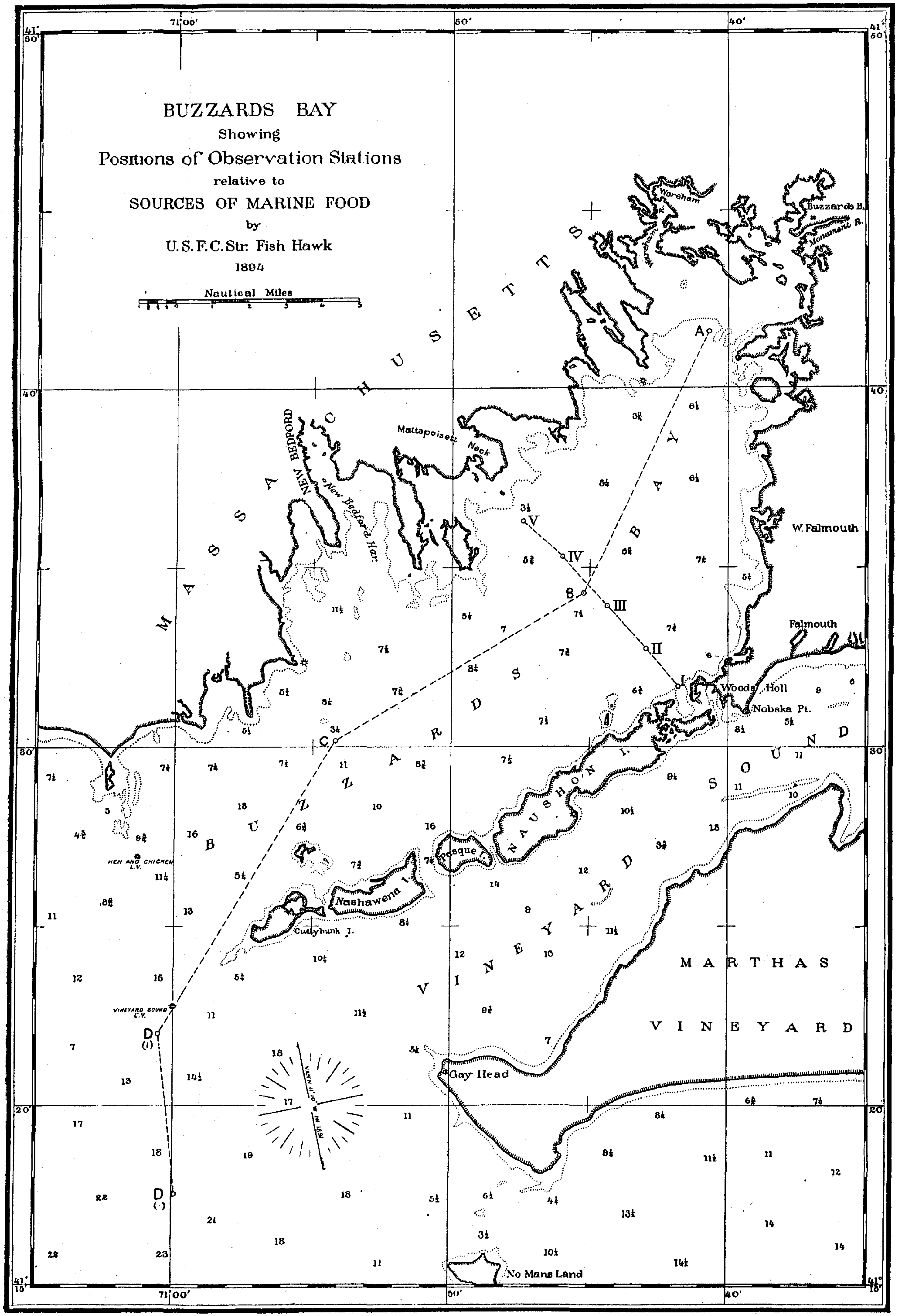

Map of Buzzards Bay (southern coast of Massachusetts) indicating the lines of sections studied, Stations A, B, C, D being the "longitudinal" section, Stations I–V being the "cross" section studied.

8.—THE SOURCES OF MARINE FOOD.

By JAMES I. PECK,
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During the summer of 1894 studies were continued, under the auspices of the United States Fish Commission, upon the food of marine fishes, and in working out somewhat in detail some of the ways in which several of them are related to their environment in these respects, and especially in trying to get a more accurate idea of the primary basis upon which they all rest; that is to say, the body of micro-organic material suspended in the water.

Much importance naturally attaches to the study of the feeding habits of marine fishes, for attention is thus immediately called to the delicate adjustments upon which their life-history is based, especially in their young and defenseless stages of growth; and in no better way can the resources of any given species be approached than in understanding the possibilities of its obtaining sufficient food supply, together with its liabilities of falling a prey to other species.

Such studies, moreover, lead to very broad considerations of the resources of the ocean, such as logically involve all its wealth of living substance, and so it is that the two sections of this paper, although dealing with such different subjects, are yet phases of the same theme.

I. THE FOOD OF CERTAIN FISHES.

Having ascertained in 1893 the food of the menhaden,* which is not carnivorous at all, but subsists upon microorganic material filtered from the water, I have now considered the squeteague, which is a voracious and insatiable devourer of other species, and which visits the New England coast as a summer migrant and is taken regularly in the traps here located. Five hundred and seventy of these were examined during the month of July and the first days of August, and their food tabulated as correctly as could be done by me, as it was taken from the stomachs of the fish when brought in each morning from the traps. This method is of course subject to somewhat unnatural conditions, because when confined in traps they may fall upon victims imprisoned with them, or they may be deprived of their normal quantity of food by their inclosure, but it seems to me that, after all, the results are not materially changed.

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* See U. S. F. C. Bulletin for that year, p. 113.

The following tabulated statement is so classified as to express graphically the main constituents of the food of the squeteague:

Date.	Number of specimens examined.	Containing menhaden.	Containing adult herring.	Containing butter-fish.	Containing young herring.	Containing squid.	Containing small crustacea.	Containing nothing.	Miscellaneous.
July 4	8				2 (3)	1 (4)	3 (many).	3	
5	11	1 (1)		1 (2)		3 (3)		6	
6	8				2 (2)	3 (4)		5	
7	4				1 (1)	2 (3)		1	
9	20		5 (5)	1 (1)	4 (many)			11	
10	30	2 (2)	7 (7)	3 (3)	8 (very many)			9	1 hermit crab.
11	33	2 (2)		6 (6)	5 (few)	2 (2)	4 (few)	17	1 small crab.
13	17	3 (3)	1 (1)	4 (5)	4 (14)	3 (6)		5	1 knot seaweed.
14	30		1 (1)	6 (8)	5 (many)	3 (3)	1 (3)	16	
16	37		2 (2)	13 (18)	2 (several)	3 (4)		18	1 lobster (soft).
17	56	5 (5)	1 (1)	6 (7)	2 (2)	5 (5)	3 (many).	35	Shrimps, with other crustacea.
18	43	1 (1)		4 (4)	1 (1)	1 (1)	3 (few)	34	
19	7						1 (2)	6	1 small crab.
23	31			6 (8)	6 (many)	3 (3)		19	3 annelids and 2 lady crabs.
24	40		3 (3)	6 (6)	29 (many)	4 (4)	2 (few)	3	1 small crab.
25	15		4 (4)	1 (1)	3 (few)			8	
26	20	1 (1)	2 (2)		1 (1)			16	
27	12							12	
28	26	2 (2)	5 (7)	1 (1)	4 (7)	3 (5)		11	
30	27	2 (2)	13 (15)	1 (1)	3 (few)	1 (1)	3 (few)	5	
31	14		3 (3)	5 (17)	5 (several)			4	
Aug. 1	17			2 (7)	5 (many)	1 (1)	8 (many).	2	1 mackerel.
2	14		5 (5)	5 (8)	6 (several)	2 (2)	1 (1)		Squid contained 1 young fish.
7	11		1 (1)				1 (1)	6	Young scup.
8	13							13	2 annelids.
9	13		1 (1)	3 (5)				10	
10	7		3 (4)	6 (22)	1 (2)	1 (1)			
11	6				1 (2)			5	Young scup.
	570	19 (19)	57 (62)	80 (130)	100 (very many)	41 (52)	30 (many).	280	
Per cent		3.3	10	14	17.5	7.2	5	49	

NOTE.—The figures and words in parentheses indicate the number of victims found in the given number of squeteague. The figures without parentheses indicate the number of squeteague containing such victims; thus, 19 squeteague contained in their stomachs (19) menhaden as victims, 57 squeteague contained (62) adult herring as victims, and so for the other columns following. The column headed "Miscellaneous" includes victims not otherwise enumerated.

It will be seen that the column of the table headed "young herring" is the one most constantly filled, and that the aggregate number of fish included in it (100) is larger than in any of the other columns where food is found, covering 17½ per cent of the whole number of fish studied. It is very evident, in fact, to the investigator that schools of young herring, menhaden, and alewives, with young fish of other species found less often during this particular period, are especially sought by the squeteague. In a single specimen 25 inches long were found 166 young 2-inch herring. It seems hardly credible that one fish could manage to consume this number at a single meal, but very frequently they thus get opportunities of gorging themselves—from a single school, too, since the process of digestion had acted uniformly upon the whole.

In the next left-hand column* one sees that butter-fish (*Stromateus triacanthus*) also form a large part of the food of this species. I have found as many as 7 small-sized victims (all together weighing 8½ ounces) in a single squeteague, while 14 per cent of the whole number examined contained these victims. In the column recording the fish feeding upon squid one sees a large representation; 7 per cent of the whole number of squeteague examined used them.

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*In this column also are included young bluefish, which often occur, and in the nearly digested state can with difficulty be distinguished from small butter-fish.

I think that the food materials thus far mentioned, i. e., young fish, butter-fish, and squid, are closely interrelated, and that the young fish are again the central point, for one finds upon examining the stomachs of the butter-fish that they are carnivorous, feeding upon small fish; in fact, one was taken from a squeteague which was itself in the act of capturing a minnow, which stuck, half-swallowed, from its mouth. The squid, as is well known, swims along under schools of young fish, rising now and then to the surface with great accuracy and securing its prey. One can often see them during the summer in the large pool of the station of the Fish Commission at Woods Hole, Massachusetts, feeding upon small silversides at the surface.

I have many times in the same way watched young bluefish from the wharf as they swim along 3 or 4 feet beneath a school of young fish at the surface, changing their position, direction, and their rate constantly, according to the movements of their victims above them. At times a continuous stream of schooling silversides would pass along the end of the wharf as far as the eye could discern them, while just as regularly, though of course in much fewer numbers, one could see a scattered column of young bluefish, a few feet beneath, moving in exactly the same manner, rising constantly into the mass above, as one might plainly know by the scattering, even out into the air, of the invaded minnows. The schools of young herring, menhaden, and alewives, are subject to the same foes, and one can imagine that it is in this way that the giant squeteague also regulates its feeding times and places to this kind of material, preying at once both upon the young herring and their enemies, which fall so easily to its strength and swiftness. It is often found also that when the young fish are fed upon in abundance by the squeteague, small crustacea—amphipods, and less often small shrimps—and also the green remains of many annelids (*Phyllodoce*) are frequently taken with them. These organisms also swarm in shallower areas frequented by young fish, for these latter prey upon the smaller crustacea, larvæ, and copepods, while some of the larger kinds of the crustacea are consumed by the squeteague directly.

Not only are young fish used by the squeteague, but the adults of the same species, and one can see by reference to the table before given that the columns devoted to adult menhaden and herring have a good representation, especially the latter. So well adapted for its predaceous life is the squeteague that it swallows a large thick menhaden more than half its own length, while the full-grown herring figures very commonly in the same way as food.

The food of the squeteague (*Cynoscion regale*) may be characterized perhaps most clearly by a concrete instance: On the morning of July 23 there was taken a large specimen whose stomach contained an adult herring, in the stomach of the herring were found two young scup (besides many small crustacea), and in the stomach of one of these young scup were found copepods, while in the alimentary tract of these last one could identify one or two of the diatoms and an infusorian test among the mass of triturated material which formed its food. This is an instance of the universal rule of this kind of food; the squeteague captures the butter-fish or squid, which in turn have fed on young fish, which in their turn have fed upon the more minute crustacea, which finally utilize a microscopic food supply. And the food of the squeteague must be regarded as a complex of all these factors, a resultant of several life-histories to the given environment. Moreover, circumstances arising to modify any of the separate factors cause correlative changes throughout the whole series.

The species most like the squeteague as regards its food material in this locality is the bluefish (*Pomatomus saltatrix*). Only thirty-eight of these, however, were obtained by me during the summer; not a sufficient number for any complete analysis, yet they indicate somewhat the feeding habits of this notably predaceous animal. Thirty-two per cent contained adult menhaden, 18 per cent contained butter-fish, 10 per cent herring, 8 per cent squid, and 3 per cent young fish. Thirty-nine per cent contained nothing at the time of capture, although not much can be based upon the last fact, since this fish is well known to disgorge its food when captured by hook and line. Moreover, all that can be said of the food of the squeteague applies equally well to the bluefish, and as regards habits of feeding they may be in most respects associated together.

Another class of food of fishes may be illustrated by the sea bass (*Serranus atrarius*), which is a bottom feeder. Though only forty specimens were obtained in the period studied, they probably give a fair representation of the general feeding habits of the fish, and the results may perhaps be more easily considered if tabulated:

Date.	Sea bass examined.	Containing lobsters.	Green crabs.	Lady crabs.	Hermit crabs.	Amphipods.	Young fish.	Mollusks.	Nothing.
July 6	10	....	....	1 (2)	1 (1)	7 (very many)	....	1 (1 Crepidula)	1
7	4	....	3 (6)	1 (1)	1 (1)	....	....	1 (1 Urosalpinx)	....
18	2	....	1 (1)	1 (2)	1 (2)	1 (1)	....	1 (1 Solen)	....
26	5	2 (3)	....	3 (9)	....	1 (many)	....	....	....
28	7	....	3 (22)	1 (4)	....	1 (2)	2 (9 sculpins)	1 (1 Urosalpinx)	2
Aug. 3	1	....	....	1 (2)	....	....	1 (2 sculpins)	....	....
4	4	....	3 (5)	....	....	....	2 (2 sculpins)	....	1
6	4	2 (2)	3 (5)	2 (5)	....	....	1 (1 sand eel)	1 (1 Natica)	....
13	3	....	2 (8)	....	....	....	1 (2 sculpins)	....	1
Total.	40	4 (5)	15 (49)	10 (25)	3 (4)	10 (many)	7 (16)	5 (5)	5

NOTE.—The figures and words in parentheses denote the number of victims. The figures without parentheses indicate the number of sea bass containing such victims.

From this table will be seen how largely the sea bass depends for its food upon various crustacea; not a single fish containing food was without them, while most of the specimens examined contained many crustacea of several genera. The young lobster from the bottom is especially conspicuous with the other crustacea taken by the sea bass; four fish obtained by me contained five young lobsters averaging 5½ inches in length. Several specimens of young lobsters, all of about the same size, were also obtained from a fish-market at Vineyard Haven, where this fish is dressed. Young fish—but only those of strictly bottom habits—were also much preyed upon by the sea bass; also lamellibranch mollusks of several genera. The habits of this species are therefore eminently carnivorous, and yet its immediate food is widely removed from those species of fish heretofore considered.

A few specimens of two other of our migratory fishes were also examined to illustrate somewhat further the material used by bottom-feeding fish; these were the scup (*Diplodus argyrops*) and the tautog (*Tautoga onitis*). While only a few were examined, the various constituents seemed so constant, both in quantity and general make-up, that one may get a fairly good detailed idea of their food from studying a relatively few specimens. Thus in these rocky-bottomed localities, covered over with thick banks of algæ, the large simple alimentary tract of the tautog is almost invariably filled with lamellibranch Mollusca—*Solen*, *Mytilus*, and the like, together with many of the smaller similar forms—all of which have evidently been torn from their attachments and broken up by the sharp incisor-like teeth at the front of the mouth; the shells and all are consumed in incredible numbers by this sluggish hunter. The food of the scup, however, is somewhat more varied, comprising a wider range of victims, but of the same general character as belong to the bottom fauna. Thus one finds, in fish taken by hook and line, a great quantity of amphipods, some of the compound ascidians (*Leptoclinum*), many small lamellibranch mollusks, and at times very many of the sand-dollars (*Echinarachnius parma*) ground up with sand and deep black mud of the bottom from which they were feeding, just above which also the amphipods are usually so abundant.

Now, on the floor of these littoral waters the food of the lamellibranch mollusca is of course drawn from the microscopic organisms living suspended in the water above, which the animal obtains from the currents of water passing through its gills and mantle. The tautog, therefore, which consumes these molluscan victims to so large an extent, is only one step removed from their primary food supply of microscopic organisms, and is directly dependent upon such a supply, although not quite actually using it itself. So also the predaceous gastropods which feed upon other mollusks are directly conditioned upon the ability of some members of their food supply, by however many steps in the series they may be removed, to obtain the microscopic organisms from the surrounding water.

With regard to the great group of the Crustacea I have not yet had the opportunity of demonstrating the steps by which their victims are passed on from one form to another, from the primary feeders upon microscopic food up to the higher forms. They are fierce devourers of their own kindred at least, as may be abundantly proven if any one group—as the crabs—be investigated, for smaller species are constantly preyed upon by the larger. They are scavengers to some extent, as dead material comes to them, and they also secure the young fish alive when their size will permit them, but the necessity of masticating their food before eating makes the identification of the material harder to follow.

It is entirely probable that some vegetal feeders may be found among the adult crustacea, as is certainly true to some extent in *Panopeus*, but the larval history is without doubt largely conditioned upon the Protozoa and Protophyta, amid which the earliest free-swimming stages are passed. Vegetal feeders, indeed—i. e., those using marine algæ and the like—may exist in every large order of animals, but under the present conditions they are manifestly quite too few to supply the food material of the larger carnivorous forms, and we are inevitably brought back to a food supply similar to that of the menhaden, which forms the stable basis upon which marine animal organisms of all classes are laid. This is not a new fact, of course, but it is one which will bear demonstrating in many ways and under many circumstances. Professor Brooks has recently shown* how all marine life has been evolved out of these ancient pelagic conditions; and any rational and thorough consideration of fisheries problems must eventually descend in steady steps to them.

There have now been shown in several cases how marine food is elaborated, as it were, along different lines, from the primary sources of supply; the squeteague and bluefish stand farthest removed in one way, the sea bass in another, the scup and tautog less distantly in another. Many fish, such as the herring, alewife, and shad, fall into another group, since they use mainly the minute crustacea; and so the plan might be enlarged to include many other species, always leading back, however, to the microscopic basis which is so easily demonstrated through the feeding processes of the mussels and the menhaden.

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* The genus Salpa, p. 167.

II.—OBSERVATIONS ON THE PLANKTON OF BUZZARDS BAY.

In order to contribute toward a knowledge of the quality, quantity, life-history, and conditions of environment of this primary food supply, consisting of Protozoa, Protophyta, free-swimming larvæ and the like, many observations were made during the earlier part of the summer of 1894 with respect to the surface water in the larger harbor at Woods Hole, where collections of the organisms were systematically obtained from measured quantities of the water at different times of the day and tide, and under different conditions of temperature. Likewise, by means of the steamer *Fish Hawk*, which was provided with suitable apparatus for the purpose,* I was enabled to collect many samples from the waters of Buzzards Bay, not only at the surface, but also at mid-depth and at the bottom. A definite section was laid out across the bay (see plate 64, Stations I–V) and another running longitudinally (Stations A–D) through the same body of water some distance out to sea. These lines of section were divided into equal intervals with definite stations established, in order that a rigid system of representative localities might be followed, by a study of which a knowledge of the bay as a whole might be increased; and it is earnestly hoped that these studies may be but a preliminary to wider observations which may reveal to some degree at least the possibilities of such lines of research in the understanding of the biology of these littoral waters.

If one will dip up a small dish of sea water and place in it some bits of algæ scraped from a pile or an old float it will, especially if allowed to stand a day or two in the laboratory, present a wonderful complex of organisms of the most varied types. In order to express some of the ways in which the organisms in common sea water interact upon one another I have given in plate 65 some pen-and-ink drawings illustrating, as well as I could by these means, the comparative forms and sizes of some of the commonest types, under a magnification of about a thousand diameters. (A partial identification of these is given in the explanation of this plate.)

If, now, one can imagine all these organisms as seen alive under the microscope, there would appear the greatest diversity of habits. For instance, the large infusorian *c* glides swiftly and gracefully through the field, turning this way and that, bending with its flexible body around or under or over obstacles, stopping now at a colony of bacteria, now at a diatom, searching, as it were, for material suitable to its taste. As the cell is figured in the drawing it is occupied apparently in digging with its band of strong cilia at the colony of bacteria against which it rests; after remaining in this locality, even for several minutes, it suddenly turned about to the left, quickly ate the diatom there represented, and glided out of the field of vision.

Other infusoria are constantly appearing; thus the *Mesodinium m* represented in the center of the plate is a rapid mover by means of the strong blades of the membranellæ placed upon one face of it. This cell also is a strong swimmer and a predaceous consumer of many organisms inferior to itself in size. Just above the last-named cell are represented two flagellates, at *k*, whose flexible flagella give the characteristic rolling movement of the organisms. Three other small flagellate infusoria are

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* In addition to large funnels with detachable tubes, in which a film of sand is laid upon a roll of wire gauze (which closes the bottom end of the tube of the funnel), for filtering out the organic material, the large steam pump of the vessel was used in drawing up water from any desired depth through a 2-inch hose.

haunting the colony of bacteria at *i;* one of the two flagella on each, by its corkscrew movement, gives direction and motion to the cell, while the other drags along behind quite passive. These are very abundant; several may be in sight at the same time. Another infusorian, *n* is also prominent both by its strong cilia and its peculiar movements. One of these will suddenly appear in the field of the microscope and after remaining perfectly motionless for some time, except for the rapid rotation of a band of long cilia at the mouth end, will disappear with such a quick jump that with the high-power lens it can hardly be detected.

Besides these infusoria heretofore mentioned, which come and go in restless irregular sequences, there are other animal cells which are almost motionless, simply floating through the water, reaching out their long delicate protoplasmic threads, which entangle their prey upon all sides. Such an organism, for instance, is represented by the heliozoan at *g.* The perfect regularity of these radii in the living animal is very beautiful; each one of them is very sensitive to stimuli and capable of a slow regular withdrawal into, or further extension from, the parent cell at the center. One also may see the numerous irregular thickenings upon very many of these threads, especially if the organism is actively feeding. The cell figured has in its grasp two of the small flagellates which came into contact with its outlying snare, and were thus, very slowly at first and more rapidly as they neared the cell, drawn into the material of the central organism. This particular heliozoan in twenty minutes had in this way consumed three of these small flagellates and captured a fourth. The process of engulfing one of these small food particles is very interesting to the observer; the whole organism stretches out to meet it (as it draws near the central cell) along the lines of the radius upon which it was captured, but all the processes are very gradually carried out, and the globular form of the central mass is not much disturbed notwithstanding the active streaming of the protoplasm in the direction of the victim.

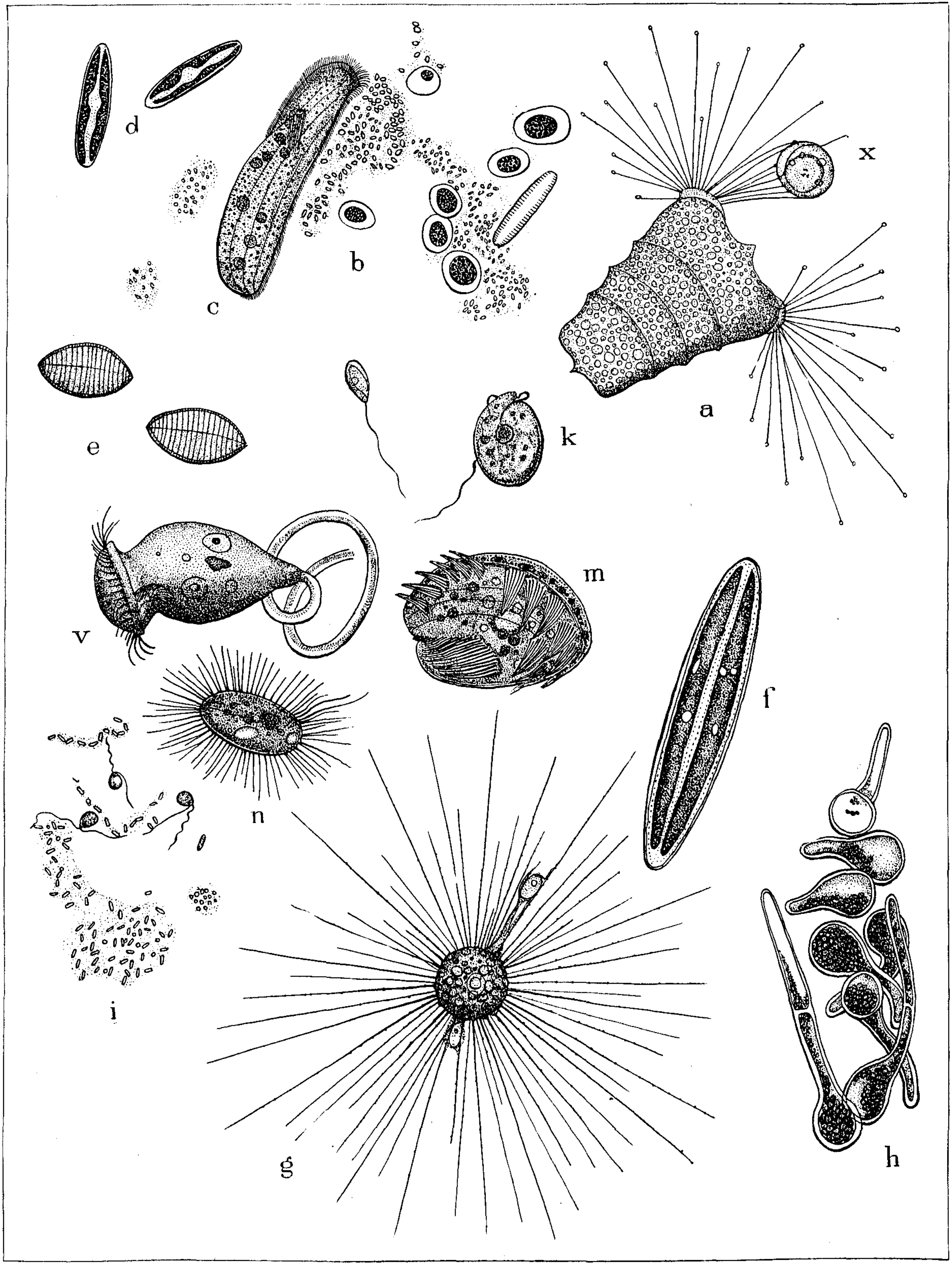
One other organism of similar plan is represented at *a.* This is the infusorian *Acineta*, from whose test the protoplasmic filaments, each tipped with a delicate knob, project only at definite corners. This, too, ensnares its prey at a considerable distance, penetrating its victim with the strong pseudopodia, by which the food particle is ingested by the central mass. The particular *Acineta* figured is represented as reproducing itself by a kind of budding, the daughter cell *x* being derived from the mother organism through one corner, where the protoplasmic "tentacles" are thrust out. The young one will then lead a free-swimming life for a season in passing to the adult condition. Yet another type of the marine infusoria may be illustrated by the stalked *Vorticella* (*v* in the plate). This can range about over a relatively quite large area, being tethered, as it were, and securing safety by the quick contraction of the stalk. Food is brought to the organism in two large vortexes of water, caused by the rapid rotation of the collar of strong cilia. One can see particles of material thus drawn down into the mouth, and when those are secured which are fit for food they are quickly retained. The cell is always exceedingly sensitive and quick in all its motions. One often sees them attached to the shells of copepods, by which they are carried about and secure a greater range of locomotion and area. Under the microscope the vortexes of water may be readily seen by the small bits of material carried in them, which are thus swept in toward the organism.

Vegetal organisms of course constitute a very large part of the material bred in such a portion of water as is here considered. Especially numerous are such diatoms as are represented at *f* and *d*, which have the characteristic gliding motion back and forth over the field among the other organisms. Great bunches of stalked forms, of free-living species, of bundles, and chains of many varieties of these could easily be added from other positions on the field under consideration, and they form also the prey of organisms larger than themselves. Colonies of bacteria, especially in their zooglea investment, are everywhere visible, and at the time when this material is represented the alga at *h* had overspread the entire inner surface of the glass. Some of the resting cells are shown at *b*, some of the germinating ones at *h*. Among these bunches of growing algæ are the favorite resorts of many of the organisms heretofore described.

If one can imagine the figures of plate 65 to be moving about upon the field of a microscope, each one according to its characteristic habits of living, feeding, and reproducing by division of each cell into two or more, among much other growing algæ, with débris of different kinds, then some idea might be gained of the wealth of life which inhabits, or may inhabit, ordinary sea water in the place where this small quantity was taken. Just as the piles of the wharf are occupied by small animals of different orders—the creeping nudibranch mollusks and amphipods crawling around among the algæ and Hydrozoa for food—and as these comprise many forms which branch out to ensnare their prey, as hydroids and sea-anemones, and are associated with many other sessile forms which create currents of water by strong appendages thus to bring themselves food—such as the barnacles and Bryozoa—all intertwined with a small forest of delicate algæ of several tints and many forms; so also if we increase our powers of vision in the same places the same story is seen to be repeated by a much more numerous and diversified series of forms, of similar adaptations but so small as to be quite unsuspected in our ordinary means of observation by the unaided eye. They also consume each other in the same manner, and themselves in turn become the victims of other and larger foes.

I have therefore figured these organisms heretofore described, and mentioned something of their habits in their environment, not with the view of adding new scientific descriptions or drawings to those already given by others, but rather to graphically call attention to the aggregate meaning of this kind of living organisms in their particular associations, such as make them and their cogeners the broad staple food basis upon which marine life hangs. The presentation of a few of these forms gathered from a few drops of water especially selected, may naturally lead to the consideration of the wide range of similar forms of life which one may ordinarily gather from the surface of the littoral waters of these localities, and may thus help to bring about an understanding of some of the ways in which they are interrelated, what precede and what depend upon them, and some of the conditions regulating the problems of their distribution. To do this at all broadly is at present impossible, but observations upon the quantity of material may be one of the steps in the process of understanding some of the other features attending the study, and it is the purpose of the following account to describe such a series of quantitative observations.

Some of the vegetal micro-organisms, on account of the definite investment of the cell, as the siliceous skeleton of the diatoms, or the thick sculptured wall of the Peridinia, are the most readily preserved and distinguished in material filtered out from the water; moreover, they are eminently characteristic of given localities and exceedingly abundant. The following illustrations of the distribution of marine organisms are drawn therefore from them, to include also of minute crustacea only the copepods



This plate illustrates organisms very abundantly found in common sea water that has stood a few days in an open, shallow dish. *a*, *Acineta* with embryo budding off; *b*, resting *spores of Alga*, with bacteria; *c*, *Chilodon; d*, small *Navicula; e*, *Cocconeis; f*, larger species of *Navicula; g*, heliozoan, with two entrapped infusoria; *h*, germinating Alga cells; *i*, small colony of bacteria in zooglea stage, with small flagellate infusoria near by; *k*, flagellate infusorian; *m*, infusorian, *Mesodinium; n*, ciliate infusorian; *v*, *Vorticella*, with small portion of its stalk. Magnified 1,000 diameters.

PLATE 66.

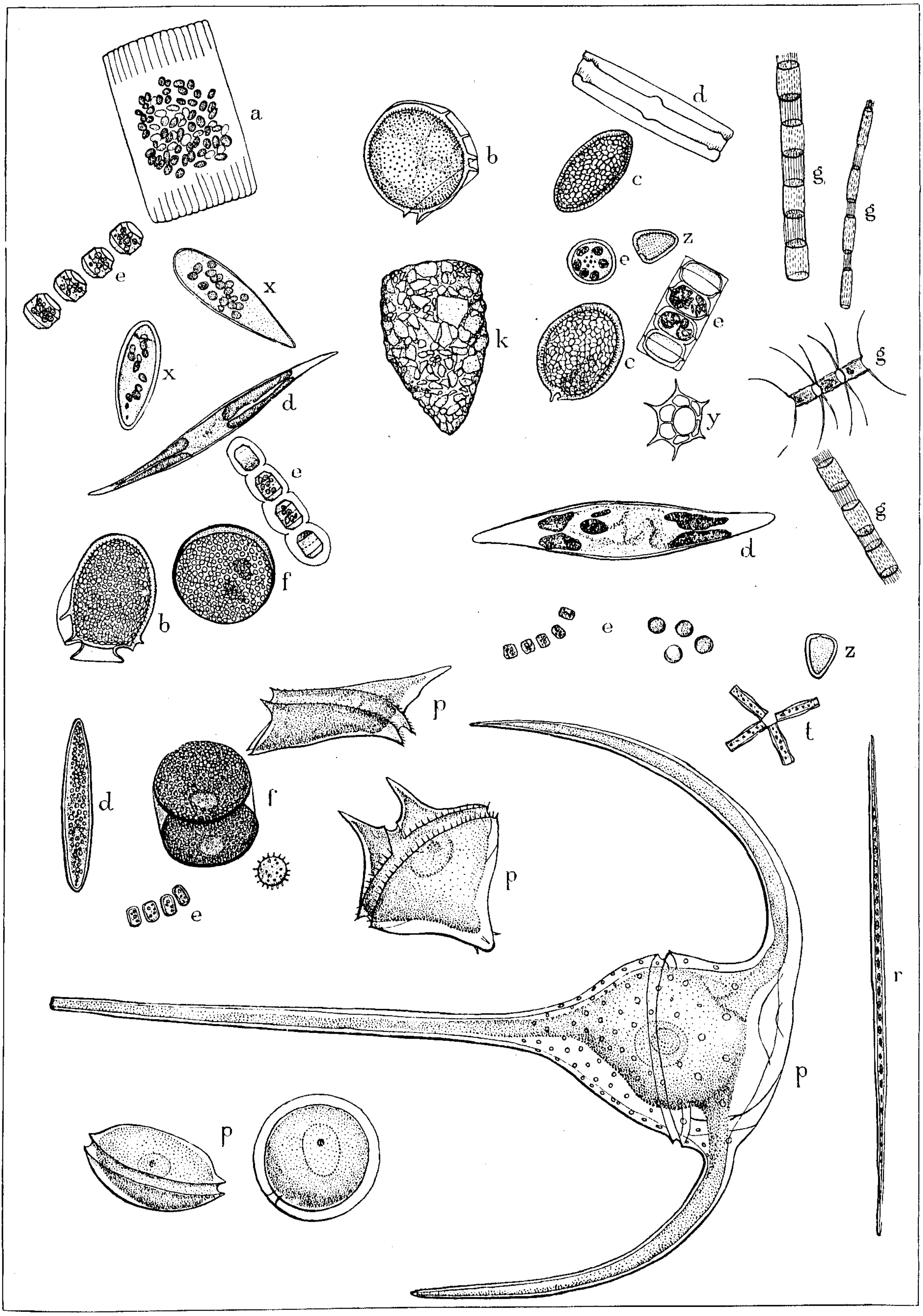
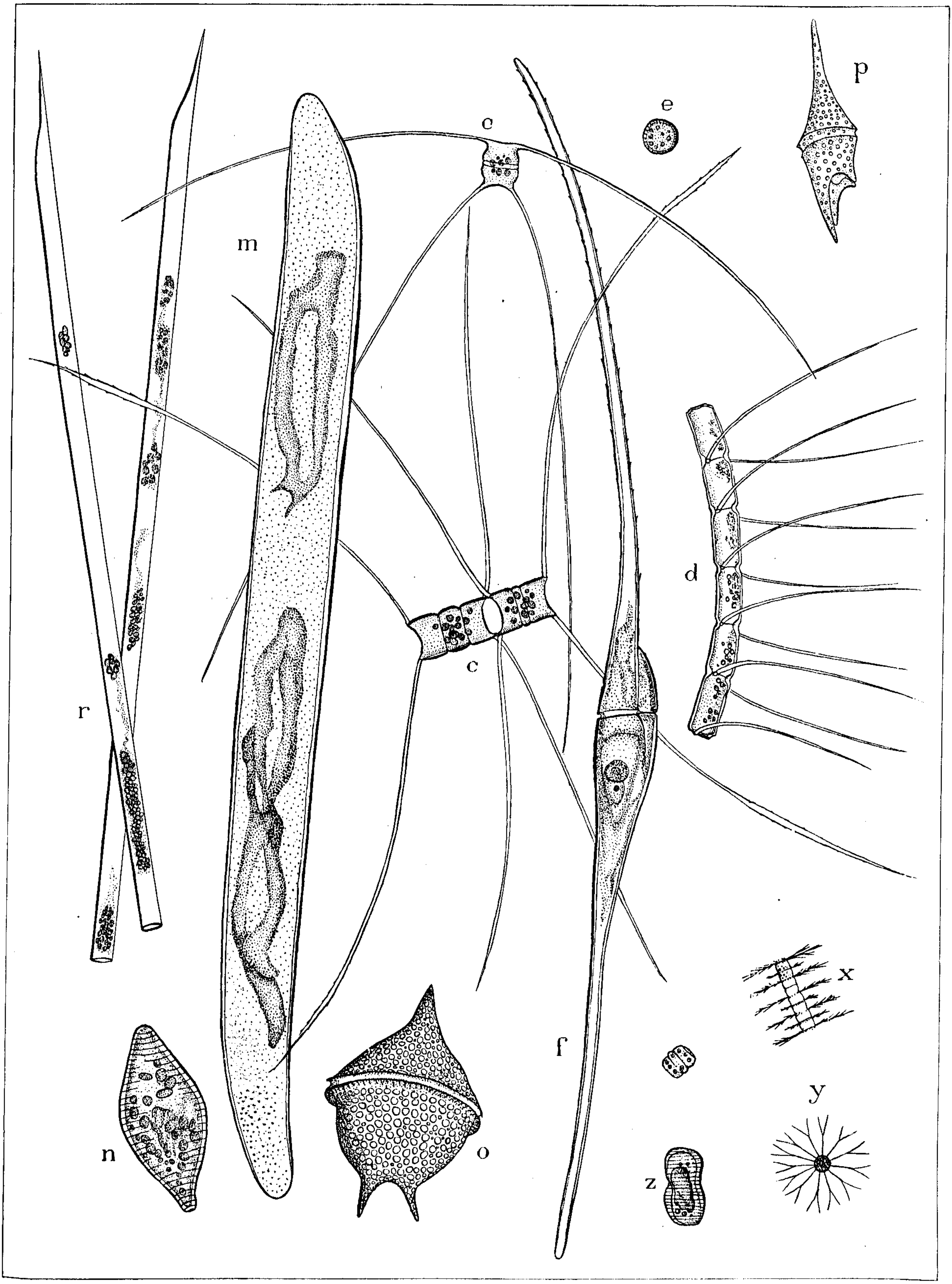


Plate 66 illustrates organisms common in the Plankton of Buzzards Bay, most of which enter into plattings represented on plates 68–71. *a*, *Striatella;* *b*, *Dinophysis;* *c*, *Exuviælla;* *d*, *Stauroneis*, *Pleurosigma*, *Navicula;* *e*, *Melosira*, *Cyclotella;* *f*, *Coscinodiscus;* *g*, *Melosira costata*, with small *Chætoceros*, called *Chætoceros* in the text of this paper and in the plattings; *k*, *Codonella;* *p*, *Peridinium* and *Ceratium;* *r*, *Homœocladia;* *t*, *Tabellaria;* *x*, *Surirella;* *y*, *Dictyocha;* *z*, unknown diatom. Magnified 500 diameters.



Organisms common in Plankton of Buzzards Bay, continued: *c*, *d*, *Chætoceros*; *e*, *Melosira*; *f*, *Peridinium fusus*; *o*, *P. divergens*; *p*, *P. fusca*; *m*, *Pleurosigma*; *n*, *Navicula*; *r*, *Rhizosolenia* divided into two parts; *x*, *y*, side and end view of *Chætoceros* chains (little magnified); *z*, *Pinnularia*. Magnified 500 diameters.

as being of wide and abundant distribution and ready recognition. Such selections of organisms of course will leave out many important details of distribution, for if all the animal organisms, larvæ, other infusoria and the like, could be determined at the same time with these plant cells and flagellates, the two kingdoms would perhaps show many interrelations. But a study of these few vegetal organisms and Infusoria alone, in Buzzards Bay, will give some of the manifold characteristics of the Plankton of such a body of water. The bay itself is shallow, with broken shore line (see plate 64), fed by many streams, of very uniform bottom, and not subject to marked tidal changes.

There are also represented upon plates 66 and 67, under a magnification of 500 diameters, some of the chief representative organisms to which the following accounts of distribution and quantity apply. In the tabulated estimates several genera are grouped together under one heading in order to simplify the plattings of quantities. Thus the group *Melosira* includes all those lettered *e* in plate 66, the small *Cyclotella* being classed with the other and larger forms; in estimating this group the actual numbers of individuals is taken, although they are often laid in short chains. So also the estimated *Peridinia* are based upon the forms *p* (plate 66), *o*, *p*, and *f* (plate 67). *Chætoceros* takes in not only the larger forms represented at *c*, *d*, *x*, *y* of plate 67, but also the forms at *g* (i. e., *Melosira costata*) on plate 66, since it is impossible, with the low power used in making these estimates, to distinguish perfectly the finer structure of these small chains, and the chain of *Melosira costata*, usually about the length represented in the upper *g*, is so similar in appearance under a low magnification to that of short chains of the small *Chætoceros* that they were classed together in platting. This of course is an unfortunate complication in grouping and counting, and it is to be remembered that the *Chætoceros* hereafter discussed includes at times almost wholly the ones here designated at *g*, plate 66, i. e., principally the small *Melosira costata*. The *Navicula* group is inclusive of all the diatoms of that general outline—*Pleurosigma*, *Stauroneis*, and the like, at *d* of plate 66, *m* and *n* of plate 67. *Rhizosolenia* includes only *r* of plate 67 (one individual being divided into two equal parts in this drawing). Many *Exuviællæ* are normally present, as *c* of plate 66. The infusoria *Dinophysis* (*b*) and *Codonella* (*k*) are also readily preserved and were estimated, but the results are not tabulated. Many other organisms of course were common, some of which are here represented, while a partial classification of each one will be found in the explanation of plates at the close of this paper.

Suppose now that the ship start from Station A (plate 64), at the upper extremity of the bay, at 11.35 a. m., September 27, being low-water slack, upon a course running the length of the bay and out some distance to sea (along the course A B C D, plate 64). As the vessel proceeds over her course she encounters the incoming tide, therefore meeting in succession any changes which may be caused by a Plankton drifting in from outside waters. Three samples—surface, mid-depth, and bottom—in a vertical, are taken at each station, from which the organisms are filtered and their results tabulated. At the surface of Station A (see plate 68) are found countless numbers of the diatoms, which will be classed with *Chætoceros* (being in reality *Chætoceros* plus the small *Melosira costata*), the relative numbers of which were so numerous that they could not be limited by the scale here used in platting the distribution. At mid-depth and bottom (4 fathoms) of Station A are also found great quantities of these same diatoms, insomuch that other organisms are relatively few indeed. In the first 8 miles of the course, however, from Station A to B, there is a marked diminution in this group of plant cells, so much so that in the vertical taken at Station B (6 fathoms) there are only about a tenth as many as in the former instance, which dimunition affects the numbers at surface, mid-depth, and bottom in about the same ratio. In the same 8 miles, however, that mark the lessening of *Chætoceros* there is a very notable increase of the round diatoms which are here classed together as *Melosira;* there are thus at Station B more than ten times as many as were previously obtained at A, this increase also affecting surface, mid-depth, and bottom numbers of *Melosira* in about the same ratio. In like manner all the other organisms here estimated (i. e., *Peridinium*, *Exuviællæ*, *Lauderia*, *Rhizosolenia*, *Navicula*, with the copepods) show at B an increase over the quantity at A, this being especially true of the *Peridinia* and *Exuviællæ.*

As the ship advances now to Station C (8½ fathoms), another distance of 8 miles, against the flowing tide, there is again a further diminution, not only of *Chætoceros* forms, but also of most of the other organisms, except the copepods and the large diatoms, *Lauderia* and *Rhizosolenia*, which increase at about the same rate for surface, mid-depth, and bottom distribution, while it is to be noted that *Lauderia* becomes very abundant at the bottom of this vertical at C.* From C, however, out to the last collecting-point of the day, D, 9½ miles, there is a general diminution of all the organisms except the copepods, which as regularly increase, until at the close of the course the organisms obtained from the given samples of water in the vertical at D are much fewer than they were at the outset from A. The *Chætoceros*, which was so abundant at A, is all but absent at D, while all the other organisms except copepods have suffered very marked changes. It is to be noted also that Station D is nearly four times as deep as A, that the mean temperature of the water is 4° colder, and that the amount of microscopic organic débris in suspension (flocculent, yellow-colored, "amorphous" matter) at D is relatively very much greater than it was at A.

In order to express the exact relations which these kinds of organisms bear to each other as regards quantity, at the different points studied in this representative section, reference is made to plate 68, which is a platting of the relative numbers representing each kind of organisms in their distribution at surface, mid-depth, and bottom. The plan of platting adopted on plates 68–71 in illustration of the planktonic distribution is plain. All the organisms used are placed in separate columns under each of the respective stations—A, D, etc. The three collecting points in a vertical—i. e., surface, mid-depth, and bottom—are so placed in order at each station, while the relative abundance of each of the factors may be read by the numerals graduated upon the left-hand margin of the plate. The relative quantities of all the organisms are constantly maintained, except that the copepods are a hundred times multiplied as compared with the others, as will be explained hereafter, while the quantities of *Melosira* are so great that one-half their relative number is used upon the plates; their whole number, however, is given in the tables in the text following. In order also that comparisons may be made from the totals of these organisms at the different points, the following table is inserted:

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* The large species of *Lauderia* here referred to are not figured in plates 65 and 66, and Prof. Hamilton Smith, of Geneva, N. Y., informs me that it is an unusual if not new species. The same gentleman, who has done me the great kindness of studying the tangle of *Melosira costata* and *Chætoceros* found at Station A, as above described, says that he has never before seen those forms from American shores, and that they have been hitherto regarded as characteristic of Oriental—especially Chinese—waters, but that he has detected them in the waters of the Firth of Say, Scotland.

Letter M, September 27, 1894, 11.35 a. m. at Station A, low-water slack; reaching Station D at 3.20 p. m., third hour of flood tide; wind southeast, force 5; sky partly cloudy.

Organisms.	Surface.	Middle.	Bottom.	Stations.			
				A	B	C	D
Copepods	23	13	13	7	8	10	24
Peridinium	53	22	20	10	43	30	12
Exuviælla	57	49	51	24	64	50	19
Chætoceros	1, 424	758	407	2, 241	240	104	4
Melosira	339	230	202	40	439	269	23
Lauderia	25	29	33	....	18	62	7
Rhizosolenia	19	23	20	7	23	30	2
Navicula	23	29	20	12	29	26	5
Total	1, 940	1, 140	753	2, 334	856	571	72
Average temperature (°F.)	....	....	....	66. 1	66. 5	65. 3	62
Depth (fathoms)	....	....	....	4	6	8. 5	15

In this table the copepods are estimated upon a different basis and are therefore not added in making up the totals. Otherwise all the organisms of the surface of all the stations are added into the first column of numbers, all those from the mid-depth into the second column, and all those from the bottom into the third. So also the same numbers are properly distributed according to their occurrence at the respective stations A, B, C, D, the total sum of the surface, mid-depth and bottom being represented in each number. Such a table shows in the first place that the sum total of all these organisms at the surface is greater than those of mid-depth, which latter are in turn more abundant than those of the bottom. Also that this is the rule for each separate factor of the series except the *Exuviælla*, least at mid-depth, and the *Lauderia* forms, which are slightly most abundant at bottom, and the *Rhizosolenia* and *Navicula* forms, which are most abundant at mid-depth. Similarly the sum total of all the various groups of organisms at A is much greater than at any of the succeeding stations, the numbers diminishing very rapidly, especially between A and B, and between C and D. It is to be noted, however, that this remarkable abundance of material at A is due very largely to the item *Chætoceros*, with its abundant *Melosira costata*, and if this be left out of the calculation, Station A will be seen to be next to D as regards numbers, being much less than either C or B. Station B is the richest in these organisms, all reaching their maximum excepting *Lauderia* and *Rhizosolenia*, which increase to Station C, especially at bottom. The *copepods* also increase most rapidly from C out to D. All of these features are analyzed into their component parts by the platting on plate 68, from which the distribution of these several forms may be compared.

The same section run three days earlier is represented in the same way by the platting on plate 69, and the totals of the organisms by the following table:

Letter K, September 24, 7.45 a. m. at Station A, low-water slack; 11.53 a. m. at Station D, third hour of flood; wind north-northwest, force 5; sky clear.

Organisms.	Surface.	Middle.	Bottom.	Stations.			
				A	B	C	D
Copepods	13	5	6	4	2	6	12
Peridinium	59	13	7	14	23	38	4
Exuviælla	65	39	25	38	36	52	3
Chætoceros	1, 891	1, 273	1, 126	3, 609	610	67	4
Melosira	266	91	60	87	170	146	14
Lauderia	21	8	13	....	2	25	15
Rhizosolenia	24	11	14	5	12	31	1
Navicula	19	18	30	14	18	31	4
Total	2, 345	1, 453	1, 275	3, 767	871	390	45
Average temperature (°F.)	....	....	....	70. 5	69	67. 5	64
Depth (fathoms)	....	....	....	4	7. 5	7. 5	15. 5

Here again there is the greatest quantity of *Chætoceros*, which extends out to Station C in such quantities that the scale used in platting (see plate 69) can not represent them at the surface or mid-depth until they fall to a relatively small figure at Station C, while from this point on to D they steadily diminish to a minimum, so that *Chætoceros* of surface Station A stands related to surface Station D as 3,609 is to 4, while mid-depth and bottom samples indicate the same relations, though to a less marked extent. So also, as in the section before described, the diatoms *Melosira* culminate at Station B, while all the other forms culminate at C, diminishing gradually to D, which is relatively poorest in vegetal micro-organisms, but richest in *Copepoda.* At this date also the water at Station D contained very much of flocculent organic débris, more by far than was found at any of the other points studied.

Reference also to the preceding table (Letter K) shows that of the totals of all the organisms considered, the greatest number is to be found at the surface, a less number at the mid-depth, and the least number at the bottom, even in the shallow waters here under observation. This is not, however, true of each individual factor in the series, since some of the items of bottom distribution are greater than that of the same organisms at mid-depth or surface distribution, as is apt to be the case with *Lauderia*, *Navicula*, and *Rhizosolenia* groups. It is also true that the greatest quantity of total organisms is found at Station A, diminishing in regular sequence as one proceeds out to D, where very few are met with. This aggregate, however, is of course determined largely by the great numbers of *Chætoceros* in the first two stations, while if these be omitted in the reckoning the organisms will be seen to be most abundant at Station C. The relative vertical distribution, however, remains the same, being greatest at surface and least at bottom. Here also the *Lauderia* are most abundant some distance from the shore and at mid and bottom depths. The copepods also are most abundant at Station D. In all the essential features, therefore, these two sets of observations agree as to the way in which these organisms are disposed through the water.

The same section was also studied at a still earlier date (September 13), but an unfortunate loss of the material taken from mid-depth at Station A and surface at Station C rendered the observations too incomplete for platting for comparison. Nevertheless, by representing the missing sample in each case by the one next below it, the compilation has been finished and is given in the following table:

Letter E, September 13, 1894, 12.20 p. m. at Station A, low-water slack; 4.40 p. m. at Station D, three-fourths flood; wind southwest, force 3; sky clear.

Organisms.	Surface.	Middle.	Bottom.	Stations.			
				A	B	C	D
Copepods	14	6	5	6	13	1	5
Peridinium	33	29	24	8	44	26	8
Exuviælla	78	89	53	20	108	69	23
Chætoceros	191	174	160	304	56	137	28
Melosira	421	315	268	148	484	299	73
Lauderia	34	111	76	....	7	11	203
Rhizosolenia	42	32	22	4	13	37	42
Navicula	37	30	22	18	27	37	7
Total	836	780	625	502	639	616	384
Average temperature (°F.)	....	....	....	69. 8	69. 3	67. 7	63. 3
Depth (fathoms)	....	....	....	3. 5	3	8	15. 5

Although I do not think it is safe to depend upon all the relative details of this table on account of the two deficient samples, yet certain conclusions are evidently admissible. In the first place even the two available samples of the vertical taken at Station A show beyond a doubt that the *Chætoceros* had not then attained at that locality the great abundance which they showed at the later dates heretofore described, while at all the succeeding stations they extend much farther from the shore in considerable quantities, as at B and C, and at D in much greater proportion than they did two weeks later.

It is also to be noted that *Lauderia* was at this earlier date much more abundant than on the two subsequent dates described here, being by far the most characteristic organism at Station D; of 78 bottom organisms at this locality, 70 were *Lauderia* of one, or at most two, species. There was at this time also relatively very little of the flocculent amorphous débris suspended in the water at Station D.

The above table also shows the increase of micro-organisms at Stations B and C, and agrees with the two preceding ones in showing more organisms at the surface than occur at either mid-depth, or at bottom where there are least.

The extent to which the Plankton of Buzzards Bay may be shifted by the tidal currents might be tested by running this same longitudinal section on an ebbing tide by which the ship would register a somewhat different set of conditions from those here recorded, while the line should be extended out as far at least as the Gulf Stream (60 miles distant) in order to show the relation between the offshore and littoral quantities and distribution of these and other forms as they might occur.

The section across the bay (plate 64, Stations I–V) was designed to get as near a synchronous series of observations as was possible upon any given tide or fraction thereof. The whole distance was divided into four equal intervals, the stations being then about a mile and a half apart, and a vertical of surface, mid-depth, and bottom samples was taken at each station.

Letter N, shown by the platting on plate 70, represents the distribution of this material under consideration in a cross section of Buzzards Bay on the day following the longitudinal section given on plate 68, and there is a great regularity in the results obtained. The irregularity is confined almost entirely to the one group *Chætoceros* (plus the *Melosira costata*) which from Station IV begin to increase very rapidly for the last mile of the course to Station V at surface, mid-depth, and bottom samples in the same manner, until at the last collecting point, Station V, they form by far the greater part of the aggregate organisms and, as in previous instances of the kind already cited, the other organisms are especially few.

Of such other organisms except *Chætoceros*, the general rule is that they gradually increase as one approaches the middle of the section, and then decrease again as the other limit is reached; this is especially noticeable in the group *Melosira*, which is the chief element as regards abundance and continuity in occurrence in these cross-section analyses. The copepods also conform to the same distribution, i. e., are more abundant at the middle portion of the bay than at either end.

The following table gives the arrangements of the total organisms for each group in their proper order at the several stations:

Letter N, September 28, 1894, 3.10 p. m.; low water; wind east-southeast, force 5; sky clear.

Organisms.	Surface.	Middle.	Bottom.	Stations.				
				I	II	III	IV	V
Copepods	26	14	11	7	19	16	7	2
Peridinium	52	20	15	14	14	24	23	12
Exuviælla	51	33	37	14	32	39	19	17
Chætoceros	1, 626	577	495	217	226	175	285	1, 795
Melosira	376	268	282	151	200	274	192	109
Lauderia	24	16	15	17	21	14	3	....
Rhizosolenia	27	20	26	34	8	17	9	5
Navicula	83	51	76	35	52	52	31	40
Total	2, 239	985	946	482	553	595	262	1, 978
Average temperature (°F.)	....	....	....	67	67	67	67	67. 5
Depth (fathoms)	....	....	....	3	7. 5	6. 75	5. 75	4. 5

It is again here seen that the greatest total of the organisms is located at the surface, an intermediate quantity at mid-depth, the least at the bottom, while *Melosira*, *Rhizosolenia*, and *Navicula* have a tendency to increase at bottom distribution, as has been previously demonstrated by the tabulated results of the sections taken longitudinally, letters M, K, and E, through this body of water; also that the greatest number of organisms in a given vertical are found at Station III, if one excepts the one item of *Chætoceros* at Station V. Taken in connection with letters K and M, heretofore described, one can infer that there is at these dates a belt of water next the shore line which is heavily charged with the minute *Chætoceros* (plus *Melosira costata*), which here far exceed in number all the other organisms of the verticals in which they occur taken together, but which rapidly disappear as one gains the more open waters of the bay. It may be presumed also that this belt extends far around on the eastern shore, but the swift tides which sweep over Station I make the conditions there very different from those obtaining at the other end of the section, i. e., at Station V.

The only collecting done by the *Fish Hawk* at nighttime over this course is given in the cross-section Letter H (low water), of which the platting on plate 71 represents the distribution of the organisms. This section presents the greatest irregularities in distribution of any one studied, and thus offers many contrasts to the previous instances cited, due, I think, to the removal of the influences of daylight.

In the first place one notices especially the irregularity of the distribution of the *Melosira* group, which seem to lie in a thick windrow, especially at bottom, at Station II, although they are otherwise quite abundant and quite regularly distributed. So also the *Chætoceros*, which are relatively so few that no attempt was made to express them on the platting except at Stations IV and V mid-depth and bottom), seem to lie in a stratum at middle depth of Station IV and shade away toward the bottom of Station V. Otherwise there is considerable regularity in the distribution of the organisms, with a tendency now to increase at Station II, instead of at Station III as was the case in the cross section heretofore described. The copepods are very uniformly distributed, being most abundant also at surface.

The following table presents in order the classified distribution of total organisms of this cross section:

Letter H (low water), September 18, 1894, 2.45 a. m., low-water slack; wind north-northwest, force 2; sky overcast, hazy.

Organisms.	Surface.	Middle.	Bottom.	Stations.				
				I	II	III	IV	V
Copepods	24	9	5	7	9	7	6	9
Peridinium	76	59	27	20	45	32	29	36
Exuviælla	143	112	154	91	103	52	79	84
Chætoceros	14	119	59	2	12	5	99	74
Melosira	652	592	1,160	340	1,081	325	384	274
Lauderia	14	16	20	32	7	8	....	3
Rhizosolenia	46	25	38	64	22	9	4	10
Navicula	58	68	89	34	63	39	33	46
Total	1,003	991	1,547	583	1,333	470	628	527
Average temperature (°F.)	....	....	....	68.1	69	69	69.1	69
Depth (fathoms)	....	....	....	4	7.5	7	6	4

From this table the irregularity of distribution is plainly illustrated, this being the first instance in which the surface organisms have not exceeded in quantity the mid-depth or bottom. This is evidently due to a withdrawal of organisms from the surface, while the peculiarly obscured condition of the light may be held responsible for the failure to become as regularly localized as is usual, as well as for the change from the ordinary daytime vertical arrangements in such a way as to well illustrate the effects of heliotropism, or rather the lack of the same, for the influences of so little light would produce weak results except in such organisms as the freeswimming larvæ or copepods. This is well shown by the copepods, for in this cross section taken at nighttime 85 per cent of the whole number observed are found at the surface, while in all the other observations, taken as they were at daytime, only 52 per cent on an average were found at the surface. The night in question was unusually dark, with a thick haze, and in the shallow water of this bay the much disturbed vertical distribution would be expected except in the case of such organisms as the copepods, which can most easily change their location in the water, and are known to be so abundant normally at the surface during the nighttime. It is also fair to suppose that even the normal nighttime distribution would be materially affected by such extreme darkness as was experienced upon this course.

This same section was retaken on the following forenoon and on high tide water with results represented by the following table:

Letter H (high water), Sept. 18, 1894, 10.35 a. m., high-water slack; wind NE., force 3; sky cloudy.

Organisms.	Surface.	Middle.	Bottom.	Stations.				
				I	II	III	IV	V
Copepods	10	5	4	9	2	1	3	4
Peridinium	100	46	43	3	64	23	57	42
Exuviælla	141	132	113	40	162	73	44	67
Chætoceros	102	81	39	16	32	9	21	144
Melosira	550	408	485	234	428	302	281	198
Lauderia	4	7	24	11	12	8	3	1
Rhizosolenia	40	44	31	12	20	21	6	6
Navicula	54	59	87	49	47	27	40	37
Total	991	777	822	365	815	463	452	495
Average temperature (°F.)	....	....	....	68.3	68.5	69	69	69.3
Depth (fathoms)	....	....	....	4.5	8	7.5	7	5

The preceding figures were compiled from material in which two samples were missing, but inasmuch as they were one surface and one bottom, a mid-depth in the same vertical was used in the stead of each, and I believe the general results are very little disturbed. It here appears that on the return of daylight the organisms are again arranging themselves in the relations previously described, there being more total organisms at the surface than at either mid-depth or bottom, and while the total at bottom still exceeds those at mid-depth, this is due to the diatoms, which usually show this peculiarity of increasing at bottom, i. e., those here grouped as large species of *Lauderia* and *Navicula*. It is also noteworthy that in this series the copepods are not so abundant as they were in the preceding instance—i. e., the same section taken at low water at nighttime. The vertical at Station II also shows the most organisms on this series; and for all the stations the *Melosira* group is the most important factor, as it was likewise in the series taken eight hours earlier on this same date.

I had fully expected to find a section taken at high water, or on a strongly flowing tide, to be richer in these organisms than the same section taken at low water, but such has not proven to be the case. This is perhaps explained by the fact that as the longitudinal sections of Buzzards Bay show a marked decrease in this material as the open waters of the ocean are approached, so also a strong incoming tide in these shallow depths would tend to materially affect the numbers of organisms at the center of the bay by bringing in a great bulk of water from the outside, which is relatively poor in these. As this tide drifts out again the aggregate material is brought out from more inshore localities, thus increasing the amount of material in low-water analyses as compared with those taken at high water.

In all that has thus far been proposed concerning the quantitative analyses of these organisms, the actual number per liter of ocean water has not been given, for the reason that the numbers tabulated were the ones actually observed under the microscope, from which the numbers in any given quantity of water must be estimated. The relative estimates here given are obtained in the following way: Five liters of water at each sample were filtered through a film of fine white sand at the bottom of a large funnel, the filtrate of organisms remaining upon the sand was then gently washed off in a small quantity of sea water and treated with a strong solution of formalin; when the material had thus been killed and had entirely settled to the bottom of the vial, the first formalin was decanted off and a fresh solution added, until the bulk of the formalin, including the filtrate, stood at just 15 cubic centimeters. Thus the organic material in a bulk of 5,000 cubic centimeters of water is collected into a bulk of 15 cubic centimeters of preservative, i. e., 333⅓ cubic centimeters of sea water are represented by every 1 cubic centimeter of the preserved material. The separation of the material—the filtrate—from the sand required the greatest care, but certainly all our errors were on the side of underestimation, inasmuch as we could not exaggerate the amount of organic matter in each 5,000 cubic centimeters of water used, and great pains were taken to transfer all the organisms from the sand to the preservative without loss. All the material here studied was collected in exactly the same manner by the same apparatus and persons.

The next step in the estimation is to compute the number of organisms in one cubic centimeter of the preserved material, and this was done by means of the "Rafter cell" and micrometer (1 inch) eye-piece, the latter being so graduated into squares that one square in the eye-piece views a thousandth part of the surface of the 1 cubic centimeter, arranged on the stage of the microscope in the "cell"; for as the Rafter cell is 1 millimeter deep, to 1,000 square millimeter surface, each field of the eye-piece micrometer estimates 1 cubic millimeter out of the total 1,000 cubic millimeters inclosed in the Rafter cell; that is to say, as one counts the number of organisms in any one field of the microscope (a two-thirds inch objective being used) it represents a one-thousandth part of the 1 cubic centimeter of filtrate under consideration.*

The practice was observed of carefully studying over the entire field and then of tabulating the organisms from ten representative fields of the instrument, and these are the numbers given in the foregoing tables except the copepods, which were so few relatively and so large that it was my practice to count them with a lower power objective in the whole one cubic centimeter of filtrate under study. They are in numbers, therefore, *one hundred times multiplied* as compared with the other material tabulated. Two cells were always used in order to get a more complete representation of the 15 cubic centimeters of filtrate, and 20 or even 25 squares were counted from each 1 cubic centimeter in the Rafter cell until it was found that those averages did not very materially differ from the estimates based upon 10 squares, which were therefore finally taken as the basis of tabulation.

The *actual quantity of organisms per liter* of littoral ocean water as computed by these data must therefore be obtained *by multiplying each of the factors heretofore used in the tables (except the copepods, which must be multiplied only by 3) first by 100 and then by 3.* This gives the actual numbers of organisms in the normal ocean water as something truly wonderful, and I shall hope to substantiate or correct these estimates in the future, but for the present am convinced of the reliability of the comparative results, both because the material was handled so systematically in the same ways throughout and because the end results compare so regularly.

In order also to make these estimates as representative as possible those organisms were selected, as has been before stated, which were most numerous and of constant occurrence in the material as it came under the microscope, and which were provided with such skeletal elements as would resist dissolution in the process of filtration and preservation. And it is for this reason that although continual records were made of various other genera of infusoria, no general conclusions were based upon them, since they die so easily and wholly disintegrate. So, also, other diatoms of less usual occurrence were systematically recorded, though not given a place in the tables presented. All these plankton analyses, moreover, were made at the biological laboratory of Williams College during a busy term of teaching, at intervals, and the facts merely recorded and put on file, and it was only as such a study of the material was completed that the platting and tabulation were done, and then for the first time were the relations of the organisms seen.

These facts, and especially the harmony of surface, mid-depth, and bottom observations at each point acting as checks upon each other, give evidence as to the truth of the distribution shown. The truth is all too partial, no doubt, even for the organisms cited, to say nothing of the whole series of animal organisms which were associated with them in their natural environment. But I am convinced of the value of numerical

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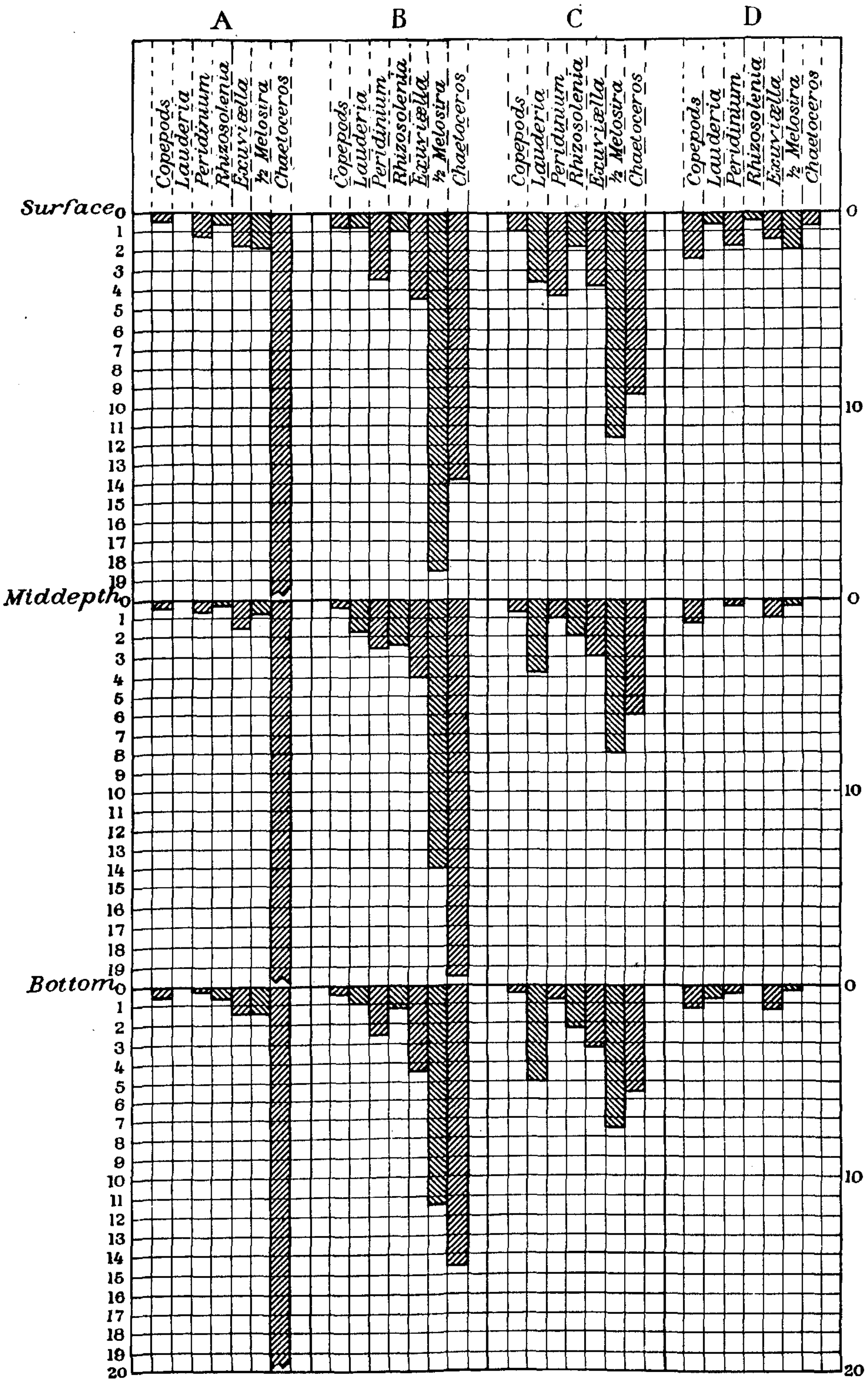
* This quantitative apparatus was first provided for me at the laboratory of the Boston Water-Works in the autumn of 1889, where it is still in use; this particular pattern of cell and the micrometer were designed, I believe, by Mr. G. W. Rafter, of Rochester, N. Y. It consists of a rectangular metal rim mounted upon an ordinary microscope slide, to be covered with a long coverslip. The inclosed contents then measure uniformly 1 mm. in depth, 20 mm. in width, 50 mm. in length, i. e., 1 cubic centimeter.

estimates in dealing with planktonic studies as giving definite data for larger comparisons to be gained by such lines of research. In many respects the classing together of several species of genera of organisms under one typical group is misleading; for instance, in the Peridinium family, heretofore platted and tabulated, there is a marked separation between genera such as *Ceratium*, which is closely limited to surface, and those extending more evenly down to the bottom samples, such as *Glenodinium* and *Gymnodinium* forms; other instances of this kind are noticeable, even in the shallow waters here investigated. The grouping together of allied organisms, therefore, or adding into totals, may lead to some more general results, but the finer analysis of the distribution of each species individually lays the foundation.

Of course numerical estimates of a Plankton may always be subject to Professor Hæckel's criticism, when he compares it to a farmer's estimating the yield of hay or grain by counting the number of blades of grass or kernels of grain, etc. But a numerical estimate of the constituents of the water expressed in terms "per liter" will certainly give as valid a basis for comparison of the same body of water under different conditions, and of different bodies of water also, as any other way, and will be a much more accurate test, I believe, than any volumetric results or data expressed in weight of material in suspension. For in these last cases the greatest disturbance would be caused by the presence of the organic débris, which is often most abundant where the real living material secured is at a minimum. The volume of filtrate secured from a given sample of water is no guaranty whatever of the actual bulk of living organisms contained therein. And I believe that with an efficient apparatus a numerical estimate of each class would show many constant interrelations; but planktonic distribution is so very variable that statements about one locality would not necessarily apply to other bodies of littoral waters, however alike the seeming conditions of environments might be.

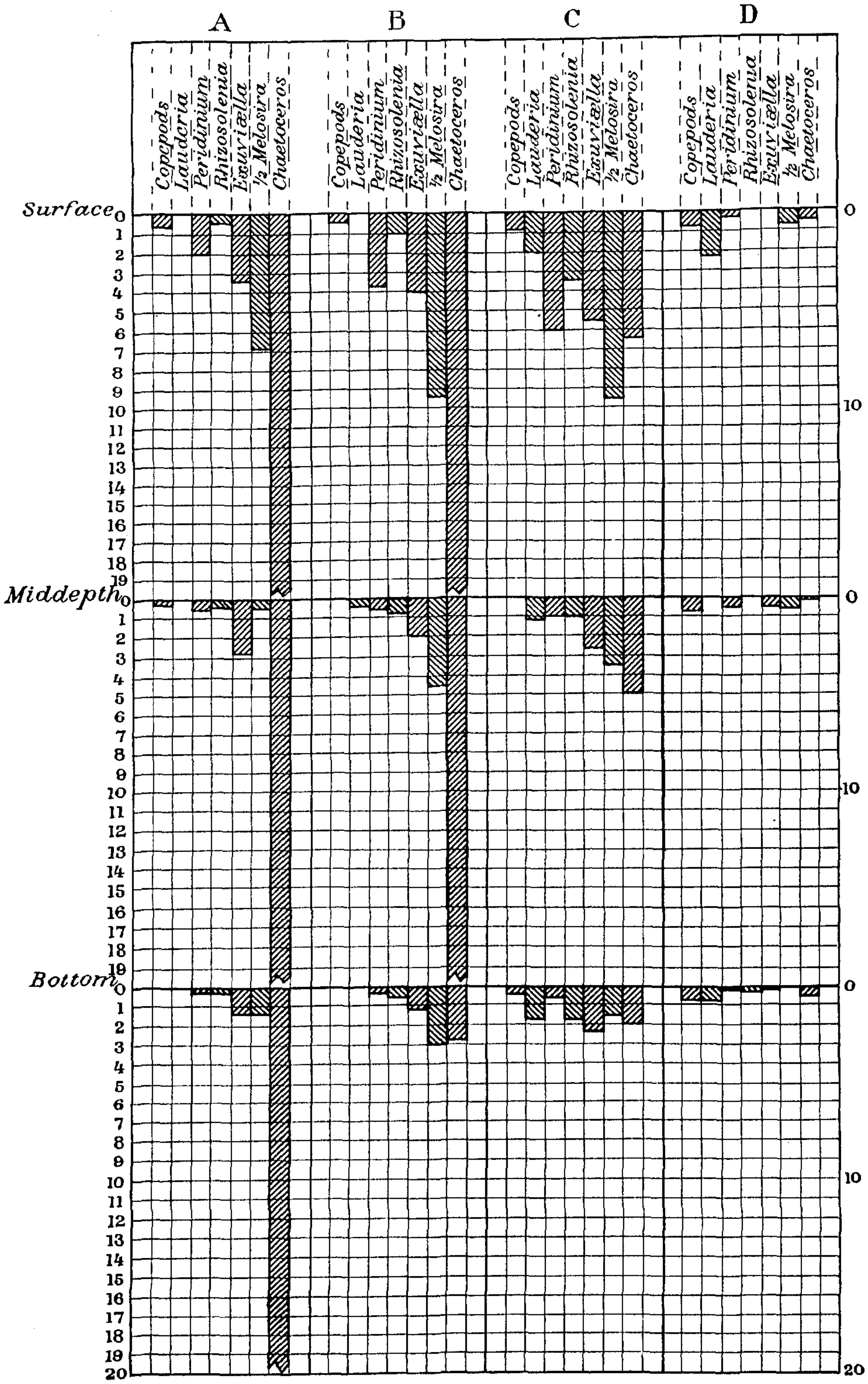
It is in the hope that studies carried on in this manner may contribute to a wider understanding of the resources of ocean water, not only from a purely economic standpoint—valuable as that might be—but for the sake of the biology of the organisms themselves, that this paper is here offered. The author sincerely regrets that at present he is without the opportunities of giving the observations here recorded their full treatment, but ventures to present the plan of the work through the means offered by the United States Fish Commission, as some token of the appreciation he feels for the liberal encouragement and help always extended to biological work by its present administration. My thanks are also due to my friend Mr. N. R. Harrington for the fidelity shown by him when in charge of the apparatus as these collections were taken; and also to all the officers of the *Fish Hawk* for their willing cooperation in every detail. The plan of the lines of sections of the survey was developed by the Commissioner of Fish and Fisheries, Marshall McDonald, and every hope is felt that this or other work of its kind may tend toward the solution of some of the ends desired by him.

WILLIAMS COLLEGE,
Williamstown, Massachusetts, December 23, 1894.



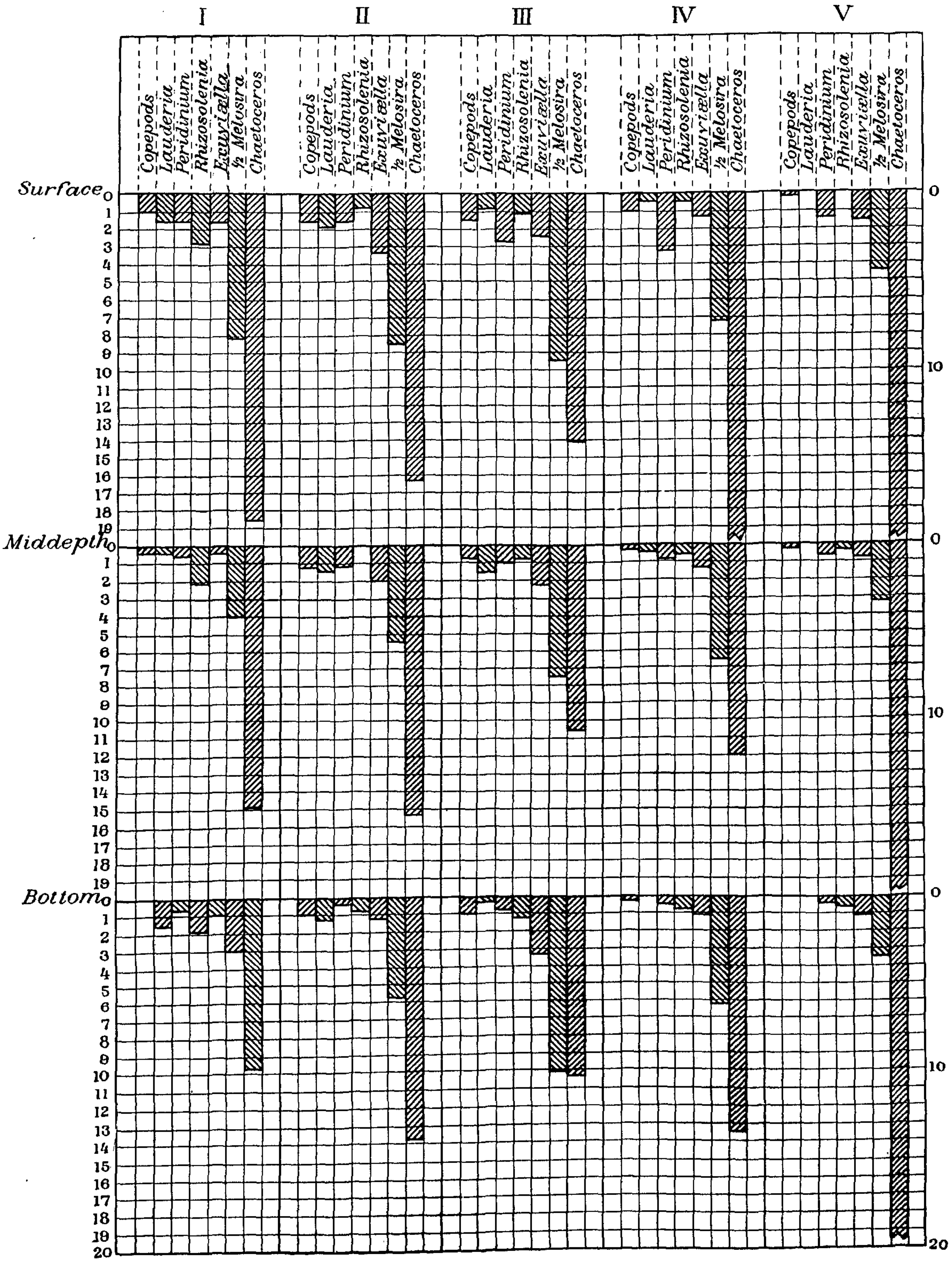
LONGITUDINAL SECTION, LETTER M.

Platting of the organisms of the longitudinal section designated "Letter M," the totals, together with the other data descriptive of the course, being tabulated on page 361 of the text of this paper. The same organisms are recorded under each station, A to D; their relative abundance at surface, mid-depth, and bottom is indicated upon left-hand margin of the diagram. In this and the following plates (69–71) the Copepoda are a hundred times multiplied as compared with the other organisms, but all the others are platted to the same scale except that only one-half the quantity of *Melosira* is used.



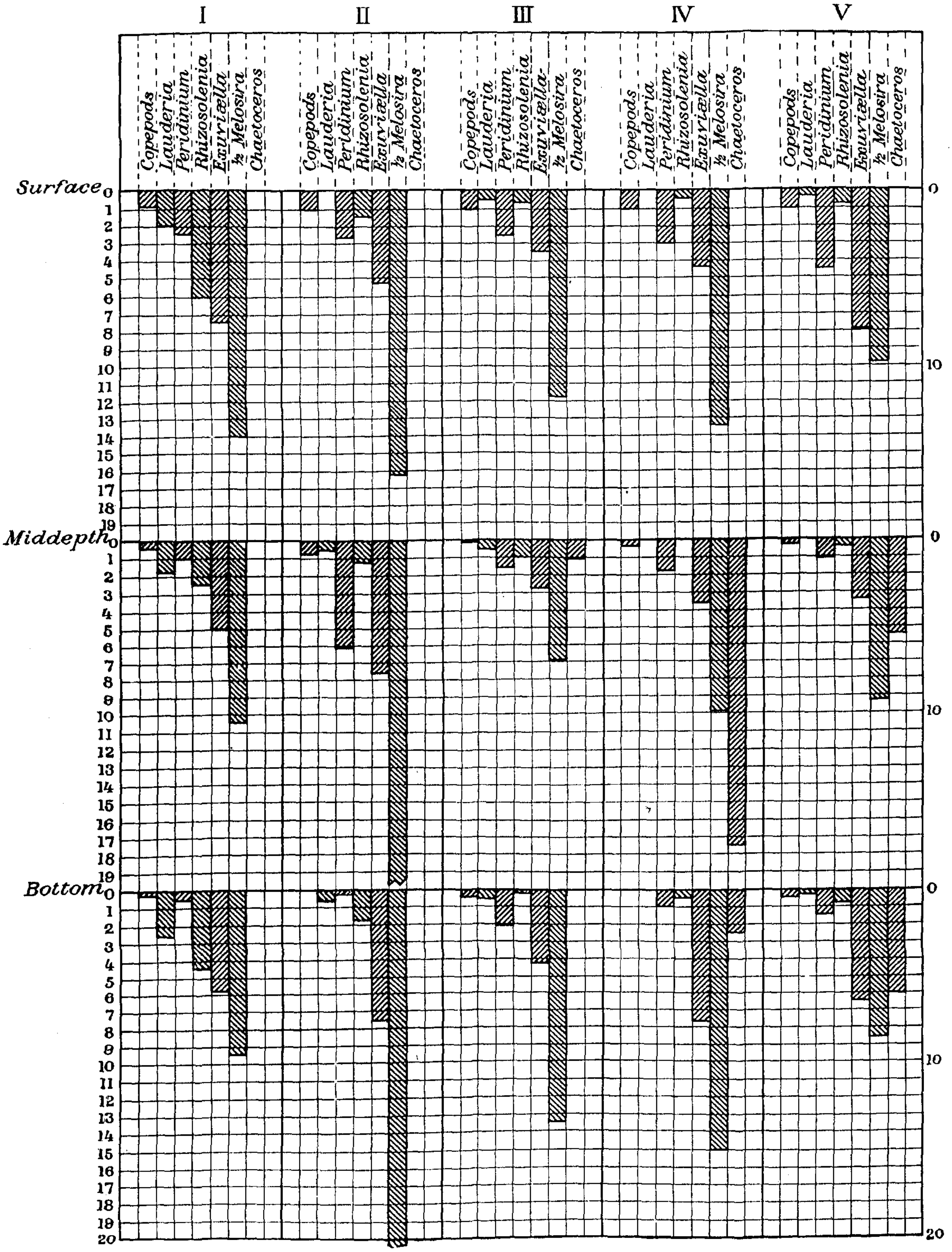
LONGITUDINAL SECTION, LETTER K.

Platting of organisms as obtained from longitudinal section called "Letter K," as tabulated by totals on page 361 of this report, together with temperatures, depths, and other data.



CROSS SECTION, LETTER N.

Platting of the same groups of organisms as obtained from the cross section "Letter N," the totals being tabulated on page 364, with the other data descriptive of the course.



CROSS SECTION, LETTER H (AT LOW WATER).

The same groups as collected from cross section "Letter H" (low water), totals of organisms tabulated on page 365 of this paper, together with other data descriptive of the course.