13.—THE PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF THE NATURAL OYSTER-GROUNDS OF SOUTH CAROLINA.

BY BASHFORD DEAN.

The following report deals with the character and conditions of the South Carolina oyster-grounds, aiming from their study to point out the natural advantages offered by the State for successful oyster-culture. It is based upon observations and experiments made by the writer while attached as naturalist to the U. S. Fish Commission steamer *Fish Hawk*, during the investigations from December, 1890, to March, 1891. An account of the region examined and maps representing the same will be found in the report of Mr. John D. Battle, entitled, "Report on an Investigation of the Coast Waters of South Carolina with reference to Oyster-Culture."

I.—OYSTER LEDGES AND FLATS.

The entire coast margin of the State, if the immediate ocean shores be excepted, is in the main well provided with natural beds. These, however, are strangely unlike the beds occurring naturally further northward, since in great part they are here found skirting the shore in fringing tidal reefs, living as much of their life in air as in water. Often at low tide the oyster ledges appear to the eye curiously like a low hedge of frosted herbage, grayish-green in color. A nearer view discloses branching clusters or clumps of oysters, densely packed together, whose crowded individuals now become modified or distorted according to their position on the cluster. The individuals that cap the cluster project upward like flat-tipped fingers, slender, narrow, and long, whose shape has given them throughout the South the names "cat tongues," "raccoon paws," or "raccoons." In many localities, as throughout the region of Skull Creek, the raccoon ledges, continuing for ages to encroach upon the stream bed, have formed vast oyster flats, acres, sometimes miles, in extent.

In the stream bed, or, indeed, below the low-water mark, oysters are rarely found, and whenever found are to be regarded as having fallen from the neighboring ledges. As so great a proportion of the State natural beds are raccoon or of raccoon origin, the formation and conditions of these interesting oyster colonies should first be examined.

Ages ago, in South Carolina, the oyster lived under conditions that appear to have been more favorable than those of to-day. There can be but little doubt, from the evidence of shell marls and fossils of the phosphate deposit, that in ancient times there must have been a greater supply of fresh water entering gravel-bottomed bays and estuaries. The character and volume of these ancient streams must have tempered the sea water and produced the most thrifty conditions for the living of the oyster. In the Pliocene (Miocene?) we here find the fossil shells of myriads of oysters that were decidedly of a brackish-water type, small, single, and thin-shelled, reminding one of the Blue Points of Great South Bay. The shells are rounded, regular in shape and perfect in outline, attesting the peaceful conditions of their ancient life. They show no trace of clustered living.

The natural causes that afterwards destroyed the prosperity of a molluscan age are yet to be ascertained. Certain it is that the incurrent streams were sufficient in force and volume to gully out valley and moor, and to roll seaward from far-distant places the huge fragments of mire-loving animals. It is not until we examine the deep layers of soft, black, river ooze, forming to-day above the phosphate, that we find the first oysters of a raccoon-like type. In the deepest ooze-layers the remains of clustered oysters are few and fragmentary, suggestive of age, transportation, and hard usage. Nearer the shore, and in shallower mud-banks, oysters of all gradations of bunching characters may be found everywhere.

There seems abundant evidence for regarding the living oysters of the State as the survivors of an ostreous golden age, survivors that have struggled successfully against changed and adverse conditions of living. They have become inured to extreme saltness of water, almost that of the sea; they have learned to avoid the submerging mud by growing in clustering masses and by casting anchor along the firm shore-line, often having to build the very land on which to survive. They have learned to live their life as much in air as in water, and in their out-of-water position to endure the cold of winter and the scorching heat of the sun. Even under these hard conditions the oyster's struggle for existence is *still an uncertain one*. Huge shell banks, miles in length, often 10 feet in height, have been in time formed of raccoon clusters, whose anchorage along the muddy margins has been unstable. A tide unusually strong will roll up and scatter high along the dry beach many bunches of living shells. These are often seen, weeks perhaps out of water, still guarding jealously the few remaining drops of life-giving moisture.

The appearance and formation of raccoon beds may be understood most clearly by referring to the accompanying illustrations of typical natural beds, selected from a series of photographs taken by the writer during the cruise. They represent an oyster ledge (Plate LXII), an oyster flat (Plate LXIII), and an oyster island (Plate LXIV). Plate LXV marks the tidal zone of oyster life, indicated everywhere at lowest tide upon stakes and piling. Plate LXVI shows an extended raccoon-bearing locality.

The oyster ledge* (Plate LXII) is seen from the shore side. The dark-colored shore strip exposed by the receding water shows the limits of high and low tides. In this zone will be seen the living raccoon clusters anchored in the soft mud, some in massive colonies, appearing velvet-like, as in the left of the plate, others scattering, as in the right, anchored less firmly in the soft ooze. The white beach composed of dead shells has for its lower margin the line of high water, a line that is well marked in the picture; this beach, literally a shell heap, rises gently to a firm crest 10 feet above high tide. The size of the shell heap points to its antiquity; many shells are

* Stono River, east shore, 3 miles from mouth, March 6, 1891.

fragmental, water-worn, curiously packed together by ages of water action, often implanted mosaic fashion with shells vertical. A large, dark-colored, living clump is seen prominently on the beach, and smaller clusters are to be noted in a receding dark-dotted line.

The portion of an oyster flat,* shown in Plate LXIII, is seen from the water side. The low, irregular banks of mud are capped with oyster clusters. The sides of the mud banks are extremely soft, engulfing and gradually stifling the raccoon clusters that fall from above. Many of the holes seen in the sides of the mud bank are the gradually disappearing gravestones of buried oysters. The larger holes mark the breathing currents of sinking oysters that are stifling 6 inches below. The entire backbone of the mud bank will be found, by probing, to consist of dead shells around which the mud has gathered. Large living clusters, budding out from the bank, will in time form a peninsula, as seen in the plate. The sink-holes and draining-trenches are naturally of value, preventing the accumulation of mud upon the living raccoons. Marsh grasses encroach very slowly, forming dry land as they go, and limiting by their margin the line of oyster growth.

The oyster island† (Plate LXIV) deserves a passing notice, occurring very often throughout small creeks draining marsh land, extremely noticeable, since nowhere else in the neighborhood are oysters plentiful. It furnishes an interesting example of the oyster's powers of land building. In a region where steep and soft muddy banks have prevented oyster ledges from forming, a single cluster, anchoring on the shore by some chance, gives rise to an outcropping "island," formed entirely of oysters; its framework of dead shells; its flat, dome-like summit bristling with living clusters. The island, accordingly, originating as a cluster attached to the soft bank, continues its growth as a small peninsula and pushes out into the sluggish stream. The stream current aids its formation; its framework is firmly packed with gradually accumulating mud; its growth broadens outward into a portly island of oysters, whose small and narrow peninsula beginnings (where the man in the picture is standing) are almost lost to sight.

That the zone for the attachment of oysters‡ (Plate LXV) is, in South Carolina, between the levels of high and low water may be noted upon stakes and piling everywhere. The maximum size and abundance of oysters, naturally attached, will be seen from the picture to be midway between tide marks. The significance of this zone of oyster attachment is hereafter discussed.

THE OYSTER CLUSTER AND ITS ORIGIN.

Raccoon oysters, in their physical character, as briefly shown, have grown in bunches, clumps, and interlocked colonies, with manifest purpose. To grow in clusters was the oyster's successful expedient in its struggle for survival. Grown in clusters, in the first place, the oyster is less apt to sink in the stifling mud than if separate; the raccoon anchorage, moreover, is apt to be a firm one, at the same time holding the individuals as high up from the mud as possible. Equally important is the function of the cluster in allowing the greatest possible number of oysters to survive in the smallest possible surface space.

* Skull Creek, January 13, 1891.

† May River (Skull Creek Region), 1 mile from mouth of Skull Creek, January 12, 1891.

‡ Sullivan Island, steamboat wharf, March 12, 1891.

In the matter of anchorage the oyster has certainly proved very adaptable. Every oyster of a raccoon reef, as Prof. Ryder has pointed out,* owes its position in life to its ancestors. When in its swimming stage every natural obstacle stood in its way; they alone extended a friendly shell for it to cleave to—they who in their turn were fastened to their ancestral shells, and so back indefinitely. In no place, perhaps, may this interesting phylogeny be better examined than in South Carolina. Eight superincumbent generations have been counted upon a single shell, *i. e.*, No. 2 attached to No. 1, No. 3 to No. 2, etc. Should the muddy floor below be of medium softness the cluster is found to be a more permanent one, for increase in the weight of the growing load presses the cluster down and keeps it firmly rooted, and the sinking ancestral shell may in time disintegrate without injuring the stability of the bunch. On the other hand, should the character of the bottom prevent the basal shell from sinking and the bunch from thus becoming rooted, the cluster is apt to be capsized by storm or tide and rolled up on the beach to perish. Should the bottom, again, be of medium softness, the anchorage becomes a curiously firm one, owing to the conditions of oyster growth. All the individuals of a cluster tend to bend out of their normal direction, and to assume in their growing tips a vertical position.† The basal oyster tends to become flat in its position, or is pressed somewhat slantwise into the bottom. So firmly may a bunch become thus established upon a flat, sunken shell, that it is sometimes extremely difficult to dislodge.

In economizing space the adaptability of the bunching form is noteworthy. A tall cluster, whose free end occupied an area of about a square foot, was found to represent the shells of 186 oysters. So crowded sometimes are the individuals of a cluster that their shape will be as irregular as the space they are allowed to grow into. Sometimes, growing vertically, side by side, they become of the proportions of a razor shell (*Solen*), curious in the delicate fluting of their exposed tips. The basal shells, less crowded, become with age stout, broad, and heavy. The extreme lightness of the terminal shells appears to be unvarying, caused partly by their crowded quarters and partly by their out-of-water position. This provision of lightness of terminal shells is admirably designed to give a living to the maximum number of individuals with a minimum chance of overturning the entire cluster.

The origin of the clustering condition is due undoubtedly in the main to the general soft, muddy character of the oyster's ground. It is a building process where the oyster has had for ages to manufacture a place sufficiently firm whereon to anchor its fortunes. To do this it has had to drive into the mud, like irregular piles, the shells of ancestors, near and remote. There can be but little doubt that the beginnings of an oyster reef were of the smallest; a single firm point projecting above the softest mud flat, that has proved sufficient for the attachment of a single cluster, will in time give rise to a reef. The shells dropping and sinking around the primitive cluster will, in time, become the nuclei of congregations of other clusters.

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* Maryland Fish Commission, 1881, p. 27.

† Many instances have been noted in capsized bunches where the tips of the individuals seeking the vertical position have succeeded in changing their direction of growth by an angle of 90°.

II.—OYSTERS DETACHED FROM RACCOON LEDGES.

Throughout the oyster waters of the State there is no question of greater practical importance than that of the general absence of young oysters or spat in the deeper water. Wherever oysters have been found below the level of low tide, as in many of the shallow creeks, they may usually be referred to the neighboring raccoon beds for their accidental origin. Clusters may be seen which are gradually undermined by changing currents, and their progress may later be traced as they slowly roll down a firm shelving bottom into deeper water. Accordingly, we are not surprised to find that "dropped-off" raccoons occur more commonly in marginal waters in scattering irregular beds, rarely in compact masses, and more rarely still in any great number.

That deep-water oysters are generally of raccoon origin seems confirmed also by the absence of spat in their neighborhood.* Whatever may have occasioned the death or absence of oysters in the younger stage, it has certainly been of no serious detriment to the well-being of "dropped-off" raccoons. They appear to have outgrown what is perhaps a disease of infancy, and under their new conditions of getting a livelihood they are greatly changed for the better. The bunching condition in deeper water becomes gradually less marked, the decay of basal shells allowing the individuals to separate. These now begin to lose their raccoon features, and in the end become "single" oysters. As a raccoon, its shell was long, slender, thin, almost to transparentness; its puckered free-edge was knife-like in its sharpness; its body was watery, swollen, and flaccid; its "meat" transparent, showing plainly the contained vessels and viscera; its palps and hood were blistery and distended; its pericardium swollen and atrophied; the edges of its transparent mantle thickened and heavy.† As a single oyster, it proves the benefit of the changed or deep-water conditions of living, and becomes portly, well-fed, and solid, different in every way from its former self. Its shell is now rounded and heavy, blunt at the "nib" and regular in shape. The table oysters of the State, in many instances especially well flavored, are almost entirely of this character.

Nature has thus demonstrated conclusively the simplest method of oyster-culture, how to transmute a tasteless raccoon into a table oyster. It is neither difficult nor costly to scatter in marginal waters about a fathom in depth, where the bottom is suitably firm, the raccoons raked from the neighboring ledge. The time required for the raccoon to acquire the features of single oysters will of necessity vary according to season and locality. The period of "conditioning" may be considerably shortened by separating the clustered oysters before planting, and a few months will probably be found to effect a marked change in the oyster's condition.

* A few exceptions have been noted in the report of Mr. John D. Battle.

† The bettering of the condition of the raccoon oyster during early spring or late winter months has been pointed out by Mr. Battle. The improved feeding conditions which spring offers the exposed oyster may perhaps serve as a strong aid in its struggle for survival, enabling it to reserve nutriment, which later is developed into generative products.

III.—ABSENCE OF OYSTER SPAT IN DEEP WATER.

The shells of exposed oyster ledges are usually well adapted for collecting spat, especially those clusters that immediately fringe the stream. A few feet below the level of low tide the appearance of spat becomes unusual, and still more unusual as the water gradually deepens. The question of why oyster spat is absent in deep water is of practical importance to oyster-culture in this region. To determine the cause would settle definitely the method to be pursued in the collecting of young oysters and thus prevent a possible waste of labor and capital. Some of the more important reasons assigned to this absence of the young in the deeper water are as follows:

(1) The extreme density of the water preventing the swimming embryos from sinking at the fixative stage; a suggestion of Lieut. Robert Platt, U. S. N., commanding the steamer *Fish Hawk*.

(2) The extreme softness and film-covered character of the bottom preventing the oyster from fixing.

(3) The suspension of slowly depositing silt in the deeper water, whose clogging action is fatal to the delicate respiration of the microscopic young.

(4) Changes in the composition of the oyster-bed water, either in its salts or food constituents, at different levels.

If the view of Lieut. Platt be established, the process of spat-collecting will be a simple one for the culturist. If the silt and mud theories be correct, the importance of establishing the relation of the size of the seed to be planted successfully to the character of the bottom is a vital one. If the water variations at different depths are at all marked, showing that oyster food is greatest in amount near the shore in shallow water, and that there, too, occur the best conditions of saltness and liminess of the water, a valuable suggestion is gained. It will likewise be of value to determine whether all or some of these possible causes act in concert.

1. Density of water preventing oyster fry from settling.—It can be shown most clearly that South Carolina oysters, living in a water density of 1.017 to 1.024 specific gravity, occur only on raccoon reefs between the extremes of high and low water marks. At low water it is interesting to note how clearly the stakes and piling define this oyster belt, as we have seen in Plate LXV. The region of mid-tide mark shows the greatest luxuriance of growth; the oysters decrease gradually in size and number above and below, becoming straggling and finally disappearing. Occasionally, as the pile is eaten by teredos, the oysters drop to the bottom and become of the "dropped-off" raccoon type. If the proposition be proven that the embryo at the fixative stage can not sink in water of high density, but must form raccoon ledges, some corollaries must naturally follow:

(1) Spat should in no instance be found in deep water of high specific gravity.

(2) As the water becomes fresher, the oysters, with spat of undeniably recent attachment, as in the North, should be found in favorable localities covering the bottom; and, accordingly,

(3) As the water becomes less salt the raccoon ledges should gradually and entirely disappear.

Of course, the only indisputable proof would be to fertilize eggs, carry the embryos as far as possible into the swimming stage, and by actual experiment show that the floating powers of the young become more marked as the saltness of the water increases. The experiment would not be an impracticable one, for fresh water-specimens might easily be arranged in a set of graduated densities by the addition of natural salt. Should it be shown, for example, that in water of 1.023 oyster fry would occur only at the surface, and that in water of 1.016 the young might be found pervading equally the water volume, there could be little doubt of the value of the view of gravity fixation. Circumstantially, however, many opposing facts render this view untenable as long as positive proof is wanting.

(*a*) Spat has been sparingly found affixed to deep-water shells, but we must admit that it may have been attached before the host itself dropped into deeper water.

(*b*) The second corollary certainly does not maintain. Notwithstanding the water becomes fresher in character, deep beds of single oysters do not become common in an increasing ratio. Such as are found rarely have spat attached, and in every way appear still to represent the dropped-off raccoons.

(*c*) As the water becomes less dense, raccoon ledges do not disappear. Oyster ledges occur in Winyaw Bay, where the specific gravity of the water is as low as 1.010.

(*d*) It is well known that a deep set forms naturally in some regions, as about Long Island, New York, where the specific gravity in some places is as high as 1.021; and, moreover, I have recently examined in Florida oyster rocks well covered with spat in water of a density of 1.025 and at a depth of 10 feet.

Again, granting an unexpectedly delicate osmotic character to the young, it may be shown that, if the embryo float, it must keep at surface level; for as the specific gravity of the water is often the same at top and bottom, the embryo, if it sink a few inches, might equally well sink many feet. Heavy barges of the Coosaw Phosphate Mining Co. never draw less than a foot, yet their bottoms are bristling with oysters.

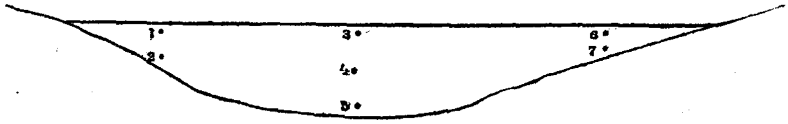
2. The view that the swimming embryo is unable to effect a successful fixation in the deeper waters, on account of the slime-covered character of the bottom and the softness of the muddy bank, might readily be true of many localities examined. The stream bed of many water-courses is formed of the softest and lightest muddy ooze, into which an object, such as an oyster shell dropped as a collector, would unfailingly pass, sometimes to a depth of many feet, as experiments have shown near Port Royal. This ooze layer is widespread in the larger river basins; its extent and character render oyster-culture in its immediate neighborhood almost impracticable; it covers the river phospate rock with a layer sometimes 15 feet in thickness. There have been, doubtless, many cases where oyster-culture has been discouraged by the absolute failure of plants made upon an insecure or shifting bottom. It is evident that the more surface the planted oyster can expose to the soft bottom, or, in other words, the larger and lighter the oyster, the more apt is it to survive, although its efforts in that direction are not apt to improve its commercial quality. A number of specimens have been retained, showing how skillfully mud masses have been plastered into the oyster shell, forming, indeed, an intricate series of mud galleries honeycombing the shell. The general truth of this view as affecting bottom set is of course untenable, as is proved by the oyster-bearing piles. There are, moreover, many localities where the cleanliness of the bottom will compare favorably with that of the best grounds of the Long Island coast.

3. The suggestion as to amount of silt carried in suspension, especially in deeper water, should be carefully considered. We must bear in mind the extreme delicacy of the breathing arrangements of the young oyster, as pointed out by Prof. John A. Ryder, and it is to be remembered that injury to the young caused by silt-bearing water was the cause of the failure of the most careful experiments upon the artificial propagation of the oyster.

Along the South Carolina coast the question of silt suspension becomes of very great interest in the light of geology. Formations are here found (phosphate rock, marls, and fish-bone beds) that in richness of fossils and in extent are curiously unique. For ages the coast regions within the limits of South Carolina must have been a collecting basin or sink, receiving the washed-out drainings of hundreds of square miles. That the fresh waters of the State are still carrying seaward an amount of silt greater perhaps than occurs elsewhere to the north or south, great enough, indeed, to stifle frail microscopic oysters, is therefore in no way remarkable; that flats and shoals are changing and forming constantly and rapidly in rivers and river mouths by the gradual settling of the heavier sediment is abundantly proven.

In the water, at the surface, middle, and bottom, at every locality examined, there is present, in a more or less marked way, a heavy sediment, although the water itself has appeared clear. This sediment is exceedingly fine, in the surface water often requiring three days to settle. So very gradually is it deposited that the living organisms in the water will seldom be thrown down and included in it. It consists of the microscopic particles of clay and silica and, to my surprise, of the fossil tests and fragments of tests of the diatoms of the Ashley group. The occurrence of these fossils is, however, under the circumstances a very natural one. My attention was first called to the recurrence of numbers of dead shells of *Coscinodiscus radiatus*, for which I was at a loss to account. This form I remembered occurred fossil, as well as recent, and the finding in this genus of *radiolatus* and *granulatus* and many other well-known forms confirmed my decision. It is evident that the amount of this impalpable sediment may vary greatly from natural causes, and the variation in the turbidity of river water is sometimes quite remarkable. There can be little doubt that this silt is injurious to the young oyster, and its presence in quantity may readily suffice to account for the entire absence of oyster spat in deep water. The greater the volume of the water mass, the greater would, of course, be the amount of suspended silt; the nearer the surface the less silt, and conversely.

The amount of silt in a given specimen may readily be determined with a fair degree of accuracy, but it is impossible to learn whether the results obtained are relatively great or small, since I can find no standard of comparison. However, I give in brief the results of the following experiments. A stream section across the Ashley, just



below the drawbridge, was selected.* Specimens of water were taken on March 11 from midstream and on the margins, in a fathom of water, at the points numbered in the diagram. Five hundred cubic centimeters of each specimen were shaken and carefully filtered, and the filtrate then dried and weighed. The weight doubled gave the weight of sediment per liter.

* Beds of raccoon oysters are abundant there.

The following were the results:

Locality.	Sediment (grams per liter).
Surface:	
1. West bank	0.70
3. Midstream	.75
6. East bank	.72
Deeper:	
2. West bank	1.00
4. Midstream	1.00
5. Midstream, bottom	1.60
7. East bank	1.40

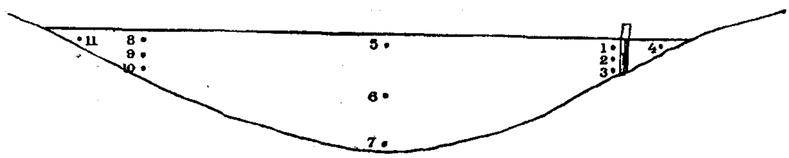
It is noteworthy that the greater proportion of the sediment is present in midstream, where oyster set does not occur, and that the minimum amount of sediment occurs at the marginal surface, where the oyster ledges are found. The exposure to air of these tidal reefs allows the sediment to dry and possibly gives the oyster an opportunity to expel any ingested mud. My notebook states that the sediment from the marginal water is "extremely oily, clogging the fine filter paper, rendering the filtering process an extremely slow one. The filtrate leaves a waxlike smear near the point of the paper funnel."

Enough has probably been said in this connection to show the necessity in practical oyster-culture of collecting spat on floating collectors and of allowing it to attain before planting a considerable size, the larger the better. To plant successfully, the oysters should certainly be not less than 2 inches in diameter. The necessity of an unshifting and fairly solid bottom is of course obvious. If the collecting surface be a horizontal one, the under side will be found to collect the greatest amount of spat. This condition was found to occur in all of the natural floating collections examined. Barge bottoms as successful collectors have already been noted. All phosphate barges have yearly to be scraped of their compact, densely crowded set, the oysters within this time thriving remarkably, specimens 3 inches in length having been taken the present season (February, 1891) from the barges of the Coosaw Mining Company.* In this position the young oysters are in water bearing evidently the minimum amount of silt, and, from their down-turned position, least affected by the gradual depositing of sediment.

4. The question as to variations in the composition of water at different depths tending to be of benefit to marginal oysters has proven a comparatively unimportant one. Marginal surface waters do not differ in composition materially from those deep in midstream, and therefore can offer no remarkable inducement to the formation of raccoon ledges. They are neither remarkably fresher nor richer in lime for shell building; they offer no conditions of far greater abundance of food or greater freedom from impurities that might account for the absence of oysters in deep water. Neither do the tides appear to bring about any strikingly beneficial changes in the character of marginal waters.

* Dr. C. Bunting Colson: "History of the Mill-Pond Oyster and Cause of its Disappearance"; Proc. Elliott Society, March, 1888.

With a view to the examination of these questions, analyses were made of water specimens collected at such points as to represent the entire section of a stream. Thus, in the accompanying diagram, representing a theoretical stream section, water specimens would be collected by means of the water cup at each of the positions numbered 1 to 11. A set of specimens, thus representing the character of the cross section of the stream, would be collected at the half tides and at high and low tide. The collection and analyses of specimens would be so arranged that, in point of time, the comparison of tides might be as accurate as possible.



For a more complete comparison three sets of such examinations were made at different localities; one, near Beaufort, South Carolina, of a typical river mouth with deep water; a second, of a neighboring shallow, oyster-bearing stream; and, finally, a similar section over the raccoon beds of the Ashley River in the neighborhood of Charleston. The variations in the results, as seen in the appended tables (pp. 357–361), were too slight to be of practical importance. Comparative study shows, however, that changes in water layers do occur, changes that if more marked would tend to favor somewhat the growth of marginal rather than of ledge oysters, thus:

(*a*) Saltness, as a rule, slightly increases with the depth of water. There appears, however, to occur (a foot or two below the surface) a stratum slightly salter than the water immediately above or below it. Extreme marginal waters are least salt, having per gallon about $\frac{1}{200}$ in weight less of chlorides than in deep water.

(*b*) Carbonates (lime) increase with the depth of water.

(*c*) The amount of salty and limy ingredients are, in the localities examined, but little affected by the changes of tides.

(*d*) The greatest amount of decaying organic matter appears to be carried in the deeper midstream. The water is there most impure at low tide and purest at high water. The extreme marginal waters show a noticeable increase of impurities, evidently from surface drainage.

(*e*) The most noteworthy variation shown by the analytic study will be seen in the organic element of the water, representing in general oyster food. The greatest amount appears almost invariably to occur in marginal waters near, and a fathom or two below, low-water mark. In the South Carolina waters examined the marginal waters appear (probably from the character of the bottom, higher temperature, and less rapid current) to afford the best conditions for the attachment and rapid increase of minute plant life. As nearly as the organic results can be determined, it would appear, with due allowance, that marginal waters contain double the amount of oyster food found in midstream. Tides appear to have but a slight effect upon increasing or diminishing the amount of oyster food. The best feeding conditions of the water are during the rising of the tide, which appears to carry shoreward from the deeper waters a number of pelagic forms. High tide contains the next highest percentage of oyster food. The poorest feeding conditions are shown at low water.

IV.—GENERAL CHARACTER OF THE BOTTOM AND ITS LIFE.

If we exclude the mud layer that has been referred to as often forming the stream basins throughout the State, the character of the bottom adapting it for oyster-culture is in no way remarkable. Hard mud, sandy, shelly, or coarse gravelly bottoms occur in more or less extended tracts in all the waters of the State—a practical question that has already been discussed in the topographical report.* In these favored tracts plant and animal life are extremely abundant and every condition is favorable for the growth and reproduction of the food of the oyster. Some small tracts will be found covered with a low growth of red seaweeds, whose fronds, teeming with minute organisms, are the natural nurseries of the oyster's food. These seaweed localities may usually be regarded as among the best of places for oyster-planting, especially where rapid fattening is desired; since, as a rule, they mark the most beneficial conditions of bottom, current, warmth of water, and feeding.

V.—THE FOOD OF THE SOUTH CAROLINA OYSTER.

Success in oyster-culture depends to a very great extent upon the feeding conditions that the oyster can obtain. The French culturists have long shown that oysters, like fowls, should be well fed if they are to be marketed. They have demonstrated in the use of the still pond (*claire*), how to provide the best conditions for a profusion of food organisms as the surest aid to the rapid and tasteful conditioning of the oyster. The *claire* is shown to be a marine hotbed for the minute plants preyed upon by the oyster. It is a pond, shallow and well warmed, almost currentless, whose salt water is kept uniformly tempered by fresh streams, whose bottom is so disposed that sediment, otherwise often fatal, will deposit naturally in trenches, and not over the prolific beds of oyster-food organisms. It has been shown that, under favorable conditions of feeding and living, an oyster may become of marketable size and quality in one-third of the time required under its natural (*i. e.*, undomesticated) conditions. Undomesticated oysters are accordingly dependent to a large degree for their thriftiness upon the amount of food their natural surroundings afford.

In the United States but little attention has yet been directed to examining the food conditions offered by different localities as a natural aid to oyster-culture. We are apt to look upon all salt waters as offering far and wide the same essential feeding conditions. We forget that streams in different regions differ widely in their water composition, rate of current, shallowness, and warmth, and that thus one, favorably circumstanced, might far surpass its neighbors in its general fitness for oyster-culture.

In the studies of the Carolina waters it has therefore been deemed important not merely to state the natural characters of the oyster-bearing waters, but also to compare, as carefully as possible, the general and especially the feeding conditions of all the localities of the State examined. Comparisons of value might then be drawn with the natural conditions known to maintain in profitable northern oyster-grounds.

*An investigation of the coast waters of South Carolina with reference to oyster-culture. By John D. Battle. Bull. U. S. Fish Commission, 1890, pp. 303-330.

In discussing the question of South Carolina oyster food in its many aspects, the general character should first be examined. The oyster, it is well known, is quite an epicure in its feeding, preying almost entirely upon the minute, lowly organized plants that float or swim in its neighborhood. With shell slightly opened, and with the dark-colored sensory margins of its mantle protruding, it draws into its shell a narrowing, food-bearing water current. At once it draws in the current, carefully screens out the minute food particles, and passes out a stream of filtered water. It avoids, if possible, ingesting sand or mud.

The food organisms are readily taken for examination from the oyster's stomach. The tip of the soft body of the oyster is removed by a single clip of the scissors, and a pointed pipette is introduced at once into the stomach cavity, and the fluid contents, rich golden-brown in color, are drawn up. The stomach contents of a number of oysters from the same locality may be taken and put in labeled homeopathic vials, from which a number of dippings of both sediment and fluid should at once be examined.

Oyster food, it will be found, consists mainly of diatoms, a particular kind of minute, lowly organized plant, that have the remarkable power of moving freely about in the water. Unlike any other plants, they are incased in a pair of saucer-like glassy shells, fitted one to the other like the lid to a pill box. These delicate shells are the natural prey of every microscopist. He admires their varied shapes (round, S-like, elliptical, or three-cornered) and tests his lenses upon the delicate pits, ridges, and traceries shown in their glassy structure. A photomicrograph (Plate LXVII, Fig. 1) shows the delicate basket-work markings of a cleaned shell of a *Surirella gemma*, a diatom not uncommon in Carolina oyster stomachs. The glassy cases of the minute plants appear in no way to inconvenience the oyster's digestion. The mucilaginous sheathing that encases prominently many diatoms is first dissolved, and the digestive juices find their way through the intricate glassy valves, speedily attacking and reducing the jelly-like contents, together with the inclosed golden-brown pigment pellets. The emptied diatoms appear to settle gradually, and are soon brushed by countless cilia from the stomach to the intestine.

The food organisms of the Chesapeake oyster are given by Prof. Ryder in the report of the Maryland Fish Commission for 1881, p. 20. The food of the Long Island oyster is discussed by the writer in the report of the New York Oyster Investigation, 1886. In the latter paper was noted the extreme importance of the plant element of oyster food, examination showing that about 90 per cent of the ingested organisms were diatoms. The animals ingested were few in number, and sometimes unwelcome.

In South Carolina the elements of the oyster food are practically those of Long Island. The proportion of its component organisms may thus be generally stated:

	Per cent.
1. *Animal life*—(*a*) Crustaceans, (*b*) worms, (*c*) protozoans	5
2. *Vegetable*—(*a*) Diatoms	90
(*b*) Fragments and reproductive bodies of seaweeds	2
(*c*) Pine pollen	3

ANIMAL ELEMENT OF OYSTER FOOD.

(*a*) *Crustaceans* are uncommon, even the more minute entomostracans. Fragments of a copepod were twice noted, but were of so large a size (antennæ, meral plates, and leg segments), that they were probably ingested piecemeal, together with unwelcome mud and sand. This view is apparently confirmed by the presence in the same stomach of such out-of-the-way articles of diet as the antennæ of the sand fly (*Chironomus*) and bunches of cells of pine and palmetto. Eggs of shrimp-like forms have occasionally been noted.

(*b*) *Vermes.* Eggs of annelids have been found, but nothing rotifer-like.

(*c*) *Protozoans* constitute the main animal element of oyster food. In some localities, where there occurs a direct ingress of the ocean waters, numbers of *Foraminifera* are occasionally found, *Polystomella*, *Textilaria*, and *Rotalia* being the prominent types. But many of these were probably stirred up by some unusual action of the water. Oysters from a well-examined locality, after a heavy rain, showed a large proportion of *Foraminifera*, many dead shells among them. The monothalamian rhizopods, *Arcella* and *Euglypha*, are abundant in several localities. Infusorians are uncommon. But few bell animalcules were found throughout the season, even in the stomachs of those oysters that harbored *Pinnotheres*. A number of the ciliates were noted, especially *Trachelius*. In almost every specimen would be found, separate, however, numbers of a small gregarine, a monocyst, perhaps in a young stage. Parasitic *Opalina* is also not uncommon.

Spicules may finally be mentioned as among the valueless animal relics found in the oyster stomach. These in a cleaned condition are given off in myriads by the disintegration of sponges, mainly *Cliona*, and of gorgonian corals, and have been ingested while in process of settling.

PLANT ELEMENT OF OYSTER FOOD.

(*a*) *Diatoms.*—The diatoms taken from the oyster offer a rich field for the student in rare forms and variety of species. Many of the diatoms named in the New York report as the food of the Long Island oyster have been found to occur in the Carolinian oyster. In the southern oyster the greater saltness of the water is at once apparent in the richness of many forms of food regarded as exclusively marine, as *Triceratium favus* and several *Triceratia*, apparently undescribed, that I have seen from the Caribbean Sea. The lack of brackish-water diatoms affords a marked contrast to the Long Island forms. In the present connection it would hardly be of value to give the list of even those which I have been able to identify. The diatoms of the Carolina waters have never been thoroughly studied systematically, and there are very many, especially of *Cymbella*, *Navicula*, and *Nitzschia*, that are probably undescribed.

The bulk of the diatoms consisted of minute species of elongated forms. The prominent genera represented were *Navicula* (*didyma* E., a very common species), *Amphora*, *Cymbella*, *Pleurosigma* (*littorale* W. Sm., a prominent species), *Synedra*, *Grammatophora*, *Surirella* (*limosa* Bai. and *gemma* E., prominent), and a number of species of *Amphipleura*. Of the rounded forms, three species were common in every locality examined, *Cyclotella rotula*, *Coscinodiscus radiatus*, and *Actinocyclus undulatus*. The following genera occur prominently but sparingly throughout the State: *Triceratium*, *Biddulphia*, *Stephanopyxis*, and *Cerataulus*.

In the North the bulk of the food appears to be mainly the larger (and therefore more nutritious) *Melosiræ* and kindred forms that occur often in ribbons and exhibit little activity in the water. The southern oyster from his forced altitude must needs put up with the smallest and most active of diatoms.

(*b*) *Fragments and reproductive bodies of seaweeds.*—Broken-off bits of seaweeds are very uncommon. Not a fragment of ulva was noted, and scarcely a bit of the more delicate red seaweeds. Occasionally will be found a slender, spindle-shaped resting cell of one of the *Œdogonia*. Zoöspores may sometimes be noted. The little wriggling nematoid-like *Spirillum bryozoon*, Pritchard, has in some instances been found abundant. Later in the season oogonia of many forms will probably be found, as they are in the North.

(*c*) *Pine pollen.*—Pollen of the cone-bearers has been found in stomachs from every locality examined (December to April), sometimes extremely abundant. It is undoubtedly in early spring an important food element, a unique one, certainly. Of the enormous amount of pollen scattered in "sulphur showers" in so rich a pine region as Carolina, a large part finds its way into the water, floats for a day or two, and is appropriated in part by the ledge oysters as the tide rises. Another part becomes water-soaked and is ingested by the oysters of lower depths. The abundance of pollen may be noted not merely on the deck of the vessel, but even in sulphur eddies in the stream itself, as prominently shown in Parrott Creek.

That this extraordinary food is of nutritive value is apparent in the changes in color and shape that the pollen grains undergo, caused without doubt by the process of digestion. In many instances where the protoplasmic contents of the granule have been dissolved out the outer corky layer of the cell wall ruptures in irregular fissures. With this fortuitous food supply so early in the year, the oyster can prepare for early spawning. The total amount of food, moreover, is by this increment rendered more uniform during spring and summer, the increase of diatoms in summer tending to compensate for the loss of pollen.

AMOUNT OF OYSTER FOOD OCCURRING IN SOUTH CAROLINA WATERS, AS DETERMINED BY ANALYSIS.

It is of value in examining the oyster-bed water of a new locality to be able to compare its food-bearing character with that of a well-known oyster-ground as a standard, *e. g.*, Great South Bay, Long Island (Blue Point), or the north side of Long Island, as shown in the New York Report of 1886. A comparison of fair accuracy may be made by means of water analysis. The test of a large number of South Carolina localities will be found appended.

In determining the food value of a given water specimen the following method,* in brief, was adopted. A couple of liters of water were taken by means of the water cup from a foot above the bottom, aiming thereby to obtain a fair specimen of the oyster's living medium. The specimen could not well be taken nearer the bottom on account of the risk of including the loose organic matter resting there, which would not normally be included in the food of the oyster. If carefully collected, the water specimen when examined in the laboratory would, as a rule, be found to be free of floating organic impurities. Such a specimen would now be agitated vigorously and allowed

*The bacterio-quantitative method was early tried for this work, but was found unreliable.

several minutes to settle. The living organisms upon which the oyster might feed do not meanwhile descend to form a part of the slight sediment. The volume of water necessary for organic analysis may now be carefully drawn up in a pipette thrust well into the jar. The specimen represents the average prevalence of oyster food in the given locality, and, if properly collected, it may be proven by the microscope to be free practically from the organic matters which should not be included in the food of the oyster.

The Wancklin method of determining the albuminoid ammonia is then followed. With skillful handling this method is certainly an accurate one, the Nessler color test readily determining the presence of $\frac{1}{1000}$ of a part of ammonia in 1,000,000 parts of water. The free ammonia given off when the water is merely boiled, must be considered as representing ammoniacal salts, derived in great part from disintegrated tissue, and marks the impurity of the water. The solid organic matter in the water, which we will have to allow is mainly oyster food, is thus left coagulated. A strong caustic now introduced destroys this organic residue, and the product of combustion is quantitatively determined as albuminoid ammonia. That the amount of albuminoid ammonia in uncontaminated salt water will (with due biological precautions) represent the quantity of organisms present must be conceded. In the present work this method was followed for lack of a better one.

Referring to the albuminoid ammonia results in the table of analyses, we may get some general idea of the food character of the water, as well as of local differences. We may see, for example, the general uniformity in the albuminoid constituents, averaging perhaps about $\frac{12}{100}$ parts per 1,000,000 in almost every locality in the State. This amount is certainly not as great as that shown in the oyster-grounds of the north side of Long Island; but, on the other hand, its uniformity in food constituents must make it at least a more than fair feeding-ground. In a general way the waters of the north side of Long Island are a third richer in their feeding constituents than those of South Carolina, while Great South Bay* (Blue Point), which is practically a huge "claire" built by nature on French principles of oyster-culture, is thrice richer.

The effect of tide and depth of water upon the total amount of oyster food in a given locality has already been described.

The general appearance of some of the typical organisms from the stomach contents of the South Carolina oyster has been outlined in Plate LXVII, Fig. 2, which represents the objects as magnified about 225 diameters. Nos. 1 to 20 are common forms of diatoms.

* In this connection it is to be noted that brackish waters (sp. gr. 1.010 to 1.012) are apparently richest in oyster food. The studies of the Great South Bay, for example, whose density is kept uniformly low (1.010 to 1.013) by the entrance of a number of small, fresh, sluggish streams, show the presence of the greatest *profusion of diatoms*, both in number and species. In American oyster-culture the time is not far distant when oyster ponds of this favorable character will be employed for preparing oysters for market. In introducing the French systems, however, careful studies are yet to be given the questions of compensation of labor and of altered conditions of locality.

TIME OF FEEDING OF THE OYSTER.

The question of the time of feeding of the oyster will be an interesting one in the management of culture ponds. Here the ingress of water can be definitely regulated by tides day or night, to suit the feeding habits of the oyster. That the rising tide is the dining time of the oyster has usually been conceded; how far feeding activity is governed by daylight or darkness is, however, a question of interest. The results of the following examinations are noteworthy.

In a favorable locality* three gatherings of twenty oysters each were made, all from the same station, at 7:20 a. m., 1 and 5:30 p. m. Care was taken to select oysters in every way similar in size and character, freedom from oyster-crabs, bryozoans, or sponges. The stomach contents were taken within half an hour after the time of collection. The total quantity of food in process of digestion at these times of day could then be crudely compared. To determine comparatively the richness or quality of food contents of each set of specimens, a simple color test was devised. The total food-bulks were placed in separate Nessler glasses (15 cubic centimeters, slender), and to the two darker fluids distilled water was carefully added until the three specimens, viewed from above, were of the same color. The volumes in each tube, now of about the same nutritive value, were readily measured and compared. The following are the results: †

Time of day.	Color.	Amount in cubic centimeters of contents of 20 stomachs.	Food contents of 20 stomachs rendered of the same nutritive value and their bulks compared (cubic centimeters).	Time.	Tide.	Depth.	Water temperature.	Water, sp. gr.	Remarks.
						Feet.			
Morning..	Pale watery ..	.5	.5	7.20	¾ flood ..	20	60	1.0225	Weather, foggy; bottom, packed shells.
Noon	Rich greenish-brown.	2.5	12.5	1.00	½ ebb ...	12	60	1.0239	Weather, bright; bottom, sponges, bryozoans.
Night.....	Light ocherous	1.5	5.0	5.30	Low	8	60	1.0225	Weather, clear; bottom, red seaweeds.

It is noteworthy that during the night the oysters had been practically foodless; that, although the tide had well risen in the morning as late as 7:20, the oysters had fed but little; that the bulk of ingested food was taken during the strongest daylight, morning and afternoon. This suggestion, as to the feeding habits of the oyster, is not a surprising one when we remember that it is during the strongest sunlight that diatoms, as plants keenly sensitive to the sun, are most active and are known to migrate in floating clouds from bottom to surface.

* Myrtle Bush Creek, near Port Royal, February 10, 1891; a fine bed of "dropped-off" raccoons.

† The accompanying conditions of water are given in the table of analyses, p. 359, Nos. 108–110.

VI.—MESSMATES AND ENEMIES; SPAWNING SEASON.

THE OYSTER CRAB AND ITS RELATION TO ITS HOST.

The oyster crab as a messmate has doubtless been the subject of comment from prehistoric times. Pliny quaintly speaks of it as a discreet doorkeeper, who, in return for safe quarters, pinches the oyster, warning it to close its shell in time of need; while Plutarch, as if unwilling to be outdone by his voluminous rival, ascribes the commensalism to motives of partnership, the crab contributing his eyesight, the oyster his entrapping shell. Small fish, sadly deluded and captured, are feasted upon. Prof. Verrill has noted that it is the female only that takes refuge within the oyster's shell. Prof. Ryder has added to its interest by showing that to its body are attached clusters of bell-animalcules (*Zoöthamnium*), whose progeny are of food value to the oyster, and that in turn even the bell-animalcules pay toll to the common host in the broken-off vibriones that infest them. He accordingly regards the crab as a food nursery whose presence is of benefit to the oyster.*

In the Carolina waters excellent opportunity is offered for the study of the oyster crab. It was often found in as many as 5 per cent of the oysters opened. All individuals were apparently of one species, *Pinnotheres ostreum*, Say; more than one female was never noted infesting a single oyster. In most instances the crab is found well thrust in between the palps, usually between the middle ones. Occupation at this position is evidently annoying to the oyster, for the palps sometimes show thickened outgrowths, or are malformed and stunted in size.

That the crab is of value to the oyster as a purveyor or as a nursery for food appears (from many notes that have been made) extremely doubtful. It must be admitted on the one hand that, in almost every instance, *Zoöthamnium* colonies have been found in every variety of position and abundance. As a rule, however, the clusters are small and infrequent. In position they are usually moored to the crab's basal leg segments. In the matter of food there can be no doubt that the crab secures many of the small crustaceans which are not normally the oyster's prey. But on the other hand, the stomach contents of the crab consist in great part of the minute organisms, diatoms, pine pollen, zoöspores, and infusorians, sought by the host. And as the closest examination of the oyster's stomach failed in every case to show the presence of the bell-animalcule or its swarmers, as a compensatory food tribute, the benefits derived by the oyster from a tenant that can not be ejected appear somewhat doubtful. The crab will be found to crowd itself snugly between the oyster's palps, where food organisms are constantly collecting, and at this point may readily help itself to a selfish share of the incoming food.

The hairs of leg tips and mouth parts of the messmate are curiously specialized for arresting the slime-coated patches of oyster food. At the distal end of the dactylopodite the stout recurved hairs are most numerous, holding, as may actually be seen, as if with the teeth of a rake, the slime-entangled masses of organisms. The slender

*Ryder, Maryland Fish Commission, 1881, p. 24.

hairs of the mouth parts, notably of maxillæ, are disposed in rows like the teeth of a comb, and are apparently of service in carding out the arrested food supply. In most instances the crab is found with the carapace toward the left valve; the legs on the side of the oyster's mouth are straightened out, those of its right side flexed. In this position the recurved leg hairs may serve admirably to entangle the food. This process of impaling the food patches upon the spike-like leg hairs may even be rendered more complete by the brushing action of neighboring cilia of the oyster.

THE ENEMIES OF THE OYSTER.

The oyster-planter in South Carolina will fortunately have but few natural enemies to deal with. Starfishes and drills (*Urosalpinx*), the dreads of the northern culturist, rarely occur; nor do the larger whelks and periwinkles appear to be dangerously plentiful. At all events, the out-of-water character of the majority of the natural beds would render them in a very slight degree subject to these enemies. Below the mark of low water the boring sponge (*Cliona*) is occasionally abundant. Some localities that offer naturally the most admirable conditions for oyster-culture are rendered practically useless by the greatest profusion of sponges. All the oysters that can here be tonged are sadly impoverished; their entire energies have been directed to cementing over the mouths of galleries that are continually piercing the lining of the shell. Many infested shells are coarsely granulated upon their inner faces, and may readily be crumbled between the fingers. Curious malformations in shell occur when the tormented mollusk has had to form a new hinge or new plates for the attachment of the muscle. In fresher and muddier waters the dropped-off raccoons sometimes become covered with barnacles (*Balanus*), being in some instances literally encumbered with them.

THE SPAWNING SEASON.

Dr. C. Bunting Colson, of Charleston, who has carefully studied the raccoon oyster, states* that the spawning season extends from the middle of March to the middle of August. Oysters with ripened ovaries were noted in the shallow creeks of Winyaw Bay on January 10. Spawning oysters were taken near Charleston in February. Individuals appear to differ widely in the time of their spawning, although taken from the same station. In some cases a portion of the reproductive lobes appears to be far more mature than the remainder. It is probable that cases of intermittent spawning occur throughout almost the entire year whenever favorable conditions of temperature prevail. To determine the season at which set occurs some interesting notes may be made from the oyster-covered bottoms of phosphate barges. These are drawn from the water, at stated times for necessary repairs, and the oysters thoroughly removed. A barge bottom thus shows, for example, in February, spat one-sixteenth to one-eighth of an inch in diameter, occurring not uncommonly upon oysters 2½ inches long, that were certainly not older than the launching of the barge in September.

* Elliott Society, March, 1888, p. 199.

VII.—ANALYSES OF OYSTER-BED WATERS OF SOUTH CAROLINA.

In order to compare the various oyster-bearing waters of the State, a table of analyses is given at the end of this report. In this table the localities are arranged in order of time of their examination by the *Fish Hawk*. The waters of Winyaw Bay and its tributary creeks in the northern part of the State are given in analyses 1 to 4; those in the neighborhood of Charleston in analyses 5 to 10 and 135 to 176; those of the Stono and Edisto rivers, St. Helena Sound, and through the Coosaw River, in analyses 111 to 134; still farther southward, in the neighborhood of Beaufort and Port Royal, in analyses 23 to 110; and, finally, through the region of Skull Creek to the Savannah River, in analyses 17 to 22.

The difficulties in analytic work encountered on board of a vessel are unavoidable, and allowance must be made for the slight errors that salt-bearing air and an insecure balance are apt to cause. For accuracy, all standard solutions were prepared in the laboratory of Dr. Doremus, of the College of the City of New York, and forwarded to the vessel. In method of determinations Wancklin was followed, with modifications offered recently by Leffmann and Beam in their "Water Analysis," 1891.

The specimens for analysis were collected at stations that would present most accurately the general character of the body of water. They were, therefore, usually taken in midstream, about a foot from the bottom. To evade organic changes, analyses were made within twenty-four hours after collection of specimens. Suspended materials, that so often occurred, had to be examined with the greatest care. Their character was determined microscopically, and every precaution was taken, as we have suggested on pages 348–349, to avoid the inclusion in analyses of decaying sedimentary organic materials.

The results of the organic work have already been commented upon. The wide variations in amount of free ammonia is noteworthy, and doubtless attributable to the saturation of the waters by the organic salts brought down through extensive swamp tracts, and is entirely of vegetable origin. The extremely high percentage of total chlorides (occasionally 2,500 grains per gallon) is remarkable throughout. The most favorable conditions of saltness would be about 1,800 grains of chlorides. Of this total, common salt would constitute about four-fifths; magnesic and potassic chlorides make up the remainder. The total solids given in the tables are at the best approximate, owing to the lack of facilities for evaporating to absolute dryness in a laboratory on board ship.

The determination of carbonates (lime) in the tables is interesting rather than important. The results prove, however, that the Carolina waters are apparently well calculated to aid the rapid growth of shell structures.

A contrast chemically of Long Island waters with those of Carolina shows that the latter are decidedly salter and offer slightly poorer conditions of feeding.

VIII.—EFFECT OF PHOSPHATE DREDGING UPON THE OYSTER WATERS.

It has been claimed that dredging for phosphate rock (one of the most important industries of the State) pollutes the waters and renders whole regions totally unfit for oyster-culture, and it seems natural that the extent of the industry would exercise some effect upon the life of neighboring waters. In the Coosaw River, for example, a dozen dredgers in the space of 3 miles collect daily about 1,000 tons of washed phosphate rock. This continued work might affect the neighboring water in two ways: (1) chemically, by causing substances, gases, acids, or salts that have been imprisoned in rock or marl, to be taken into solution by the water; or (2) mechanically, by churning or creating a marked muddiness of the water, the material in suspension becoming gradually deposited wherever carried by the currents.

In the first case, to determine any noteworthy chemical changes, a number of water specimens were specially collected; several from the neighborhood of dredgers on either side of Coosaw River, one at the mouth of Parrott Creek. and all of bottom water. The following are the results:

(1) That the salty constituents of the water appear in no way abnormal.

(2) That the ammonias are increased in a marked way, doubtless from the churned-up organic matters which may at once be detected by the microscope, perhaps in part from the dissolved salts of the marl or phosphates. The free ammonia in the immediate neighborhood of dredgers shows as great a proportion as $\frac{12}{100}$ parts per 1,000,000, ten times as great an amount as shown at Port Royal. This ammoniated condition of the water can hardly be regarded as of serious danger to neighboring life.

(3) That the phosphoric ingredient of the water exists in so slight a degree as to be altogether innocuous. No better biological proof is needed than the presence of large gorgonias, sponges, and bryozoans anchored to the fragments of the phosphate rock itself. Water from the neighborhood of Coosaw Dredge No. 5* shows $\frac{15}{100}$ parts per 1,000 of phosphoric acid, the highest result obtained. Off the mouth of Dale Creek, about half a mile distant, the phosphoric acid contained is but $\frac{2}{100}$ parts per 1,000. The alkaline ingredients of the water render impossible the presence of phosphoric acid in an unprecipitated condition, save perhaps as a trace. The amount of phosphate present, slight as it is, is doubtless due to the suspended particles of the phosphate rock. Chemically, therefore, the neighboring waters are not dangerously polluted by the dredging of phosphate.

The injury that would befall life in the neighborhood of dredging is due almost entirely to the mechanical formation and deposit of sediment. The murkiness of the water, the heavy character of the fine, gray silt, and the continual current shiftings of bottom are the causes that render the entire neighborhood for miles about practically unfit for oyster-culture. Particular note was made in the shallow water of the character of the depositing sediment and of the entire absence of living oysters. The daily amount of waste sand, mud, and marl that is sifted out into the stream by the washing processes is almost incalculable. One great dredger, for example, before reaching the phosphate rock, cuts through a dozen feet of overlying material.

* Then in Coosaw River, 1 mile above the mouth of Parrot Creek, 1,000 yards from right shore.

IX.—GENERAL SUMMARY.

In the foregoing notes a number of suggestions have been deduced relating to oyster-culture in the State of South Carolina. We may, for example, infer:

(1) That marketable single oysters may be cultivated in the neighborhood of oyster ledges in all shallow streams whose bottom is sufficiently firm to bear up the weight of the shells and sufficiently unshifting to prevent their engulfment. To establish in any particular locality the suitable character of the bottom, experiments may readily be made.

(2) That the supply of seed oysters may be obtained at once and in great plenty from raccoon ledges and flats. That the oysters should, if possible, be separated from the cluster with due regard to character and size. That the size of the raccoon "seed" should be at least that of a silver dollar, to enable it to resist the invasion of mud and the silt-bearing character of the water. That the seed, although sadly impoverished in its raccoon condition, will in time become changed decidedly for the better in size and quality. That the time required to render the oysters of a marketable quality will depend upon the feeding and living conditions of the locality, and upon the care with which the seed clusters have been separated. A single season, judging from the growth of oysters of a known age (attached to phosphate barges) would probably be sufficient to render the oyster of marketable value.

(3) That if spat is to be collected for purposes of culture, the use of floating collectors of any design is preferable. The down-turned faces of the collector prove most valuable by reason of the lack of sediment accumulation. The destruction by teredos of floating collectors made of scraps of wood or bark suitably disposed, will allow the seed oysters to be planted gradually and automatically.

(4) That to plant, in deeper water, clean shells as spat-collectors would in this region be futile. This result will prove true in waters apparently free from silt.

(5) That marginal waters from the level of low tide to about a fathom in depth will be found best suited for oyster-culture. In this zone the oyster will no longer be exposed to the hardship of raccoon life. If the bottom is favorable, it will here be least subjected to accumulating silt and will receive the most favorable conditions of temperature and feeding.

In conclusion, I desire to express my thanks to those who have so kindly aided me throughout my studies. To Lieut. Robert Platt and the officers of the *Fish Hawk* and to my associates I am indebted for very many courtesies extended to me during the winter. To Dr. C. Bunting Colson, of Charleston, my thanks are due for many valuable notes upon oyster-culture in South Carolina.

In the preparation of the foregoing paper the principal references have been as follows:

Ryder: Experiments in Oyster-Culture; Maryland Fish Commission Report, 1881.
Brooks: Development of the American Oyster; 1880.
Brooks: American Oyster; Johns Hopkins University, 1891.
Winslow: Reports on Oyster Beds of Tangier Sound, etc.; Maryland Fish Commission Report, 1880.
Winslow: Reports on Oyster Beds of the James River; U. S. Coast Survey, 1881.
McCrady: Food of the Oyster; Proceedings Boston Soc. Nat. Hist., 1873.
Colson: Mill-pond Oyster of Charleston; Elliott Soc., March, 1888.
Renaud: Notice sur l'huitre Portugaise et Française cultivée dans la Baie d'Arcachon; 1878.
Lockwood: American Oyster; New Jersey Report of Statistics, 1882.
Turrell: La Pisciculture et la Parcs à Coquillages de la rade de Toulon; Bull. de la Soc. d'Acclimation, Paris, 1878.
Ingersoll: Oyster Industry, Tenth Census.
Möbius: Ueber Austern; Hempel & Parey, Berlin, 1870.
Möbius: Die Auster und die Austernwirthschaft; Hempel & Parey, Berlin, 1877.
Bouchon-Brandeley: Ostréiculture dans la Mediterranée; Wittersheim, Paris, 1878.
Drake: Oyster-Grounds of Georgia; U. S. Coast Survey, 1890.
Pritchard: Infusoria; Wittaker, London, 1861.
William Smith: Synopsis of British Diatomaceæ; Van Voorst, London, 1856.
Bailey: Diatoms of South Carolina; Smithsonian Contributions, 1853.
A number of articles in New York Fish Commission Reports; 1884–87.
Memoir upon Composition and Variation of Ocean Water: *Challenger*.
Memoir upon Composition and Variation of Ocean Water; Forchhammer, Phil. Trans., 115.
Wolle: Diatomaceæ of North America; Bethlehem, Pa., 1890.

Table of analyses of South Carolina oyster-bed waters.

No.	Date.	Locality.	Weather.	Temperature of water.	Tide.	Depth (feet).	Specific gravity (corrected).	Chlorides (salt) (grains per gallon).	Total solids (grains per gallon).	Carbonates (grains per gallon).	Ammonia, parts per million.		Remarks.
											Free.	Albuminoid.	
1	1890. Dec. 31	Jones Creek (Winyaw Bay), 200 yards above mouth of Divide Creek.	Clear...	46.5	$\frac{2}{3}$ F	7	1.0171	1,998	2,302	....	....	....	Raccoon ledges, shell bottom; heavy rust-like sediment.
2	31	Jones Creek, *mouth of* Duck Creek.	...do....	48.5	$\frac{2}{3}$ F	21	1.0239	2,402	2,688	....	.024	.260	Hard sand.
3	31	Jones Creek, near mouth on east shore.	...do....	52	$\frac{3}{4}$ F	5	1.0249	2,544	2,886	....	.059	.064	Do.
4	31	Sign Creek, 100 yards from mouth of Jones Creek.	...do....	47.5	$\frac{1}{6}$ E	11	1.0095	1,218	1,490	....	.032	.192	
5	1891. Jan. 9	Ashley River, near mouth, (100 yards off West Point Mills).	...do....	50	H	Surf. 5	1.0229	2,408	2,740	7.6	.040	.185	
6	9	......do......................	...do....	50	H	Mid.	1.0231	2,492	2,761	7.8	.038	.188	
7	9	......do......................	...do....	50	H	Bot. 20	1.0228	2,441	2,750	8	.033	.190	
8	9	......do......................	...do....	50	L	Surf. 5	1.0215	2,306	2,678	....	.0065	.165	
9	9	......do......................	...do....	50	L	Mid.	1.0217	2,319	2,686	7.6	.008	.165	
10	9	......do......................	...do....	50	L	Bot. 20	1.0218	2,338	2,700	7.6	.020	.170	
11	11	Savannah River, 1 mile above mouth.	...do....	46	H	20	1.0153	1,932	2,301	7.5	.063	....	Heavy sediment, partly organic, plant tissues, fossil diatoms.
12	12	Wright River, ½ mile above mouth.	...do....	47	H	10	1.0113	1,198	1,752	7.2	.270	.400	No oysters; soft mud, turbid; disintegrating plant tissues of sediment inseparable from living organisms. Impossible therefore to indicate food value of locality by high percentage of alb. am.
13	14	New River, near mouth	...co....	47	$\frac{1}{2}$ F	30	1.0176	1,980	2,312	7.2	.120	.50	
14	14	New River, 1 mile above Walls Cut.	...do....	47.5	H	12	1.0148	1,912	2,300	5	.132	.51	
15	14	Cooper River, in lower mouth..	...do....	49	$\frac{5}{6}$ E	14	1.0132	1,863	2,287	5.7	.115	.494	
16	15	Cooper River, in west mouth of Bull Creek.	...do....	50	$\frac{1}{6}$ E	12	1.021	2,430	2,689?	7.5	.0028	.070	Water clear, bottom soft.
17	16	Cooper River, 2 miles from upper mouth.	...do....	51	$\frac{3}{4}$ F	8	1.0213	2,230	2,508?	7.5	.0028	.080	Water clear, bottom hard.
18	16	Cooper River, in upper mouth..	...do....	51	$\frac{5}{8}$ F	11	1.0218	2,416	2,666?	7.5	.0015	.080	Water clear, bottom hard.
19	19	Mackay Creek, in lower mouth	...do....	49	$\frac{5}{8}$ E	24	1.0214	2,274	2,593	7.2	.0110	.0935	Bottom sandy, no raccoons.
20	19	Mackay Creek, 1½ miles below upper mouth.	...do....	49	1st F	31	1.0222	2,419	2,764	7.2	.0065	.135	Few raccoons.
21	22	Okeeteet River, in mouth.......	...do....	53	$\frac{1}{6}$ F	11	1.0212	2,348	2,628	7.8	.014	.085	Clear, hard sand; no oysters.
22	23	Okeeteet River, 1 mile above mouth.	...do....	53	$\frac{1}{6}$ F	7	1.0215	2,308	2,660	7.5	.011	.105	Do.
23	23	Battery Creek, in mouth (Port Royal).	...do....	52	$\frac{1}{2}$ E	18	1.023	2,486	2,757	8	.010	.160	Slightly cloudy, soft mud.
24	23	Beaufort River, midchannel, buoy 9.	...do....	51	$\frac{2}{3}$ E	26	1.0233	2,496	2,784	7.7	.0065	.130	Do.
25	23	Chowan River, head of navigation.	...do....	54	1st F	3	1.0224	2,360	....	7.2	.022	.140	Slightly cloudy, soft mud; raccoons.
26	24	Beaufort River, 1 mile above mouth.	...do....	55	$\frac{1}{2}$ E	12	1.0226	2,430	2,736	7.7	.030	.125	Ebbs dry, except in channel.
27	24	Beaufort River, west shore, near mills.	...do....	53	$\frac{1}{3}$ E	20	1.0224	2,477	2,774	7.6	.012	.1075	Hard sand; no shells.

Table of analyses of South Carolina oyster-bed waters—Continued.

No.	Date.	Locality.	Weather.	Temperature of water.	Tide.	Depth (feet).	Specific gravity (corrected).	Chlorides (salt) (grains per gallon).	Total solids (grains per gallon).	Carbonates (grains per gallon).	Ammonia, parts per million.		Remarks.
											Free.	Albuminoid.	
	1891.												
28	Jan. 24	Beaufort River, off Beaufort wharf.	Clear ...	54	⅓ E	16	1.0225	2,430	2,793	7.6	.010	.081	
29	24	Port Royal, off piles of railroad wharf.	...do	50	H	17	1.0223	2,474	2,781?	7.55	.0045	.0855	
30	24	......do	...do	50	H	8	1.0226	2,520	2,884?	7.60	.004	.0890	
31	24	......do	...do	49.5	H	.5	1.0223	2,452	2,788?	7.5	.000	.087	
32	27	Whale branch (Broad River)...	...do	52	⅓ E	16	1.0212	2,330	2,680	7.6	.026	.105	Hard, black mud.
33	27	Popotaliko River, 2½ miles above mouth.	...do	54	⅚ E	12	1.0145	1,646	2,156	5.9	.0335	.140	Hard, black mud; black inorganic sediment.
34	29	Port Royal, stream section at railroad wharf.	Foggy ..	53	½ F	.5	1.0229	2,460	2,722	7.6	.010	.105	East shore, at outer pile.
35	29	......do	...do	53	½ F	Mid.	1.0229	2,464	2,720	7.7	.012	.130	Do.
36	29	......do	...do	53.5	½ F	Bot. 23	1.0231	2,460	....	8.2	.0135	.145	Do.
37	29	......do	...do	53	½ F	.5	1.0229	2,458	2,760	....	.0135	.085	Midstream, channel.
38	29	......do	...do	53	½ F	Mid.	1.0229	2,464	....	8	.0135	.090	Do.
39	29	......do	...do	53.5	½ F	Bot. 26	1.0229	2,476	2,789	8.1	.020	.0955	Do.
40	29	......do	...do	54	½ F	.5	1.0229	2,419	....	7.7	.019	.116	New west bank.
41	29	......do	...do	54	½ F	Bot. 8	1.0229	2,430	....	7.4	.018	.129	20 yards off west bank.
42	29	......do	...do	53.5	½ F	.5	1.0229	2,350	....	7.5	.020	.132	Near east bank.
43	29	......do	Clear ...	55.5	H	.5	1.0229	2,458	2,826	7.65	.004	.1055	East shore, at outer pile.
44	29	......do	...do	54.5	H	Mid.	1.0229	2,464	2,830	7.5	.002	.0995	Do.
45	29	......do	...do	54	H	Bot. 23	1.023	2,475	2,900	7.55	.0096	.1140	Do.
46	29	......do	...do	55	H	.5	1.023	2,508	2,940	7.8	.0053	.1030	Midstream, channel.
47	29	......do	...do	54.5	H	Mid.	1.023	2,504	2,938	7.82	.0085	.0920	Do.
48	29	......do	...do	54	H	Bot. 26	1.023	2,492	2,862	7.6	.0045	.0670	Do.
49	29	......do	...do	55.5	H	Bot. 3	1.0227	2,464	....	7.6	.010	.089	Near east shore, over raccoons.
50	30	......do	Cloudy .	57	½ E	.5	1.023	2,352	2,672	7.9	.010	.1225	East shore, at outer pile.
51	30	......do	...do	57	½ E	Mid.	1.023	2,486	....	7.7	.004	.1040	Do.
52	30	......do	...do	57.5	½ E	Bot. 25	1.023	2,530?	2,848	7.9	.0215	.1235	Do.
53	30	......do	...do	57	½ E	.5	1.0228	2,464	2,720	7.85	.0175	.0590	Midstream, channel.
54	30	......do	...do	57	½ E	Mid.	1.0228	2,484	....	7.85	.0105	.0920	Do.
55	30	......do	...do	58.5	½ E	Bot. 26	1.0234	2,506	2,840	7.8	.0011	.0535	Do.
56	30	......do	...do	57.5	½ E	.5	1.0219	2,464	....	7.7	.009	.1292	Near west bank.
57	30	......do	...do	57	½ E	Bot. 7	1.0228	2,500	....	7.7	.011	.119	20 yards off west bank.
58	30	......do	...do	59.5	½ E	.5	1.0226	2,460	....	7.9	.012	.130	Near east bank.
59	30	......do	...do	60	½ E	....	....	....	....	....	....	....	
60	Feb. 3	......do	Clear ...	60	L	.5	1.0231	2,424	2,744	7.7	.0025	.1000	East shore at outer pile.
61	3	......do	...do	60	L	Mid.	1.0231	2,464	....	7.9	.0125	.1445	Do.
62	3	......do	...do	60	L	Bot. 18	1.0231	2,521	2,801	8	.0200	.1105	Do.
63	3	......do	...do	60	L	.5	1.0231	2,464	2,709	7.7	.00335	.0660	Midstream, channel.
64	3	......do	...do	60	L	Mid.	1.0233	2,486	2,747	7.9	.0150	.0760	Do.
65	3	......do	...do	60	L	Bot. 18	1.0233	2,508	2,798	8.1	.0135	.0810	Do.
66	3	......do	...do	60	L	1	1.0211	2,492?	....	7.9	.0130	.100	Near west bank.
67	3	......do	...do	60	L	Bot. 7	1.0211	2,464	....	7.6	.011	.1160	20 yards off west bank.
68	3	......do	...do	60	L	.5	1.0229	2,424	....	7.6	.004	.1100	Near east shore.
69	4	Jericho Creek, section of stream at Brotherhood's wharf.	...do	59	½ F	.5	1.0223	2,458	2,718	7.5	.0027	.1115	East shore, at outer pile (water clear, bottom hard or sticky mud, shelly near shore).
70	4	......do	...do	58.5	½ F	Mid.	1.0222	2,413	2,781	7.8	.0043	.1310	Do.
71	4	......do	...do	58.5	½ F	Bot. 16	1.0223	2,430	2,760	7.85	.0031	.1220	Do.
72	4	......do	...do	56	½ F	.5	1.0221	2,418	2,700	7.2	.0145	.1120	Midstream.
73	4	......do	...do	57.5	½ F	Mid.	1.0222	2,440	2,741	7.2	.0150	.1355	Do.

Table of analyses of South Carolina oyster-bed waters—Continued.

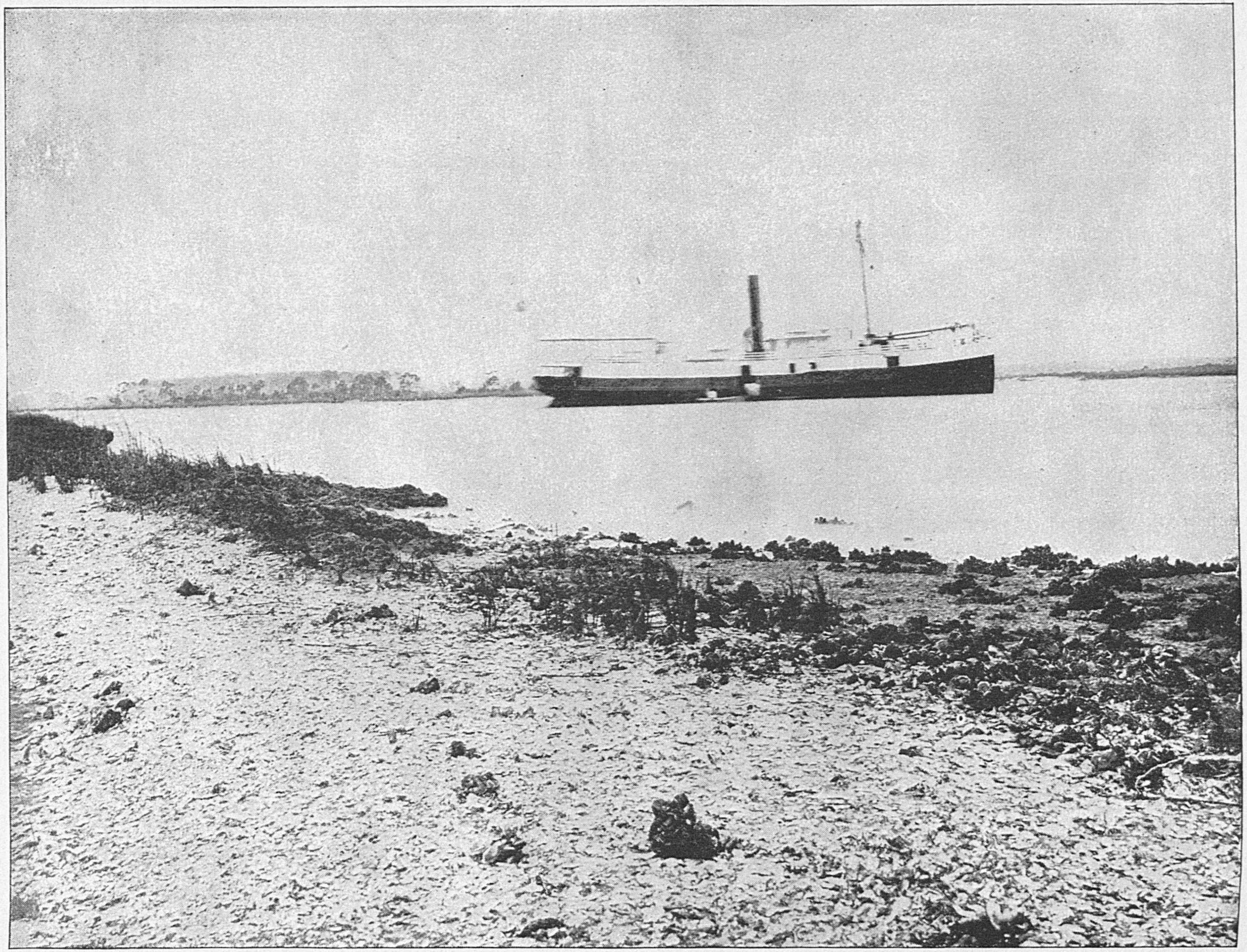
No.	Date.	Locality.	Weather.	Temperature of water.	Tide.	Depth (feet).	Specific gravity (corrected).	Chlorides (salt) (grains per gallon).	Total solids (grains per gallon).	Carbonates (grains per gallon).	Ammonia, parts per million. Free.	Ammonia, parts per million. Albuminoid.	Remarks.
	1891.												
74	Feb. 4	Jericho Creek, section of stream at Brotherhood's wharf.	Clear ...	58	$\frac{1}{2}$ F	Bot. 14	1.0221	2,436	-2,790	7.5	.0200	.1060	Midstream.
75	4	......do	...do	59	$\frac{1}{2}$ F	1	1.022	2,408	2,703	7.3	.005	.1018	Near west bank.
76	4	......do	...do	58.5	$\frac{1}{2}$ F	Bot. 13	1.022	2,446	2,740	7.4	.002	.1119	20 yards off west bank.
77	4	......do	...do	57.5	$\frac{1}{2}$ F	2	1.0221	2,401	2,709	7.3	.0113	.1075	Near east shore (under piles).
78	5	......do	...do	55.5	L	.5	1.0223	2,346	2,783	7.55	.002	.1181	East shore, at outer pile.
79	5	......do	...do	55	L	Mid.	1.0225	2,430	....	7.85	.0039	.1304	Do.
80	5	......do	...do	55	L	Bot. 12	1.0225	2,458	....	8	.0081	.1206	Do.
81	5	......do	...do	55.5	L	.5	1.0222	2,418	2,738	7.75	.0113	.0875	Midstream.
82	5	......do	...do	55	L	Mid.	1.0222	2,418	....	7.8	.004	.100	Do.
83	5	......do	...do	55.5	L	Bot. 14	1.0221	2,419	2,745	7.9	.0045	.070	Do.
84	5	......do	...do	58	L	1	1.0225	2,412	....	7.4	.006	.108	Near west shore.
85	5	......do	...do	55	L	Bot. 9	1.022	2,408	....	7.6	.005	.110	20 yards off west shore.
86	5	......do	...do	56	L	1	1.0224	2,380	....	7.3	.010	.117	Near east shore.
87	6	......do	...d0	54.5	$\frac{1}{2}$ E	.5	1.0227	2,446	2,788	7.6	.0033	.1115	East shore, outer pile.
88	6	......do	...do	54.5	$\frac{1}{2}$ E	Mid.	1.0225	2,474	2,790	7.7	.0033	.1233	Do.
89	6	......do	...do	54.5	$\frac{1}{2}$ E	Bot. 16	1.0225	2,508	2,800	7.7	.004	.0955	Do.
90	6	......do	...do	54.5	$\frac{1}{2}$ E	.5	1.0225	2,452	2,801	7.6	.0013	.1205	Midstream.
91	6	......do	...do	54.5	$\frac{1}{2}$ E	Mid.	1.0227	2,464	....	7.75	.0021	.1310	Do.
92	6	......do	...do	54.5	$\frac{1}{2}$ E	Bot. 12	1.0227	2,502	2,809	7.8	.0003	.0905	Do.
93	6	......do	...do	54.5	$\frac{1}{2}$ E	1	1.0225	2,452	....	7.5	.0221	.116	Near west shore.
94	6	......do	...do	54.5	$\frac{1}{2}$ E	Bot. 9	1.0225	2,458	....	7.7	.0228	.101	20 yards off west shore.
95	6	......do	...do	54.5	$\frac{1}{2}$ E	.5	1.0225	2,458	....	7.4	.0220	.099	Near east shore.
96	9	......do	...do	59.5	H	.5	1.0221	2,464	....	7.3	.003	.150	East shore, outer pile.
97	9	......do	...do	58	H	Mid.	1.0222	2,488	....	7.4	.004	.160	Do.
98	9	......do	...do	58	H	Bot. 21	1.0227	2,490	....	7.5	.006	.161	Do.
99	9	......do	...do	57.5	H	.5	1.0226	2,464	2,788	7.3	.034	.155	Midstream.
100	9	......do	...do	58	H	Mid.	1.0226	2,486	....	7.7	.033	.150	Do.
101	9	......do	...do	57.5	H	Bot. 17	1.0226	2,486	....	7.8	.020	.145	Do.
102	9	......do	...do	59.5	H	1	1.0221	2,402	2,758	7.25	....	....	Near west shore.
103	9	......do	...do	58	H	Bot. 16	1.0226	2,440	2,767	6.9	....	....	20 yards off west shore.
104	9	......do	...do	58.5	H	.5	1.023	2,460	....	6.9	.021	....	Near east shore.
105	5	Myrtle Creek, 1 mile above Brotherhood's.	...do	54	L	5	1.0221	2,408	2,730	7.2	.0013	.0615	Best of oysters, running into stream bed; bottom hard; mud and gravel.
106	5	......do	...do	53.5	L	Mid.	1.0222	2,270	....	7.35	.00065	.104'	
107	5	......do	...do	55	L	Bot. 12	1.0222	2,380	2,770	7.45	.00065	.0865	
108	9	......do	Foggy ...	58.5	H	.5	1.0228	2,424	2,778	7.5	.0118	.0915	Specimens taken at same time as those of analyses 96 to 104.
109	9	......do	...do	58.5	H	Mid.	1.0228	2,444	2,797	7.7	.0046	.1165	
110	9	......do	...do	59	H	Bot. 18	1.0227	2,464	2,798	7.5	.0046	.0830	
111	17	Coosaw River, near red buoy 6..	Clear ...	64	$\frac{1}{3}$ F	Hard 10	1.0189	2,234	2,686	7.2	.080	.120	Gray silicious and clayey sediment. Microscopic particles of organic substances included, mainly fragments of moss and marsh grass. Many tests of fossil diatoms sometimes occur.
112	17	Coosaw River, at ferry..........	...do	64	L	Soft 18	1.0197	2,251	2,650	7.	.063	.120	
113	17	Coosaw River, off mouth of Dale Creek.	...do	64	L	16	1.0211	2,234	2,620	6.9	.0665	.110	
114	17	Coosaw River, off mouth of Parrott Creek.	...do	64	$\frac{1}{5}$ F	Soft 16	1.0199	2,076	2,686	6.8	.1180	.160	
115	19	Coosaw River, east shore opposite mouth of Dale Creek.	...do	65	$\frac{5}{8}$ E	Soft 10	1.0198	2,006	2,528	7.1	.0499	.2325	
116	19	Coosaw River, off mouth of Little Chenken Creek.	...do	66	$\frac{3}{4}$ E	Soft 11	1.0132	1,484	1,732	5.4	.0566	.2675	

Table of analyses of South Carolina oyster-bed waters—Continued.

No.	Date.	Locality.	Weather.	Temperature of water.	Tide.	Depth (feet).	Specific gravity (corrected).	Chlorides (salt) (grains per gallon).	Total solids (grains per gallon).	Carbonates (grains per gallon).	Ammonia, parts per million. Free.	Ammonia, parts per million. Albuminoid.	Remarks.
	1891.												
117	Feb. 19	Coosaw River, inside mouth of Bull River.	Clear ...	64.5	1/6 E	Soft 22	1.018	1,964	2,286	6.4	.0432	.170	Sediment less notable; organic fragments, profusion of diatoms.
118	18	Coosaw River, ½ mile south of mouth of Bull River.	...do	65	7/8 E	Soft 17	1.0198	2,184	2,620	6.5	.053	.1625	
119	19	Combahee River, within mouth, off west bank.	...do	64	1/2 E	Hard 1	1.0179	1,908	....	5.95	.040	.162	Heavy clayey sediment; living forms, decaying plant tissues; odor marshy.
120	19	South Wimbee, 2½ miles above mouth.	...do	67	L	Hard 12	1.0184	2,004	....	6.4	.039	.159	Very little sediment; organisms mainly living.
121	24	St. Helena Sound, 300 yards off southeast end of Morgan Island.	...do	66	1/2 E	Hard 30	1.0206	2,282	2,555	7.45	.0332	.1575	After wind storm, silicious sediment; living organisms plentiful; fossil diatom tests.
122	24	Morgan River, inside mouth of Village Creek.	...do	62.5	1/8 F	Hard 11	1.0207	2,186	2,620	7.05	.0266	.15	
123	25	Ashepoo River, 1½ miles above mouth (Mosquito Creek).	...do	65	1/6 E	Hard 14	1.0128	1,400	1,662	6.15	.0199	.2275	Water slightly cloudy; flocculent dark sediment, clayey, with many organic particles.
124	25	Ashepoo River, near mouth......	...do	64	1/6 E	Hard 24	1.0231	2,446	2,674	7.65	.0133	.1325	Slight ocherous sediment; decaying organisms absent.
125	Mar. 3	McCloud Creek, 3½ miles above mouth.	Windy .	57	H	Hard 10	1.0194	2,228	2,608	6.9	.0466	.140	
126	3	Wadmelaw River, near mouth.	Clear ...	56	1/8 F	Hard 33	1.0196	2,152	....	6.6	.0533	.1335	
127	4	Steamboat Creek, opposite Edisto landing.	Cloudy .	56	L	Hard 25	1.0202	2,177	2,346	6.7	.0466	.1375	
128	4	North Edisto, opposite mouth of Leadenwah Creek.	...do	57	L	Hard 40	1.0219	2,382	2,620	7.35	.0399	.1425	
129	4	North Edisto, opposite mouth of Bohicket Creek.	...do	57.5	1/8 F	Hard 18	1.0228	2,418	2,701	7.4	.0466	.1320	
130	4	North Edisto, opposite mouth Townsend River.	...do	56	1/8 F	Hard 60	1.0233	2,390	2,691	7.6	.0133	.1220	
131	4	North Edisto, in mouth of Bohicket Creek.	Clear ...	56.5	1/2 F	Hard 11	1.0228	2,412	2,801	7	.0133	.1217	
132	6	Stono River, west branch, 3 miles above mouth of Kiawah River.	...do	54	5/6 E	Hard 20	1.0237	2,582	2,684	8	.0332	.125	
133	6	Stono River, over mud flats of Kiawah River.	...do	54.5	1/8 F	Hard 11	1.0242	2,626	2,900	7.95	....	....	
134	6	Stono River, 1 mile above mouth.	...do	58	1/2 E	Hard 18	1.0236	2,480	2,829	7.8	.0006	.1115	
135	8	Cooper River, section of stream from custom-house dock.	...do	56	H	.5	1.0221	2,408	2,628	7.95	.0019	.080	At custom-house bulkhead.
136	8	......do	...do	56	H	Mid.	1.0221	2,412	2,624	8.05	.0013	.095	Do.
137	8	......do	...do	55.5	H	Bot. 10, soft	1.0221	2,430	2,701	8.05	.0013	.135	Do.
138	8	......do	...do	55	H	.5	1.0221	2,424	2,656	7.4	.0013	.085	Midstream, black buoy.
139	8	......do	...do	55	H	Mid.	1.0221	2,480	2,618	7.5	.0066	.115	Do.
140	8	......do	...do	55	H	Bot. 36	1.0222	2,430	2,706	7.9	.0053	.165	(Cloudy sediment, clayey and silicious.)
141	8	......do	...do	56.5	H	Mud .5	1.0222	2,408	....	7.5	.0046	.130	East shore at stake, over raccoons.
142	8	......do	...do	56.5	H	Bot. 6	1.0222	2,424	....	7.6	.0026	.100	Do.
143	9	Ashley River, stream section at Charleston bridge.	...do	59	H	.5	1.0227	2,357	....	7.45	.0039	.140	E. bank; v. p. 342 for notes.

Table of analyses of South Carolina oyster-bed waters—Continued.

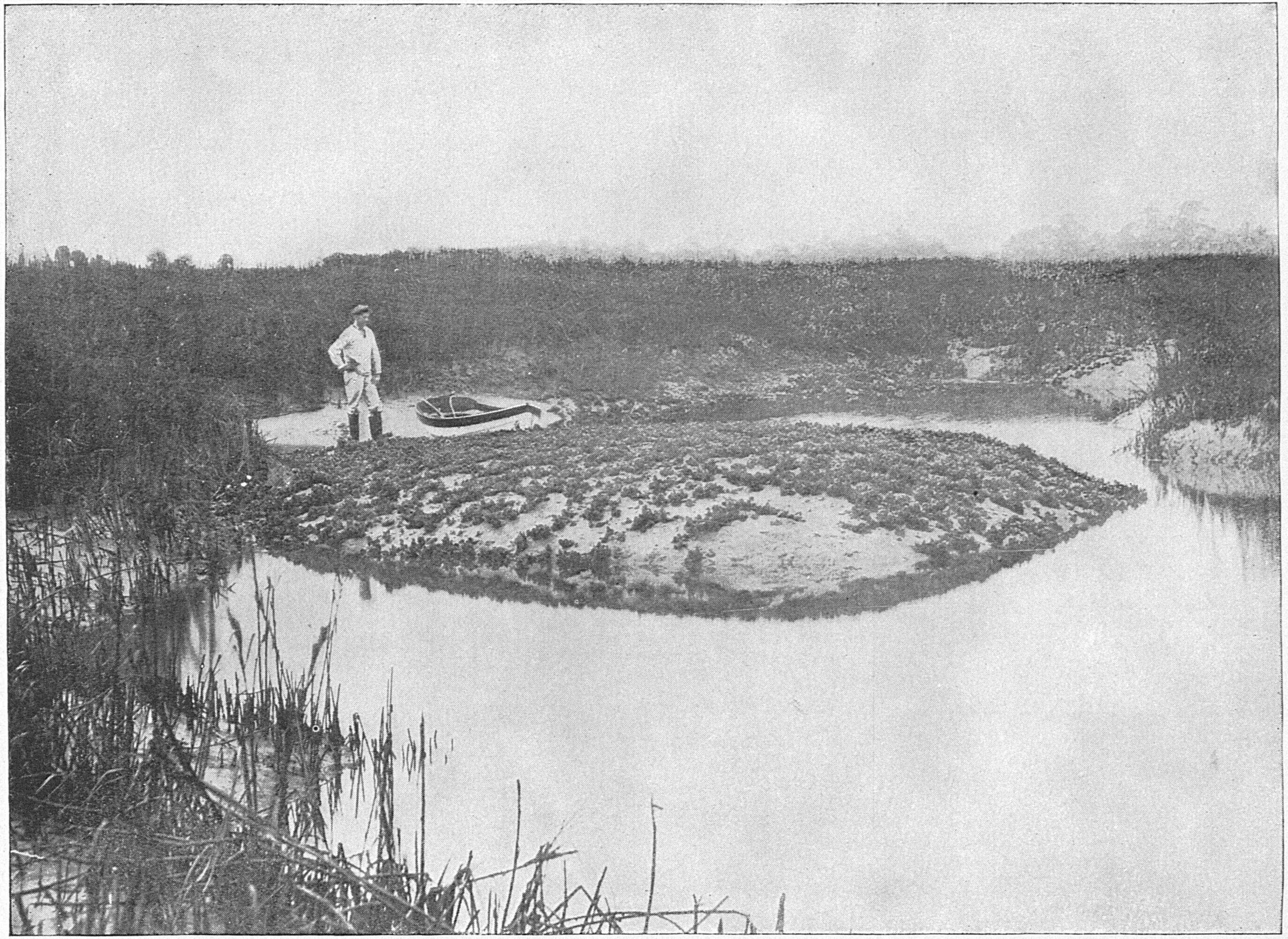
No.	Date.	Locality.	Weather.	Temperature of water.	Tide.	Depth (feet).	Specific gravity (corrected).	Chlorides (salt) (grains per gallon).	Total solids (grains per gallon).	Carbonates (grains per gallon).	Ammonia, parts per million.		Remarks.
											Free.	Albuminoid.	
	1891.												
144	Mar. 9	Ashley River, stream section at Charleston bridge.	Clear	59	H	Mid.	1.0227	2,397	2,601	7.55	.0033	.115	E. bank upon sediment.
145	9	do	do	59	H	Bot. 8	1.0227	2,380	....	7.6	.0026	.165	Do.
146	9	do	do	58	H	.5	1.0227	2,380	....	7.15	.0006	.102	Midstream, at drawbridge.
147	9	do	do	57.5	H	Mid.	1.0223	2,402	2,687	7.25	.0019	.125	Do.
148	9	do	do	57.5	H	Bot. 38	1.0225	2,419	....	7.55	.0006	.0985	Do.
149	9	do	do	58.5	H	.5	1.0225	2,368	....	7.45	.0006	.135	West bank, 50 yards off.
150	9	do	do	58	H	Mid.	1.0225	2,391	2,650	7.3	.0006	.130	Do.
151	9	do	do	57.5	H	Bot. 4	1.0225	2,374	....	7.6	.0006	.115	Do.
152	9	do	do	58	L	1	1.0210	2,195	2,434	7.6	.0466	.095	E. bank.
153	9	do	do	58	L	.3	1.0208	2,230	2,412	7.7	.0199	.145	Midstream, at draw.
154	9	do	do	57.5	L	Mid.	1.0201	2,288	2,500	7.7	.0066	.154	Do.
155	9	do	do	57	L	Bot. 30	1.0201	2,244	2,581	7.75	.0099	.122	Do.
156	9	do	do	57.5	L	.5	1.0207	2,234	....	7.25	.0019	.16	W. bank, as before.
157	9	do	do	57.5	L	Mid.	1.0205	2,234	2,609	7.25	.0013	.165	Do.
158	9	do	do	57.5	L	Bot. 8	1.0211	2,234	....	7.75	.0006	.180	Do.
159	11	do	do	57	½ E	.5	1.0220	2,329	....	7.8	.0166	.105	E. bank, as before.
160	11	do	do	57	½ E	Mid.	1.0222	2,334	2,689	7.6	.0099	.11	Do.
161	11	do	do	57	½ E	Bot. 7	1.0222	2,340	....	7.5	.0099	.145	Do.
162	11	do	do	57	½ E	.5	1.0220	2,352	....	7.6	.0013	.066	Midstream, as before.
163	11	do	do	57	½ E	Mid.	1.0222	2,368	2,709	7.6	.0166	.065	Do.
164	11	do	do	56.5	½ E	Bot. 31	1.0222	2,374	....	7.55	.0332	.0825	Do.
165	11	do	do	57	½ E	.5	1.0218	2,352	....	7.2	.0013	.106	W. bank, as before.
166	11	do	do	57	½ E	Mid.	1.0218	2,352	2,703	7.35	....	.106	Do.
167	11	do	do	57	½ E	Bot. 8	1.0218	2,340	....	7.2	.0006	.070	Do.
168	12	do	Rainy	62	½ F	.5	1.0198	2,201	....	7.4	.046	.210	E. shore, as before.
169	12	do	do	62	½ F	Mid.	1.0198	2,201	....	7.5	....	....	Do.
170	12	do	do	62	½ F	Bot. 8	1.0198	2,201	....	7.5	....	....	Do.
171	12	do	do	59.5	½ F	.5	1.0205	2,299	....	7.5	.0066	.145	Midstream, as before.
172	12	do	do	59	½ F	Mid.	1.0208	2,324	2,699	7.6	.0199	.1075	Do.
173	12	do	do	59	½ F	Bot. 30	1.0208	2,324	....	7.6	.0099	.1250	Do.
174	12	do	do	59.5	½ F	.5	1.0203	2,267	....	7.5	.0266	.160	W. shore, as before.
175	12	do	do	59.5	½ F	Mid.	1.0207	2,286	2,680	7.6	.0332	.150	Do.
176	12	do	do	59	½ F	Bot. 24	1.0206	2,299	....	7.6	.0266	.135	Do.



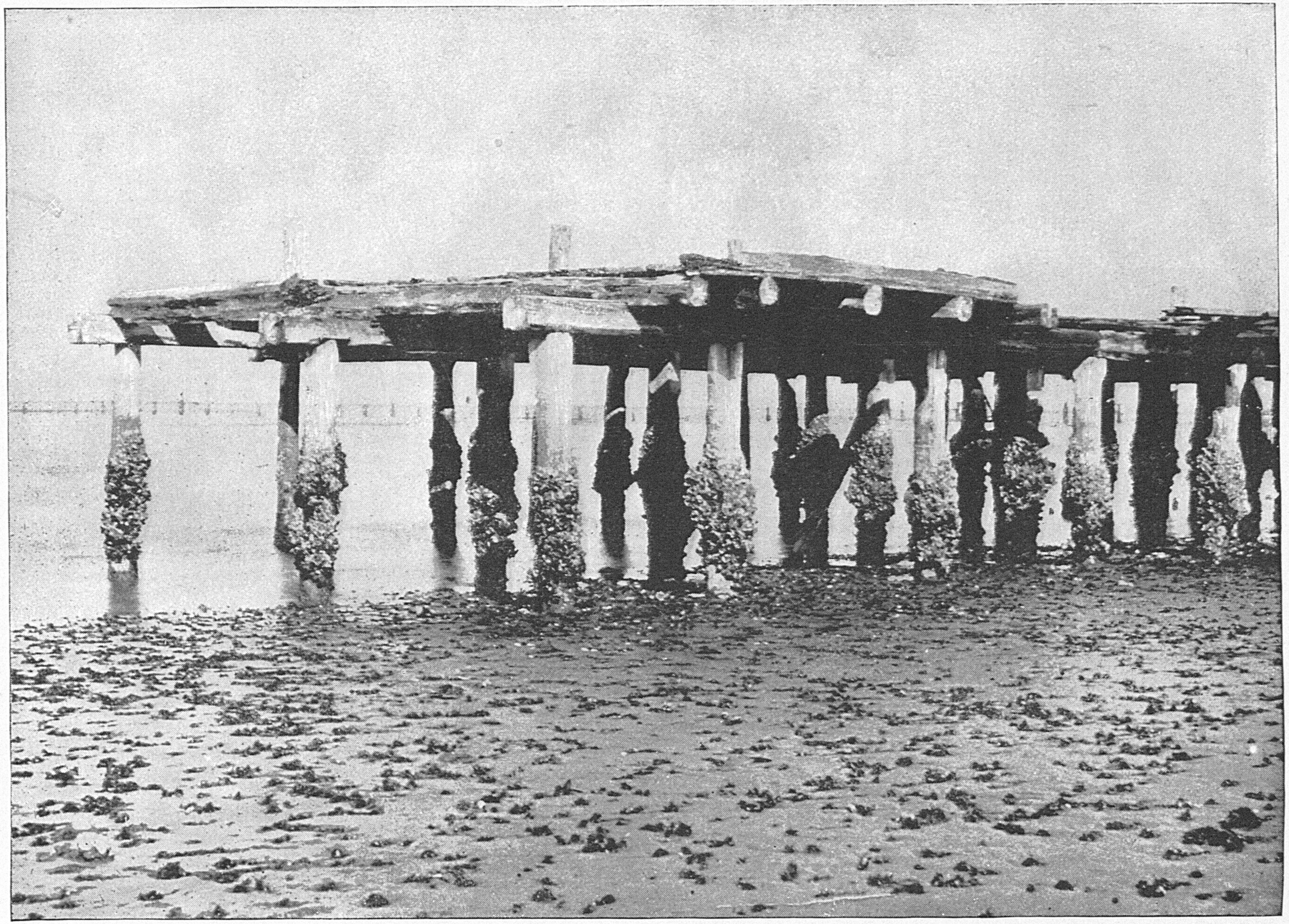
FRINGING OYSTER LEDGE SHOWING LIVING RACCOON OYSTERS, AND THE METHOD OF FORMATION OF SHELL BANKS. STONO RIVER, EAST SHORE, 3 MILES FROM MOUTH, MARCH 6, 1891.

PLATE LXIII.

OYSTER FLAT, SHOWING MUD BANKS AND NATURAL DRAINING TRENCHES. SKULL CREEK, IN WEST MOUTH, JANUARY 13, 1891.



OYSTER ISLAND. A DENSE COMMUNITY OF RACCOON OYSTERS OCCURRING IN MUDDY, MARSH-DRAINING STREAMS. IN SMALL CREEK FLOWING INTO MAY RIVER, 1 MILE FROM MOUTH OF SKULL CREEK, JANUARY 12, 1891.



TIDAL ZONE OF OYSTER DISTRIBUTION IN SOUTH CAROLINA, INDICATED UPON PILING OF WHARF. SULLIVAN ISLAND, MARCH 12, 1891.

AN OYSTER FLAT, SHOWING FAR AND WIDE THE EXTENT OF RACCOON AREAS.

The plate presents more clearly the general character of an extended raccoon region, of which Plate LXIII illustrates but a small proportion. The locality, as in Plate LXIII, is in Skull Creek, near its west mouth, January 13, 1891.

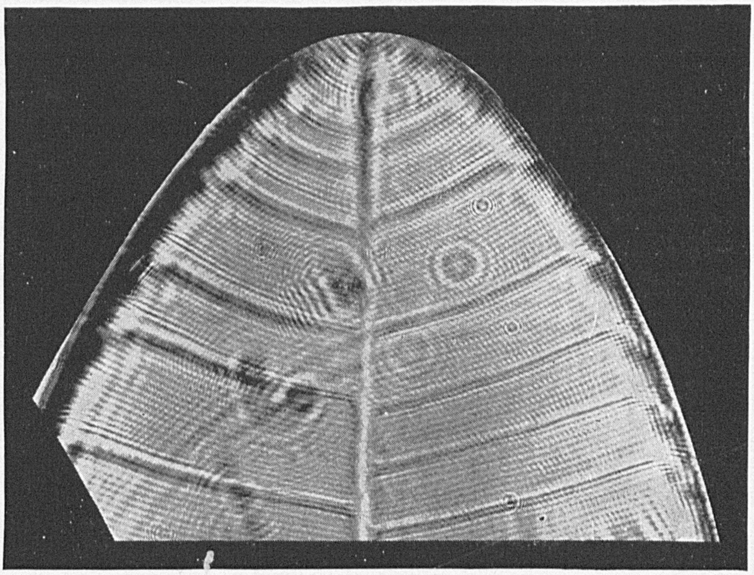


FIG. 1. A PHOTO-MICROGRAPH OF THE DIATOM, SURIRELLA GEMMA, ENLARGED ABOUT 1,600 DIAMETERS.

The tip of the frustule is alone given, to indicate the character and texture of the glassy surface. The photograph was taken with a one-fourth inch objective of Powell and Leland, by Prof. Wm. Statford, of the College of the City of New York.

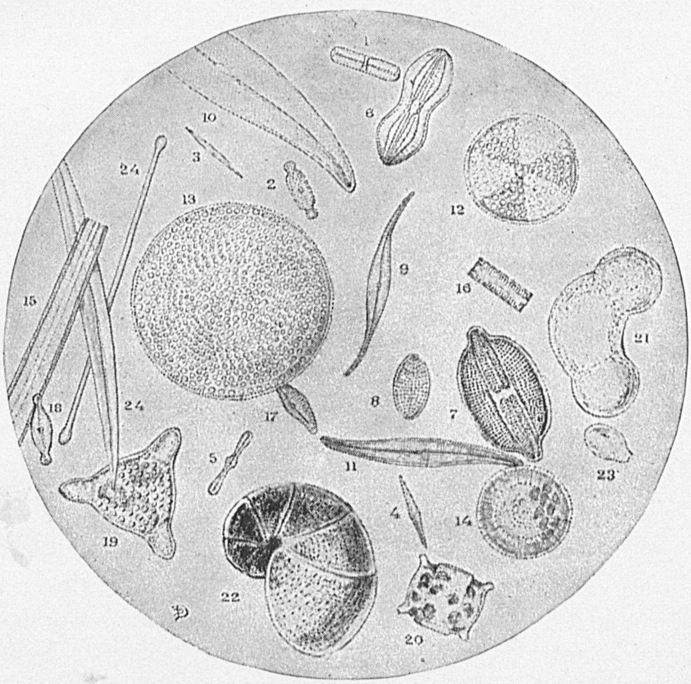


FIG. 2. FOOD OF SOUTH CAROLINA OYSTER. A FEW OF THE TYPICAL ORGANISMS (× 225).

Numbers 1 to 20 are diatoms.

1-5. Navicula (Bory).
6. N. didyma (K).
7. Pinnularia radiosa (?) (K. S.).
8. Amphora sp. (K.).
9. Pleurosigma fasciola (E. S.).
10. P. littorale (S.).
11. P. strigosum (S).
12. Actinocyclus undulatus (K.).
13. Coscinodiscus radiatus (E.).
14. Cyclotella rotula (E.).
15. Synedra sp. (E.).
16. Diatoma sp. (De C.).
17. Cymbella sp. (Ag.).
18. Mastogloia smithii (Thw.).
19. Triceratium alternans (Br. Bai.).
20. Biddulphia sp. (Gr.)
21. Grain of pine pollen (Pinus rigida).
22. Foraminifera (Rotalia).
23. Zoöspore (Ulva ?).
24. Spicules.