud and sand during the December, 1920, cruise. (Salinity 30.96 per mille, water temperature 11.6° C.).

The large tube-inhabiting annelid *Diopatra cuprea* is undoubtedly a common form on muddy sand flats in Chesapeake Bay, since it is known to be common in shallow waters along the coast from South Carolina to Cape Cod (Pratt, 1916, p. 290). Our collections were made by dredging in the comparatively deep parts of the bay; and since it is seldom possible to catch this worm except by careful digging, it is not surprising that only one specimen was obtained. This one, strange to say, was collected in the beam trawl which contained in addition a large quantity of specimens of various sorts. It was taken during the March–April cruise, 1921, at area *A* off Cape Charles City where there was considerable black mud—in other words, in one of the "deep holes" of the bay (43 meters). The salinity and temperature of the water were 28.27 per mille and 11.5° C.

Another tube-dwelling annelid that has been found along our Atlantic coast from North Carolina to Cape Cod and which, as Treadwell has pointed out, is difficult to capture, is *Chaetopterus*. It undoubtedly is fairly abundant in Chesapeake Bay, for many fragments of tubes (one with a piece of the worm inside) were collected. These were all taken in the lower half of the bay from the mouth of the Potomac River to the region of Cape Charles (areas *Q*, *O*, *C*, *B*, *A*, *E*, *F*, and *G*). The salinities and temperatures of the water in which the tubes were found ranged from 17.70 to 28.08 per mille and 10.1° C. to 24.8° C.

Streblospio benedicti has been reported by Webster (1886, p. 150) and by Webster and Benedict (1884, p. 728) from the shores of New Jersey and Maine. Our survey has dredged it from the upper part of Chesapeake Bay, in shallow water only (10 to 22 meters). Webster has spoken of it as being abundant on Mytilus beds and in ditches to which the tide has access. The indications are, judging from these observations and from the fact that this species was found as far north as Bloody Point (areas *V* and *W*) in Chesapeake Bay, that it is at home in brackish water. The salinities of the water in which the six specimens in our collection were found ranged from 10.08 to 17.27 per mille. They were dredged during the July and October cruises in water whose temperature was 20° C. to 23° C.

Two species of *Scolecolepis* (*Scolecolepis viridis* and *S. tenuis*) are known from the Chesapeake. The former occurs in large numbers within a small area in certain places (for example, area *V*, which is close to the mouth of the Severn River). This species is known from Cape Cod to New Jersey. Evidently it can live in water of low salinity, for all of the specimens collected by our survey came from water the salinity of which was not more than 16.60 per mille. Specimens were especially abundant at an area where the salinity was as low as 9.16 per mille. Specimens were collected on the January and March–April, 1921, cruises when the water temperature was as low as 1.3° C. Only a few small specimens of *S. tenuis* were collected, and these came from area *B* not very far from the mouth of the bay (salinity 23.87 per mille, temperature 20.0° C., October, 1920).

Large numbers of specimens of *Polydora ligni* were collected. Treadwell speaks of this species as being "the species represented by the largest number of individuals in the collection." Many of the specimens were larval forms, however, and even the adults did not seem to be sexually mature. The larval forms were found distributed all over the bay, but those which had reached the adult form seemed to be restricted to the lower half.

One specimen was collected of a species of Polydora, probably Andrews' *Polydora commensalis*, since, although mutilated, it showed one of the distinguishing characteristics of that species. Furthermore, it was found in a region of shells, mud, and sand where this species might occur. The specimen was collected well up in the bay at area *R'* off the mouth of the Patuxent River. (Depth 7 meters, salinity 12.64 per mille, temperature of water 23.9° C., August, 1920, cruise.)

Treadwell describes a new species, *Prinospio plumosa*. A number of specimens of this annelid were dredged during the August and October, 1920, cruises (depths from 8 to 48 meters) at areas *R*, *R'*, *L'*, *M*, *N'*, *H'*, and *J*. It will be seen that specimens were taken from the middle third of the bay—that is, from the mouth of the Patuxent River to the mouth of the Rappahannock River in waters where the salinities and temperatures ranged from 15.39 to 25.21 per mille and 19.2° C. to 24.8° C.

Glycera americana, which has been reported in various places from South Carolina to Cape Cod, was caught on one occasion only in Chesapeake Bay. Two specimens were taken at area *B* in the lower bay during the August, 1920, cruise. (Depth 12.8 meters, salinity 24.34 per mille, and temperature 25° C.) Another species of Glycera, *G. dibranchiata*, was more widely distributed, judging from our collections. It was found in the mouth of the bay and as far north as the mouth of the Patuxent River at depths of 16 to 46 meters. The salinities and temperatures ranged from 16.60 to 31.74 per mille and 10.2° C. to 17.3° C.

Goniada oculata described by Treadwell from material collected on the coast of Porto Rico was taken quite frequently in Chesapeake Bay during the cruises of August, October, December, 1920, and March–April, 1921. It was found at depths from 11 to 46 meters where the salinity and temperature of the water ranged from 15.00 to 23.87 per mille and 10.1° C. to 24.8° C. One specimen (the above data do not refer to it) was taken on the 40-fathom line just outside of the bay and the rest from areas distributed from James Island to the mouth; that is, the lower two-thirds of the bay.

Another widely distributed annelid in Chesapeake Bay is *Pectinaria gouldii*—an annelid that lives in a tube of conical shape. It was brought up from areas *Z*, *S*, *N'*, *J*, *I*, *Q*, and *D*, which are fairly well distributed from the mouth of the Magothy River to the region of Cape Charles City, not far from the mouth of the bay. It was taken at depths from 8 to 44 meters where the salinities and temperatures of the water were from 8.89 to 21.83 per mille and 7.5° C. to 24.8° C. The specimens were collected during the July, August, October, December, 1920, and the March–April, 1921, cruises.

Maldane elongata, which makes tubes of mud and which has been reported from muddy and sandy regions along our coast, was found in the mouth of the bay (area *G*) where the bottom was black mud and sand. It was brought up from a depth of 23 meters. The salinity and temperature of the water were 30.96 per mille and 11.6° C.

Praxiothea torquata was taken on several occasions in Chesapeake Bay, but all of the specimens collected were found in the mouth of the bay and the adjacent regions. They were collected from depths of 11 to 42 meters where the salinities and temperatures of the water ranged from 23.87 to 30.96 per mille and 10.9° C. to 25.0° C.

Three species, *Eupomatus dianthus*, *Terebella ornata*, and *Loimia turgida*, were collected in very small numbers and only from the lower part of the bay. The first is one of the serpulids which is known to be very common from Florida to Cape Cod. It was found on a rocky bottom at 13 meters. (Salinity 18.47 per mille and temperature of water 23.2° C., July, 1920, cruise.) The second, which is known from Cape Cod to North Carolina, was represented only by immature forms. The third, which was described by Andrews from Beaufort, N. C., came from a depth of 28 meters where the bottom was a mixture of clay, shells, sand, and mud. (Salinity (?) and temperature of the water 10.1° C., December, 1920, cruise.)

The annelid collection as well as the data on salinity, temperature, depth, character of the bottom, seasonal distribution, and distribution from the head of Chesapeake Bay to its mouth, deal with the deeper portions of that body of water, which naturally were the only regions that could be visited by the U. S. S. *Fishhawk* and the U. S. S. *Albatross*. The shore which includes the more or less steep strip between high and low tide, the sand flats, the mud flats, the quiet bays, etc., remain to be investigated.

It seems probable that the character of the bottom for some burrowing and tube-forming annelids is important—at least regions where there is deep, soft, foul mud are unfavorable habitats for nearly all of the polychaetous annelids. Some places on the bottom of the bay are covered with such deposits; and, in general, the deeper parts of the bay show a layer of firm mud of varying thickness. It is of interest to note that the only two really common annelids taken in the bay, *Nereis limbata* and *Polydora ligni*, are known to live in muddy regions, the former frequenting foul and brackish waters and the latter making use of mud in constructing its fragile tubes. Both of these species showed a wide distribution over the areas visited on our cruises. On the other hand, there are regions of sand here and there all over the bay, so that if the presence of these sandy places is all that is necessary for the life of worms that make tubes of grains of sand, such annelids might be found widely distributed over the bay.

It is known that many annelids live on the organic matter which is found in the sand or mud in which they burrow (M'Intosh, 1885, p. ix), as in the case of *Arenicola marina* (Flattely and Walton, 1922, p. 192, from Davison, 1891), that others such as *Cirratulus tentaculatus* (Flattely, 1916) while living buried in sandy mud do not pass it through the alimentary canal but select nutritive food particles—for example, algal spores, diatoms, and general organic débris outside of the body. Also it is known, according to Flattely (1922, p. 192), that tube worms such as Sabella, Pectinaria, Sabellaria, Serpula, etc., depend for their food on currents set up by the cilia on the gill filaments. Still others devour small crustaceans, zoophytes, and sponges; and a few, according to M'Intosh (1885, p. ix), feed on Fuci and other algæ. Such a variety of feeding habits must be a factor in the distribution of the polychaetous annelids in Chesapeake Bay, although our data are not of a character to throw much light on such a relation. Shore, sand-flat, and mud-flat observations should be ideal for studying a problem of that sort.

There are forms which stick to the underside of rocks and inside of shells, or hide in rocks and crevices, or conceal themselves between ascidians, barnacles, roots, cavities of sponges, etc., such as species of Lepidonotus, Harmothoe, and others (Verrill and Smith, 1873, p. 397).

Also some annelids, such as species of Sabellaria, Serpula, Sabella and Spirorbis, form tubes which are attached ordinarily to rocks, stones, shells, etc. (Verrill and Smith, 1873, pp. 321–323). Habits of this sort which depend on the presence of large more or less stationary bottom materials must also have an effect on distribution.

No close relationship of distribution to temperature can be made out, although the data show that many of the species are able to live in water of a wide range of temperatures. However, the large majority of the forms collected seem to be more southern forms.

It is evident, also, that many of the species of annelids are distributed through waters of widely differing salinities, as examples, *Nereis limbata*, *Goniada oculata*, *Pectinaria gouldii*, and others.

Undoubtedly some of the annelids collected were living in situations which were not well suited to them, since the currents during fall and spring tend to carry plankton, including worm larvæ, far up in the bay. Under those conditions a worm which lives at its best in water of a high salinity might have its larvæ carried to regions of low salinity where they would settle down and continue to live, although under unfavorable conditions.

Only one species representing the Hirudinea has been taken in our collections, and this one has been identified through the courtesy of Dr. J. Percy Moore, as the fish-leech, *Piscicola punctata* (Verrill).

ARTHROPODA

CRUSTACEA

COPEPODA

The free-swimming copepods of Chesapeake Bay and the region immediately outside the bay have been studied by C. B. Wilson. He has made the identifications and has studied the distribution of the various species.

The results of his work show very clearly that only two or three species were present in sufficient numbers in the bay during our cruises to be of much economic value; that of these, 2 species, *Acartia clausii* and *A. longiremis*, were distributed over the whole bay from the region of Baltimore to the mouth of the bay throughout the year; that 10 species at least, including especially the 2 just mentioned, must have been able to accommodate themselves to a large range of salinities, since they were found all over the bay in addition to the ocean; and that there were 19 species caught outside of the bay between the 100-fathom line and the mouth, which were not discovered in our very numerous towings made throughout the year in the bay. The absence of these 19 species, which for the large part have been found outside of such bodies of water as Chesapeake Bay in other parts of the world, may be ascribed to the low salinity existing in the bay; but it is not possible at the present time to establish such an assumption absolutely as a fact, since our towings outside of the bay were made only during the August, 1920, cruise. Furthermore, there are numerous other factors, such as presence or lack of the proper kind of food, associations with other forms—for example, *Sapphirina gemma*, which is a commensal in Salpa, light, depth, temperature, etc.—which might have to be taken into consideration.

Wilson's studies have brought to light the following species from Chesapeake Bay and the region just outside of the capes. He has divided them into groups according to their distribution.

UNIVERSAL IN BAY AND OUTSIDE

Acartia clausii Giesbrecht, *A. longiremis* (Lilljeborg), *Centropages hamatus* (Lilljeborg), *C. typicus* Krøyer, **Harpacticus gracilis* Claus, *Oithona brevicornis* Giesbrecht, *O. similis* Claus, *Paracalanus parvus* (Claus), *Pseudocalanus elongatus* (Boeck), *Pseudodiaptomus coronatus* Williams, and **Microthalestris littoralis* G. O. Sars (the last species is pronouncedly littoral and was not found in the collections made outside). Two other species, *Labidocera aestiva* Wheeler and *Ectinosoma curticorne* Boeck, were almost universally distributed.

CONFINED ALMOST TO INNER BAY

[North of Maryland and Virginia line]

**Canuella elongata* Wilson, **Cletodes longicaudatus* (Boeck), **Dactylopusia brevicornis* (Claus), *Ectinosoma normani* T. and A. Scott, *Harpacticus littoralis* G. O. Sars, **Robertsonia chesapeakensis* Wilson, **Tachidius littoralis* Poppe, *Eurytemora americana* Williams, *E. hirundoides* (Nordquist), and **Mesocyclops gracilis* (Lilljeborg). Three other species, **Hemicyclops americanus* Wilson, *Candacia armata* Boeck, and **Bomolochus eminens* Wilson occurred in very small numbers at one or two areas.

CONFINED ALMOST TO OUTER BAY

[South of Maryland and Virginia line]

Alteutha depressa Baird, *Calanus finmarchicus* (Gunnerus), *Corycaeus carinatus* Giesbrecht, *C. elongatus* Claus, **C. venustus* Dana, **Cryptopontius gracilis* Wilson, **Oithona spinirostris* Claus, *Oncaea minuta* Giesbrecht, **Labidocera wollastoni* (Lubbock), *Pontella meadii* Wheeler, *Temora longicornis* (Müller), **T. turbinata* (Dana), *Tisbe furcata* (Baird), *Microsetella norvegica* (Boeck), *Harpacticus chelifer* (O. F. Müller), and *Diosaccus tenuicornis* (Claus). In addition the following species, in very small numbers, were found at one or two areas: **Temora discaudata* Giesbrecht, *Pontella pennata* Wilson, and *Caligus schistonyx* Wilson.

FOUND ONLY OUTSIDE OF THE BAY

[Between the capes and the 100-fathom line]

**Amallophora brevicornis* G. O. Sars, *Anomalocera patersoni* Templeton, **Calanus helgolandicus* (Claus), *Centropages bradyi* Wheeler, *Euchaeta norvegica* Boeck, *Mecynocera clausii* I. C. Thompson, *Metridia lucens* Boeck, **Pontella atlantica* (Milne Edwards), *Rhincalanus nasutus* Giesbrecht, *Clytemnestra rostrata* (Brady), *Macrosetella gracilis* (Dana), **Corycaeus lubbockii* Giesbrecht, **C. speciosus* Dana, *Oithona plumifera* Baird, *Oncaea venusta* Philippi, *Sapphirina gemma* Dana, and **S. sinuicauda* Brady, *Corycaeus robustus* Giesbrecht, *C. rostratus* Claus.

These lists total 64 species: 13 universal, or almost so, over the bay; 13 almost confined to the inner bay; 19 almost confined to the outer bay; and 19 outside of the bay only. Not less than 19 of the 26 species listed under "universal" and "inner bay" occur in such bodies of water as Chesapeake Bay or at least frequent coastal waters in other parts of the world, and these 19 do not include the new species and the species whose distribution is very little known. Of those listed under "outer bay" (19) a much smaller number (6) are characteristic of estuaries in other regions, while those listed for "outside of the bay" (19) include not more than 3 or 4 species which are recorded as being estuarine forms. In other words, the number of estuarine forms found during our cruises decreases, passing from the inner bay to the region outside of the capes. On the whole, from this point of view, the distribution of the free-swimming copepods found by us in Chesapeake Bay and the region immediately outside of the bay is much like that of the same copepods in other parts of the world.

Twenty-two of the species listed above (those with an asterisk) are either new species (named and described by Wilson but still unpublished) or those which have not been reported hitherto from the eastern coast of North America.

There are included in the complete list 1 species, *Bomolochus eminens*, which is known to occur parasitically in the gill cavity of the false Spanish sardine, *Clupanodon pseudohispanicus*; 1 species, *Sapphirina gemma*, caught free-swimming but known to be a commensal in Salpa; 1 species, *S. sinuicauda*, also caught free-swimming but probably a commensal in Salpa; 1 species, *Caligus shistonyx*, an external parasite on the menhaden, *Brevoortia tyrannus;* and 1 species, *Mesocyclops gracilis* which is a fresh-water form.

Most of the copepods caught in Chesapeake Bay have been present in such small numbers that any extended discussion of their ecology is not permissible; but one species especially, *Acartia clausii*, which Wilson has singled out as of much biological and economic importance in the bay, owing to its abundance at times and constant presence during our cruises, deserves some attention. The catches of this copepod have been studied by Wilson, and his findings bear out the statements of Farran (1910, p. 77), Willey (1920, p. 201 and 1921, p. 187), and Bigelow (1926, p. 171) with respect to the neritic character of this species. Its occurrence in Chesapeake Bay during the cruises of July, August, October, December, 1920, and January, March–April, and May–June, 1921, in rather large numbers at practically all areas, the presence of egg-bearing females and larval stages at certain times, the high percentage of this species in the copepod catches, and its comparative scarcity in oceanic waters indicate that this form is one of the shallower, neritic waters and that it is endemic in Chesapeake Bay.

This form has been found along our coasts as far north as the Arctic Circle by Willey (1920, p. 20 K), in the St. Lawrence River 90 miles from Quebec by Herdman, Thompson, and Scott (1898, p. 76), in the Gulf of St. Lawrence by Scott (1907, p. 49), in Narragansett Bay by Williams (1906, p. 648), in the Gulf of Maine by Bigelow (1926, p. 171), in Woods Hole by Fish (1925, p. 145), and by our survey in and immediately outside of Chesapeake Bay. The data are not sufficient as yet to tell whether it belongs primarily to the northern or southern regions of our Atlantic coast. Bigelow's cruises from Cape Cod to Chesapeake Bay in 1913 and 1916 did not bring it to light, but it was found in small numbers outside of the mouth of Chesapeake Bay on our August, 1920, cruise and at the same time much more abundantly at nearly all of the areas in Chesapeake Bay.

Wilson, from an examination of the females of *Acartia clausii* (and *A. longiremis* as well) found that during the July, 1920, cruise these forms were carrying eggs, and that the same was true on the January, 1921, cruise. This indicates, as he states, that there are two breeding seasons for these species in Chesapeake Bay—one during the summer and the other in the late winter. Correlated with these two breeding seasons one would expect maximum numbers of individuals to appear some time after. Judging from the catches made during the March–April, 1921, cruise, conspicuously large numbers occurred at that time, since the counts at several of the areas visited were very much higher than those of any other cruises. It should be mentioned, however, that towings were made only in the upper part of the bay—areas *R*, *R'*, *S*, *T*, *V*, *W*, *Y*, and *Z*—on that cruise. The indications are that the March–April cruise was taken at a time which was close to the spring maximum. It is more difficult to detect a well-defined autumnal increase corresponding to the summer breeding season from a study of the catches, but there was undoubtedly a general increase in numbers during the October, December, 1920, and January, 1921, cruises, so that the seasonal abundance in the upper part of Chesapeake Bay at least corresponds rather closely to the seasonal occurrence found by Fish (1925, p. 145) at Woods Hole during the period from June, 1922, to May, 1923. The counts made of the catches of the summer cruises were the lowest of the year.

Little can be said of the vertical distribution of *Acartia clausii* in the bay, owing to the methods employed in making the towings, but it is clear that large numbers of this species may occur at the surface in the daytime; and it is probable, as Wilson states, that they may be distributed in various proportions from the surface to the bottom. Bigelow (1926, p. 175) has found this species more abundant at the surface at times but also repeatedly more plentiful at some deeper level in the Gulf of Maine.

Acartia clausii has been recognized in Europe as a form which is able to flourish in abundance in water of low salinity such as is found in the Belt Sea, where the average of 8 stations was 18.42 per mille, and in the mouth of the English Channel, where the average for 17 stations was 30.20 per mille (Farran, 1910, p. 77). One can not escape the conclusions that this copepod, as is shown by Wilson, may be found abundantly and in good condition in waters of even much lower salinity in Chesapeake Bay. As examples, the bottom net showed the following counts in round numbers during the March–April, 1921, cruise: Area *Z*, 75,000 (salinity $<$12.42 per mille); *V*, 17,500 (salinity $<$9.17 per mille); *T*, 15,000 (salinity $<$11.51 per mille); *S*, 60,000 (salinity $<$16.19 per mille); *R′*, 2,900 (salinity $<$11.85 per mille); and *R*, 1,400 (salinity $<$16.61 per mille). The specimens captured in the upper bay during this cruise can not be considered as *only* immigrants which had drifted in with the autumnal and winter currents, for individuals were found at those same areas, although in smaller numbers, on all the other cruises. In addition, they were found at all areas visited, and these were very numerous and widely distributed. *Acartia clausii* was practically universal in occurrence over the bay and on all the cruises with the possible exception of the one made in March–April, 1921. Even on this cruise the same would hold true, for the upper part of the bay (areas *R*, *R′*, *S*, *T*, *V*, and *Z*) and very probably for the whole bay. Our data do not show higher surface counts for *Acartia clausii* in the region of the mouths of rivers; nor can it be said that there were larger numbers on one side of the bay than the other, corresponding possibly to a difference in the degree of salinity. The data for the bottom samples are not suitable for such a comparison.

The European records (Giesbrecht, 1892, p. 776; Scott, 1894, p. 68; Sars, 1903, p. 151, and Farran, 1910, p. 77) show that *Acartia clausii* is distributed in the cold and the warm water regions. While specimens of this species are found most abundantly in Chesapeake Bay during the colder months, considerable numbers are present at other times, and the records show that they may occur in waters which range in temperature from at least 4° C. to 27° C.

CIRRIPEDIA

Two species of barnacles have been brought to light from the offshore waters of Chesapeake Bay: *Balanus improvisus* Darwin and *B. eburneus* Gould. All of the specimens collected during the cruises of August, October, December, 1920, and January, 1921, were identified by Dr. H. A. Pilsbry at the request of the United States National Museum.

The first species, *Balanus improvisus*, was taken by far the most frequently and was found distributed from the mouth of the bay to as far north as area *S* off James Island. It was collected from the following areas: *G*, *G′*, *F*, *C*, *D*, *A*, *Q*, *O*, *M*, and *N′*. At the latter area, which is in the mouth of the Potomac River, the specimen obtained was living in water of a salinity that was not more than 13.96 per mille, while specimens at area *G* (in the mouth of the bay) were in water whose salinity was not more than 31.74 per mille.

This form is given a wide distribution both by Darwin (1854) and by Gruvel (1905). The latter describes its distribution as along the English Channel, the coasts of France, Patagonia, Colombia, in the Rio de la Plata, and along the coast of the United States. It has also been reported from Nova Scotia. Sumner, Osburn, and Cole (1913, p. 130) point out that definite localities for its occurrence in the

United States have not been mentioned by the authors and express the belief that it occurs at Woods Hole. The indications are that this barnacle is a southern form.

Ordinarily, *Balanus improvisus* has been found attached to floating wood, shells, etc. In the Chesapeake it has been taken at areas where the depths ranged from 10 to 46 meters; and in other parts of the world, according to Gruvel (1905, p. 231), it has been found from the level of low tide to 35 or 40 meters.

Judging from the literature, *Balanus improvisus* is not commonly found along the coast of the United States, but it seems quite probable that further investigation will show it to be much more abundant than the records indicate at the present time.

Balanus eburneus is a species which is generally recognized as a brackish-water form. It was originally described by Gould (1841) from Salem, Mass., and is known to occur in other places along the coast of the United States. According to Gruvel (1905, p. 234) it has been found on the coast of Honduras, Venezuela, Jamaica, and Trinidad. In Chesapeake Bay it was collected near the mouth of the Potomac River at areas *Q* and *O* where the bottom salinity was 20.58 and 20.91 per mille, respectively. The depths at these areas were 15 and 8 meters. This species seems to be a southern form.

It is evident from our records that barnacles occur well up in Chesapeake Bay, but shore collecting undertaken by the writer has shown that there is at least one species still unidentified which is quite abundant on piles and other objects and that it flourishes as far up Chesapeake Bay as the mouth of the Patapsco River and probably farther. In this region the salinity may fall so low during the spring months that the water is almost fresh.

AMPHIPODA

The species of amphipods which are listed below represent the catch made during a single cruise, that of May, 1920. These have been identified by C. R. Shoemaker, of the division of marine invertebrates of the National Museum. A considerable amount of material collected on other cruises still awaits study so that undoubtedly more species will come to light when this is done. However, it has been the experience of those who undertook the survey of the Woods Hole region that in Buzzards Bay, which is a body of water much like Chesapeake Bay, the collections of bottom-dwelling amphipods showed a paucity of species as compared with Vineyard Sound (Sumner, Osburn, and Cole, 1913, p. 132).

The following is a list of the species: *Monoculodes edwardsi* Holmes, *Stenothoë cypris* Holmes, *Batea catharinensis* Müller, *Leptocheirus* species (new), *Ericthonius brasiliensis* (Dana), *Corophium cylindricum* (Say), *Cerapus tubularis* Say, *Paracaprella simplex* Mayer and *Caprella acutifrons* Latreille.

But little can be said of the relation of distribution to salinity, temperature, depth, season, or latitude at this time. However, the new species of Leptocheirus was found off Sandy Point, Md., where the bottom salinity was 5.76 per mille, and none of the rest of the species so far as we have records was taken at areas where the bottom salinity exceeded 21.00 per mille. These low salinities are accounted for by the fact that all of the specimens collected came from areas where the depths did not exceed 14 meters—in other words, from shallow water areas.

Monoculodes edwardsi was found at areas *L′* and *K′* not far from the mouth of the Potomac River. The bottom salinity at the first area was 13.09 per mille, and at the last 9.42 per mille. This species, which was described by Holmes (1905, p.487) from a specimen found at Woods Hole, Mass., was spoken of by him (1903, p.275) as having a distribution from Cape Cod to Cape Hatteras.

Another species described by Holmes from Woods Hole (1905, p. 484) is *Stenothoë cypris*, which was found by him upon the piles and among seaweeds and which was given a distribution like *Monoculodes edwardsi* (1903, p. 278). It was collected at areas *C* and *K*, the former off New Point Comfort and the latter near the mouth of the Potomac River. The bottom salinities at these two areas were 20.65 per mille, and 13.09 per mille, respectively.

The amphipod *Corophium cylindricum*, which lives in soft tubes but may be free (Holmes, 1905, p. 522) and which has a distribution from Cape Cod to Cape Hatteras, according to Holmes (1903, p. 288), was found at areas *B* and *C* between Cape Charles City and New Point Comfort (bottom salinity for area *C*, 20.65 per mille). Mary J. Rathbun (1905, p. 75) found it "very abundant among weeds and hydroids about piles of wharves and almost everywhere in shallow water, to a depth of 30 fathoms."

Cerapus tubularis is another amphipod of this coast distributed, according to Holmes (1903, p. 288), from Cape Cod to Cape Hatteras. This interesting amphipod lives in a black, cylindrical tube which it carries around with it, according to Smith (1880, pp. 274–276). The specimens from which the identification was made were found at area *B*, between New Point Comfort and Cape Charles City. The bottom salinity for this area during the cruise is not known, but the salinity for a nearby area (*C*) where the depth was about the same was 20.65 per mille.

A South Atlantic species described by Fritz Müller from the coast of Brazil is in our collection. It is *Batea catharinensis*. Specimens were taken at the two areas *B* and *C* in the same region as the last species and in water where the bottom salinity was 20.65 per mille for area *C* and probably very nearly the same for area *B*. Recently C. R. Shoemaker (1926, p. 1), after studying the complete collection of Chesapeake amphipods taken from 1915 to 1921, found that "this genus was common in almost every part of the bay."

In addition to this southern species, a widely distributed form, *Erichthonius brasiliensis* (Dana), occurs in the bay. The individuals of this species occupy tubes affixed to hydroids and algæ. According to Stebbing (1906, p. 672), the species is found in the "Atlantic with adjoining seas (Europe from south and west Norway (depth 19–75 meters) to Adriatic and Bosphorous; Rio Janeiro; Vineyard Sound); North Pacific (San Francisco, depth 4 meters)."

The specimens collected in Chesapeake Bay during the May cruise were found at area *C* (depth, 13 meters; bottom salinity, 20.65 per mille).

Another widely distributed amphipod which occurs in Chesapeake Bay is *Caprella acutifrons* Latreille which, according to Mayer (1890, p. 56), was found there long before the present survey, in August, 1879.

Finally, specimens of *Paracaprella simplex* Mayer were caught at areas *B* and *C* on the line between Cape Charles City and New Point Comfort. The depth at these areas was 13 meters and the bottom salinity at area *C*, 20.65 per mille.

The bottom salinities have been given for the areas at which specimens of amphipods were found; but it does not follow that all of the specimens were taken in waters of the salinities given, since specimens are not always at the bottom. While many live in the sand, under stones, and in crevices of sponges, ascidians, etc., and some among hydroids and various water plants, they may at times be taken at or near the surface in Chesapeake Bay, as our records show. Fish (1925) found a similar vertical distribution at Woods Hole. The bottom salinities are of value in this connection however, since they give a satisfactory idea of the maximum salinity for the area, so that specimens were probably living in water of lower salinity. No data are given as to temperature, since the thermometers used during that cruise were not of the reversing type which records bottom temperatures.

ISOPODA

As in the case of the amphipods, the species listed below were those taken on the May cruise, 1920. They probably represent only part of the species which have been collected in later cruises but which have not been studied. The list is as follows: *Aegathoa oculata* (Say), *Erichsonella attenuata* (Harger), *Edotea triloba* (Say), *Idothea baltica* (Pallas) and *Edotea montosa* (Stimpson).

The first species, *Aegathoa oculata,* is a parasitic form which is known from New England to the West Indies (Richardson, 1905, p. 217) and which was found at Crisfield, Md., years ago. We collected this form at area *B,* off Cape Charles City. No fish were caught at this station, and the records do not indicate that the specimen was attached to anything at the time of capture.

So far as records from various sources show, the isopod *Erichsonella attenuata* is not widely distributed. It is known to frequent eelgrass along the coast of New Jersey and Connecticut but, according to Harger (1878, p. 357), it has not been found north of Cape Cod. The studies of Wallace (1919), Macdonald (1912), and Stimpson (1853) do not show its occurrence along the Atlantic coast of Canada. During our May, 1920, cruise it was taken at area *Z,* not far from Baltimore. The salinity of the water in that region did not exceed 6.00 per mille. As pointed out by Harger, the known distribution of this form indicates that it is a southern form.

Edotea triloba, another isopod which Harger (1880, p. 429) speaks of as a southern form, since that time has been found very abundant in the Bay of Fundy between low-tide mark and 15 fathoms (Wallace, 1919). It has been collected along the coast from Maine to New Jersey in shallow water and was taken in Chesapeake Bay at areas *G* and *C.* The depths and bottom salinities at these areas were 24 meters, 25.77 per mille, and 13 meters, 20.65 per mille, respectively. Apparently it may be found on almost any sort of bottom.

The cosmopolitan isopod, *Idothea baltica,* has been found along the Atlantic coast of Canada and the United States as far south as North Carolina at least. In Chesapeake Bay it was caught at areas *A* and *B,* not far from the mouth of the bay. The depths at these areas were 13 meters and 40 meters; the salinities, 24.33 per mille and 29.34 per mille (at 39 meters), respectively.

Another species of Edotea, *E. montosa,* which is considered by Wallace (1919, p. 26) as grading into *E. triloba* and *E. acuta* and which has been known heretofore from Long Island Sound to the Bay of Fundy, was taken at area *A* under the same conditions as *Idothea baltica.* This species had been classed by Harger (1880, p. 429) as a northern form.

SCHIZOPODA

The Schizopoda are represented in Chesapeake Bay by the well-known species *Neomysis americana* (Smith), formerly called *Mysis americana,* and two other species—one *Mysidopsis bigellowi* Tattersall and another which will be designated as *Mysidopsis* sp. nov. until it has been studied and described by Doctor Tattersall. The last two species are quite uncommon in our collections, but *Neomysis americana* was taken on every cruise during the year (1920), and there is much evidence to indicate that it is endemic in Chesapeake Bay.

While catches of *Neomysis americana* in tow nets can never give a very satisfactory idea of the numbers present in Chesapeake Bay during different times of the year, since the individuals are not swarming in the water at all times but may be hidden among water plants, etc., yet the catches in the bottom net (nonclosing), which was attached to a small beam trawl and towed for 10 minutes, are of interest. During the January cruise the numbers brought to the surface were large—for example in round numbers, 1,000 at area *F*, 8,000 at area *B*, 5,500 at area *Q*, 7,000 at area *J* and 40 at area *R'*. No bottom hauls were made north of area *R'*, but the vertical nets showed the presence of Neomysis as far north as area *W* off Bloody Point. A similar distribution was found when the March cruise was taken, but the numbers were smaller. Very small catches (ordinarily less than 100 specimens) were obtained on the May, July, and August cruises except on one occasion at area *G* during the July cruise, when 4,000 specimens were caught. A few specimens were captured on the 100-fathom line just off the mouth of the bay during the August cruise. The counts were larger when the October and December cruises were taken than during the summer.

In January and March, 1920, the specimens collected were mostly of large size, but on the May cruise only small individuals were found. During the July, August, October, and December cruises the towings brought to light somewhat larger specimens. On the January and March–April cruises (1921) mostly very large specimens were caught, while on the May–June cruise (1921) the specimens were mostly small again as during the cruises of about the same periods in 1920.

These size relations are in keeping with the observation of Fish (1925) for Woods Hole, that *Neomysis americana* breeds in the winter. In fact, eggs and young and large specimens with brood sacs were taken during the January, 1920, cruise. The great majority of the specimens were large; only a few were small, and these were evidently recently hatched and immature. The conditions found on the March cruise were similar to those just mentioned, but in the May catches the large individuals were scarce. Some of these, however, had brood sacs containing very young larvæ. In the July towings the large specimens so characteristic of the earlier months of the year were not present, but on the other hand specimens of more than one-half the size of those large specimens (probably the partly grown young of the earlier months) made up the whole catch. Some of the specimens just mentioned had brood sacs filled with eggs, and there were a few larvæ present. During the October cruise the conditions were much as in July—eggs and young larvæ were found in the brood sacs and there were some very young specimens free from the parent. The material from the December cruise contained no individuals with eggs or with young, although in a few specimens the remains of a brood sac could be seen. The cruises of January, March–April, and May–June, 1921, showed the breeding conditions as on the January, March, and May cruises of 1920.

These observations indicate then that breeding individuals are present throughout most of the year in Chesapeake Bay, a condition which was thought likely by Smith (1879) when he studied Neomysis farther north.

It is evident from a study of large numbers of surface towings that Neomysis does not ordinarily frequent the surface waters in Chesapeake Bay during the daytime, but there is evidence to show that it may appear there in large numbers when the intensity of the light is low, even when there is a distinct stratification of the water and there is a large difference between the salinity of the surface and bottom layers. Only a few cases of this sort appear in our records, probably because towings were seldom made late in the evening and never during the night. At area *A*, during January, 1920, between 5 and 6 p. m., 250 specimens and 120 specimens were found in the No. 5 and No. 20 surface nets; at area *F*, during December, 1920, between 5 and 6 p. m., 1,380 specimens and 180 specimens were taken in the No. 18 and No. 6 surface nets; and at area *Q*, during January, 1921, between 5 and 6 p. m., 2 specimens and 2 specimens were caught in the No. 18 and No. 6 surface nets, respectively. On one occasion specimens were captured at the surface early in the afternoon (2 to 3 p. m.), but the sea was rolling, and the sky was partly cloudy and foggy. This occurred at area *G*, in October, 1920, and there were 7 specimens found in the No. 6 surface net.

It is evident from the records obtained by our survey and from the distribution found by other workers in more northern waters that *Neomysis americana* may live in waters of a wide range of salinities and temperature.

As a fish food this form is probably of considerable importance; for it has been found in the stomachs of the ocellated flounder, the spotted flounder, the shad, the mackerel, and sea herring, sometimes in great numbers. It is of interest that the period of maximum abundance during the year 1920, according to our towings, was in the early months of the year just before and at about the time when the migration of anadromous fishes into the bay occurred.

STOMATOPODA

The common squilla, *Chloridella empusa* (Say), formerly known as *Squilla empusa* Say, has been found in Chesapeake Bay. In June, 1880, it was collected by W. G. Taylor; in 1882 it was taken near Barren Island and also at stations 1075, 1076, 1077, and 1058 by the U. S. S. *Fish Hawk*; in October, 1921, it was found in the Rappahannock River by W. C. Schroeder, and again by the same collector in May, 1922, on a trip from Crisfield to Cape Charles. During our cruises a specimen was taken at area *D* in January, 1920. I am indebted for identification and other information to the division of marine invertebrates of the National Museum.

In addition to the specimens mentioned above, which were identified by the United States National Museum, other squillas were captured at areas *L*, *L′*, *H*, *R*, *X*, and *B* which undoubtedly are of the same species. They were collected during the cruises of March, April, July, 1916, and March, 1922, from areas distributed from near Cape Charles City, not far from the mouth of the bay, to area *X*, off Bloody Point. It is evident from the distribution of this crustacean in Chesapeake Bay that it may live in water of widely differing salinities—approximately, according to our records, from 26.00 per mille or a little more to 16 or a little less. Undoubtedly this form lives also in water of a much higher salinity, for it is known to occur along the shores of the open ocean.

Since *Chloridella empusa* lives in other regions between the tide lines and in shallow water and since it is a burrowing form, probably its distribution in Chesapeake Bay is more extensive than our records show.

CUMACEA

One Chesapeake species of Cumacea has been identified by the United States National Museum as probably *Oxyurostylis smithi* Calman. This crustacean, for which Calman (1912, p. 676) made a new genus as well as species, is known from Casco Bay, Me., to Calcassieu Pass, La. The fact that it is sometimes taken at the surface and that it has only a slightly calcified integument suggests to Calman that it is adapted for a partly pelagic life. Fish (1925, p. 152) found it in the plankton in greater numbers during the breeding season and most abundant usually after a storm.

Ten specimens were captured at area *K*, off the mouth of the Potomac River, in May, 1920. It is not known at what depth they were taken; but the bay at that area was 10 meters deep, and the bottom was of yellow sand. The salinity ranged from 11.15 per mille at the surface to 13.09 per mille at the bottom.

DECAPODA

The Chesapeake survey is fortunate in having the aid of the United States National Museum for the identification of the decapod crustacea. It is indebted to the division of marine invertebrates of that institution, and especially to Dr. Mary J. Rathbun and to Dr. Waldo L. Schmitt, who have generously studied, identified, and listed the various decapods collected on our cruises.

It is important to note that the lists given below not only include the specimens taken by the Chesapeake survey but also those which have been collected from Chesapeake Bay and vicinity during the last 50 years. These specimens have been deposited in the United States National Museum and identified by its staff. Consequently, the material has been collected in various ways, such as by dredging, trawling, and towing in the offshore waters, by seining near shore, by collecting along the tide lines, by collecting in marshes, rivers, and creeks connected with Chesapeake Bay, and by dredging, trawling, and towing immediately outside of the mouth of Chesapeake Bay.

The three lists which follow deal with Chesapeake Bay only and are little more than records of the names of species and the regions in which they have been found. They are not intended to show the limits of distribution, since much of the material is not the result of systematic collecting over the whole bay. The distribution of species in Chesapeke Bay, so far as the author considers permissible from the data, will be given in other lists.

Upper bay only (north of the mouth of the Potomac River).—One species of decapod, *Pinnixa sayana* Stimpson, was taken from the upper part of the bay and from no other region. The records in this case show that it was collected only on two occasions. Since this species probably lives in the tubes of annelids and since no special effort was made to find it, the data are insufficient to draw any conclusions as to its distribution.

Lower bay only.—Shrimps: *Penaeus setifera* (L), *P. brasiliensis* (Latr.) (probably), *Trachypenaeus constrictus* (Stimpson), *Parapenaeus constrictus* (Stimpson), *Hippolysmata wurdemanni* (Gibbes), *Crago packardi* (Kingsley), *Hippolyte pleuracantha* (Stimpson). Porcellanids: *Euceramus praelongus* Stimpson. Thalassinids: *Callianassa stimpsoni* Smith, *Upogebia affinis* (Say). Hermit Crabs: *Pagurus pollicaris* Say, *Clibanarius vittatus* (Bosc.). Crabs: *Ovilipes ocellatus* (Herbst), *Portunus gibbesii* (Stimp.), *Arenaeus cribrarius* (Lamk.), *Cancer irroratus* Say, *Neopanope texana sayi* (Smith), *Panopeus herbstii* Edw., *Pinnotheres maculatus* Say, *Pinnotheres ostreum* Say, *Pinnixia cylindrica* (Say), *Pinnixia chaetopterana* Stimpson, *Ocypoda albicans* Bosc., *Uca pugilator* (Bosc.), *Uca pugnax* (Smith), *Libinia emarginata* Leach, and *Pelia mutica* (Gibbes).

Upper and lower bay.—Shrimps: *Palaemonetes carolinus* Stimpson, *P. vulgaris* (Say), *Crago septemspinosus* (Say). Hermit Crabs: *Pagurus longicarpus* Say. Crabs: *Callinectes sapidus* Rathbun, *Hexapanopeus angustifrons* (Benedict and Rathbun), *Rithropanopeus harrisii* (Gould), *Eurypanopus depressus* (Smith), *Sesarma (Holometopus) cinereum* (Bos.), *Uca minax* (LeConte), and *Libinia dubia* M. Edw.

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The lists just given include those species which were found in the bay, while the list which follows contains the species which have been collected outside, not far from the mouth of the bay.

Outside only.—Shrimps: *Pandalus leptocerus* Smith, *Caridion gordoni* (Bate), *Hippolyte acuminata* Dana, *Latreutes fucorum* (Fabr.), *Spirontocaris pusiola* (Krøyer), *Spriontocaris polaris* (Sabine), *Palaemon tenuicornis* Say, *Pontophilus brevirostris* Smith. Galatheids: *Munida iris* A. M. Edw. Hermit Crabs: *Catapagurus gracilis* Smith, *C. sharreri* M. Edw., *Pagurus acadianus* Benedict, *P. kroyeri* (Stimp.), *P. politus* (Smith). Hippas: *Emerita talpoidia* (Say). Crabs: *Homolo barbata* (Fabr.), *Bathynectes superba* Costa, *Portunus (achelous) spinimanus* (Latr.), *Portunus sayi* (Gibbes), *Cancer borealis* Stimp., *Sesarma (Sesarma) reticulatum* (Say), *Collodes robustus* Smith, *Euprognatha rastellifera aclita* A. M. E. (probably), *E. rastellifera marthae* Rathbun, *Hyas coarctatus* Leach.

A few specimens were collected both outside and in the lower bay.

Outside and lower bay.—Shrimps: *Penaeus setifera* (L.), *P. brasiliensis* (Latr.), *Parapenaeus constrictus* (St.), *Crago septemspinosus* (Say). Hermit Crabs: *Pagurus longicarpus* Say, *Pagurus pollicaris* Say. Crabs: *Ovalipes ocellatus* (Herbst), *Cancer irroratus* Say, *Neopanope texana sayi* (Smith), *Panopeus herbstii* Edw. (probably), *Sesarma (Holometopus) cinereum* (Bosc.), *Ocypoda albicans* Bosc., *Uca pugilator* (Bosc.), *Uca pugnax* (Smith), and *Libinia emarginata* Leach.

The localities for two species, *Hepatus epheliticus* (L.) and *Callinectes ornatus* Ordway, have not been determined.

A study of the lists just given shows that only 1 species was found exclusively in the upper bay (its distribution may be more extensive); that 11 were common to both the upper and lower bay; that 27 were found exclusively in the lower bay; that 25 were taken only outside of the bay; and that the localities of 2 were not determined. This makes a total of 66 species.

The lists below are designed to show the probable distribution of the decapods (for which we have sufficient data) in the offshore waters of Chesapeake Bay; that is, exclusive of the shallow water shore forms and the forms in rivers and creeks. The conclusions arrived at are based on our systematic collections during cruises covering a considerable period, checked to some extent by data from shore, river, and creek collections which, however, have been of an unsystematic nature.

Our data do not afford evidence to show that there are any species of decapods which are distributed exclusively in the offshore waters of the upper bay; that is, above the mouth of the Potomac River.

Decapods of the offshore waters of upper and lower bay.—*Palaemonetes carolinus* Stimpson, *P. vulgaris* (Say), *Crago septemspinosus* (Say), *Pagurus longicarpus* Say, *Callinectes sapidus* Rathbun, *Rithropanopeus harrisii* (Gould), *Eurypanopeus depressus* (Smith), *Hexapanopeus angustifrons* (Benedict and Rathbun), and *Sesarma (Holometopus) cinereum* (Bosc.).

Decapods of the offshore waters of lower bay only.—*Peneus setifera* (L), *Trachypeneus constrictus* (Stimpson), *Crago packardi* (Kingsley), *Euceramus praelongus* Stimpson, *Pagurus pollicaris* Say, *Ovalipes ocellatus* (Herbst), *Portunus gibbesii* (Stimp.), *Cancer irroratus* Say, *Neopanope texana sayi* (Smith), *Panopeus herbstii* Edw., and *Libinia emarginata* Leach.

Almost all of the 18 species of shrimps or shrimplike forms found in Chesapeake Bay and the immediate vicinity have been found in such small numbers that no more information concerning them can be given than that which appears above. Three species, however, *Palaemonetes carolinus*, *Palaemonetes vulgaris*, and *Crago septemspinosus*, deserve more attention, since they have been collected more often in Chesapeake Bay and since we have more data concerning the environmental conditions under which they live.

Palaemonetes carolinus, which is known to occur all along the eastern coast of the United States (Kingsley, 1899), seems to be a shallow-water form, judging from the data at hand and one which is more often taken along the region near the tide lines. It has been caught very seldom on our cruises, probably because these cruises were confined to the offshore waters.

Three specimens only were taken—one at area *Z* in December, 1915 (depth, 17 meters), another at area *I* in January, 1921 (depth, 12 meters; salinity 13.19 per mille at bottom; temperature, 3.4° C. at bottom), and a third at area *V* in March, 1921 (depth, 14 meters; salinity, 11.32 per mille at bottom; temperature, 9.6° C. at bottom). All of these specimens were captured on the winter and spring cruises and none on the summer cruises. The same condition, we shall see, holds true for *Palaemonetes vulgaris*, another shore form, but not for *Crago septemspinosus*, which frequents deeper water. The United States National Museum has another lot of *P. carolinus* consisting of a rather large number of specimens (over 289) evidently collected near the shore by collectors not connected with our survey. All of these specimens with the exception of two were taken during the summer months, and it might be inferred that in the winter this species migrates into deeper water, but the absence from the lot just mentioned of any specimens collected during the winter time may be due to the fact that ordinarily collectors do not go on trips at that time of the year. While the capture of some specimens of *P. carolinus* during our winter and spring cruises and our failure to find any specimens on the summer and fall cruises favors the plausible assumption that there is migration of this form from the shallow, cold water to the deeper, warm water during the colder months and vice versa with the approach of the warmer season, there is still insufficient evidence to establish it as a fact.

It is clear from data collected by the United States National Museum that *Palaemonetes carolinus* is found ordinarily in shallow water and that it flourishes in water of very low salinity. Specimens have been collected at various places along the western shore of Chesapeake Bay in Maryland and also well up in the rivers—for example, at St. George Island, Lower Machodoc Creek, and Blakistone Island, which are, respectively, 10, 20, and 25 miles up the Potomac River. Collections have been made also at Island Creek, which is 12 miles up the Patuxent River.

Undoubtedly this species may be found along the shores and in the rivers of the eastern shore of Chesapeake Bay, although none has been recorded from that region. It has been collected, however, at Smiths Island, Northampton County, Va., probably close to shore, just outside of the mouth of the bay, and there is good reason to believe that it will be found close to shore and in the rivers of the lower part of the bay.

Little is known of the breeding habits of *Palaemonetes carolinus* except that 12 ovigerous specimens were collected 20 miles up the Potomac River, in Lower Machodoc Creek, during July, 1919. Evidently, then, this species, like many others, breeds during the summer.

Palaemonetes vulgaris, the commmon shrimp or prawn, occurs along the whole eastern coast of the United States but is especially abundant in bays and estuaries (Say, 1817). Like *P. carolinus*, it was taken infrequently on our cruises but somewhat more often than that species. All of the adult specimens were caught at areas located in the region between the mouth of the Potomac River and the mouth of the bay. However, the United States National Museum has specimens in their collection which have been found in various places all over the bay from the region of Love Point to Cape Charles City, but practically all of these specimens were collected in shallow water near the shore. Neither our records nor those of the National Museum show that *P. vulgaris* makes its way far into the rivers.

As in the case of *Palaemonetes carolinus*, there are indications that *P. vulgaris* migrates into deeper water during the colder months; for all the specimens, with the exception of two, collected during our cruises were taken during the colder months.

The two exceptions were ovigerous and were found at the shallow area *O* (8 meters) during the July cruise, 1920. The occurrence of these egg-bearing specimens in July and the finding of the larvæ of this form only during the July and August cruises of 1920 show that the breeding season was during the summer months. On those two cruises the larvæ were found at areas covering practically the whole bay (*U*, *V*, *W*, *Q*, *A*, *D*, *H′*, and *R′*).

Crago septemspinosus, which has been known under the names *Crangon septemspinosus* Say and *C. vulgaris* Smith, was by far the most common shrimp in our collections during the years 1915, 1916, 1920, 1921, and 1922. It is known to frequent deeper water than *Palaemonetes vulgaris* (Verrill, 1874, p. 45) and is called the "sand" or "grey shrimp" because it is common on sandy bottoms. In the Chesapeake it was collected from all the areas visited with the exception of *U*, which is not far from Baltimore. Probably it is more abundant in the lower two-thirds of the bay, although like *P. carolinus* it has been found at St. George Island and Blakistone Island 10 and 25 miles, respectively, up the Potomac River, and in Island Creek, which is about 10 miles upstream from the mouth of the Choptank River.

Ovigerous specimens of *Crago septemspinosus* were taken at all seasons of the year; but they were caught most abundantly during the fall, winter, and spring cruises. The summer cruises brought to light few ovigerous specimens. Juvenile individuals were reported by Schmitt from our July, August, October, December, 1920, and our March, 1921, cruises. At Woods Hole, Mass., Bumpus (1898) found Crangon breeding during March, and Thompson (1899) during September, while Fish (1925, p. 156) reports "great numbers of adult females bearing eggs in Naragansett Bay" in the month of May, 1922. Bumpus' statement that "* * * it would be interesting to learn when this species is not pregnant," is well put.

Peneus setifera and *P. brasiliensis*, the two large shrimps of markets, have been collected from the lower bay and from such rivers as the Rappahannock, but in small numbers. Evidently they are more at home farther south along the coast.

All the rest of the shrimps collected were found outside only or, in a few cases, in the lower part of the bay and in small numbers. The localities where they have been taken are indicated in the lists given above. Three species, *Hippolyte acuminata*, *Latrutes fucorum*, and *Palaemon tenuicornis*, were collected at the surface only.

The Galatheidea are represented in our collection by the single species *Munida iris* A. M. Edw. Over 1,400 specimens have been collected off Chesapeake Bay by various collectors and placed in the United States National Museum. The records show that these were taken at depths varying from 78 to 328 meters. Evidently it is a form of the deeper and more saline waters. It was never taken inside of the bay during our cruises; but in August, 1920, when we visited several stations located along a line extending from the mouth out to the 100-fathom line, 5 specimens were collected—2 probably at 78 meters and 3 probably at 216 meters (I say "probably" because a nonclosing net was used.) The surface and bottom salinities at the 78-meter station, which was only a short distance from the mouth, were 29.91 and 33.29 per mille. The temperatures were 24.1° C. and 8.5° C. This species must be very abundant in places, for as many as 250 specimens have been collected at a single dredging station.

A rare species of the family Porcellanidæ, namely, *Euceramus praelongus* Stimpson, was collected on three occasions: During October, 1915, off the Inner Middle

Ground between Cape Charles and Cape Charles City; during December, 1915, at area *L*, a little above the mouth of the Potomac River; and during July, 1916, at area *G* in the mouth of the bay. This species which is known to occur along the coast of Carolina and Florida was found in waters of low salinity such as those of the region of the mouth of the Potomac River and also of localities where the salinity was fairly high, as at area *G* (surface 24.90, bottom 31.64 per mille).

Two burrowing forms, *Callianassa stimpsoni* Smith and *Upogebia affinis* (Say), were collected, the first at areas *F* and *B* and the last at area *G*. None were found above the extreme lower part of the bay and none where the bottom salinity was less than 22.69 per mille. All were taken with a commercial dredge known as the "orange-peel bucket," which penetrates to a considerable depth. Other specimens have been found along the shores of Virginia, according to the records of the United States National Museum.

All but three of the eight species of hermit crabs in the collection have been dredged outside of the bay only, in rather deep water off the coasts of Maryland and Virginia. Two of the three species, *Pagurus longicarpus* Say and *P. pollicaris* Say, have been found commonly in the lower bay and outside. The other species, *Clibanarius vittatus* (Bosc), which is known to occur along the coast from North Carolina southward, was not collected on our cruises and is represented in the National Museum only by two specimens, both from Gunston, Va., far up in the Potomac River.

Pagurus longicarpus was collected from the following areas: *E*, *F*, *G*, *A*, *D*, *O*, *J*, *I*, and *R*. With the exception of three specimens collected at *R* and in the immediate vicinity of that area, all of the 170 specimens were taken below the mouth of the Potomac River. This form was found living in water the salinity of which varied from 30.60 to 17.95 per mille, and the data show that it has been collected during every season and during practically every month of the year. Not much can be said of its breeding habits, but an ovigerous female was collected in October, 1915, off York Spit Light, in about the middle of the bay.

Pagurus pollicaris, the so-called "warty hermit crab," seems to have its distribution in the offshore waters of Chesapeake Bay limited to the southernmost part. It was taken some twenty different times during our cruises but only at areas *G'*, *E*, *G*, *F*, *A*, and *D*, or localities in the near vicinity of those areas. It has been found at all seasons of the year (January, March, April, June, July, October, December), and the occurrence of ovigerous females during the month of April indicates a spring breeding season. Specimens have been found living in water the salinity of which ranged from 18.91 to 30.96 per mille.

No hippas were collected during our cruises. This little crustacean is usually found burrowing in sandy beaches or the shallow waters of sand flats. While our failure to get any specimens does not necessarily indicate its absence from Chesapeake Bay, the records of the National Museum support such a conclusion, since they do not show that it has been collected along the shores of the bay. However, outside of the bay at Virginia Beach, Va., specimens of the hippa, *Emerita talpoida* (Say), have been collected, and they are now in the Museum's collection.

The best known, if not the most common, crab that is found in Chesapeake Bay is the "edible crab" or "blue crab," *Callinectes sapidus* Rathbun, which is found along almost the whole Atlantic coast of the United States. It frequents especially the muddy bottoms of bays and estuaries. This crab was taken infrequently in our offshore dredging and trawling in Chesapeake Bay, and most of the specimens which were captured were juveniles. However, on one occasion, a large catch of

Callinectes was made by us with the beam trawl. This occurred at area *G′*, off Old Point Comfort, where the depth measures about 28 meters. It was during the December, 1920, cruise that the specimens were caught when the bottom water temperature was 10.1° C. The collection consisted of 32 female and 15 male specimens, mostly of large size. All of them were inactive, owing, no doubt, to the low temperature of the water (Churchill, 1919). In the same haul of the beam trawl, which as usual lasted for 10 minutes, 11 flounders and 26 croakers were captured.

Since Callinectes is known to occur all over the bay and even well up into the rivers, it must be capable of living in waters of a great range of salinities.

The "mud crab" *Neopanope texana sayi* (Smith) has been taken in larger numbers on our cruises than any crab found in the bay, but none have been collected north of the mouth of the Potomac River. The specimens of this species which have been deposited in the United States National Museum by other collectors came from the lower bay, judging from the data where the localities are known definitely. Our specimens have been found at areas *A, B, C, D, F, G, G′, I, J, K, O,* and *Q*. No specimens have been reported from the Potomac River, even at area *M, N,* and *N′* in its mouth. The records of others show that this species is distributed from Provincetown, Mass., southward and that it frequents muddy bottoms in bays and sounds. The character of the bottom, the large numbers of specimens collected, the occurence of ovigerous females and juvenile forms indicate that Chesapeake Bay is an ideal locality for this mud crab.

Specimens have been found at all seasons of the year and during the July, 1920, cruise ovigerous females have been captured. Undoubtedly summer is the breeding season. During the cruises of the fall, winter, and spring, juveniles, probably developing from eggs of the previous summer, have been collected; but on the summer cruises according to our records they have not been found.

The salinity and temperature records show that for 26 hauls the bottom salinity ranged from 14.79 to 31.62 per mille and the bottom temperature from 4.2° C. to 25.2° C.

Rithropanopeus harrisii (Gould), which may be included under the "mud crabs" and which was formerly classed under the genus *Panopeus*, was caught but once during the survey's cruises—namely, at the mouth of the Eastern Bay, where the depth was 37 meters and the bottom was soft, black mud. Undoubtedly, the occurrence under such conditions was unusual. It has been collected frequently along the shores of Chesapeake Bay, both in the upper and lower regions, and often in creeks and rivers. Rathbun (1905) reports it from near the high-water mark under stones and Gould (Rathbun, 1905), has found it in Cambridge marshes and clinging to floating seaweed in the Charles River. The most abundant catches from Chesapeake Bay deposited in the United States National Museum have come from tributary creeks and rivers.

Specimens have been collected during all seasons of the year. Ovigerous ones have been found in June and September and juvenile forms in June, July, August, and September.

Eurypanopeus depressus (Smith), another "mud crab," apparently lives out farther from the shore, for it was taken in regions where the depth of water ranged from 11 to 48 meters. Specimens were captured at areas *K, P,* and *I*. Others were found near area *R* and off the mouth of the Potomac River. Females bearing eggs were captured in April and juvenile forms in April, October, and December.

Hexapanopeus angustifrons (Benedict and Rathbun) is another common "mud crab" in the offshore waters of Chesapeake Bay. It has been taken from regions where the depth ranges from 8 to 48 meters. The indications are that it is not a shore form, for the records of the United States National Museum do not include any specimens found on shore collecting trips. Rathbun (1905) speaks of its being found on oyster grounds in Connecticut, and the same is undoubtedly true in the Chesapeake. It was brought up quite often from regions of shelly bottom during our cruises. Forty hauls of dredges, nets, and trawls brought to light over 100 specimens of this crab during the 1915, 1916, and 1920 cruises. They were taken at areas *G*, *G'*, *A*, *C*, *D*, *E*, *H*, *J*, *K*, *L*, *R*, and *S* (close). None was caught farther up the bay than the region of area *S*, which is along the line between Governors Run and James Island.

We have no records of any being taken in rivers or creeks, but it is possible that they may be found there, in the deeper waters especially, where there are oyster bars.

Hexapanopeus has been found in the bay during all seasons of the year. The water in which specimens were caught varied in temperature from about 4° C. to about 25° C. The range of bottom salinities was from about 18.00 to almost 32.00 per mille. These figures are based on 19 hauls and 50 specimens.

Little is known concerning the breeding habits of this species, but the collection contains one ovigerous specimen caught at area *E* in July, 1920, and several juvenile forms taken during the cruises of October, December, 1915, and April, 1916.

The Pinnotheridae, which includes those small forms which live commensally with various invertebrate animals, are well represented in Chesapeake Bay. Since it was not feasible to make any special effort to collect these interesting little crabs, the number of specimens is very small. *Pinnotheres maculatus* Say, the "mussel crab" (Rathbun, 1905) has been collected on two occasions, once off the mouth of the Potomac River and once at area *D*. The female is known to live in the gill cavity of the mussel, *Mytilus edulis*, and the male to lead a free-swimming existence. Also, the female is known to frequent *Pecten tenuicostatus*.

Pinnotheres ostreum (Say), which has similar habits to those of *P. maculatus* except that it is a commensal in the oyster, probably is distributed over all those parts of the bay where oysters are found. However, none was collected on our cruises, and only a few specimens from Chesapeake Bay are in the United States National Museum. Most of these came from the southern part of the bay.

Pinnixa cylindrica (Say), *P. sayana* Stimp., and *P. chaetopterana* Stimp., which are commensals of certain tubiculous annelids, were caught very seldom. *P. cylindrica* was captured once at area *L*, near the mouth of the Potomac River, in about 37 meters of water; *P. sayana* was found near the mouth of the Patuxent River—that is, at area *R* and at a locality near that area where the water was 48 and 7 meters deep, respectively; finally, *P. chaetopterana* was taken in 16 meters of water at area *F*, which is in the mouth of the bay. One haul of the "orange-peel bucket" in the latter case brought up 5 males and 6 females.

Two species of the genus Sesarma, *Sesarma cinereum* (Bosc) and *S. reticulatum* (Say), coming from Chesapeake Bay and vicinity, are in the collection of the United States National Museum. Neither of these has been collected on our cruises, which is not surprising, for they are shore or shallow-water forms. *S. cinereum*, called the "wood crab" and occurring "under logs and drift and about wharves, wooden piles, etc." (Rathbun, 1900, p. 583), has been collected from several localities in the bay: Near Thomas Point (between areas *V* and *Z*); Island Creek in the mouth of the

Choptank River; Mobjack Bay; Hampton, Va.; and Lynnhaven Inlet near the mouth of Chesapeake Bay. In addition it has been found on Smiths Island, Northampton County, Va., which is just outside of the bay. Evidently this form, which, it may be mentioned, has a known distribution from Cape Cod to Florida and along the shores of the Gulf of Mexico, is a shallow-water form.

It has been collected in Chesapeake Bay during the months of June, July, August, September, and December. Undoubtedly, it may be found there at other times. Females carrying eggs have been found during the month of July.

Sesarma reticulatum (Say), which lives in burrows on salt marshes (Rathbun, 1905, p. 4) and which seems to be a better-known form than the previous species, has not been reported from Chesapeake Bay up to the present time, although it seems probable that it will be. However, one specimen has been taken just outside of the bay at Smiths Island, Va.

Ocypoda albicans Bosc., commonly known as the sand crab or ghost crab of sandy shores, has made its way into the extreme southern part of the bay, and has been caught by those collecting for the United States National Museum, at Buckroe Beach, Willoughby Point, Wallops Island, and near Fort Monroe, Va. That region is probably near the northern limit for full-grown specimens of Ocypoda. Only the young have been found in New England, according to Rathbun (1905). Undoubtedly *Ocypoda albicans* is a creature of the sandy shores of the open seas where the winters are mild. The observations of others indicate that Ocypoda is not well fitted to withstand freezing temperatures, so it seems probable that the low-winter temperature of the north is the important factor in limiting its northern range.

Specimens have been collected in the lower bay and in the close vicinity of its mouth during the months of May, August, and September. However, more systematic collecting may show its presence there in the winter time.

So far as the records show, none of the 57 adult specimens collected from the bay and the immediate vicinity was ovigerous.

The fiddler crabs are represented by three species in Chesapeake Bay: *Uca minax* (LeConte), *U. pugilator* (Bosc.), and *U. pugnax* (Smith). These shore crabs have a known distribution from Cape Cod to Florida and then along the shores of the Gulf of Mexico. *Uca minax*, which has been found in salt marshes and also in regions where the water is nearly fresh (Rathbun, 1905, p. 2), has been collected farther up in Chesapeake Bay than any of the other species. Specimens have been caught at Chesapeake Beach, Md., which is about as far up the bay as the line made by areas *V*, *W*, and *X*. Other specimens have been found along Mobjack Bay, Buckroe Beach, and Lynnhaven Inlet, all of which localities are in the southern part of the bay. None is recorded as from outside of the bay. Further investigation, probably, will show that it has made its way up the shores of the rivers. One ovigerous specimen was found during the month of July.

The other two species of fiddler crabs, *Uca pugnax* and *U. pugilator*, have been collected in the lower part of the bay and outside only. An ovigerous specimen of *U. pugilator* was found during the month of July. The known distribution of these forms outside of Chesapeake Bay is the same as that for *U. minax* (Rathbun, 1900).

Six species and one subspecies of spider crabs are listed from Chesapeake Bay and the immediate vicinity. Four of these—*Collodes robustus* Smith, *Euprognatha rastellifera acuta* A. M. E. (probably), *Euprognatha rastellifera marthae* Rathbun, and *Hyas coarctatus* Leach—are deep-water forms which have been dredged near the mouth in the open ocean.

Collodes robustus Smith was dredged in water from 102 to 328 meters, but in other regions it has been found at from 90 to 683 meters (Rathbun, 1925, p. 119). Its known distribution is from Massachusetts to North Carolina, and it has been found during all seasons of the year. Ovigerous specimens have been caught off Virginia in March and off Massachusetts in August and September.

Rathbun's subspecies marthæ of *Euprognatha rastellifera* A. M. E. has been dredged off Chesapeake Bay in water varying in depth from 105 to 306 meters, but farther north it has been found in water from 81 to 419 meters deep. It has been collected at all seasons of the year, but only one specimen, according to the records published by Rathbun (1925, p. 98), was found with eggs. This individual was collected in July off Marthas Vineyard in exceptionally shallow water (81 meters) for that species.

Euprognatha rastellifera acuta A. M. E., which is the more southern subspecies (Habana, Porto Rico) but which has been found as far north as near Marthas Vineyard, is probably represented in our collection by one juvenile specimen. This was taken off the mouth of the bay in 102 meters of water.

Hyas coarctatus Leach, which is commonly called the toad crab, has been dredged along the Atlantic coast of North America from Newfoundland to North Carolina. The records of Rathbun (1925, p. 260) show that it occurs in water ranging from 9 to about 350 meters. It has not been found in the bay, but a few specimens have been taken off of the coast of Virginia.

The so-called common spider crab, *Libinia emarginata* Leach, occurs in Chesapeake Bay, but it has been brought to light only by dredging in water ranging from 7 to 46 meters. All of the specimens collected were from the extreme southern part of the bay where the salinities near the bottom ran from about 21.00 to 31.00 per mille, and the water temperatures from 8.8° C. to 21.9° C. It was caught several times at areas *G*, *G'*, and *A*. A few specimens have been found also in Hampton Roads and off the Inner Middle Ground. There is one specimen in the Chesapeake collection of the United States National Museum which came from outside of the bay, off Virginia Beach. *Libinia emarginata* has been dredged during all seasons of the year, but the records show no ovigerous individuals. Most of the specimens are in the juvenile condition. Rathbun (1925, pp. 311–313, pp. 314–317) records its distribution along the Atlantic coast of North America from Nova Scotia to West Florida, and she finds it occurring on all sorts of bottoms in comparatively shallow water.

Another spider crab, *Libinia dubia* M. Edw., is much more widely distributed over Chesapeake Bay than the former species, and apparently in some localities at least it lives in shallower water (Rathbun, 1925, p. 318). It has been collected at areas *A*, *D*, *E*, *H*, and *Y*, the latter area being off Love Point, not far from Baltimore. In addition it has been taken in the following localities: Hampton Roads, Norfolk, Chincoteague, Tangier in Virginia, and off the mouth of the Rappahannock River, off York Spit, Thomas Point, and Tilghman Island. Apparently *L. dubia* is more at home in Chesapeake Bay than any other spider crab, but we have no records of its occurrence in the rivers. Possibly the lack of specimens from such localities is due to the fact that very little dredging has been undertaken in the rivers, although we are not accustomed to think of spider crabs as frequenting water of very low salinity. While *L. dubia* is known to range along the Atlantic coast from Cape Cod down into the Gulf of Mexico, no specimens have been reported outside, in the region of Chesapeake Bay. Undoubtedly this form may live in water of low salinity, for it has been found as far north as *Y*, where the salinity at the bottom is often not more than 16.00 to 17.00 per mille. Nearly all of the 29 specimens constituting the Chesapeake collection in the National Museum are juvenile forms, as in the case of *L. marginata*. No ovigerous specimens were collected. The records show that specimens of *L. dubia* have been found in the bay at all seasons of the year. We have temperature records taken near the bottom for the areas at which this form was collected. They range from 7.9° C. to 24.4° C.

Finally, there is the spider crab, *Pelia mutica* (Gibbes), which has been collected along the Eastern Shore in Tangier Sound and a few other localities. Specimens of this form were collected by U. S. S. *Fish Hawk* in June, 1891, but none has been taken on the Chesapeake survey cruises during 1915, 1916, 1920, 1921, and 1922. It should be mentioned, however, that Tangier Sound was not visited at regular intervals during these cruises. *P. mutica* is known to frequent bays and sounds. (Rathbun, 1925, p. 279.)

It is clear that some of the crustacea collected from Chesapeake Bay and vicinity have been found exclusively outside of the bay, where the salinity is high, that some have been found exclusively in the bay, where the salinity is much lower. But our data show that others occur in both regions, even though the range of salinities is very great. Furthermore, there is good reason for believing that some crustacea migrate from one end of the bay to the other at certain times of the year. So it seems probable that some crustacea can survive a great range of salinities, at least if the changes take place gradually. Fredericq (1898, p. 831) has been able to increase or diminish to a large extent the salts in the blood of the crab, *Carcinus maenas*, by placing the specimen successively in water of greater or less salinity. Also, he (1889) finds that the blood of *C. maenas* varies with the degree of salinity of the water in which the animal is living. The investigations of other workers such as Issel on copepods, Herdman on copepods, Schmankewitsch on *Artemia salina* (see Flattely and Walton, 1922), and Loeb (1903) on Gammarus show that these forms are able to stand a wide range of salinities. More recently Adolph (1925) has found that a marine species of Gammarus "will live indefinitely if transferred to sea water diluted with distilled water up to 0.5 per cent (0.005 M), or concentrated by the addition of salts up to 160 per cent (1.56 M, corrected for ionization)."

Why some forms have been found only in the lower part of the bay or outside, or in both regions and not in the upper part of the bay, are questions which can not be answered without a careful study of the habits and physiology of individuals of each species in as many of the environments to which they may be subjected in nature.

ARACHNOIDEA

The Xiphosura or horseshoe crabs are represented in Chesapeake Bay by one species, the common *Limulus polyphemus* (L), which was taken in the beam trawl on several occasions. It was found in September, 1916, at area *A*; in January and December, 1920, at *G'*; and in May, 1920, at *F* and *E*. Only eight specimens were captured, all of which, as may be seen from the areas listed, came from near the mouth of the bay. The bottom salinities and temperatures for these areas (area *G'* during the December cruise excepted) ranged from 22.60 to 29.22 per mille and from 2.7° C. to 23.4° C., respectively. The records indicate that *L. polyphemus* may be found throughout the year in the bay, but only in its lowermost portion.

At least one species of the order Pycnogonida has been found by us in Chesapeake Bay. It has been identified, tentatively, by the United States National Museum as *Anoplodactylus lentus* Wilson. It was collected at area *G* in the mouth of the bay during the May, 1920, cruise. The bottom salinity at this area was 25.77 per mille and the temperature 13.8° C.

MOLLUSCA

The rather large number of mollusca which have been collected by us are now in the hands of the United States National Museum, awaiting identification.

ECHINODERMATA

The echinoderms collected during the Chesapeake survey have been identified by Dr. Hubert Lyman Clark, to whom I am much indebted for a list of the species and additional information concerning their geographical distribution.

The number of species is small, but no smaller than might be expected from a rather fresh estuary with a muddy bottom. All of the specimens collected, with one exception, were found either in that part of Chesapeake Bay below the mouth of the Potomac River (most of these were taken not far from the mouth of the bay) or just outside of the bay a short distance.

A list of the species follows: *Asterias forbesi* (Desor), *Stephanaster gracilis* (Perrier), *Echinarachnius parma* (Lam'k), *Amphiodia sp.*, *Amphipholis squamata* (Delle Chiaje), and *Amphioplus abdita* (Verrill). In addition to these echinoderms, which were identified by Clark, a few specimens of the holothurian, *Thyone briareus* (Lesueur), the common red sea urchin *Arbacia punctulata* (Lam'k), and the starfish *Luidia clathrara* (Say) have been found.

The echinoderm, which was captured by far the largest number of times in Chesapeake Bay during the cruises of 1916, 1920, 1921, and 1922, was the common starfish *Asterias forbesi*, which was brought to the surface on 54 occasions. It was collected during the following cruises: April, June, July, September, 1916; January, March, May, July, December, 1920; January, March–April, May–June, 1921; and January, March, 1922. Undoubtedly it may be found in the bay any time during the year but ordinarily only in the region below the Maryland and Virginia line. It has been taken at areas *E*, *F*, and *G* in the mouth of the bay, at area *G'* off Old Point Comfort, at various localities between these two regions, at areas *A*, *B*, *C*, and *D*, which mark a line from Cape Charles City to New Point Comfort, and at areas *Q* and *O*. It will be seen that no specimens were collected above the line marked by areas *H*, *H'*, *Q*, and *O*, which runs from the mouth of the Rappahannock River to Sandy Point. Apparently this form can stand a considerable range of salinities and temperatures, for it was found on bottoms where these ranged from somewhat less than 20.00 to 32.00 per mille and 4.2° C. to 24.4° C. Specimens were taken at depths from 8 meters at area *Q* to 46 meters at area *A*. Frequent catches were made at the latter area, and these were in general the largest made in the bay. The Biological Survey of Woods Hole and Vicinity (Sumner, Osburn, and Cole, 1913, pp. 111–112) showed that *A. forbesi* was encountered with the most frequency of any echinoderm in that region and that it together with *Arbacia punctulata* were the ones taken most often in Buzzards Bay. Similarly in Chesapeake Bay *A. forbesi* was the form most frequently encountered.

Judging from our collections, the starfish *Luidia clathrata* seldom enters the bay. Only on two occasions has it been taken—once in January, 1916, at area *H* and once in July, 1916, at area *F*.

At least two species of brittle stars were found in Chesapeake Bay. One, *Amphioplus abditus*, was taken in August, 1920, at areas *G*, *F*, and *E*—that is, in the mouth of the bay at depths from 16 to 24 meters. The bottom salinities at these areas were all above 30.00 per mille and the temperatures ranged from 15.5° C. to 20.9° C. The other species, *Amphiodia sp.*? (probably *atra* Stimpson according to Clark), was found at area *B* during the same cruise at a depth of 13 meters. At this area the bottom salinity was 24.34 per mille and the temperature 25.0° C.

One species of sea urchin, *Arbacia punctulata* was taken on six of the cruises (June–July, 1916, December, 1920, and January, 1921). Without exception they were found in the mouth of the bay and in four out of six cases at area *G* where the bottom salinities and temperatures varied approximately from 29.00 to 32.00 per mille and 5.9° C. to 21.0° C.

The holothurian, *Thyone briareus*, showed a somewhat more extensive distribution in Chesapeake Bay than the rest of the echinoderms. Specimens were found at areas *A*, *B*, *G'*, *G*, and *P* during the cruises of January and May, 1920, May–June, 1921, January and March, 1922. It will be seen that while most of the specimens were taken in the lower part of the bay, one was found a short distance above the mouth of the Potomac River (area *P*). The indications are that this form is able to stand a wide range of salinities and temperatures. Three other echinoderms are listed above as having been captured during our cruises, but all of these were found outside of the bay between the mouth and the 118-fathom line (216 meters). The starfish, *Stephanaster gracilis*, the common sand dollar, *Echinarachnius parma*, and the ophiuroid, *Amphipholis squamata*, were all found on the same cruise, August, 1920, along the 118-fathom line. The latter was also brought up along the 43-fathom (79 meters) and 20-fathom (37 meters) lines during the same cruise.

It is worthy of note that five species of echinoderms, *S. gracilis*, *E. parma*, *Aphipholis squamata*, *Amphioplus abditus*, and *Amphiodia sp.*? were taken during the August, 1920, cruise when a trip to the 118-fathom line was made in addition to usual trips over the bay.

A review of the eight species of echinoderms shows that only two species, *Asterias forbesi* and *Thyone briareus* have been found far inside the mouth of Chesapeake Bay.

Through the courtesy of Dr. Hubert Lyman Clark I have received the following information concerning the distribution of some of the species: Speaking of the starfish, *Stephanaster gracilis*, and the sand dollar, *Echinarachnius parma*, he says of the former, "A West Indian species. Its occurrence in Chesapeake Bay is noteworthy"; and of the latter, "A *northern* species. Its occurrence at the same station with the preceding species is noteworthy." At the time the above was written Doctor Clark had not been informed that the station in question was outside of the mouth of the bay. However, undoubtedly, the occurrence of a West Indian and a northern species at the same station, even outside of the bay, is worthy of note. Concerning the species of Amphiodia he says: "* * * the Amphiodia is perhaps the most important of your captures. If it is *atra*, as seems probable, its type locality is Charleston, S. C."

CHORDATA

HEMICHORDATA

Fragments of a species of Balanoglossus, probably *Dolichoglossus kowalevski* (A. Agassiz), have been brought up by the beam trawl and orange-peel bucket. These came from about 11 meters off Lynnhaven Roads and from somewhat deeper water off the mouth of the Potomac River. The salinities and temperatures at the bottom were 28.30 per mille, 10.9° C., and 18.93 per mille, 2.7° C., respectively. Also specimens of Balanoglossus have been reported from areas *S* and *X* farther up the bay. Balanoglossus undoubtedly occurs in abundance on the sand flats in the southern part of the bay.

UROCHORDATA

The dredging records show that the ascidian, *Molgula manhattensis* (DeKay), was widely distributed over the northern half of the bay. It was taken in largest numbers in the region between the Patapsco River and Kent Island. Only a very few specimens were found below the mouth of the Potomac River, and none, so far as our records show, below the mouth of the Rappahannock River.

CEPHALOCHORDATA

No specimens of Amphioxus have been discovered in our dredgings, but *Branchiostoma virginiæ* Hubbs (formerly known as *B. lanceolatus*) has been found on several occasions by collectors. See Rice (1880), Hubbs (1922), and Hildebrand and Schroeder (1928).

VERTEBRATA

The only vertebrates collected on our cruises were fishes; and these have been reported in another publication by Hildebrand and Schroeder (1928), together with an extensive collection made by them both inshore and in deep water.

CONCLUSIONS

The conclusions arrived at below are based on data resulting from frequent ecological investigations of some thirty areas widely distributed over the offshore waters of Chesapeake Bay. These investigations have been undertaken, usually, during all seasons, often over a period of two or three years and in a quite uniform manner.

1. Chesapeake Bay is a shallow, tidal, slow-moving body of water, averaging, in offshore regions, from 9 to 12 meters (30 to 40 feet) in depth. Water of oceanic salinity (35 per mille) does not enter the bay but large volumes of fresh water are emptied into it by many rivers.

2. A deep-water channel, which lies for the most part nearer the eastern shore of the bay, shows, at intervals, deep-water holes, some of which attain a depth of a little over 47 meters (156 feet).

3. The bottom is largely muddy with few rocky areas; but along the shores, especially in the southern part of the bay, there are sandy regions.

4. While Chesapeake Bay is a tidal body of water, the currents are weak; and there are, ordinarily, no extensive replacements of fresh water by sea water and vice versa during flood tide and ebb tide, respectively. It follows that salinity samples collected from one end of the bay, to the other during a period of four or five days afford a fairly good idea of the salinity conditions for the whole bay during that time.

5. On the other hand, there are regions, such as at the mouths of rivers, at the head of the bay, and at the mouth of the bay, where the salinity may change rather rapidly, especially during periods of river freshets, unusually high tides, and long-continued wind from one direction. Furthermore, the study of deep-water currents shows that, during the autumn and winter, the deep water at times may move continuously, although slowly, into the bay during periods which are considerably longer than those of the ordinary flood tide.

6. The surface salinity records for the mouth of the bay show a variation from approximately 19.00 to 30.00 per mille and for area *U* near the head of the bay from approximately 3.00 to 12.00 per mille. The more saline water was found as a rule along the eastern side.

7. The bottom salinity records for the mouth of the bay show a variation from approximately 26.00 to 32.00 per mille and for area *U*, near the head of the bay, from approximately 6.00 to 17.00 per mille. The more saline bottom water was found on the eastern side of the bay except near the mouth of the Potomac River, where the deep channel approaches the western side.

8. A sharp increase in salinity somewhere between the surface and 20 meters is quite marked in certain regions during the summer and autumn. Such a condition is found especially along the deep-water channel, sometimes at the mouths of rivers, and usually at the mouth of the bay. At times during the winter and spring months this condition is not so evident.

9. Sometimes, especially during the early part of the year, when large quantities of fresh water enter the bay and when there is a greater tendency toward instability, the water approaches a homohaline condition from surface to bottom.

10. While water samples could not be collected simultaneously at the various areas visited during a cruise, the salinity values obtained point strongly toward the conclusion that the salinity of the bay as a whole decreases markedly in the early part of the year, that it increases gradually during the middle of the year, and that it reaches a maximum toward the latter part of the year.

11. The same data, as might be expected, show a decreasing range of salinity values with few exceptions from the mouth to the head for each depth investigated.

12. The surface temperature at the mouth of the bay varies at least from 4° C. to 27° C. (area *G*) and near the head of the bay (area *U*) from 0.0° C. to 25° C. We have not been able to formulate any definite rule for the distribution of surface temperature with reference to the east and west sides of the bay.

13. The bottom temperature at the mouth of the bay varies at least from 3.6° C. to 21.0° C. (area *G*) and near the head from at least 0.9° C. to 24.4° C. (area *U*). During the summer cruises the coldest bottom water was found along the deep-water channel, while during the winter cruises this channel contained the warmest water.

14. A discontinuity in range of temperatures from the surface to the bottom occurs, especially during the warmer months of the year, when the water is more stable. This discontinuity often corresponds closely in depth to that of the discontinuity of the salinity.

15. The temperature data for the winter cruises indicate that there was a decreasing range from the mouth to the head and that this was partly due to the entrance of the warmer water from the ocean; during the spring cruises the temperature data showed that these relations were not constant; during the summer cruises the deep-water temperatures showed an increasing range from the mouth to the head, and this undoubtedly was partly due to the entrance of ocean water, which is of a lower temperature than that of the bay water at this season; finally, the temperatures of the autumnal cruises indicate that, at that time, the summer conditions were changing to those of the winter.

16. Practically a l of the marine planktonic diatoms found in Chesapeake Bay during the year 1916 belonged to the neritic temperate group, only one neritic arctic

and no neritic tropical species having been found. The oceanic forms were represented by very few species and small numbers of individuals. One oceanic tropical and two oceanic boreal arctic species were found. Marine bottom or semi-bottom (tycopelagic) diatoms occurred abundantly.

17. While the diatom collections and counts were not made daily in any one locality, the study of large numbers of surface and deep-water samples from regions widely distributed over the bay indicates that during the years of 1916 and 1920 there was a well-marked spring maximum. There are also indications of an autumnal-winter increase after a summer minimum, but the diatom counts are ordinarily not nearly so high as those of the spring cruises. The diatom counts for the summer almost invariably show a marked decrease when compared with those of the spring.

18. Ordinarily, high diatom counts were found at times of low salinity, but it does not follow that low salinity was the cause of the high counts.

19. Total diatom counts at areas in the mouth of the bay, where the depths are shallow and the currents comparatively rapid, were found to be low.

20. Surface and most deep-water samples of the littoral bottom diatom, *Skeletonema costatum*, taken during the cruise of October, 1915, show that the largest counts were near the mouth of the Potomac River. The vertical distribution of this diatom showed the highest counts usually at intermediate depths. The maximal counts were found during the spring cruises.

21. *Paralia sulcata*, a tychopelagic diatom with a heavy test, was also found in largest numbers near the mouth of the Potomac. The bottom samples as compared with surface and intermediate samples contained almost invariably the largest numers of specimens. The maximal counts occurred during the spring cruises.

22. The fresh-water protozoan, Difflugia, which is ordinarily a bottom form, was found widely distributed over the bay during all the cruises in the year 1916. The largest numbers were taken during the July and September cruises.

23. The silicoflagellate, *Dictyocha fibula*, was caught most abundantly in the lower half of the bay. Probably it has an autumnal maximum.

24. The most abundant peridinian listed by Cunningham for Chesapeake Bay was *Ceratium furca*.

25. *Noctiluca miliaris*, one of the cystoflagellates, was found on nearly every cruise during 1915 and 1916, but it was only in the lower end of the bay that individuals of this species were caught in abundance.

26. Comparatively few sponges were dredged in the offshores water of Chesapeake Bay. Undoubtedly this scarcity is due largely to the muddy character of the bottom and to the lack of solid objects for attachment.

27. Large quantities of hydroids belonging to the genus Thuiaria have been found in Chesapeake Bay throughout the year, although the indications are that they are in greater abundance during the spring months. Much of the material collected was loose but not floating at the surface. Three species of this genus are represented, *Thuiaria argentea*, *T. cupressina*, and *T. plumulifera*.

28. The Hydromedusa, *Nemopsis bachei*, was brought in by the townets in greater abundance than any other species in the collections made during 1920 and 1921 (H. B. Bigelow). The records indicate that it is present throughout the year.

29. The jellyfish, *Dactylometra quinquecirrha*, occurs in large numbers in Chesapeake Bay and is usually in the "Chrysaora stage." Records for 1915 and 1916 (Radcliffe) and observations of others support the view that it is abundant in the late

summer and autumn. During the latter season especially it is found well up in the rivers emptying into the bay. Evidently it can stand wide ranges of temperature and salinity.

30. One gorgonian, probably *Leptogorgia virgulata* (Lm'k), has been found at many stations in the lower part of the bay, but since we have never brought it in attached to rocks, stones, or other objects it may have been swept in by the currents from the ocean.

31. Only one species of sea anemone has been taken in the offshore waters of the bay; and, judging from our dredging records, it was confined to the upper half of the bay, showing that it is able to live in water of low salinity.

32. Observations made on the occurrence of ctenophores in Chesapeake Bay support the view that there is a scarcity of full-grown specimens, at least, during the spring months, that the numbers increase in early summer, that they reach a maximum in the late fall, and that during part of the winter they are still present.

33. No live corals were found in the bay.

34. The nematodes are represented by at least a dozen genera and upward of 20 species, according to Cobb.

35. Of the three species of sagittas found in Chesapeake Bay, *Sagitta elegans* was by far the most abundant. There is much evidence which supports the conclusions that this form was scarce in the bay during the July and August cruise, 1920; that during the October and December cruises, 1920, the numbers were larger, although the specimens were young; and that during the late winter cruise, January, 1921, the numbers were large and some of the specimens almost adult. At the time of the March–April cruise, 1921, maximum numbers were caught, many specimens of which were of large size.

36. The largest numbers of *Sagitta elegans* were found near the mouth of the bay during the cruises of July, August, October, December, 1920, and January, 1921; but during the March–April cruise, 1921, large numbers occurred in the extreme upper part of the bay. It is significant that in this same region, at the same time, the largest catches of copepods for all the cruises were made, and that copepods are known to be the food of sagittas.

37. The occurrence of *Sagitta elegans* near the head of the bay during the March–April cruise of 1921 was probably not peculiar to that year, for the log shows that on the March cruises of 1920 and 1922 sagittas were caught in almost exactly the same areas.

38. All our records show that *Sagitta elegans* frequents the layers below the surface during the daytime and that it is able to withstand a large range of salinities.

39. Evidently the presence of solid objects upon which Bryozoa may attach themselves is an important factor determining distribution; but the occurrence of one species only near the mouth of the bay, where the salinity is comparatively high, and another only well inside of the bay, where the salinity is much lower, indicate strongly that salinity is an important factor in distribution (Osburn's view also).

40. Echinoderms are not abundant in Chesapeake Bay, but the common starfish, *Asterias forbesi,* is undoubtedly present throughout the year but only in the region from the mouth of the Potomac River southward. The largest catches were made at area *A*. The salinity and temperature records show that this starfish can live in waters which range from 20.00 to 32.00 per mille and 4.2° C. to 24.4° C.

41. The holothurian, *Thyone briareus,* while not so common in our collections, has a similar distribution to *Asterias forbesi.* Other echinoderms have been taken only near the mouth of the bay and so infrequently that they need no further comment.

42. There are only two abundant annelids, *Nereis limbata* and *Polydora ligni*, which are found widely distributed in the offshore waters of the bay. They have been collected during all seasons of the year. These species and such others as *Goniada oculata*, *Pectiniaria gouldii*, and *Paranaitis speciosa* are evidently able to live in waters of widely differing salinities and temperatures.

43. Four species, *Streblospio benedicti*, *Scolecolepis viridis*, *Prinospio plumosa*, and *Pectinaria gouldii*, have been dredged only from that part of the bay extending from the mouth of the Potomac River to near the mouth of the Patapsco River, and consequently from waters of low salinities.

44. The following were found only in the lower half of Chesapeake Bay, where the salinities are much higher: *Lepidonotus squamatus*, *Harmothoe aculeata*, *Nereis dumerilii*, while *Myriana cirrata*, *Glycera americana*, *Maldane elongata*, *Praxiothea torquata*, *Eupomatus dianthus*, *Terebella ornata*, and *Loimia turgida* were only discovered near the mouth of the bay.

45. While there is no proof from the data at hand that the degree of salinity is a factor governing the distribution of the annelids in Chesapeake Bay, yet there are indications that such is the case. However, it is certainly true that the character of the bottom and the occurrence of the proper kind of food are important factors.

46. One species representing the Hirudinea was found in the offshore waters of the bay. It was the fish-leech, *Piscicola punctata*.

47. Of the 64 species of copepods collected, only two—*Acartia clausii* and *A. longiremis*—have been found sufficiently abundant in the bay to be of economic importance. These were distributed over the whole bay from the region of Baltimore to the mouth and were caught during all the cruises throughout the year. Ten species, including the two mentioned, must have been able to accommodate themselves to a large range of salinities, since they were collected, in good condition, all over the bay, in addition to the ocean. Both of these species have been found breeding in Chesapeake Bay.

48. Two species of barnacles, *Balanus improvisus* and *B. eburneus*, have been collected in the deeper waters of the lower part of Chesapeake Bay (from the mouth of the Potomac River to the mouth of the bay). However, along the shores of the bay there is at least one unidentified species which is found frequently on piles as far north as the mouth of the Patapsco River.

49. The collection of amphipods, consisting of nine species, represents merely the catch made during the cruise of May, 1920. All of the specimens came from the shallower areas and from water that did not exceed 21.00 per mille in salinity.

50. Information concerning the isopods of Chesapeake Bay is limited to material collected on the cruise of May, 1920. Five species were found.

51. The most abundant schizopod caught during our cruises was *Neomysis americana* (formerly known as *Mysis americana*). Large numbers of surface towings show that this species does not ordinarily frequent the surface waters in the daytime. Specimens were captured during all the cruises taken in the year 1920 (January, March, May, July, August, October, and December). Some breeding individuals were found on almost all of the cruises. The records show that this form can live in waters of a wide range of salinities and temperatures.

52. One species of stomatopod, *Chloridella empusa* (called *Squilla empusa* by the earlier systematists), has been caught in the bay. This common, shore-dwelling marine form has been found distributed from near the mouth of the bay to a region

off Bloody Point in waters the salinities of which ranged from about 26.00 to 16.00 per mille.

53. The only cumacean found on our cruises was probably *Oxyurostylis smithi.* Several specimens were captured in May, 1920, off the mouth of the Potomac River.

54. Collections of decapods made in each case in a similar manner, at different seasons during the year, and at widely distributed areas in the offshore waters of the Chesapeake Bay did not bring to light any species confined to the upper half of the bay. On the other hand, a number of species have been found only in the lower part of the bay and outside.

55. Of the 18 species of shrimps or shrimplike forms only *Palaemonetes carolinus, P. vulgaris,* and *Crago septemspinosus* have been found in abundance. *P. carolinus* frequents shallow water along the tide lines and flourishes in water of low salinity. It breeds in the summer time and may be found many miles up rivers where the water is almost fresh. *P. vulgaris,* on the other hand, has not been reported from river waters, although it is found in shallow waters near tide lines. It has a summer breeding season. *C. septemspinosus* frequents the deeper areas of Chesapeake Bay, but it also, like *P. carolinus,* has been found in some of the rivers. Ovigerous specimens have been collected at all seasons.

56. Two species of hermit crabs, *Pagurus longicarpus* and *P. pollicaris,* have been found in considerable numbers. Both were confined almost entirely to the region extending from the mouth of the Potomac River to the mouth of the bay. Specimens were captured in waters ranging from about 18.00 to 31.00 per mille in salinity and were found at all seasons during the year. An ovigerous specimen of the first species has been caught in the autumn, and several ovigerous specimens of the second species have been found in the spring.

57. The common edible crab, *Callinectes sapidus,* which is such a familiar form along the shores of Chesapeake Bay, was taken infrequently in our dredging and trawling. Such specimens as were captured were usually juveniles. But in December, 1920, off Old Point Comfort 32 female and 15 male specimens, mostly of large size, were caught in the trawl. All of these specimens were inactive, owing, no doubt, to the low temperature of the water (10.1° C.). It is well known that Callinectes is distributed all over the bay and well up into the rivers. Evidently individuals of this species can live in waters of wide ranges of temperature and salinity.

58. The "mud crabs" are well represented, four species having been found. Two of these, *Neopanope texana sayi* and *Hexapanopeas angustifrons,* occurred in considerable abundance. The former has been caught only in the southern half of the bay, while the latter has a little wider distribution. Both species are to be found throughout the year, and they breed during the summer. They have been taken from waters of wide ranges of temperature and salinity.

59. Five species of "commensal crabs"—three from the tubes of annelids, one from the oyster, and one from the mussel—have been collected.

60. Spider crabs are classed as marine forms, but three species have been found in Chesapeake Bay. *Libinia dubia* has been taken in many places and as far north as Love Point, near Baltimore. No ovigerous specimens have been found, and nearly all have been in the juvenile condition.

61. The distribution of the crustacea in the bay indicates that there are many forms which can live in waters of a wide range of salinities and temperatures.

62. Horseshoe crabs have been found only at the areas close to the mouth of the bay.

63. Balanoglossus and Amphioxus occur in the lower part of Chesapeake Bay, while the ascidian, *Molgula manhattensis*, has been taken in large numbers from the region between the mouths of the Patapsco and Rappahannock Rivers—in other words, in the less saline part of the bay.

64. The only vertebrates collected on our cruises have been fishes.

BIBLIOGRAPHY

ADOLPH, E. F.

1925. Some physiological distinctions between freshwater and marine organisms. Biological Bulletin, Vol. XLVIII, No. 5, May, 1925, pp. 327–335. Woods Hole, Mass.

ALLEN, E. J.

1914. On the culture of the plankton diatom *Thalassiosira gravida* Cleve, in artificial sea water. Journal, Marine Biological Association of the United Kingdom, N. S., Vol. X, No. 3, October, 1913, pp. 417–439. Plymouth.

ALLEN, E. J., and E. W. NELSON.

1910. On the artificial culture of marine plankton organisms. Journal, Marine Biological Association of the United Kingdom, N. S., Vol. VIII, No. 5, March, 1910, pp. 421–474, 1 text fig. Plymouth.

ANDREWS, E. A.

1892. Report upon the Annelida (Polychæta) of Beaufort, N. C. Proceedings, United States National Museum, Vol. XIV, 1891 (1892), pp. 277–302, pls. XII–XVIII. Washington.

APPELLÖF, A.

1912. Invertebrate bottom fauna of the Norwegian Sea and North Atlantic. *In* The Depths of the Ocean, by Murray and Hjort. xx, 821 pp., 575 text figs, 4 maps, 9 pls. London, p. 483.

APSTEIN, CARL.

1906. Plankton in Nord- und Ostsee auf den deutschen Terminfahrten. Wissenschaftliche Meeresuntersuchungen, Kommission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel und der biologischen Anstalt auf Helgoland, Neue Folge, Band 9, Abteilung Kiel, 1906, pp. 1–26, 14 figs., 10 tables. Kiel und Leipzig.

1911. Chaetognatha. Bulletin Trimestriel, Conseil Permanent International pour l'Exploration de la Mer. Résumé des Observations sur le Plankton des Mers Explorées par le Conseil pendant les Années 1902–1908, Part II, 1911, pp. 170–175, 24 pls. Copenhague.

ATKINS, W. R. G.

1923. The phosphate content of fresh and salt waters in its relationship to the growth of the algal plankton. Journal, Marine Biological Association of the United Kingdom, N. S., Vol. XIII, No. 1, December, 1923, pp. 119–150, 8 figs. Plymouth.

1925. Seasonal changes in the phosphate content of sea water in relation to the growth of the algal plankton during 1923 and 1924. Journal, Marine Biological Association of the United Kingdom, N. S., Vol. XIII, No. 1, December, 1923, pp. 700–720, 8 text figs. Plymouth.

1926. The phosphate content of sea water in relation to the growth of the algal plankton. Journal, Marine Biological Association of the United Kingdom, N. S., Vol. XIV, 1926–27 (1926), pp. 447–467, 5 figs. Plymouth.

BAILEY, L. W.

1917. Notes on the phytoplankton of the Bay of Fundy and Passamaquoddy Bay. Contributions to Canadian Biology, 1915–16 (1917). Supplement, 6th Annual Report, Department of Naval Service, Fisheries Branch, pp. 93–104. Ottawa.

BIGELOW, H. B.

1914. Oceanography and plankton of Massachusetts Bay and adjacent waters. November, 1912–May, 1913. Bulletin, Museum of Comparative Zoology at Harvard College, Vol. LVIII, No. 10, 1914, pp. 385–419, 7 figs., 1 pl. Cambridge.

1914a. Explorations in the Gulf of Maine, July and August, 1912, by the United States Fisheries schooner *Grampus*. Oceanography and notes on plankton. Bulletin, Museum of Comparative Zoology at Harvard College, Vol. LVIII, No. 2, pp. 29–147, 38 figs., 9 pls. Cambridge.

BIGELOW, H. B.—Continued.

1915. Exploration of the coast waters between Nova Scotia and Chesapeake Bay, July and August, 1913, by the United States Fisheries schooner *Grampus*. Oceanography and plankton. Bulletin, Museum of Comparative Zoology at Harvard College, Vol. LIX, No. 4, 1915, pp. 149–359, 82 text figs, 2 pls. Cambridge.

1917. Explorations of the coast water between Cape Cod and Halifax in 1914 and 1915 by the United States Fisheries schooner *Grampus*. Oceanography and Plankton. Bulletin, Museum of Comparative Zoology at Harvard College, Vol. LIX, No. 8, 1917, pp. 161–357, 100 figs, 2 pls. Cambridge.

1917a. Explorations of the United States Coast and Geodetic Survey steamer *Bache* in the western Atlantic, January–March, 1914, under the direction of the United States Bureau of Fisheries—Oceanography. Appendix V, Report, United States Commissioner of Fisheries, 1915 (1917). Bureau of Fisheries Document No. 833, 62 pp., 53 text figs., 1 chart. Washington, pp. 51–60.

1922. Exploration of the coastal water off the northeastern United States in 1916 by the United States Fisheries schooner *Grampus*. Bulletin, Museum of Comparative Zoology at Harvard College, Vol. LXV, No. 5, July, 1922, pp. 87–188, 53 text figs. Cambridge, pp. 124, 159, 184.

1926. Plankton of the offshore waters of the Gulf of Maine. Bulletin, United States Bureau of Fisheries, Vol. XL, Part II, 1924 (1926), pp. 1–509, 134 figs. Washington.

BIGELOW, ROBERT PAYNE.

1890. The marginal sense organs in the pelagidæ. Johns Hopkins University Circular, Vol. IX, No. 80, 1890, pp. 65–67. Baltimore, p. 66.

BIRGE, E. A.

1898. Plankton studies on Lake Mendota. Transactions, Wisconsin Academy of Sciences, Arts and Letters, vol. 11, 1896–97 (1898), pp. 274–448, pps. XV–L. Madison, p. 295.

BRANDT, KARL.

1899. Ueber den Stoffwechsel im Meere. Wissenschaftliche Meeresuntersuchungen, Kommission zur wissenschaftlichen Untersuchung der deutschen Meere im Kiel und der biologischen Anstalt auf Helgoland, Band 4, 1899, Abteilung Kiel, pp. 213–230. Kiel und Leipzig.

1902. Ueber den Stoffwechsel im Meere. *Ibid.*, Band 6, 2 Abhandlung, 1902, Abteilung Kiel, pp. 25–79. Kiel und Leipzig.

1920. Ueber den Stoffwechsel im Meere. *Ibid.*, Band 18, Abteilung Kiel, 1920, pp. 186–429, 9 pls. Kiel und Leipzig.

1927. Stickstoffverbindungen im Meere. *Ibid.*, Band 20, 1927, Abteilung Kiel, pp. 201–292 Kiel und Leipzig.

BUMPUS, H. C.

1898. The breeding of animals at Woods Hole during the month of March, 1898. Science, new series, Vol. VII, No. 171, 1898, pp. 485–487. New York.

BÜSE, THEODOR.

1915. Quantative Untersuchungen von Planktonfängen des Feuerschiffes, "Fehmarnbelt" vom April 1910 bis März 1911. Wissenschaftliche Meeresuntersuchung, Kommission zur wissenschaftlichen Untersuchung der deutschen Meere im Kiel und der biologischen Anstalt auf Helgoland, Neue Folge, Abteilung Kiel, Band 17, 1915, pp. 231–279, 3 charts. Kiel und Leipzig, p. 251.

CALMAN, WILLIAM T.

1912. The Crustacea of the Order Cumacea in the collection of the United States National Museum. Proceedings, United States National Museum, vol. 41, pp. 603–676, 112 figs. Washington.

CHURCHILL, E. P., Jr.

1919. Life history of the blue crab. Bulletin, United States Bureau of Fisheries, Vol. XXXVI, 1917–18 (1921), pp. 95–128, 2 text figs., Pls. XLVII–LV. Washington.

CLARKE, SAMUEL F.

1882. New and interesting hydroids from Chesapeake Bay. Memoirs read before the Boston Society of Natural History, Vol. III, No. IV, 1878–1894 (1882), pp. 135–142, pls. 7–9. Boston, p. 135.

CLEVE, P. T.

1897. Diatoms from Baffins Bay and Davis Strait. Svenska Vetenskaps-Akademien, Bihang till Handlingar Band 22, Afdeling III, 1896 (1897), No. 4, pp. 1–22, 2 pls. Stockholm, p. 6.

1897a. A treatise on the phytoplankton of the Atlantic and its tributaries and on the periodical changes of the plankton of Skagerak, 1897, 27 pp. Pls. I–IV. Upsala, p. 26.

1900. Additional notes on the seasonal distribution of Atlantic plankton organisms. Göteborg's Kungliga Vetenskaps- och Vitterhets samhälle Handlingar, series 4, vol. 3, 1901 (1902), 51 pp. Göteborg.

CORNISH, VAUGHAN.

1898. On sea beaches and sand banks. Journal, Royal Georgraphical Society, Vol. XI, 1898, pp. 528–543, 628–651, 15 figs. London, p. 529.

COWLES, R. P.

1920. Salinity and density of Chesapeake Bay water. (Abstract) Anatomical Record, vol. 26, p. 382. Philadelphia.

1924. The distribution of water density and salinity in Chesapeake Bay. Internationale Revue der Gesamten Hydrobiologie und Hydrographie, Band XII, 1924, pp. 392–395, Pl. XXVI. Leipzig.

DAMAS, D.

1909. Report on Norwegian fishery and marine investigation 1900–1908, edited by Johan Hjort, Vol. II, Part I, No. 1, Plankton, 1909, pp. 93–107. Bergen.

DARWIN, CHARLES ROBERT.

1854. A monograph on the sub-class Cirripedia, with figures of all the species. The Balanidæ (or sessile cirripeds): The Verrucidæ. The Ray Society, 1853 (1854), pp. 1–684. London.

DAWSON, W. BELL.

1896. Survey of tides and currents in Canadian waters. Report of Progress, Government Printing Office, 1896, pp. 1–32, Pls. I–VIII. Ottawa, p. 20.

1897. Survey of tides and currents in Canadian waters. Report of Progress, Government Printing Office, 1897, pp. 1–49, Pls. I–III, Tables I–II. Ottawa, p. 31.

DICKSON, H. N.

1893. The physical conditions of the waters of the English Channel. Scottish Geographical Magazine, Vol. IX, 1893, pp. 17–28. Pls. I–II, Tables I–IV. Edinburgh, p. 27.

EKMAN, F. L.

1876. On the general causes of ocean currents. Nova Acta Regiæ, Societatis Scientiarum Upsaliensis, Series III, 1876, 52 pp. Upsala.

FARRAN, G. P.

1910. Copepoda. Bulletin Trimestriel, Conseil Permanent International pour l'Éxploration de la Mer. Résumé des Observations sur le Plankton des Mers, Part 1, 1910, pp. 60–80, Pls. VIII–X. Copenhague.

FISH, C. J.

1925. Seasonal distribution of the plankton in the Woods Hole region. Bulletin, United States Bureau of Fisheries, Vol. XLI, 1925 (1926), pp. 91–179, 81 figs. Washington, p. 111.

FLATTELY, F. W.

1916. Notes on the oecology of Cirratulus (Audouinia) tentaculatus (Montagu). Journal, Marine Biological Association of the United Kingdom, Vol. XI (N. S.) 1916–18 (1916), pp. 60–70, 7 text figs. Plymouth.

FLATTELY, F. W., and C. L. WALTON.

1922. The biology of the seashore, 1922, 336 pp., 23 text figs., XVI Pls. London.

FREDERICQ, LEON.

1889. La lutte pour l'existence chez les animaux marins, 1889. Paris. (Reference from Flattely and Walton.)

1898. La physiologie de la branchie et la pression osmotique du sang de l'Écrevisse. Bulletin de l'Academie Royale de Belgique, 3e serie, T. 35, 1898, pp. 831–833. Bruxelles.

GAARDER, T., and H. H. GRAN.

1927. Investigations of the production of plankton in the Oslo Fjord. Rapports et Procés Verbaux des Réunions, Conseil Permanent International pour l'Exploration de la Mer, Vol. XLII, 1927, 48 pp., 1 fig. Copenhague.

GIESBRECHT, WILHELM.
1892. Systematik und faunistik der pelagischen Copepoden des Golfes von Neapel und der angrenzenden Meeres-abschnitte. Fauna und Flora des Golfes von Neapel und der angrenzenden Meeres-abschnitte herausgegeben von der zoologischen station zu Neapel, 19 Monographie, 1892, 831 pp. atlas of 54 pls. Berlin.

GRAN, H. H.
1908. Diatomeen. *In* Nordisches Plankton, No. XIX, 1908, 146 pp., 178 text figs. Kiel und Leipzig, p. 55.
1912. Pelagic Plant Life. *In* Depths of the Ocean, by Murray and Hjort, 1912, pp. 307–386. London, pp. 365, 378.
1919. Quantitative investigation as to phytoplankton and pelagic Protozoa in the Gulf of St. Lawrence and outside the same. Canadian Fisheries Expedition, 1914–15 (1919), Department of the Naval Service, pp. 489–495, 3 tables. Ottawa, p. 492.
1929. Investigation of the production of plankton outside the Romsdalsfjord 1926–27. Rapports et Procés-Verbaux des Réunions, Conseil Permanent International pour l'Exploration de la Mer, Vol. LVI, 1929, pp. 1–112, text figs. 1–5. Copenhague.

GRAN, H. H., and A. NATHANSON.
1909. Beitrage zur Biologie des Planktons. II. Vertikalzirkulation und Planktonmaxima im Mittelmeer. Internationale Revue der gesamten Hydrobiologie und Hydrographie, Band II, 1909, pp. 580–632, pls. 20–29. Leipzig, p. 629.

GRAVE, CASWELL.
1912. A manual of oyster culture in Maryland. Fourth Report of the Maryland Shell Fish Commission, 1912, pp. 5–75, Pls. VIII–XIII. Baltimore, p. 70.

GRUVEL, A.
1905. Monographie des Cirrhipèdes ou Thécostracés, 1905, pp. xii+472, 427 text figs. Paris.

HARGER, OSCAR.
1880. Report on the marine isopods of New England and adjacent waters. Report, United States Commissioner of Fish and Fisheries, No. XIV, 1878 (1880), pp. 297–462, XIII Pls. Washington.

HARVEY, H. W.
1926. Nitrate in the sea. Journal, Marine Biological Association of the United Kingdom, Vol. XIV (N. S.), 1926–27 (1926), pp. 71–88, 3 figs. Plymouth.

HELLAND-HANSEN, BJÖRN, and FRIDTJOF NANSEN.
1909. The Norwegian sea. Its physical oceanography based upon the Norwegian researches 1900–1904. Report on Norwegian Fishery and Marine Investigations, edited by Johan Hjort, Vol. II, No. 2, 1909, pp. xx+390, 112 figs. 5 tables, XXV pls. Bergen, p. 248.

HERDMAN, W. A., I. C. THOMPSON, and ANDREW SCOTT.
1898. On the plankton collected continuously during two traverses of the North Atlantic in the summer of 1897; with descriptions of new species of Copepoda; and an appendix on dredging in Puget Sound. Proceedings and transactions, Liverpool Biological Society, Vol. XII, Session 1897–98 (1898), pp. 33–90, 4 text figs., Pls. V–VIII. Liverpool.

HILDEBRAND, SAMUEL F., and WILLIAM C. SCHROEDER.
1928. Fishes of Chesapeake Bay. Bulletin, United States Bureau of Fisheries, Vol. XLIII, Part I, 1927 (1928), pp. 1–388, 211 figs. Washington.

HJORT, J.
1896. Hydrographical-biological studies of the Norwegian fisheries. Videnskabss-elskabets Skrifter. I. Math.-naturv. Klasse, 1895 (1896), No. 9, pp. 1–75, 10 charts, 5 pls. Christiania, p. 39.

HJORT, J., and H. H. GRAN.
1900. Hydrographic-biological investigations of the Skagerrak and the Christiania Fiord. Report on the Norwegian Fishery and Marine Investigation, Vol. 1, No. 2, 1900, pp. 1–41, text figs. 1–11, 7 tables. Kristiania, p. 41.

HOLMES, S. J.
1903. Synopses of North American Invertebrates. XVIII. The Amphipoda. The American Naturalist, Vol. XXXVII, No. 436, April, 1903, pp. 267–292. Boston.
1905. The Amphipoda of southern New England. Bulletin, United States Bureau of Fisheries, Vol. XXIV, 1904 (1905), pp. 459–529, text figs. Pls. I–XIII. Washington.

HUBBS, CARL L.
1922. A list of the lancelots of the world with diagnoses of five new species of Branchiostoma. Occasional papers of the Museum of Zoology, University of Michigan, No. 105, January, 1922, 16 pp. Ann Arbor.

HUNTER, J. F.
1914. Erosion and sedimentation in Chesapeake Bay around the mouth of Choptank River. Department of the Interior, Professional Paper, 90–B, United States Geological Survey. Shorter contributions to general geology, 1914, pp. 7–15, 1 text fig., Pl. III. Washington.

HUNTSMAN, A. G.
1919. A special study of the Canadian chaetognaths, their distribution, etc., in the waters of the eastern coast. Canadian Fisheries Expedition, 1914–15, Department of the Naval Service, 1915 (1919), pp. 421–485, 12 text figs. Ottawa.

HUNTSMAN, A. G., and MARGARET E. REID.
1921. The success of reproduction in *Sagitta elegans* in the Bay of Fundy and the Gulf of St. Lawrence. Transactions, Royal Canadian Institute, Vol. XIII, 1921, Part 2, pp. 99–112. Toronto.

JOHNSTONE, JAMES.
1923. An introduction to oceanography with special reference to geography and geophysics, 1923, 351 pp., text figs. 1–64, F., Univeristy Press. Liverpool, p. 270, 291.

JOHNSTONE, JAMES, ANDREW SCOTT, and HERBERT C. CHADWICK.
1924. The marine plankton, with special reference to investigations made at Port Erin, Isle of Man, during 1907–1914; a handbook for students and amateur workers. 1924, xvi+194 pp., 20 pls., graphs I–VI. Liverpool.

KINGSLEY, J. S.
1899. Synopses of North-American Invertebrates. III. The Caridea of North America. The American Naturalist, Vol. 33, No. 392, August, 1899, pp. 709–720, 57 text figs. Boston.

KOFOID, CHARLES ATWOOD, and OLIVE SWEZY.
1921. The free-living unarmored Dinoflagellata. Memoirs, University of California, vol. 5, 1921, 538 pp., 12 pls. Berkeley, p. 98.

KRÜMMEL, OTTO.
1907. Handbuch der Oceanographie. Vol. I, Die raumlichen, chemischen und physikalischen Verhältnisse des Meeres, 526 pp., 69 text figs. Leipzig, pp. 395, 489.
1911. Handbuch der Oceanographie. Vol. II. Die Bewegungsformen des Meeres, 1911, 766 pp., 182 text figs. Stuttgart, pp. 382, 395.

LINDENKOHL, A.
1891. Notes on the submarine channel of the Hudson River and other evidences of Postglacial Subsidence of the Middle Atlantic Coast Region. The American Journal of Science, 3d series, Vol. XLI (whole number, CXLI), Art. LIX, 1891, pp. 489–499, Pl. XVIII. New Haven.

LOEB, J.
1903. On the relative toxicity of distilled water, sugar solutions, and solutions of the various constitutents of the sea water for marine animals. University of California Publications, Physiology, Vol. I, 1903, pp. 55–69. Berkeley.

LOHMANN, H.
1908. Untersuchungen zur Festellung des vollständigen Gehaltes des Meeres an Plankton. Wissenschaftliche Meeresuntersuchungen, Kommission zur wissenschaftlichen Untersuchung der deutschen Meere im Kiel und der biologischen Anstalt auf Helgoland, Neue Folge, Band 10, Abteilung Kiel, 1908, pp. 131–370, text figs. 1–23, Pls. IX–XVII, Tables A and B. Kiel und Leipzig.

MACDONALD, D. L.
1912. On a collection of Crustacea made at St. Andrews, New Brunswick. Contributions to Canadian Biology, 1906–1910 (1912), pp. 83–84. Ottawa.

MCGEE, W. J.
1888. The geology of the head of Chesapeake Bay. Seventh Annual Report, United States Geological Survey, 1885–86 (1888), pp. 537–646, text figs. 109–114, Pls. LVI–LXXI. Washington.

M'Intosh, William C.
1885. Report on the Annelida Polychæta collected by H. M. S. *Challenger* during the years 1873–76. Report on the scientific results of the voyage of H. M. S. *Challenger* during the years 1873–1876 (1885), Vol. XII, pp. i–xxxvi+1–554, Pls. I–XXXIXA, 1 map. London.

Mann, Albert.
1894. List of Diatomacæ from a deep-sea dredging in the Atlantic Ocean off Delaware Bay by the United States Fish Commission steamer *Albatross*. Proceedings of the United States National Museum, Vol. XVI, 1893 (1894), pp. 303–312. Washington, p. 304.

Marmer, H. A.
1925. Tides and currents in New York Harbor. Special Publication No. 111, United States Coast and Geodetic Survey, 1925, 174 pp., 70 tables, 52 figs. Washington, pp. 12, 17.

Marshall, S. M., and A. P. Orr.
1927. The Relation of the Plankton to some Chemical and Physical factors in the Clyde Sea Area. Journal, Marine Biological Association of the United Kingdom, Vol. XIV (N. S.), 1926–27 (1927), pp. 837–868, text figs. 1–9, Pls. I–X. Plymouth.

Mathews, Donald J.
1918. On the amount of phosphoric acid in sea water off Plymouth Sound. Journal, Marine Biological Association of the United Kingdom, Vol. XI (N. S.), 1916–18 (1918), pp. 122–130. Plymouth.

Mathews, E. B.
1917. Submerged "Deeps" in the Susquehanna River. Bulletin, Geological Society of America, vol. 28, 1917, pp. 335–346, pls. 18–20, text figs. 1–7. New York.

Mayer, Alfred Goldsborough.
1910. Medusæ of the world. Publication No. 109, Carnegie Institution of Washington, Vols. I–III, 1910, 735 pp., 76 pls. Washington, p. 174, Vol. I, pp. 583, 587, Vol. III.
1912. Ctenophores of the Atlantic coast of North America. Publication No. 162, Carnegie Institution of Washington, 1912, 58 pp., 17 pls., 12 text figs. Washington, p. 50.

Mayer, Paul.
1890. Die Caprelliden des Golfes von Neapel und der angrenzenden Meeres-Abschnitte. Nachtrag zur Monographie derselben. Fauna und Flora des Golfes von Neapel, Vol. XVII, 1890, 157 pp., 7 pls. Berlin.

Moore, H. F.
1897. Oysters and methods of oyster culture. *In* A Manual of Fish Culture. Report, United States Fish Commissioner for 1897, pp. 265–338, Pls. I–XVIII. Washington, p. 281.

Murray, Sir John, and Johan Hjort.
1912. Depths of the Ocean. 1912, xx, 821 pp., 575 text figs., 4 maps, 9 pls. London, pp. 223, 229.

Murray, Sir John, and Robert Irvine.
1893. On the chemical changes which take place in the composition of sea water associated with blue muds on the floor of the ocean. Transactions, Royal Society of Edinburgh, Vol. XXXVII, Part II, 1895 (1893), pp. 481–507, Tables A–D and I–VIII. Edinburgh.

Nathansohn, Alexander.
1906. Über die Bedeutung vertikaler wasserbewegungen für die produktion des planktons im Meere. Abhandlungen der Mathematisch-Physischen Klasse der Königlich Sächsischen Gesellschaft der Wissenchaften, Band XXIX, 1906, No. V, pp. 355–441, 1 chart. Leipzig.
1909. Beitrage zur Biologie des planktons, von H. H. Gran und Alexander Nathansohn. II. Vertikalzirkulation und Planktonmaxima im Mittelmeer, von Alexander Nathansohn. Internationale Revue der gesamten Hydrobiologie und Hydrographie, Band II, 1909, pp. 580–632, pls. 20–29. Leipzig, p. 629.
1911. Études hydrobiologiques d'après les recherches faites à bord de *l'Eider* au large de Monaco, de janvier à juillet 1909. Annales de l'Institute Oceanographique, Tome 1, No. 5, 1910, pp. 27, 3 pls. Monaco.

Nelson, Thurlow C.
1925. On the occurrence and food habits of ctenophores in New Jersey inland coastal waters. Biological Bulletin, Vol. XLVIII, No. 2, February, 1925, pp. 92–111, 2 text figs. Woods Hole.

Nutting, C. C.
1901. The hydroids of the Woods Hole region. Bulletin, United States Fish Commission, Vol. XIX, 1899 (1901), pp. 325–386, 105 text figs. Washington, p. 325.

Ostenfeld, C. H.
1913. Bacillariales (Diatoms). Bulletin Trimestriel, Conseil Permanent International pour l'Exploration de la Mer. Résumé des observations sur le Plankton des mers, Part 3, 1913, pp. 403–508, Pls. LV–XCIII. Copenhague, p. 419.
1913a. Noctiluca and Globigerina. *Ibid.*, Part 3, 1913, pp. 291–297, Pls. LIII and LIV. Copenhague, p. 292.

Pettersson, Otto.
1894. A review of Swedish hydrographic research in the Baltic and North Seas. Scottish Geographic Magazine, Vol. X, 1894, Parts I–V, and Conclusions, pp. 281–302, 352–359, 413–427, 449–462, 525–539, 617–635, Pls. I–XVIII. Edinburgh.

Pratt, Henry Sherring.
1916. A manual of the common invertebrate animals exclusive of insects, 1916, 737 pp., 1,017 figs. Chicago.

Raben, E.
1905. Über quantitative Bestimmungen von Stickstoffverbindung im Meerwasser, nebst einem Anhang über die quantitative Bestimmung der im Meerwasser gelösten Kieselsäure. Wissenschaftliche Meeresuntersuchungen, Kommission zur wissenschaft lichen Untersuchung der deutschen Meere im Kiel und der biologischen Anstalt auf Helgoland, Band VIII, Abteilung Kiel, 1905, pp. 81–98, 1 text fig., 2 maps. Kiel und Leipzig.
1905a. Weitere Mitteilungen über quantitative Bestimmungen von Stickstoffverbindungen und von gelöster Kieselsäure im Meerwasser. *Ibid.*, 1905, pp. 279–287, 2 maps. Kiel und Leipzig.
1910. Dritte Mitteilung über quantitative Bestimmungen von Stickstoffverbindungen und von gelöster Kieselsäure im Meerwasser. *Ibid.*, Band XI, 1910, Abteilung Kiel, pp. 303–319. Kiel und Leipzig.
1914. Vierte Mitteilung über quantitative Bestimmungen von Stickstoffverbindungen im Meerwasser und Boden, sowie von gelöster Kieselsäure im Meerwasser. *Ibid.*, Band XVI, 1914, Abteilung Kiel, pp. 207–229, 1 text fig., 8 tables. Kiel und Leipzig.
1920. Quantitative Bestimmung der im Meerwasser gelösten Phosphorsaure. *Ibid.*, Band XVIII, 1916–20 (1920), Abteilung Kiel, pp. 1–24. Kiel und Leipzig.

Radcliffe, Lewis.
1916. Fishery Investigations in Chesapeake Bay. Fisheries Service Bulletin, No. 14, 1916, United States Bureau of Fisheries. Washington.

Rathbun, Mary J.
1900. Synopses of North American invertebrates, XI. The Catometopous or Grapsoid Crabs of North America. The American Naturalist, Vol. XXXIV, 1900, pp. 583–592, 15 figs. Boston.
1905. Fauna of New England. 5. A list of the Crustacea. Occasional papers. Boston Society of Natural History, Vol. VII, No. 5, 1905, pp. 1–117. Boston.
1925. The spider crabs of America. Bulletin, United States National Museum, No. 129, 1925, pp. i–xx+1–613, text figs., 1–153, pls. 1–283. Washington, p. 98.

Rice, H. J.
1880. Observations upon the habits, structure, and development of *Amphioxus lanceolatus*. The American Naturalist, Vol. XIV, Nos. 1 and 2, 1880, pp. 1–19, 73–95, Pls. I–II. Philadelphia.

Richardson, Harriet.
1905. A monograph on the isopods of North America. Bulletin, United States National Museum, No. 54, 1905, pp. I–LIII+1–727, 740 text figs. Washington.

Richter, Edward.
1891. Temperatureverhältnisse der Alpenseen. Verhandlungen der 9 Deutsches Geographentag, Wien, 1891. (Reference from Planktonkunde, by Adolf Steuer), p. 72.

SANDSTRÖM, J. W.
1919. The hydrodynamics of Canadian Atlantic waters. Canadian Fisheries Expedition, 1914–15 (1919). Department of the Naval Service, pp. 221–343, 59 figs, Pls. I–XV. Ottawa, p. 235.

SARS, G. O.
1903. An account of the Crustacea of Norway. Copepoda, Calanoida, Vol. IV, 1903, 171 pp , 108 pls. Bergen.

SAY, THOMAS.
1817. An account of the crustacea of the United States. Journal, Academy of Natural Sciences, Series 1, Vol. 1, 1817, pp. 57–63, 65–80, 97–101, 155–169, 235–253, 313–319, 374–401, 423–441, 4 pls. Philadelphia, p. 248.

SCHREIBER, E.
1927. Die Reinkultur von marinem Phytoplankton und deren Bedeutung für die Erforschung der Produktionsfähigkeit des Meerwassers. Wissenschaftliche Meeresuntersuchungen, Kommission zur wissenschaftlichen Untersuchung der deutschen Meere im Kiel und der biologischen Anstalt auf Helgoland. Neue Folge, Band 16, Abteilung Helgoland, Heft 2, 1927, pp. 1–34, text figs, 1–11, 1 pl. Kiel und Leipzig.

SCOTT, THOMAS.
1894. Report on Entomostraca from the Gulf of Guinea, collected by John Rattray, B. Sc. Transactions, The Linnean Society of London, Second Series, Vol. VI, Part 1 Zoology, 1894, pp. 1–161, Pls. I–XV. London.
1905. On some Entomostraca from the Gulf of St. Lawrence. Transactions, Natural History Society of Glasgow, Vol. VII (N. S.), Part I, 1902–1905 (1907), pp. 46–52, Pl. II. Glasgow.

SHOEMAKER, CLARENCE R.
1926. Amphipods of the family Bateidæ in the collection of the United States National Museum. Proceedings, United States National Museum, Vol. 68, Art. 25, 1926, pp. 1–26, 16 figs. Washington.

SMITH, S. I.
1879. The stalk-eyed crustaceans of the Atlantic coast of North America north of Cape Cod. Transactions, Connecticut Academy of Arts and Sciences, Vol. V, 1879, pp. 27–138, Pls. VIII–XII. New Haven.
1880. On the amphipodus Genera, Cerapus, Unciola, and Lepidactylis described by Thomas Say. Transactions, Connecticut Academy of Arts and Sciences, Vol. IV, Part I, 1879–82 (1880), pp. 268–284, pl. 11a. New Haven.

SPENCER, JAMES H.
Our Climate. Useful information regarding the climate between the Rocky Mountains and the Atlantic Coast with special reference to Maryland and Delaware. Maryland State Weather Service, Edward B. Mathews, director. In cooperation with the U. S. Weather Bureau, pp. 1–29, 19 text figs. Baltimore, p. 10.

STEBBING, T. R. R.
1906. Amphipoda. I. Gammaridea. Das Tierreichs, 21 Lieferung. Crustacea, 1906, pp. i–xxxix+806, 127 figs. Berlin.

STEUER, A.
1910. Planktonkunde, 1910, 723 pp., 365 text figs. Leipzig und Berlin, pp. 197, 355, 356, and 562.

SUMNER, FRANCIS B., RAYMOND C. OSBURN, and LEON J. COLE.
1913. A biological survey of the waters of Woods Hole and vicinity. Part I. Physical and Zoological. Bulletin, United States Bureau of Fisheries, Vol. XXXI, 1911 (1913), pp. 1–442, 227 charts. Washington.

THOMPSON, MILLETT T.
1899. The breeding of animals at Woods Hole during the month of September, 1898. Science, New Series, Vol. IX, No. 225, April, 1899, pp. 581–583. New York.

UNITED STATES COAST PILOT.
1916. United States Coast Pilot. Atlantic coast. United States Coast and Geodetic Survey. Section C, Sandy Hook to Cape Henry, including Delaware and Chesapeake Bays, 284 pp. Washington.

VERRILL, A. E., and S. I. SMITH.
1873. Report upon the invertebrate animals of Vineyard Sound and adjacent waters, with an account of the physical features of the region. Report, United States Commissioner of Fish and Fisheries, 1871–72 (1873), pp. 295–773, Pls. I–XXXVIII. Washington.
VON RITTER-ZÁHONY, RUDOLF.
1911. Chaetognathi. Das Tierreich. Eine Zusammenstellung und Kennzeichnung der rezenten Tierformen. Begründet von der Deutschen Zoologischen Gesellschaft. Im Auftrage der Königl. Preuss. Akademie der Wissenschaften zu Berlin, herausgegeben von Franz Eilhard Schulze. 29 lieferung, 1911, pp. ix+35, text figs. 1–16. Berlin.
WALLACE, N. A.
1919. The Isopoda of the Bay of Fundy. University of Toronto Studies, Biological Series, No. 18, 1919, 42 pp., 12 figs. Toronto.
WEBSTER, H. E.
1879. On the Annelida Chaetopoda of the Virginia coast. Transactions, Albany Institute, Vol. IX, 1879, pp. 202–272, Pls. I–XI. Albany.
1886. Annelida Chaetopoda of New Jersey. (Originally communicated to the thirty-second report of the New York State Museum of Natural History, 1879, pp. 101–128.) Thirty-ninth annual report, New York State Museum of Natural History, 1886, pp. 128–159, Pls. (1) 4–(7) 10. Albany.
WEBSTER, H. E., and JAMES E. BENEDICT.
1884. The Annelida Chaetopoda from Provincetown and Wellfleet, Mass. *In* Report, United States Commissioner of Fish and Fisheries, 1881 (1884), pp. 699–747, Pls. I–VIII. Washington.
WELLS, R. C., R. K. BAILEY, and E. P. HENDERSON.
1929. Salinity of the water of Chesapeake Bay. Professional Paper 154–C, Department of the Interior, United States Geological Survey, 1929, pp. 105–152, pl. 13, figs. 13–15. Washington.
WHEELER, W. H.
1893. Tidal Rivers, their (1) Hydraulics, (2) Improvement, (3) Navigation. 1893, pp. 1–467, text figs. 1–75. London, pp. 54, 55.
WHIPPLE, GEORGE CHANDLER.
1914. The microscopy of drinking water, 1914, 409 pp., 72 text figs., Pls. A–F, I–XVII. New York, p. 96.
WILLEY, ARTHUR.
1920. Marine Copepoda. Report of the Canadian Arctic Expedition, 1913–1918, Vol. VII, Part K, 1920, pp 1K–46K, figs. 1–70. Ottawa.
1921. Arctic Copepoda in Passamaquoddy Bay. Proceedings, American Academy of Arts and Sciences, vol. 56, February, 1921, pp. 183–196. Boston.
WILLIAMS, LEONARD W.
1906. Notes on marine Copepoda of Rhode Island. The American Naturalist, Vol. XL, No. 477, 1906, pp. 639–660, 23 text figs. New York.
WOLFE, J. J., BERT CUNNINGHAM, and others.
1926. An investigation of the microplankton of Chesapeake Bay. Journal, Elisha Mitchell Scientific Society, vol. 42, Nos. 1 and 2, 1926, pp. 25–54, 1 pl. Chapel Hill, p. 25.
ZESKIND, L. M., and E. A. LE LACHEUR.
1926. Tides and currents in Delaware Bay and River. Special Publication No. 123, United States Coast and Geodetic Survey, Serial No. 336, 1926, 122 pp., text figs. 1–33 and A–F. Washington, p. 83.