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ECONOMIC SURVEY

JOSEPH HYDE PRATT, STATE GEOLOGIST

BULLETIN NO. 15

EXPERIMENTS IN
OYSTER CULTURE IN PAMLICO SOUND NORTH CAROLINA

BY
ROBERT E. COKER

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LETTER OF TRANSMITTAL

CHAPEL HILL, N. C., July 1, 1907.

To His Excellency, HON. ROBERT B. GLENN,
Governor of North Carolina.

Sir—I herewith have the honor to submit for publication as Bulletin No. 15 of the North Carolina Geological and Economic Survey a report by Dr. Robert E. Coker on Experiments in Oyster Culture in Pamlico Sound. This report supplements a preliminary one that was published two years ago on Oyster Culture in North Carolina.

Yours respectfully,
JOSEPH HYDE PRATT,
State Geologist.

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PREFACE

Two years ago a preliminary report was published by the North Carolina Geological and Economic Survey on Oyster Culture in North Carolina, which took up briefly the results of a series of experiments that had been carried on by the Survey in regard to the cultivation of the oyster in certain portions of Pamlico Sound. Experimental beds had been made and kept under constant observation, notes being taken regarding the density of the water; number of diatoms that it contained; growth of the oyster, etc. These experiments have been continued during the past two years and the following report on Experiments in Oyster Culture takes up in detail the results accomplished.

The experimental plants have been very successful during the four years that they have been made and to some extent cultivated and show that there are large areas in Pamlico Sound that are suitable for the cultivation of the oyster and that it can be cultivated profitably. Dr. Robert E. Coker, who has had charge of this work, has described in the greatest detail the methods employed in making the plantings in order that the results that he has obtained may be profitably used by those who wish to take up the cultivation of the oyster. Dr. Coker has been assisted in this work by Mr. Henry D. Aller, Custodian of the Beaufort Laboratory of the U. S. Bureau of Fisheries. In all these investigations, we have had the hearty cooperation of the United States Bureau of Fisheries.

It is hoped and expected that this report will be the means of awakening new interest in oyster culture in North Carolina and result in large areas of the bottoms of Pamlico Sound being entered for this purpose. It is, however, necessary that the cultivator of the oyster be given an incontestable title to the bottom upon which he wishes to cultivate the oyster. Certain legislation is necessary to insure such a title, and there is given at the end of Dr. Coker's report suggestions regarding a bill which it is believed would give an incontestable title to any grant for oyster bottoms in any of the waters of North Carolina.

JOSEPH HYDE PRATT,
State Geologist.

PLACING A BUOY TO MARK EXPERIMENTAL OYSTER PLANT.

EXPERIMENTS IN OYSTER CULTURE IN PAMLICO SOUND, NORTH CAROLINA.

By Robert E. Coker.

INTRODUCTION.

It can be no exaggeration to state that the most urgent problem confronting North Carolina in connection with the general problem of the development of its fisheries is that of the establishment of the industry of oyster culture. When one considers the immense areas of bottom covered by water of a density suitable for the growth of oysters, the abundant natural rocks, many of which yield oysters of excellent quality, and the extended regions, practically barren of oysters, but with the same conditions that characterize those that are productive, the following question suggests itself: Is the present inconsiderable, almost negligible value, of the industry of oyster culture the result of natural conditions, or of failure on the part of the State and its citizens to provide the artificial conditions under which the prospective planters of oysters might utilize the natural conditions at hand?

The culture of oysters is not a new subject in North Carolina. Begun in a very small way, and only for private purposes, at least as early as 1840, it received an impetus in 1884, subsequent to the passage of the laws of 1883, authorizing the taking up of bottoms, except in Pamlico Sound, for private culture. With the failure of planters, for various reasons, to make a success of their efforts, the acreage under cultivation fell away to almost nothing. Again in 1889, the making of the Winslow Survey of Pamlico Sound and other waters, and the adoption of this survey as applying to Pamlico Sound, gave a new impetus to the industry. Greater areas than ever before were taken up, but again the effort of the planters was a failure, and the cause of oyster culture in North Carolina received a set-back from which it has never recovered.

It is not within the province of this paper to take up in detail the causes of the several failures, but, before giving the result of our experiments, a few observations of a more or less obvious nature may be pre-

sented. The failures are attributable in part to the methods of the planters and in part to what we may call legislative conditions. As regards the methods, Dr. Grave,[1] after a study of many of the planted grounds, and of the methods used on them, says:

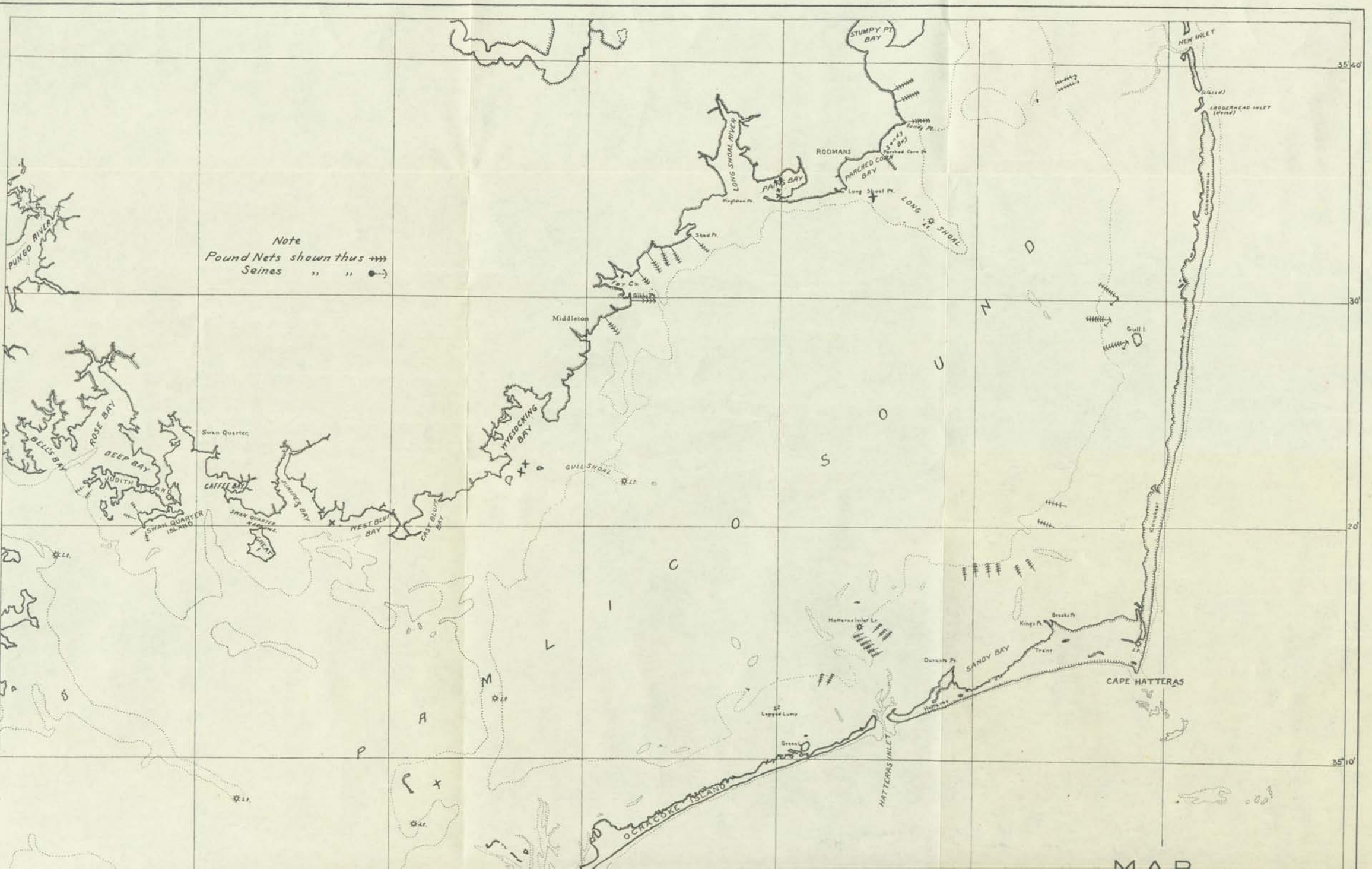
"Oyster planting has been unsuccessful both in section 24 and in Pamlico Sound. The failures, however, have not been due to insurmountable difficulties existing in the various localities, but to lack of experience on the part of the planters or to a belief that an experience in planting oysters in the North is an adequate preparation for planting in an entirely different section of the country where the conditions are very different. Each oyster-producing section has an oyster question of its own entirely separate from that of other localities, and a failure to recognize this fact is likely to lead to failure in any attempt to grow oysters. There is no oyster question, but there are many oyster questions." (Pp. 293-4.)

As regards the legislative conditions, the subject has been fully treated by the writer in a special report.[2] Two points may be repeated here. (1) The maximum limit of acreage was set at 10 acres. Wherever tried, such a limit has proven prohibitive to the development of the oyster culture industry. Only by evasion of the law so as to increase the acreage in the practical ownership of one man, could planting be attempted in Pamlico Sound with even a possibility of success. (2) No provision was made for ascertaining finally, before a lease was granted, whether or not the bottom desired was a natural rock. In consequence, there followed endless litigation and oftentimes the loss of beds as soon as they became productive. It is obvious that the industry can not thrive under constant litigation or the uncertainty that one may enjoy the fruits of successful effort. This is the crucial point; for, had the planters been able to hold what they had cultivated, it is reasonable to suppose that in time the methods would have been corrected to adapt them to the legislative conditions controlling the industry.

From such an unfortunate situation there resulted two-fold harm. (1) In a direct way, the failures of the planters worked great injury to the industry. (2) The situation offered no hope that practical efforts directed by private enterprise would bring the solution of such primary questions, as whether or not natural conditions in North Carolina were favorable to the industry and what were the proper methods to be used.

[1] "Investigations for the Promotion of the Oyster Industry of North Carolina." Caswell Grave. U. S. Fish Com. Report for 1903, pp. 243-341, 11 plates.

[2] "Oyster Culture in North Carolina." North Carolina Geological Survey, Economic Paper No. 10, 1905.


Note
Pound Nets shown thus
Seines " "
PUNGO RIVER
STUMPY PT BAY
NEW INLET
LONG SHOAL RIVER
PAMLICO BAY
PARCHED CORN BAY
ROBMANS
LONG SHOAL
LOGGERHEAD INLET
Middleton
WYSOCKING BAY
GULL SHOAL
Gull I.
ROSE BAY
BELLS BAY
DEEP BAY
JUDITH BAY
CAFFEE BAY
SWAN QUARTER ISLAND
Swan Quarter
JUNIPER BAY
WEST BLUFF BAY
EAST BLUFF BAY
PAMLICO SOUND
Hatteras Inlet Lt
SANDY BAY
CAPE HATTERAS
OCRACOKE ISLAND
HATTERAS INLET
35° 40'
30'
20'
35° 10'

These were the questions, then, to which the investigations conducted by the national and state governments were first directed.[3]

PAMLICO SOUND.

The oyster industry in North Carolina is dependent for its growth on the development of the bottoms of Pamlico Sound. The series of sounds and inlets along the North Carolina coast from Currituck to Myrtle form an almost continuous series of waterways. Currituck and Albemarle are not oyster territory. Croatan and Roanoke are small and liable to freshets, though, as will be seen later, they may be made useful in certain phases of oyster culture. The sounds and estuaries south of Bogue Inlet are all small, though offering valuable oyster grounds. Core and Bogue sounds, with their tributary rivers, while larger and very productive, are comparatively small beside the millions of acres in Pamlico Sound. To some extent this inequality is counterbalanced by the fact that Core and Bogue sounds are accessible to the many oystermen living along the shores, and they are probably the most available regions for small farms of fifty acres or less in extent. It is important to realize, however, that Pamlico Sound (see Pl. II) is as large as Long Island Sound, where over 80,000 acres are under cultivation, and something like half as large as the Chesapeake Bay, where, even though oyster culture is largely undeveloped, over 13,000 acres of bottom are held for cultivation in the state of Virginia alone. At the present time the state of Maryland is just preparing to open for cultivation the part of the bay that lies within its territory.

Nevertheless, it is by no means to be inferred, without investigation or practical experience, that Pamlico Sound may be made productive in the

[3] The following figures, taken in part from Grave's Report, show in epitome the importance of the industry of taking oysters from the natural rocks, and the decline of this industry. They point clearly to the fact that the future of the oyster industry is dependent on the development of oyster culture.

No. of bus. taken in 1887	100,000	(cir.)
" " " " " 1890	2,700,000	(estimated)
" " " " " 1893-94	60,000	
" " " " " 1896-97	40,000	

This decline followed the exclusion of Maryland, Virginia, Delaware, and New Jersey vessels that made the large part of the catch of 1890.

No. of bus. taken in 1897	858,818	
" " " " " 1898-99	2,450,000	
" " " " " 1899-00	1,900,000	
" " " " " 1901-02	693,516	
" " " " " 1902-03	658,769	From the territory under
" " " " " 1903-04	505,141	the jurisdiction of the
" " " " " 1904-05	459,485	State Oyster Commission.
" " " " " 1905-06	291,846	

same proportion as Long Island Sound or Chesapeake Bay. Its potentialities are as yet but little tested and many factors enter into the problem. We know that Pamlico Sound is the chief oyster producing water of the State; that in various parts of the sound oysters are found excellent in size, shape and flavor; that in all parts of the sound there are great areas barren or nearly barren of oysters; and that these areas sometimes include bottoms essentially similar to others that are productive. We are then presented with a number of questions:

1. How much of the sound is barren of oysters or practically so? This can only be answered by making a careful survey of the region and this is not within the scope of our present investigations.

2. Can the natural beds be made more productive? Believing that the urgent matter is that of private cultivation, our investigations have not been directed toward this question. It may merit the attention of the State after the natural beds have been surveyed and charted.

3. Is much of the barren area available for oyster-culture?

4. What are the methods suited to the diverse conditions met with in various localities?

5. What are the physical and biological conditions in Pamlico Sound that are favorable or unfavorable to the growth of oysters?

6. Is it feasible to improve the quality of the oysters produced by careful and intelligent cultivation?

These last four questions have been partly answered by the observations and experiments forming the basis of this report. It is hardly necessary to add that it is not possible fully to answer these questions from the limited number of experiments with which this paper deals.

GENERAL FEATURES OF THE SOUND.

Pamlico Sound is an almost land-locked body of water separated from the ocean by the narrow strip of Banks that extends along the northern two-thirds of the coast of North Carolina (Pl. II). Extending in a general northeast-southwest direction from Roanoke Island in Dare County to Harbor Island in Carteret and Point of Marsh at the mouth of Neuse River in Craven County, it has a length of nearly 70 miles and an average width of about 20 miles. The Sound is narrowest at the upper end where it is about 9 miles in width, but nowhere south of Long Shoal, near the upper end, is the width less than 16 miles, the distance between Ocracoke on the east and Bluff Point on the west. The greatest widths, about 26 miles, are opposite Cape Hatteras and again opposite Portsmouth "Island."

Salt water is received through four breaks in the Banks, known as Oregon, New, Hatteras, and Ocracoke Inlets, and in some degree, from Core Sound on the south. Large quantities of fresh water enter from Albemarle Sound through Croatan and Roanoke sounds, and from the Neuse, Pamlico, and Pungo rivers, and in less degree from the various small rivers, creeks and canals of the coast of Dare, Hyde, Pamlico, Craven, and Carteret counties. In consequence of there being no main outlet to the Sound, and partly in consequence of the action of the winds, referred to below, the fresh and salt water become rather well mixed so that throughout the sound there is a condition of much more uniform salinity than might be expected. It is said by some that the water is even fresher on the west than on the east, but while this does not seem to be the case, the difference is much less than might at first be supposed.

Three great shoals divide the sound somewhat roughly into four main regions (see Pl. II). The extreme northern region from Roanoke Island to Long Shoal, receives salt water from Oregon and New Inlets, and fresh water mainly through Croatan and Roanoke sounds. South of Long Shoal and extending a distance of 30 miles to Bluff Shoal is a large region receiving salt water directly from Hatteras and Ocracoke inlets and fresh water from the numerous small sluggish streams on the shores of Dare and Hyde counties. Gull Shoal extends out into this region. Bluff Shoal with Royal Shoal and the shoals off Ocracoke, make a continuous shoal, 11 feet or less in depth, which extends entirely across the Sound from Bluff Point to Ocracoke, and so partly separates the northeastern arm of the Sound from the southwestern. The latter communicates with the ocean through Ocracoke Inlet, and with Core Sound at Harbor Island. Like the northeastern, the southwestern arm is subdivided into two main regions. Brant Shoal, reaching 12 miles out from the shore of Pamlico County, south of Pamlico Point, partially separates an upper region opposite the mouths of Pamlico and Pungo rivers from a lower that receives the flow of fresh water from the Neuse River.

These regions are by no means distinctly marked off from one another. The great shoals serve to break the force of the sea and, to some extent, to deflect the currents; but the water drifts before the wind in one direction or another and the water of one region is mingled with that of the next and thus the variation of density from one region to another is less than it might otherwise be. What the conditions of salinity would be without the effect of the winds is a matter of speculation, but the fact that the winds have indirectly a marked effect in this regard, is a matter of observation as will appear below, especially in the notes on the Harbor Island plants, p. 21. In fact, the wind is a most significant factor in

the environmental conditions of oysters and other forms in Pamlico Sound. They cause the chief currents that bring food to the oysters, admit the distribution of spat, and modify the conditions of salinity. The lunar tides are noticeable only in the region of the four inlets. Elsewhere, the currents and the rise and fall of tides are governed entirely by the winds, except in so far as there must be a general irregular and more or less indefinite set of the current away from the mouths of the great rivers.

An important factor in the growth of oysters is the character of the bottom. A bottom may be so soft as not to support the weight of a shell, or with just consistency enough to prevent the oyster from completely "mudding" but allowing it to so settle in the bottom that its growth in one dimension will be out of proportion; the bottom may be of sand and of such a nature that the action of the waves and currents will cause "sanding," or the bottom may appear good but be subject to the encroachment of shifting sand-shoals, or, perhaps, to the deposition of mud. Again, there may be a variety of bottoms that are good and safe, and these may be of sand or of clay, or of mud of varying degrees of consistency, or of mud with a superficial crust of sand, or of sand with a surface layer of mud, etc.

General statements regarding the suitableness of the bottom in Pamlico Sound for oyster culture can not be made, as our observations are not extended enough. But it may be said that the Sound presents a wide variety of bottoms and the prospective planter must, here as elsewhere, supplement the information that he can obtain from the chart by actual examination of the bottom in question.

A survey of Pamlico Sound having for its object the charting and description of the bottoms, in regard to their adaptability for the purposes of oyster culture, would be an important step for the promotion of the industry. The character of the bottom in the region of each experimental plant will be described in connection with the description of the plants, and, as will be seen, our plants have been so located as to test a variety of bottoms.

METHODS OF PLANTING OYSTERS.

The object of this study has been, primarily, to learn something of the possibilities of Pamlico Sound for the cultivation of oysters, and the most direct way of approaching such a problem is to make experimental plants. It is purposed in this section to give such a general account of the conditions under which the work has been prosecuted, and of the methods of planting and of observation, as may be necessary for an understanding

of the accounts of the several plants, and for a proper interpretation of the results of the experiments.

From October, 1902 to September, 1904, I was stationed at Beaufort, 40 miles from the southern limit of Pamlico Sound. Having other duties and studies at Beaufort, I could take trips to Pamlico Sound only at irregular intervals. During this time eight trips of 4 to 30 days duration each were made. Three visits were made later, one in the summer of 1905, and two in 1906. The planted beds could not, therefore, be kept under regular observation, or examined at definite intervals. The trips were taken in such boats (launches, small schooners or sharpies) as could be obtained at the times. A good deal of time was necessarily taken in travel to and from the sound and often the small boats were confined to harbor by bad weather for several days at a time.

PLANTS.

In general, the history of a plant was as follows: On a preliminary trip a certain locality was chosen as a desirable place for the location of an experimental plant. After the making of the necessary preliminary observations, a temporary buoy or stake was placed (Pl. I and Pl. V, *A*) and left until the next opportunity to come back to the place with a schooner load of shells. At each place it was desired to employ more than one method of planting so that each *bed* consists of two to four *plants*. Sometimes it was desired to ascertain, before making a bed, if planted shells would remain above the sand or mud, or whether a set of spat would occur. Trial plants of ridges of shells would then be made and kept under observation for some time before attempting to make a bed. On subsequent trips, each bed, or every one that it was practicable to visit, was examined for set of spat, growth of oysters, and the general condition of the bed in other respects. From what has been stated above in regard to the conditions under which the work has been carried on, it may be seen that there was not opportunity for the taking up and replanting of the young oysters; that the plants had to remain without cultivation. The limitation of results imposed by this condition may be kept in mind in reading the accounts of the several experiments.

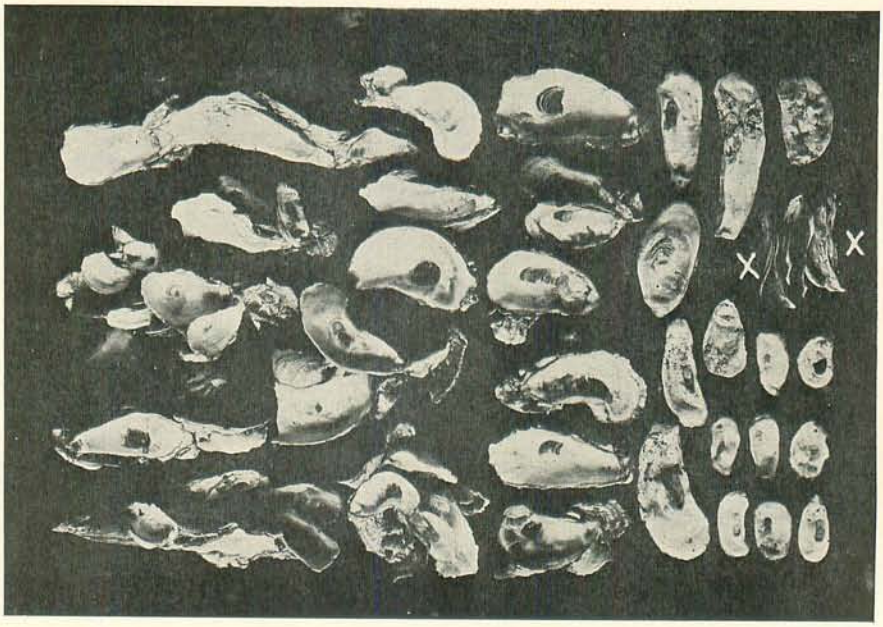
DENSITY AND CURRENTS.

As the chief reliance for results was placed in the observed history of the plants, little explanation is needed regarding the methods of making other observations. For taking the density or salinity of the water, Hilgarde's Ocean Salinometer was used. This consists of three specific gravity bulbs, registering from 1.000 to 1.0110, 1.0100 to 1.0210, and

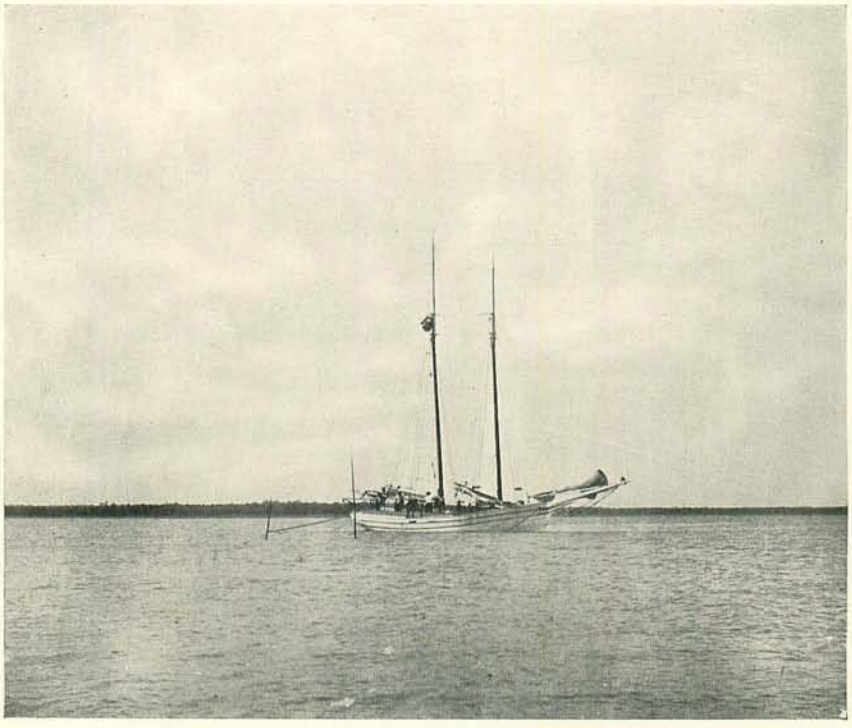
1.0200 to 1.0310, respectively. For our practical purposes it was not considered necessary to make temperature corrections of the density observations. The current-meter, designed by Professor Holmes and described in Graves' report was employed at first, but was found to have serious objections for use in Pamlico Sound, where the currents are usually comparatively slow and governed by the wind. Two modifications of the types made it well adapted for our purposes. The top-shaped float was found to offer too much surface to the wind and the waves. The currents in Pamlico Sound are caused almost altogether by the winds, but a flow may be so deflected by shoals or points of land, as to have at a given point a secondary direction at right angles or directly opposed to the wind. If the current at a certain place is slow and the wind strong and in the opposite direction, the effect of the wind, and especially of the waves on the top-shaped floater buoy may be such as to entirely check the meter, or to drive it against the current. The substitution of a light tin tube about 2½ inches in diameter by 2 feet in length was found to be a material improvement, since a float of this form offers practically no resistance to the waves. To obviate the dragging effect of the line which, when it became wet, would sink in the water, unless kept so taut as actually to retard the meter, small pieces of cork were fastened to the string at intervals of 3 feet. This served to keep the string afloat and the entire line being in view, the observer could at any time tell whether the line had been drifted to one side by superficial currents, and could, by a very slight pull, if necessary, make the line straight at the moment of taking time. One objection that may be urged against such a meter is the fact that it does not record the current at any given point, but gives the average current, at the time, for the 100 or 200 feet that the meter is allowed to run. This objection has little weight, however, since the object of an oyster planter is, not to ascertain the current at given points, but to know the average current over an area to be planted.

CULTCH.

The first plants were made with shells. It was thought then that some of the later plants might be made with seed oysters from the natural beds; but, after noting the good set of spat on all of the beds, it was decided to continue to use dry shells exclusively. Such plants are made at much less initial expense than are those made from transplanted oysters, and the value to the State of an industry of oyster culture is the greater if the planted beds are not made by the exhaustion of the natural beds. All of the beds to be described in this report have been formed, therefore, by the set of spat on planted shells. The shells were obtained



A. TYPES OF SHELLS USED FOR CULTCH. THE VERY THIN SHELLS AT RIGHT ARE PRACTICALLY VALUELESS FOR PLANTING.



B. BOAT IN POSITION FOR PLANTING SHELLS.

from the canneries at Wit and Beaufort, usually at a cost of 1½ cents per bushel, delivered on board.

There was found to be quite a difference in the character and value of the shells obtained from different parts of the pile of shells at a cannery. If the shells are taken at random, a load may contain an excessive proportion of the thin, wafer-like top shells of small coony oysters, which will "mud" on almost any botttom and are practically valueless for purposes of planting. It is worth while to take some care in the selection of the portions of a shell pile from which to load. Plate III, *A*, illustrates the shells used in making the plants. At the left are seven large clusters of shells very satisfactory for the purpose of planting, especially on softer bottoms. To the right of these, and with their long axes in the same direction, are a row and a half (9 shells) smaller but satisfactory. To the right are a number of shells placed with the long axes at right angles to those of the clusters on the left. Some of these are long, some small, but all are flat top shells and of little or no value. Ten of these shells placed on edge and in a single group supported by pins (at "X") have a total thickness hardly greater than the width of a single good shell.

METHODS OF PLANTING.

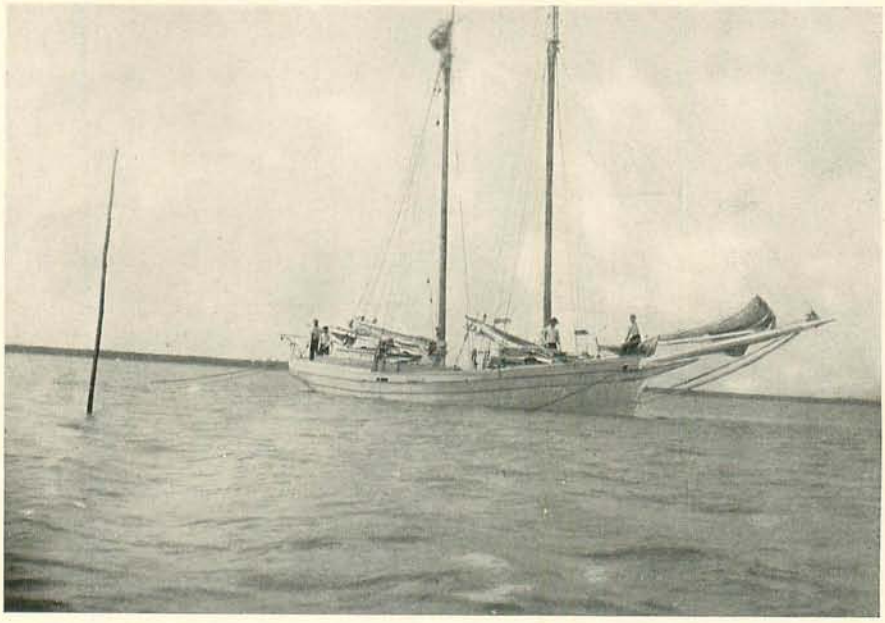
The set of spat proved so abundant that it was not found advisable to plant shells in ridges except for special purposes. Usually, the shells were placed as an even flooring, or in small lumps. When an area of a considerable size is to be planted rather thinly, a convenient method is to sail the vessel back and forth over the ground which has previously been marked off with stakes or buoys. Such a method is not adapted to small plants, or for making beds where it is desired to lay the shells in a definite manner. The plan used in making practically all of our plants permitted of planting in a very definite way and was at the same time simple and practical. The boat was handled in the following way: One end of a line lying on the stern was carried forward outside of the rigging and attached to the large anchor hanging from the bow. The anchor was then lowered, and, as the vessel fell away, the cable was allowed to pay out faster than the stern line until the lines were of the same length. The anchor would then lie opposite the middle of the vessel, which would swing broadside to the wind or current (Pl. III, *B*). Usually the boat would not lie steady in such a position, but would sheer forward or backward under the influence of wind or current. A smaller anchor would then be carried out from the bow or the stern, usually from the stern, depending on whether the vessel tended to sheer forward or astern. Sometimes, though rarely with shifting wind or current, it was necessary to use a third small

anchor. The boat having been gotten into a stable condition, a stake was placed beside the bow and to it was attached the end of a string marked off into intervals of 10 feet by pieces of cloth.

The vessel was then allowed to fall away a distance of 10 feet in the following way: The direction in which the boat pointed is noted from the compass. One man then pays out about 10 feet, or a little more, of the anchor chain forward. Two others handle the two lines from the stern. While the line to the small anchor is kept just taut enough to prevent the vessel from sheering out of position, the stern line to the main anchor is paid out, and the stern allowed to fall away until, by the compass, the boat is found to point in the same direction as at first. The vessel lies now in a position parallel to the original position, but several feet removed. By the measuring line attached to the stake off the bow, it can be known just how far the boat has been moved. If this distance is a little less than 10 feet, a little more cable can be paid out, forward and aft, until the desired position is reached. The plan is simple and worked very satisfactorily. After a little practice, all lines are paid out at once, and the vessel shifted from one position to another in a very few minutes (Pl. IV, *A*).

The shells are planted in unit squares 10 feet on the side. The number of squares to be planted on one side of the boat, or the width of the plant, depends on convenience and on the length of the vessel. Our beds were made 40 feet wide. Usually two men worked on each side of the boat. Each one was, then, assigned two squares. It it were desired to plant shells in one thickness, the planter would throw a certain number of shovelsfull (the number required to make five bushels—usually 25 shovelsfull) on each square. If it were desired to place the shells twice as thickly, twice as many shovels per square were thrown, and so on (see Pl. IV, *B*). Thus a flooring of the shells could easily be made, as thin or thick as was desired, or they could be placed in lumps or ridges. When the four squares on each side were planted, the vessel was moved 10 feet and a new set of squares planted.

The vessel used in most of our planting had a beam of 16 feet (see Pl. III, *B*). After one series of squares on each side was made, the boat was moved a distance of 10 feet. When the new squares were complete, there would, of course, be an interval of 6 feet between the last squares made on the anchor side of the vessel and the first squares made on the off-side, which latter squares were now under the vessel (the boat being 16 feet in width). The next shift was for a distance of 6 feet, so as to bring the first shells planted from the off-side just to the edge of the boat. The 6-foot interval was now properly planted in rectangles 6 x 10 feet,



A. BOAT BEING MOVED TO NEW POSITION, A DISTANCE OF 10 FEET.

B. PLANTING SHELLS FROM BOAT, THE BEGINNING OF EXPERIMENTAL PLANT.

instead of squares 10 x 10. At the same time, four more squares were made on the off-side. There was now a continuous bed of shells from the stake to the outer limit of the squares on the off-side of the boat. A long shift was then made, of a distance equal to the width of the boat, plus 10 feet—the width of the last area planted on the off-side—plus again 10 feet, the additional distance necessary to clear a space of 10 feet on the anchor side for the planting of new squares. Thus the boat was shifted a distance of 36 feet. The next shift was 10 feet, the next 6 feet, and again 36 feet, and so forth. It was found practicable to make beds 200 feet in length without taking up anchor. Complicated as the method may seem in reading, it works very simply in practice and gives definite results, if proper oversight is given to the planters to see that they plant from the edge of the boat to a distance of 10 feet and no further, and that they use the proper quantity of shells and place them in the desired way.

If the weather is perfectly calm, then the two small anchors may be placed at some distance from the vessel, one from the bow, the other from the stern, and, by means of the cables attached to them, the vessel can be hauled away for the desired distance. Usually, however, there is sufficient wind or current to bring about the shift of position when the lines are slacked.

COUNTS.

In the following pages there will appear records of the number of oysters of certain sizes per 100 shells, taken from individual plants at various times. A few remarks must be made regarding the method of making such counts. Unless otherwise specified, mudded shells were discarded in making the counts. This brings about greater uniformity in the count. It is found that the number of mudded shells taken up, especially from thick plants, varies too much with the kind of tongs used, and especially with the man handling the tongs. Thus, one tonger may simply scrape the top shells, while another tongs more deeply, taking up a larger proportion of the under shells. A good idea of the extent of mudding or sounding can be obtained by feeling the bottom with the tongs or with a sounding rod.

Sometimes the record includes a column for "dead" oysters. These should be counted only when the top shell has not fallen off, or as a rule, only when the oysters have died recently. Otherwise, one cannot tell but what the empty bottom shell is one of the planted shells. The counts of dead oysters are underestimated, therefore, and not reliable. There appears to have been comparatively few deaths of oysters over one-half

inch in length on any of the plants, so that the records of dead oysters are of little significance.

In the following pages the plants in each locality will be taken up separately. The locality and the plants will be described, the history of the plants given, and the results summarized. At the end of the paper a few considerations will be added under the head of General Summary. For convenience of description the experimental beds will be grouped under three heads: (1) The Harbor Island Region, including the plants at Harbor Island and at Chain Shot Shoal; (2) The Bays on the Northern and Western Shores, including the plants in Wyesocking and Pains Bays; (3) the Off-shore Plants, including the Cunning Harbor, Long Shoal, and Bight of Royal Shoal plants. The distribution of these plants may be seen from the map, Pl. II.

HARBOR ISLAND REGION.

Extending from Hog Island on the west to the Banks on the east is a broad high shoal, forming a partial barrier between Core and Pamlico sounds (see maps, Pl. II and fig. 1). Four prominences on this shoal form small and low islands: Chain Shot Island, Harbor Island, Wainwright Island and Shell Island. The constant interchange of water between the two sounds causes very good currents to prevail in this region. These are especially marked in the "Harbor Island Channel," a passageway extending in a northerly direction from the middle of Core Sound opposite Hog Island, by Harbor Island, to the light on "Harbor Island Bar." A second passage of much less significance is the "Wainwright Slue," between Wainwright and Shell islands.

If a broken line extending from Camp Point on Hog Island through the four islands to the Banks near Pillentery be taken, roughly, as the dividing line between Core and Pamlico sounds, two of our planted beds would be just out of Pamlico and in the upper end of Core Sound. These are referred to as the Chain Shot Shoal plant and the Harbor Island plant.

CHAIN SHOT SHOAL PLANTS.

Preliminary Observations.—Chain Shot Shoal, forming the western part and about one-third of the broad shoal referred to above, slopes away in all directions from the island near its center. A short distance south there is a high reef beyond which the bottom of hard white sand slopes away very gradually. At a distance of perhaps a quarter of a mile, and at about the fathom line, the sand gives place to the softer blue mud of the deeper water lying between this shoal and the long shoal extend-

ing in a southerly direction from Hog Island Point. These shoals were said by the local oystermen to be practically barren of oysters. At the beginning of our experimental work in Pamlico Sound it was not known whether or not there would be difficulty in getting a good set of spat in Pamlico Sound. If there should be difficulty, such shoals as these might

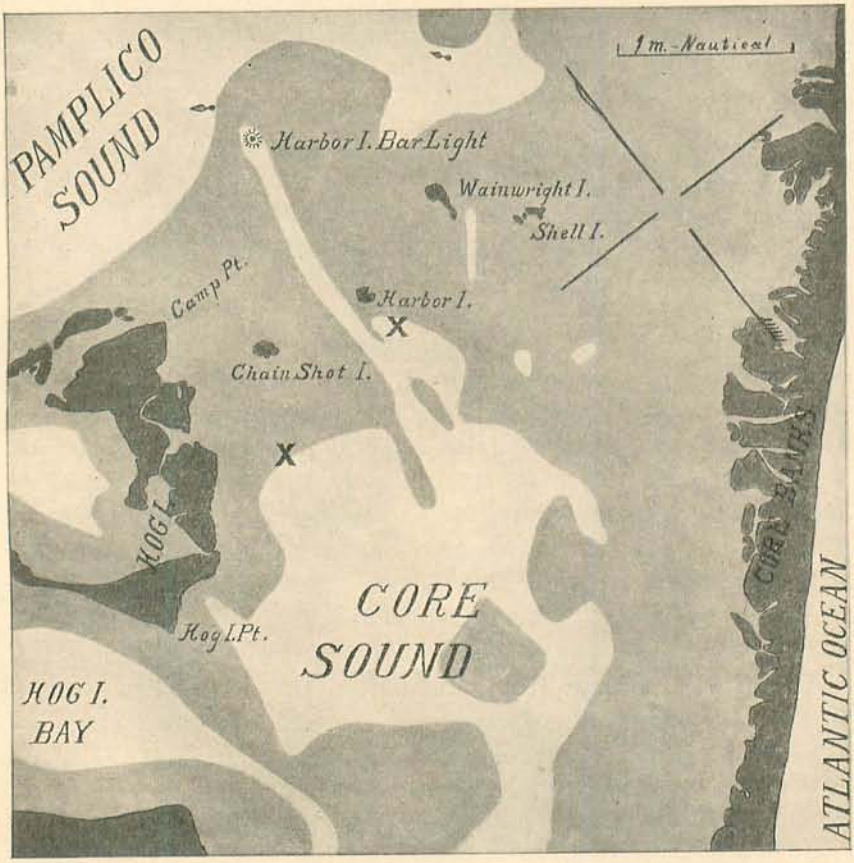


FIG. 1.—Chart of Harbor Island and Chain Shot Shoal at the junction of Pamlico and Core Sounds, showing the location of planted beds. Water less than 6 feet in depth is indicated by light shading; over 6 feet, unshaded. Oyster plants are indicated by X marks.

prove favorable grounds for seed gardens. Here are the evident favorable conditions: (1) an abundance of natural oysters within a short distance and in various directions; (2) currents of fair rate, with frequent changes of direction. The scattered oysters of the deeper water to southward, those of Hog Island Bay toward the southwest and especially those of the

well distributed growth on the shoals to the north-east about Harbor Island and the rich "Harbor Island rocks," in the channel—these natural beds might all within the same day be sources for a set of spat.

A desirable place near the southern border of the shoal, and in 3 feet of water, having been chosen, a temporary buoy was placed. Then by the usual method the surrounding bottom was tested for natural growth of oysters. Five lines were run in various directions except toward the high shoal. In all, an area about $\frac{2}{5}$ of a mile in diameter was covered, and 13 hauls with a scraping dredge made. Altogether, the dredge was hauled over about one mile of bottom. The largest haul brought a quarter of a peck of shells, 3 marketable oysters and 5 small oysters. The total yield of the 13 hauls was $1\frac{1}{2}$ pecks of shells, and 19 oysters, besides upwards of 20 young oysters and spat. The bottom was, therefore, for practical purposes, barren. The few oysters and shells were obtained chiefly at a little distance from the buoy. The location being on the shoal but near the deeper water, the bottom consisted of hard white sand with a slight admixture of blue mud. This afforded a firm basis in which there was no danger of shells settling and which would permit of planting very thinly, were it not for the fact that the location was one that was much exposed to the action of the waves. In strong southwesterly winds the waves beating on the sandy bottom in shallow water might well cause the shells to "sand up," or again, a like result might follow from the action of unusually strong currents flowing over the shoal before a northeaster. These dangers made it seem doubtful if a plant would hold, and it was determined to place the shells in comparatively high ridges.

Experimental Plant.—The preliminary survey was made November 26 and 28, 1902, and since it was desired to ascertain as early as practicable whether or not a plant on this bottom would withstand the possibly adverse conditions referred to, the plant was made with little delay, December 16. It was believed by many oystermen that the time of planting was quite unfavorable for a set of spat as a film of mud might form on the shells to prevent the successful attachment of spat. As opposed to this idea was the fact that spat sets each year on the shells of the natural rocks which have been exposed during the preceding winter season; further, the currents in such a location might be expected to keep the shells somewhat clean. In any event, it could be ascertained whether shells planted in such a position would remain above the sand.

The shells were planted in three ridges, each 45 feet long, two with an east and west direction, the third running south by west (see fig. 2).

100, 150, and 50 bushels were used in the ridges respectively. Supposing each ridge to be 5 feet wide and the shells evenly distributed, the number of shells planted on the several rows would lie in 9, 13 and 4½ layers respectively. In reality the ridges would be probably a little wider than 5 feet and would be higher in the middle and lower towards the edges. From the subsequent history of the beds it is inferred that the lowest ridge was of sufficient height to escape sanding. The ridges were subject to somewhat different conditions. The northern E. and W. ridge (100 bus.) was in shallower water and on sandier bottom than the

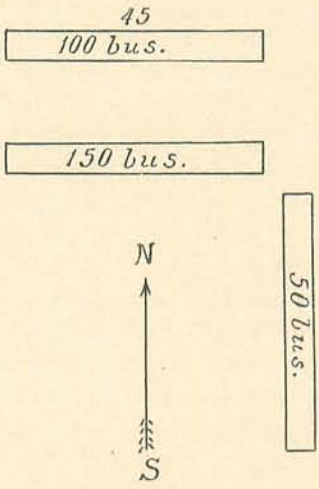


FIG. 2.—Experimental oyster plants at Chain Shot Shoal.

southern (150 bus.). The N. and S. ridge (50 bus.), which began just east of the east end of the latter ridge, and extended in a southerly direction was, in the main, in still deeper water and on softer bottom.

History of Plant.—The plant was not visited again until *June 26, 1903.* The shells were found to be comparatively clean, with a good growth of barnacles, but quite without spat. On the way to make new plants, I stopped at this bed *August 3.* There was found an abundant set of spat, all less than 1 inch in length. The most common size was ½ inch. The shells were crowded with young oysters, 30-60 or more per shell. (See Pl. V, *B,* the four shells of top row.) The following is the result of a count made *November 11* of the same year:

Chain Shot Shoal Plant, November 11, 1903.

	No. per 100 Shells. Live.	Dead.
Less than 1 inch in length	660	290 [3]
1 inch in length	285	50
1½ inches in length	111	4
2 " " "	4	..
Total oysters	1060	344+

Average length of oysters, .84 inch.
Per cent of exposed shells with spat, 100.

A small number of mussels (about 1 per shell) and ascidians (about 1 per five shells) were present, and barnacles were very numerous. There was also a small amount of serpula, crepidula, and a very little weed.

On the whole, the result for a seed-catch was excellent. There had been little sanding; there was little else on the shells to interfere with the growth of the oysters; as a result of crowding, a large number, especially of the smaller oysters, had died, a result that was highly desirable; there was still so close a set that, if in the process of transplanting, a good proportion should die, there might still be a good set left. The rate of growth had been excellent.

Meantime it has been ascertained that there was a sufficiently good set on the other plants now made, and it was decided to follow the subsequent history of this bed without transplanting to new territory.

April 21, 1904, a new count was made with the following results:

Chain Shot Shoal Plant, April 21, 1904.

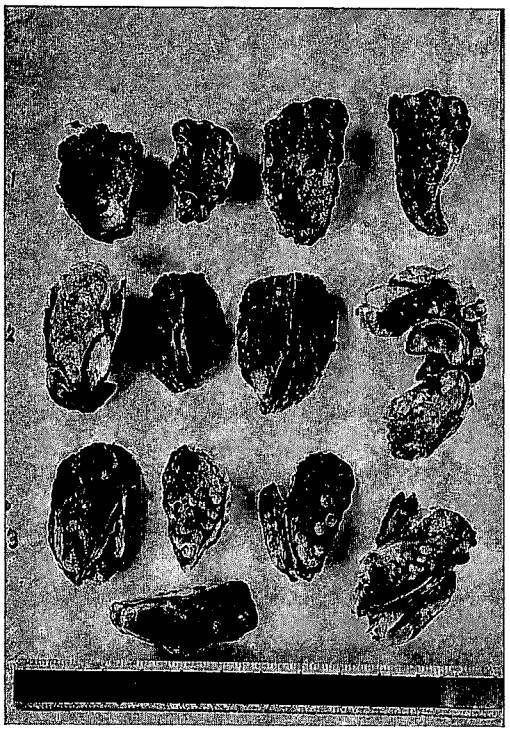
	No. per 100 Shells. Live.	Dead.
Oysters less than 1 inch in length	76	40
" 1 inch in length	112	72
" 1½ inches in length	200	36
" 2½ " " "	104	..
" 3 " " "	48	..
Total oysters per 100 shells	540	148

Average size of live oysters, 1.7 inches.
Per cent of exposed shells with young oysters, 100.

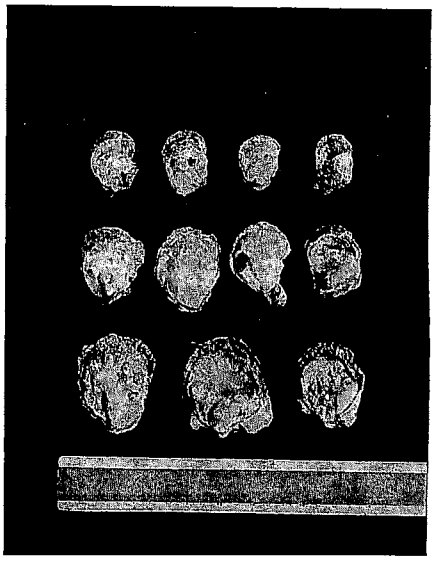
The number of live oysters per 100 shells was nearly 50 per cent less than at the time of the preceding count. Such a loss is not attributable to any special unfavorable conditions, but is the inevitable result of the overcrowding, and the diminution in number is, not only inevitable, but

[3] Besides dead oysters less than ½ inch in length, which were innumerable.

A. CEDAR CREEK AT WIT ON CORE SOUND, A TYPE OF SMALL BAYS OR CREEKS WHERE OYSTER PLANTING IS DONE ON A SMALL SCALE.



B. OYSTER SPAT ON SHELLS FROM CHAIN SHOT SHOAL PLANT.



C. OYSTERS FROM HARBOR ISLAND PLANT, SHOWING GOOD SHAPE OF OYSTERS.

is highly favorable for the further growth of the surviving oysters. In spite of the beneficial loss by death, the oysters were still too crowded for the purposes of a permanent plant, and in consequence, were assuming a "coony" shape, as shown in Pl. V, *B*,[4] second row. The growth had been good. While on November 11, 1903 two-thirds of the oysters were under 1 inch in length and only about one-tenth were longer than 1½ inches, after 5⅓ months, two-thirds of the oysters were over 1½ inches in length. The increased proportion of larger oysters was, to be sure, caused in some part by the greater number of deaths among the smaller oysters, but there was now, in spite of deaths among the oysters of all sizes, 352 oysters over 1½ inches in length as compared with 115 in November. It may be noted that after 10 months of growth one-fourth of the oysters had a length of at least 2½ inches. While this is to be discounted by the fact that the oysters were quite narrow, a very rapid growth is indicated. Because of the form of the oysters, the value of the bed as a source of seed, though still important, was now less than during the preceding fall.

Two questions yet remained to be answered: Would the reduction in number by death proceed far enough to enable the oysters to broaden and take a fair shape? Would the set of spat on these shells in succeeding years be comparable to that of 1902?

In regard to the first question, there was some further loss, but no material improvement in shape. The five lowest clusters of oysters in Pl. V, *B*, illustrate the shape and size on the *28th of September, 1904*. The count for this date, including the new set (of 1904) follows:

Chain Shot Shoal Plant, September 28, 1904.

	No. per 100 Shells.
Live oysters 1 inch in length	72
" " 2 inches in length	136
" " 3 " " "	136
" " 4 " " "	12
Total	356
Average length, Nov. 11, 1903, (4⅓ mos.)	.84
" " Apr. 21, 1904, (10 ")	1.7
" " Sept. 28 " (15 ")	2.7

[4] *Explanation of Plate V, B.*—Series of spat at Chain Shot Shoal, a locality that is particularly favorable for set of spat and for rapid growth of young oysters. The series includes: (1) Top row, 4 shells covered with young oysters about one month or less of age, taken August 3, 1903. There was no visible spat on the shells June 26, 1903. (2) Middle row; oysters 10 months old or less, taken April 21, 1904. (3) Bottom row; oysters 15 months old or less, taken September 28, 1904. The oysters of these two lower rows illustrate how over-crowding, if the shells are undisturbed, results in the production of "coony" oysters.

Many of the oysters now exceeded the cull-limit (2½") in length, but their narrowness would prevent their being marketed at this stage. The future of these oysters could be only that of "coon" oysters, the market for which would be with the canneries. Many of them could have been marketed during the following winter, but apparently, from observations made in 1905, they had not been disturbed by the oystermen. During the winter of 1905-6, at the age of about 2½ years, the available oysters were taken up, as I was informed, and were sold chiefly to a canning house. This information came, before I visited the bed in 1906, from several local oystermen, who stated that the rock had been found to be very thick and yielded large quantities of oysters.

The plants were examined again on *September 23, 1906,* when it was found that the northern E. and W. ridge had practically disappeared. The foundation was there in the sand but there was no longer a *ridge.* Some oysters were found on it in spots.

The southern E. and W. ridge was well exposed and somewhat widened. The oysters were comparatively thick, but were not, on the whole, larger, if indeed, they were not smaller, than during the previous summer. They appeared of better shape than before. A test measurement of a pile of oysters and shells taken with the tongs, gave 2 buckets (10-qt. buckets) of oysters to pass inspection to 5 buckets of cullings, consisting of shells and small oysters.

The N. and S. ridge was essentially in the same condition as the last mentioned.

The size of the oysters present, the better shape of many of them, the widening of two of the ridges, the practical disappearance of one of the ridges, and the general appearances were confirmatory of the statement, freely made by oystermen, that this bed had been worked during the preceding winter. If so, it was, in this case, no serious loss to the experimental work as the main purpose of the plant had been accomplished within the first two years.

The present condition of these ridges and their whole history point to the conclusion that a low ridge as far off shore as the middle of the N. and S. ridge will be safer from sanding than a higher ridge at the inshore position of the northern E. and W. ridge, where the depth was nearly a foot less and the bottom more sandy. Such a ridge seems satisfactory for the purpose of obtaining seed, while the others are not economically practical.

While with the cultivation which the annual working of this plant for market would give, the quality of the oysters might be much improved, the position is not one to be recommended for the purpose of plants for mar-

ket. If the shells are allowed to remain thick, the oysters may be expected to be overcrowded, while if the oysters are well scattered, the danger of "sanding" is incurred. The accumulation of weed, chiefly *Gracilaria multipartita Ag.*, is another disadvantage which, however, has not been serious in its effects on this plant. The results of the experiments suggest, however, that the bottoms a little further south and in deeper water might be adapted for the production of marketable oysters.

Set of Spat.—The set in 1903 was doubtless unusually great, but in 1904, the set in this whole region was exceptionally light, as was ascertained from records made at Wit, Harbor Island (from natural and planted oysters), Chain Shot, and Portsmouth.

Only 56% of the shells examined at the Chain Shot plant showed new oysters. The records for September 28, 1904, July 16, 1905, and September 13, 1906 are as follows:

Chain Shot Shoal Plant.

	No. Per 100 Shells.		
Length of Oysters.	1904.	1905.	1906.
Less than ½ inch.....	112	84	1520
½ inch	60	4	116
1 "	8	..	52
Totals	180	88	1688
Per cent of shells with oysters..	56	60	96
No. of oysters per shell with oysters	3.2	1.5	17.6

The set of 1904 would be satisfactory on an ordinary plant where the oysters were to remain until a market size was attained; but for a seed plant, the set of the preceding year (see above p. 16) is much to be preferred, as a number of young oysters are liable to be lost in transportation.

The record for 1905 is not representative as it was made near the beginning of the season of set, July 16. Undoubtedly, the number of spat on the shells increased during the season, but as the set here was less than at Harbor Island at the same time, and the shells had accumulated a considerable amount of weed, it was inferred that new shells should be planted for new supplies of seed. However, the set of the year (1906) has been, as the table shows, superabundant. This was probably attributable in part to the fact that the year is a peculiarly favorable one in this regard and in part to the working that these beds are supposed to have received during the past winter. The shells are noticeably cleaner and in better condition for receiving a set of spat than they were in 1905.

Inferences from Experiment.—The young oysters had (in 1903) the most favorable size and shape for transplanting in the late fall of the

year in which the plant was made. In years in which the set is very much lighter, the transplanting might well be delayed until the following spring, provided the removal is made before the oysters assume a "coony" shape.

The rate of growth is rapid, but if the oysters are left in position they form a "coony" rock and are of value chiefly to the canning houses.

The shoal at Chain Shot (fig. 1) and doubtless the other shoals in this neighborhood are excellently adapted for plants of shells for the purpose of obtaining seed. For this purpose it would seem advisable to plant at least some new shells each year.

HARBOR ISLAND PLANT.

Location.—The general features of the region have been described. Harbor Island (see map, fig. 1) is a small crescent-shaped island with a high reef, barely covered by water, extending in a S. E. direction from it for ¼ to ½ a mile. The island is hardly more than a pile of shells lifted above the water, and is of the type to which the term "rock" is often applied, as in the case of "Gull Rock" or of "Royal Shoal Rock." Back of the island, or in a general easterly direction, is the wide shoal which reaches well out into Pamlico Sound and, extending to the Banks, is continuous with the long, practically uninterrupted shoal lying along the Bank side of Core and Pamlico sounds. In a westerly direction from the island, the bottom slopes off fairly rapidly to the deep water of the channel. Going in a southwest direction from the reef referred to above, one finds a bottom of hard white sand interrupted by a strip of soft bottom, beyond which the hard sand is continued, to give place at a depth of about 8 feet to a narrow strip of firm mud, which makes a transition zone between the sand and the softer mud near the channel. The bed to be described below is so placed as to be a test of the three kinds of bottom; hard sand, firm mud, and soft mud. It is 146 feet in length and extends from the soft mud as far inshore as the beginning of the hard sand. At the time of planting the depth at the outer end was 9 feet and at the inner 7 feet.

Physical Conditions.—Many features combine to make this neighborhood highly favorable for the growth of oysters. We have referred to the fact that the interchange of water between Core and Pamlico sounds is practically uninterrupted. While these currents are largely governed by the winds, the region is not very distant from Ocracoke Inlet and it may be that the flow here is affected to some extent, especially in calm weather, by the lunar tides. At any rate the water is never still, except at the brief period of "slack" water, preceding a reversal of the tide.

Generally speaking southerly winds (from S. E. to W.) drive the water of Core Sound toward its upper end, whence it flows out into Pamlico. East and north-west winds are indifferent, permitting a flow in either direction, or making a medium tide. Northerly or north-east winds tend to pile the waters of Pamlico in its southern part, causing an overflow from Pamlico into Core. This is known as "flood-tide," and when the current is flowing from Core to Pamlico it is "ebb-tide." The water seems to be highest with northerly winds, while an outward current, from Core to Pamlico, will cause an ultimate fall of level, though for a time there may occur a rise.

One can readily observe, however, that a change in the direction of the wind is not required to produce a reversal of the current. The moderation of a breeze which has been of sufficient force or duration to cause a piling up of the water will permit the water to flow back. From this cause, and perhaps from the influence of the Ocracoke tides, there is almost always a current in one direction or another.

A second feature favorable to the growth and quality of oysters is the generally good density that prevails. Pamlico Sound is on the whole of a lower density than Core. With the frequent changes of current, the salinity of the water at this place changes rather rapidly, but the influence of Core Sound tends to keep the density well up, and the bottom density, probably changes more slowly than the surface, especially when the change is caused by the flow from Pamlico over the high shoals between the two sounds. Several observations are of some interest as showing in a clear way the indirect effect of the winds on the salinity of the water at this place. Going up Core Sound before a stiff southwest wind, I found the surface density opposite the mouth of Thoroughfare Bay, 7 miles from Harbor Island, to be 1.0190. A little later, when about three miles from the island, the surface density was found to be 1.0174. It was expected that the density at Harbor Island would be found to be about 1.0150. On the contrary, it was, at the surface, 1.0094. Evidently the effect of the Core Sound water driven up before the S. W. wind had not yet been felt. The low surface density was quite unusual, but was undoubtedly due to the overflow of the rather fresh water in lower Pamlico resulting from a recent very prolonged rainy season. Six hours later, however, the water was that of Core Sound and the salinometer registered 1.0160 at the surface and 1.0164 at the bottom. Six days later, though there had been frequent rains in the interim, the salinity here was at the unusual height of 1.0206 surface and 1.0208, bottom. The effect of the wind was, therefore, to counteract any bad effect that might otherwise have followed from the long continued rainy

season and the proximity of the enormous quantity of fresh water brought by the Neuse into the lower region of Pamlico.

On another occasion, the currents were noted for 36 hours. For the first 24 hours the wind stood in a general southerly direction, but it was sometimes so slight as to be negligible. At 8 p. m. (July 14, 1905), the current-meter showed an incoming tide flowing over the bed at a rate of about $\frac{1}{4}$ mile per hour. This current was against the wind, which was light. Eleven hours later (7 a. m.), the flow in the same direction was at a rate of $\frac{1}{2}$ mile per hour. The wind became stronger, and before noon the tide had turned. At 12.30 p. m. the ebb tide had a rate of .57 mile per hour. At 6 p. m. the water was "slack." By the following morning, a light N. W. breeze had arisen and a strong incoming tide was noted in the channel. On the bed, which is so situated as to be more in the line of outgoing and less in the line of incoming tides (see map, p. —) the current was only $\frac{1}{6}$ mile per hour. In the channel, the rate was nearly $1\frac{1}{2}$ miles per hour at 3 feet below the surface, but at a depth of 10 feet was barely over $\frac{2}{3}$ mile per hour. A decided change of salinity, especially at the surface, followed the flood-tide from Pamlico. A little before "slack water," the preceding afternoon, the density at the bed was 1.0210, bottom and surface, but on the following morning the surface density was 1.0102, while the bottom showed much less change—1.0156. Later in the day, inshore from the bed, and therefore more out of the incoming current, the bottom was still as high as 1.0192, while the surface was as low as 1.0100.

Sufficient records were not obtained to make an average value, but only once was the salinity as low as 1.0068 (surface). More often it has been from 1.0090 to 1.0150, or, as in the above instances, in the region of 1.0200.

Summing up, while the currents are undoubtedly governed in very large part by the winds, they present a seeming independence of the winds, in that there is a flow even in calm weather, and the direction of flow may be reversed repeatedly without a change in direction of wind. The density varies frequently, but the bottom density seems less liable to rapid change. In general the density seems to keep at a grade that is decidedly favorable for the production of desirable oysters.

So far, the conditions seem highly favorable. There are, however, connected with these advantages, certain disadvantages the appreciation of which is necessary for any success in oyster culture experiments in this region. The ordinary currents, though strong, may not be sufficient to cause "sanding" or "mudding," on bottoms which would be chosen for the cultivation of oysters, but the situation is one which is peculiarly

A. SHOAL OYSTERS FROM HARBOR ISLAND, NATURAL GROWTH.

B. ROCK OYSTERS FROM HARBOR ISLAND, NATURAL GROWTH.

liable to unusual tides. A strong northerly wind, for example, may cause such a banking up of the water, that before it can clear itself by overflowing through the restricted outlet into Core Sound, the level will be raised from one to three or more feet. The currents will not then be so restricted to the usual channels, but may flow over the shoals at such a rate as to cause some shifting of the bottom. Such a possible occurrence will be referred to below in connection with the history of the experimental plant. The quick changes of density might seem a disadvantage, but the condition of the natural beds opposes this view for the natural rocks of this locality are, as will be seen, unusually productive.

Natural Oysters.—The oysters of the natural growth about Harbor Island are well known for their good shape and flavor, as well as for the productiveness of the rocks. They may be considered under two heads—the shoal oysters and the "rock oysters."

On the shoal north and east of the island are found many clusters of oysters. The sand is, doubtless, liable to shift, due to the currents, and to disturbance from the beating of the waves, and to this is attributed the fact that the oysters occur, not in any solid "rock," but only as scattered clusters. They are of fair size and good shape. (See Pl. VI,[5] *A*.)

The "rocks" occur in and near the channel. The main rock is long and narrow and variously estimated to contain from one to three acres. The "Harbor Island Rock" has been thoroughly worked each year for many years, and has been proverbial for its supposed inexhaustibility. It is admitted now that the bed has been very much depleted. Undoubtedly its depletion is proceeding with every year, though it still affords employment for many tongers. The oysters are probably unexcelled in the State for shape and flavor, and many of them are of large size. Plate VI, *B*, illustrates a few of these oysters taken in September, 1906. As the photograph shows only two dimensions, the deep cup form of the shell, the best feature of these oysters, is not apparent.

In view of the disadvantageous effects of the currents and storm tides which have been referred to, the position of these invariably productive beds may be instructive. They lie chiefly along the sides of the channel, and this fact suggests that their permanence is due to the washing effect of the ordinary channel current counteracting any bad effects that might

[5] *Explanation of Plate VI.*—*A* are representative oysters from ¾ of a tub taken August 10, 1906, from shoal oysters from Harbor Island natural beds. They are not large but are comparatively good shape. *B* are rock oysters taken from natural beds near Harbor Island. These rocks in and on the sides of the channel are so thoroughly worked by the oystermen that they are practically exhausted each winter. The figure is intended to represent what would make satisfactory "half-shell" stock. A few large oysters have, however, been included. These were taken September 23, 1906.

result from the unusual currents flowing over the shoals in times of especially high tides.

In view of the generally good density, and the excellent currents, of the resulting rapid rate of growth of oysters, prolificness of natural beds, and good quality of oysters, no place I have visited commends itself more strongly as one that should be developed as far as is practicable than the Harbor Island section.

Experimental Plants.—Four plants were made July 8, 1904 with the dimensions and the positions indicated in fig. 3. No. 27 lies chiefly on soft mud while No. 30 extends on to the hard sand.

On No. 27, area 1040 square feet, 52 bushels of shells were placed as

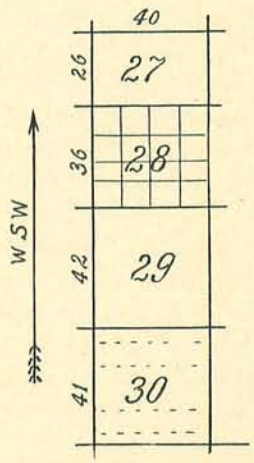


FIG. 3.—Experimental oyster plants near Harbor Island.

uniformly as possible. This method of planting was tried, not because it was believed that it was particularly adapted to the bottom, but for the reason that by this date heavier plants had been tried on soft bottoms in other localities, and it was desired, in connection with those experiments to try a light plant, to ascertain if a single layer of shells would remain clear on a soft bottom.

On No. 28, area 1440 square feet, the following method was used: On each square of 100 square feet, 10 feet on the side, 4 bushels were evenly scattered; then 3 bushels were added in such a way as to pile up toward the center. Five bushels are considered sufficient to make a single layer on such a square. The bed was, therefore, composed of a flooring with regularly distributed lumps. The bottom was rather softer at the outer part, but comparatively firm at the inshore part.

No. 29, area 1680 square feet, was planted with a very light sowing of shells: 3 bushels to 100 square feet, or about three-fifths of the quantity required to make a complete layer. The bottom was firm, and the method seemed well adapted to the bottom.

On No. 30, the quantity of shells required to make a continuous layer was used, but as the bottom was of sand and the depth not great, it was thought best to place them in low ridges. The four ridges were each 40 feet long. From the middle of ridge A to the middle of ridge B the distance was 8 feet; from B to C, 16 feet; from C to D, 8 feet.

The long dimension of the bed as a whole lies in a W. S.-W. and E. N.-E. direction. Just to southward of plants 28 and 29, plant 35 was made July 14, 1904, with oysters from the Chain Shot plant. Twenty bushels were scattered over an area of 1600 square feet. This quantity is about one-fourth of that necessary to make a continuous layer.

History of Plants.—These plants were visited rather hurriedly on *September 28* of the same year. A few shells were examined, but not a sufficient number to make a record. The set of spat on the planted shells seemed to be exceedingly light, but the young oysters were well grown. On 15 shells only 2 were noted that were less than ½ inch, while there were 6 that measured 1 inch and as many more that were between ½ inch and 1 inch. The set of spat in this entire region appeared to be very light that year, as was observed at Chain Shot (above), but on the planted oysters of No. 35 there was a better set.

The plants were examined on July 16, 1905, about one year from the date of planting. No. 27 was found to be very largely mudded and was counted lost. No. 28 was in better condition. Fifty per cent of the shells taken up were clean; 30% were largely in the mud; 20% completely mudded. No. 29, although the lightest plant, was in the best condition, due, doubtless, to the more resistant character of the bottom. The proportion of shells mudded and exposed were about the same as for 28. No. 30 seemed to have sanded a little, but the sea was too rough for a careful examination. There was much weed on this plant. Crepidulas, barnacles, and serpula were abundant on all of the shells, but it does not appear that these forms, except the weed, are of appreciable harm. Ascidians, "dugs," were few and only one muscle was noted.

It was evident that the set of spat during the preceding year had been very light, but this could not be counted unfavorable. It was quite early in the season for new spat. The records that were made are given below. In these counts, only well exposed shells were counted. The pro-

portion of mudded and partly mudded shells is given above. At this stage of the season, the new oysters, of the set of 1905, may be supposed to be included in the "less than ½ inch" and "½ inch" lists.

Harbor Island Plants, July 16, 1905.

Length of Oysters.	No. per 100 Shells. Live.				Dead.			
	27	28	29	30	27	28	29	30
Less than ½ inch...	36	220	459	188	4	9		12
½ inch	8	11	118	61	..	..		6
1 "	..	9	42	21	..	..		3
1½ inches	4	6	12	21	..	..		..
2 "	8	3	6	15	..	..		..
2½ "	4	..	6	3	..	..		..
Total young oysters,	60	249	643	309	4	9		21

The number of old oysters (1904) is small, but this would promise a good form for the oysters. (See Pl. V, *C*.)

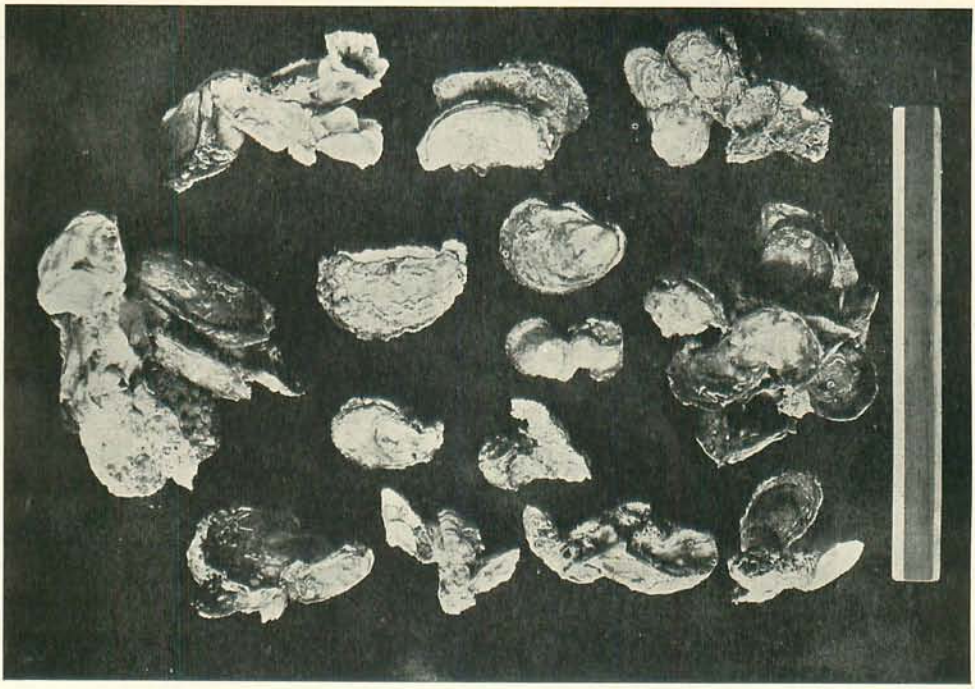
The bed was visited August 13, 1906. The roughness of the sea prevented a laying off of the bed and examination of the separate plants. Some shells and oysters were taken up, probably from No. 30, and the records then made are given below:

Oysters Presumed to be of the Sets of 1904 and 1905.

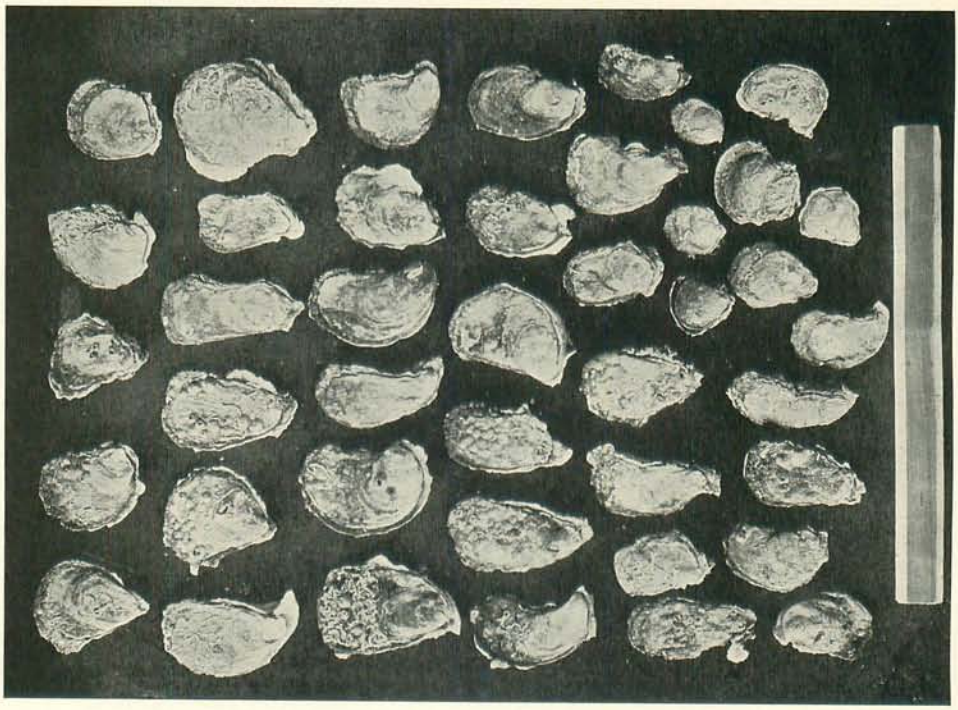
Length of Oysters.	Per 100 Shells. Live.	Dead.
Less than 1 inch.....	6	1
1 inch	39	6
2 inches	90	3
3 "	41	1
4 "	1	..
	177	11

No. of shells with oysters..... 64
Average No. oysters per shells with oysters.. 2.8

The growth has been quite good and there was an abundance of oysters on the exposed shells. Many of the shells, however, were barely exposed and bore only one or two oysters. Comparing the notes as to set of spat in 1904 (v. above) and 1905 (v. below), with this record, it is evident that the majority of these oysters are of a set subsequent to that of 1904, that is to say that they are little more than one year old.

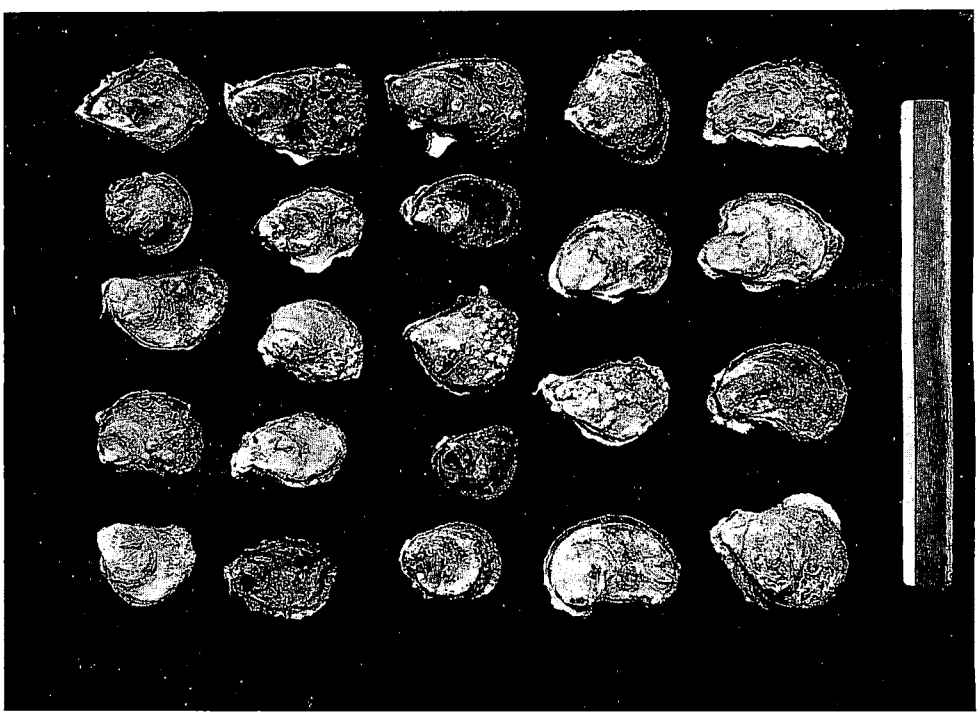


B. REPRESENTATIVE CLUSTERS FROM HARBOR ISLAND PLANT.



A. OYSTERS TAKEN FROM HARBOR ISLAND PLANT, AUGUST 16, 1906, AFTER 25 MONTHS.

B. SELECTED OYSTERS TAKEN FROM HARBOR ISLAND PLANT, SEPTEMBER 22, 1906, AFTER 27 MONTHS.



A. OYSTERS TAKEN FROM HARBOR ISLAND PLANT, AUGUST 16, 1906.

Plate VII, *A* and *B*,[6] and Pl. VIII, *A*, illustrate the oysters taken at this time.

A final visit was made September 22, 1906. Plants 27 and 28 were found to be entirely "mudded"; No. 29 was largely lost from the same cause, but on the eastward side there were found quite a number of oysters. These oysters were largely in the mud with the tips exposed and it was a little difficult to pull them from the firm mud with the tongs. It seemed evident that they could not have sunk of their own weight, but that the bottom must have been disturbed. No. 30, too, was mostly sanded, and the condition of the oysters was much as on No. 29. (See Pl. VIII, *B*.[7])

Just what has been the cause of the sanding and mudding can not be known definitely, but it may be supposed that when the water was two or more feet higher than normal, the strong currents rushing over the reef caused a shifting of the sand and mud on its slope. In view of the history of a number of experimental plants at other places to be described later, it is incredible that all of these plants would have been so largely lost in the sand and mud without the operation of some unusual cause.

Set of Spat.—It can not be said that the set has been inadequate during any of the four seasons since the beginning of the experiments in Pamlico Sound. For the first two years the set was light, a condition that has its advantages in the saving of work in subsequent cultivation. For each of the past two years, it has been more than sufficient. The table below includes records for these four years. The record for 1903, made November 11 from oysters of the natural rocks, is not representative, as the shells had been out of the water for some time and a number of the younger spat had died. These were not counted, since those that had died subsequent to removal from the bottom could not always be distinguished from those dead at the time of removal. The record for 1903, made near the beginning of a season for a set, is the average of the counts made from plants 28, 29, and 30. Of the oysters over ½ inch in length,

[6] *Explanation of Plate VII, B.*—Representative clusters of oysters taken from Harbor Island experimental plant, August 13, 1906, showing how heavy was the set of spat of 1905. As the set of spat of 1904 was very light, most of the oysters shown in the illustration can be but little more than one year old. There are 19 oysters in the middle cluster next to the ruler and 14 in the larger cluster at the opposite end of illustration. Three of the shells have only the spat of 1906.

[7] *Explanation of Plate VIII, B.*—Oysters from Harbor Island experimental plant taken September 22, 1906, showing some of the larger oysters chiefly from plant 29, and some smaller, better formed stock chiefly from plant 30. Some of these may be nearly 27 months old, but most of them are probably not over 15 months.

it was not attempted to distinguish between old and new. Of the records for 1906, that from planted oysters was made August 13, that from oysters of the channel "rocks" more than a month later.

Harbor Island.

Length of Oysters.	Number per 100 shells.						
	Nov. 11, 1903.	Sept. 28, 1904.	July 16, 1905.	Aug. 13, 1906.		Sept. 23, 1906.	
	Rock Oysters.	Plants.	Plants.	Plant (30?)		Rock Oysters.	
				Live.	Dead.	Live.	Dead.
Less than ½ inch..	68	No record; very light set, but probably adequate.	289	415	46	3465	Probably more dead spat than live.
½ inch	54		?	203	39	65	
1 "	12		—	8	8	45	
Total.....	134		289 (+ ?)	626	93	3575	

Inferences.—The results of the experiments show:

(1) That the set of spat has been fully sufficient.

(2) That growth is exceedingly rapid—faster and more satisfactory than at any other place where experiments were made.

(3) That the position of the experimental bed is an unfavorable one on account of the shifting of the bottom.

The locality has unusual advantages in currents and density. With these advantages are coupled certain disadvantages in the liability of the bottom in some places to shift, and the rapid changes of density, but that these obstacles are not insurmountable is shown by the unusual productiveness of the natural rocks, and the high grade of oysters yielded by them.

On the whole, there is no locality with which I am acquainted that would seem to promise a better yield of oysters from a plant properly located. The importance of developing the place is self-evident, and it is to be regretted that there has not been opportunity to attempt a second experimental bed.

BAYS OF THE NORTHERN AND WESTERN SHORES.

As the chart, Pl. II, shows, the northern and western shores of the Sound are indented by a large number of bays, most of which are of con-

siderable area. Most, if not all, of these bays yield good oysters, and some of them are well known for the size, quality and quantity of the oysters produced. The "Far Creek" oysters, for example, have a deserved reputation in some state markets and among dealers. Nevertheless, it is an unfortunate fact that most of the oysters of this whole region, within and without the bays, do not attain a reputation until they have been re-shipped from Norfolk, and have been deprived of their original local designation.

The writer has not had the opportunity to make observations in any of the bays of Pamlico County. What is here stated may be said to apply only to Hyde and Dare counties, the shores of which bound Pamlico Sound from the mouth of Pamlico River to Roanoke Island, a distance of over 60 miles. Along the shores are marshes and swamps, back of which the interior land is low, level and very fertile. In many places in Hyde County the soil is described as of a peaty nature, rich in organic matter. From the swamps, forests, and farming lands, and from the large lake, Mattamuskeet, many small streams flow into the bays, discharging the surface drainage. Presumably the water thus contributed to the sound is rich in the material favorable for the multiplication of diatoms, the food of the oysters. At any rate, the growth of oysters is comparatively rapid[8] and they attain a large size. The conditions are also favorable for the growth of other animals, such as mussels and ascidians, and these forms are to be reckoned with in some localities. The density is not so high as to be favorable for the growth of many forms injurious to oyster beds. The two forms mentioned above are the only ones that I have met with which may do any serious injury to the planted beds. Another difficulty to be met in places is the amount of soft mud that is deposited upon the bottom.

It was desired to make a thorough test of the capabilities of these bays by means of experimental plants. Wyesocking Bay was first chosen, but this bay presents some conditions peculiar to itself and, after some preliminary tests, it was decided to locate the plants in Pains Bay. An account of the tests made in Wyesocking will be given first.

WYESOCKING BAY.

This is a large bay situated on the southeast side of the mainland portion of Hyde County (see Chart, Pl. II and fig. 4), embracing with its tributaries probably over 3,000 acres. It contains at least one large rock,

[8] The rate of growth has proved to be more rapid on plants located near these shores than on plants in the region of Royal Shoal.

besides scattered oysters in other parts. The bay (see fig. 4) is quite wide at the mouth, but is somewhat shut in by shoals, for a pointed shoal of some length reaches out from the point of land northeast of the mouth, almost to meet the base of Gull Shoal. The latter shoal, extending at first eastward from the southwest side of the mouth, afterwards bends to a southerly direction and reaches out into the sound a distance of 6 miles. It is highest opposite the mouth of the bay where there is a low barren shelly island, or group of reefs, known as "Gull Rock." There are some features of Wyesocking Bay which prevent its being typical of the bays of this shore. Besides the numerous tributary bays and creeks,

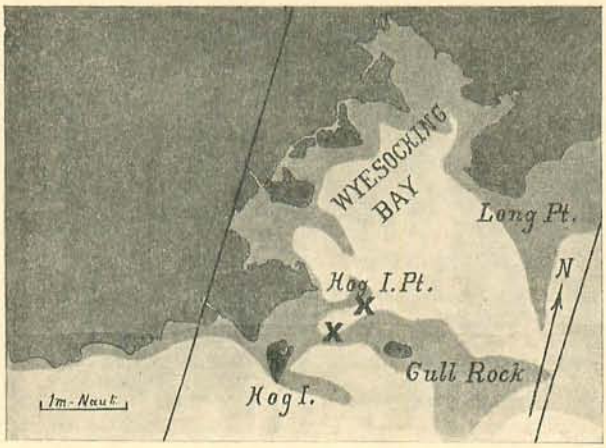


FIG. 4.—Chart of Wyesocking Bay and vicinity. Depth of water less than 12 feet and over 6 indicated by light shading; less than 6 feet by darker shading. Oyster plants are indicated by X marks.

there is, opening near the head of this bay, a canal which serves to drain Lake Mattamuskeet, a long shallow lake in the eastern portion of Hyde County. This lake is some 12 miles long, by about 3 or 4 miles wide and is said to be not more than 6 feet deep in the deepest places. The canal seems to bring a large quantity of silt, much of which is deposited in mud flats near its mouth in Wyesocking. The bay seems a particularly favorable place for the growth, not only of oysters, but of mussels and ascidians, or "dugs," as they are sometimes called by oystermen. After a fuller acquaintance with the conditions in this and other bays, and, in view of the conditions peculiar to this bay, it was decided that the experiments would have a wider value if conducted in a more representative locality.

Preliminary Observations.—The main channel of navigation entering the Bay is to the east of Gull Shoal. Leading out between Hog Island and Gull Rock there is a smaller and shallower channel, which has a depth of about 6½ feet, except where a neck or "bulkhead" of shoal reduces the depth to 5½ feet.

At this stage of the work uncertainty whether a satisfactory set of spat would be obtained on planted shells governed in large measure the location and nature of the plants. The position of the smaller channel was not very far removed from the long rock that runs in a northerly direction from the region of the N. W. point of Hog Island, and there would naturally be a current through the channel which would serve to bring the spat over the shells, and would also, it was thought, tend to keep the shells clean of the mud that might otherwise settle. At the same time such a current would make available to the oysters a larger supply of food than would be at hand in a place with less current.

After a brief reconnaisance, a temporary buoy was placed in 6 feet of water and a preliminary survey made in a way similar to that described as used on Chain Shot Shoal. The launch was run in a straight line from a temporary stake marking the off end of the oyster rock, referred to above, toward the tripod on the south point of Hog Island, a course S. W. by S. ½S. This line ran almost directly through the smaller channel. The bottom was noted as "sticky" and the depth 6-8 feet all the way up to within a few yards of the island where it became shallower. The temporary buoy was placed about mid-way on this line. Two hauls with a scraping dredge between the buoy and the tripod, covering together ⅔ of the distance, brought up only a couple of shells, with a number of ascidians and a few mussels, besides other forms, such as crabs, having no significance for present purposes. Eight more hauls were made in various directions. One of these hauls reached the edge of the oyster rock and brought up a quantity of oysters and shells, with mussels and ascidians. Altogether, mussels were gotten in four hauls, and ascidians were taken every time. Except in the one haul mentioned, only three oysters and a dozen shells were taken. The bottom was firm, chiefly sand with a thin surface layer of mud. The highest density noted was 1.0124, the lowest 1.0054; but only a few observations have been made. Winslow gives an average of 1.0120, but notes a minimum of 1.0086.

Trial Plants.—The buoy was placed December 6, 1902. There could be no spat until the next summer, but, as it was desired to test the stability of the bottom as early as possible, the trial plant was made December 16. This plant is referred to as *No. 2.* About 200 bushels of shells were

placed in two ridges separated by a space of 15 feet and each 100 feet in length.

It was hoped from this test to ascertain: (1) If the bottom would be stable. (2) If a satisfactory set of spat would be obtained. (3) If the conditions would prove favorable for the making of a plant.

The plant was visited hurriedly *June 28, 1903.* No conspicuous amount of sanding had occurred, but a thorough examination in this regard was not made. The shells taken up were clean but covered with barnacles and there was no spat observable.

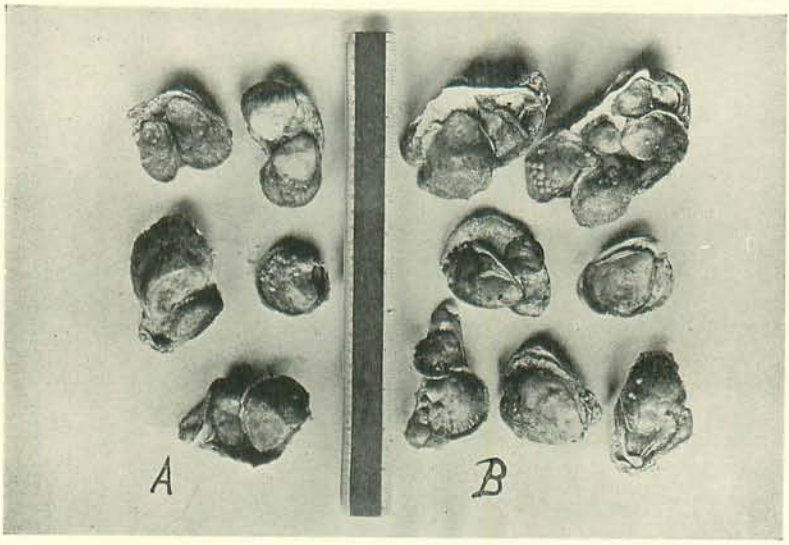
My next visit to this part of the sound was on *August 14,* when a load of shells was taken in order to make plants at this and other places. It was found, however, that the shells were "sanding." It was observed that many of the sanded shells were covered with the shells of barnacles of about the size of the larger barnacles noted on the earlier visit. From this it was inferred that much of the sanding had occurred subsequent to that time. There was no mud on the bottom, which was now of hard sand. The sand bottom extended more than 100 yards up the channel, or toward the Bay. Apparently, a wave of sand had been driven in, covering the mud, and engulfing the shells in large measure.

It was not considered advisable to make a large plant until it had been ascertained whether or not the sand-wave had stopped and the bottom had resumed a stable condition. To ascertain this a single ridge of shells was placed further up the channel and N. W. from the first plant. This plant is referred to as No. 9. The position was such that the sand bottom terminated halfway between the two plants. The bottom was described as rather stiff mud through which the pole could be thrust 1½ feet. The depth was 9 feet. The ridge was made 80 feet long and 100 bushels of shells were used. Such a ridge could readily be found, and would certainly not mud unless the bottom were disturbed.

A count of the spat was made on the shells from the first plant, No. 2, with the result that of the shells taken, *mudded and exposed,* only 16% were found to have spat attached, but there was a fair set on these shells. Following is the record:

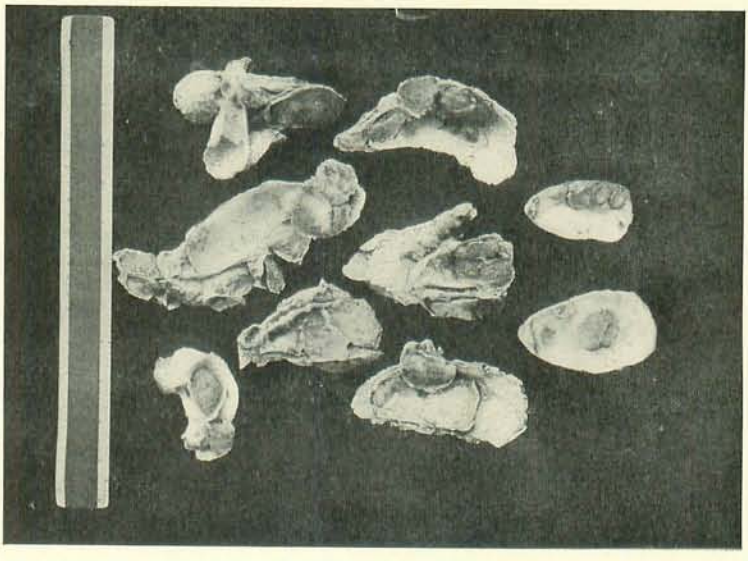
Wyesocking Bay Plant, No. 2, Aug. 14, 1903.

Length of Oysters.	No. per 100 Shells.
Less than ½ inch	25
½ inch	16
1 " " "	3
Total young oysters	45
Average No. oysters per shell with oysters	2.8
Per cent of all shells with spat	16



A. FROM NATURAL ROCK. B. FROM EXPERIMENTAL PLANT.

YOUNG OYSTERS TAKEN FROM WYESOCKING BAY.



C. OYSTERS FROM PAINS BAY EXPERIMENTAL PLANT, TAKEN AUGUST 12, 1904, AFTER 3 MONTHS.

Plant 9 was examined November 13, 1903, and the following record made:

Wyesocking Plant, No. 9, Nov. 13, 1903.

Length of Oysters.	No. per 100 Shells. Live.	Dead.
Less than 1 inch	150	6
1 inch	100	2
1½ inches	12	..
Totals	262	8
No. shells with ascidians		46
" " partly mudded		38
Per cent of exposed shells with spat		76
Average number of oysters per shells with oysters		3.4
Average length of oysters		.84 inch.

Both the set of spat and the growth were good, but there was too much mud and there was a very large number of ascidians, which, in some cases, quite overgrew the young oysters. Two planarians were noted.

Following are the records made for both plants, *May 5, 1904* and for No. 9, *July 4, 1904*. No. 2 was almost completely sanded in May.

Record of Wyesocking Bay Plants for 1904.

Length of Oysters.	No. per 100 Shells. No. 2. May 5, '04.	No. 9. May 5, '04.	No. 9. July 4, '04.
Less than 1 inch	44	64	0
1 inch	92	128	34
1½ inches	76	88	112
2 "	32	..	68
2½ "	16	..	10
3 "	..	..	2
Total young oysters	260	280	226
Average length in inches.	1.48	1.24	1.94

No. 2.—May 5, 1904. Per cent of exposed shells with oysters..96
" 9.— " " " " " " " 92
" 9.—July 4, 1904. " " " " 86

There was a heavier set on No. 9, but the advantage of the several weeks start of No. 2 is shown in the greater proportion of oysters of the larger sizes on this plant in May. It is worthy of note that after less than one year (11 months) from the date of planting No. 9, 80 oysters per 100 shells exceeded 2 inches in length and the average length of all the oysters was barely under 2 inches. Several dead oysters were noted in May—28 on plant "2" and 16 on plant "9." A few mussels had ap-

peared, but the ascidians seemed considerably less abundant now than in the fall preceding. (See Pl. IX,[9] *A*.)

Finally, these plants were visited *July 21, 1905*. At the position of No. 2 there was a bottom of hard sand beneath which a few shells could be found. I could not succeed in locating the shells of No. 9, but in the whole region of this plant the bottom had a crust of very hard sand probably 4 inches thick. It was evident that the sand wave had proceeded inwards submerging this plant as it had the earlier ridge.

Set of Spat.—There was no evident set of new spat on the 28th of June, 1903 or the 4th of July, 1904. In the former year a good set was noted later; in the latter year no further observations were made. There was a good set on shells planted August 14, 1903. It seems that the set does not appear here prior to July and this is in harmony with observations made at other places.

Summary and Inferences.—A trial plant made December, 1902, had partly sanded by the following August, due to the encroachment of a sand wave. The amount of sanding noted was greater at each succeeding visit November, 1903, May, 1904, July, 1904 and July, 1905. On the last date, no shells were found above the hard sand bottom.

A second trial plant made August, 1903, was located on mud bottom N. W. of the first ridges and in such a position that the sand bottom terminated midway between the two plants. No sanding had occurred by the following July, 1904, but in July, 1905, the bottom in this region was covered by a hard sand crust, 4 inches thick.

The set of spat was good and the early growth at a very good rate.

From experiments made in a very limited portion of a large bay, it is not to be inferred that the bay as a whole is not adapted for the purposes of oyster culture; but, in view of a number of peculiar circumstances, the bay proved ill-adapted for the purposes of our experimental plants. The peculiar conditions in this way are: The canal in one region, discharging into the bay quantities of mud; the shifting of the bottom, as noted at another place; the presence of a considerable number of mussels; and the abundance of ascidians.

PAINS BAY.

This is an oblong bay 2¼ miles in length and ⅘ of a mile wide, making off in an easterly direction from the mouth of Long Shoal River (see

[9] *Explanation of Plate IX, C.*—Oysters taken from experimental plant of Pains Bay. The plant was made June 27 and 28, 1904. The two shells on the side opposite to that of the ruler bear oysters not over 45 days old which were taken August 12, 1904. The other shells bear oysters not over three months old which were taken September 26, 1904.

Pl. II and fig. 5). It is situated about 20 miles south of Roanoke Island and near the lower limit of Dare County. The opening at the S. W. end is nearly ¾ of a mile wide, and there is a small additional opening which is referred to in the notes that follow as the "Thoroughfare," a name applied to it by some of the oystermen. When the observations were made on which the present Coast and Geodetic Survey Charts are based, there was no additional opening, but bounding the S. W. portion of the bay on the S. E. side was a narrow strip of land ⅔ of a mile long. A local oysterman states that the neck of this strip used to be intersected by a narrow ditch or "creek," across which there was a foot log. The thoroughfare is now some hundreds of yards wide and has a depth ranging to 3 feet. The heavy seas that frequently beat on the outer shores here, and, in less degree, the currents that, with changing winds, flow in

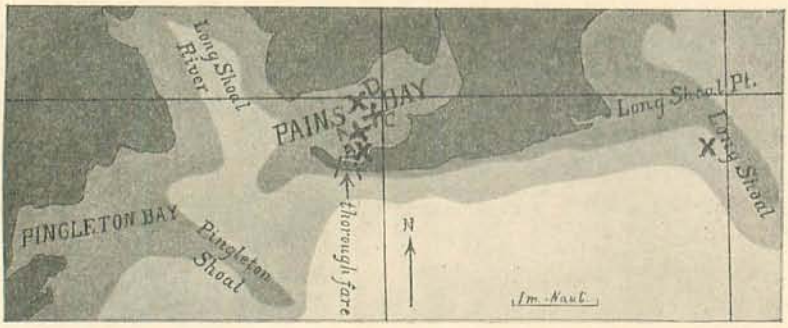


FIG. 5.—Chart of Pains Bay and Long Shoal region, including the planted beds of Pains Bay "A," "B," "C," and "D," and Long Shoal. Depth of water less than 12 feet and over 6 indicated by light shading; less than 6 feet, by heavy shading. Oyster plants are indicated by X marks.

and out of the bay, would seem to offer sufficient explanation for the enlargement of this inlet to its present size.

The depth in the bay, according to the Coast and Geodetic Survey charts, ranges from 1 to 5½ feet, but I find depths of 7 and 8 feet. On both sides of the bay there is a wide reef of firm bottom, in some places of resistant mud and in others of tough muddy sand. On the northern side there is a good deal of grass, but much of the reef on this side and nearly all of that on the southern side would seem well adapted for the purposes of planting. In the center the bottom is of very soft deep mud, the possibilities of which would seem quite problematic.

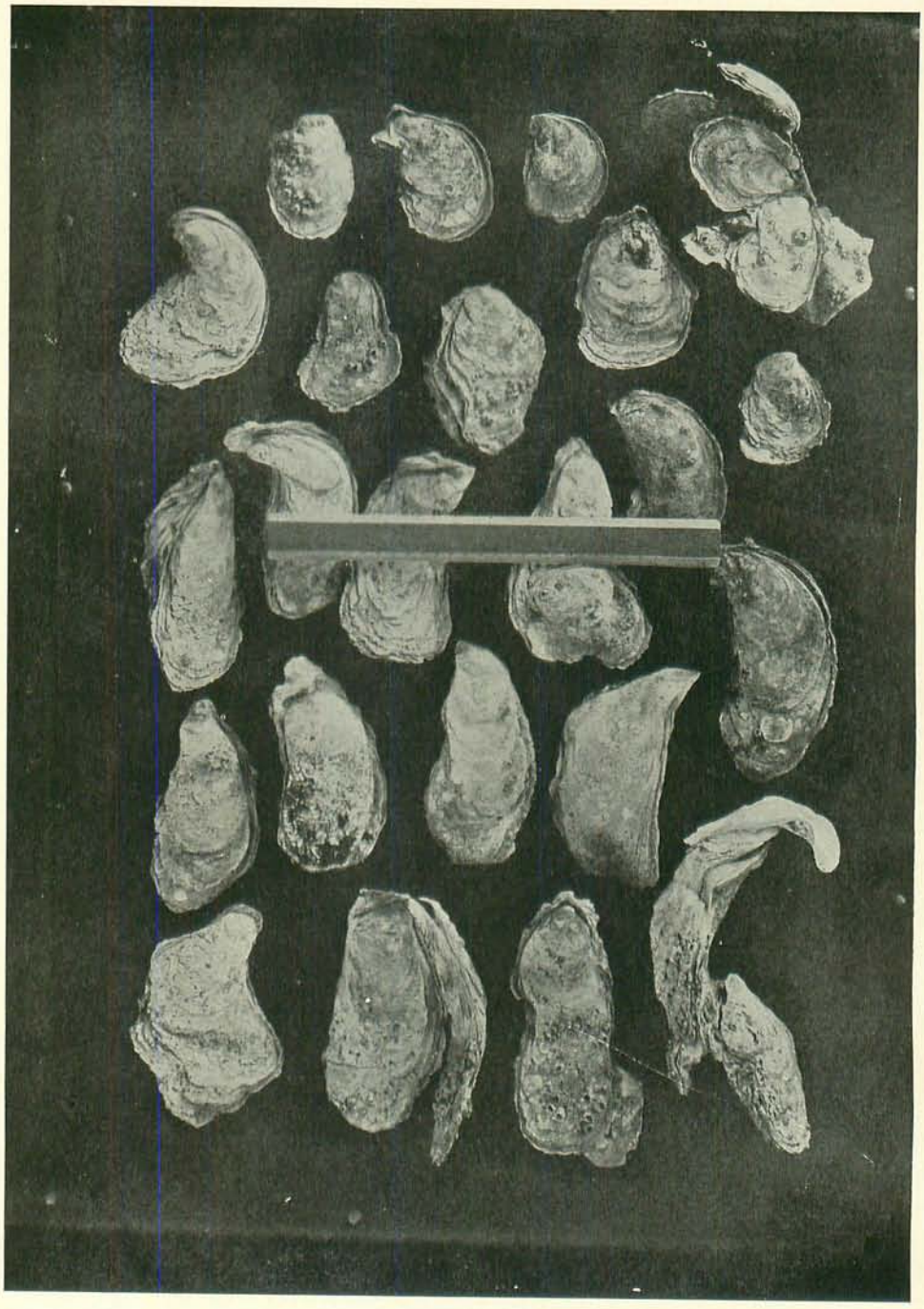
Oysters are rather widely distributed in the bay, but are in very small rocks or merely clusters scatteringly placed. I do not know of a single rock of any size. The oysters grow to a large size and many of them are

of good shape, especially at the stage when first marketable. Most of them, however, from growing in soft bottom and gradually settling in the mud, show a greater growth in one dimension and have an elongated form. Often two or more are found in clusters attached end to end. One of these, the lowest, may be represented by only the empty shell, the oyster apparently having been smothered by sinking into the mud under the increasing weight of the next oyster attached to its upper end. (See Pl. X.[10]) Many of these oysters are sold as "Far Creeks," a designation that is applied to oysters from Pains and Pingleton bays and Long Shoal River, as well as Far Creek. The oysters in these places are said to be of the same character. They are large, usually fat in season, and are esteemed for their flavor. Local oystermen state that oysters were formerly much more abundant than now, that at one time a tonger could take 25-30 tubs per day, but that now, even on a good calm day, and in the best of the season, only 8-10 tubs can be taken. Such a quantity could be found only by feeling about over a considerable area of bottom. The depletion is attributed to over-fishing by tongers and even, it is claimed, by dredgers who have at times worked in this bay in violation of the law.

Through the lower part of Long Shoal River, Pains Bay opens into Pamlico Sound near its upper end. Northerly winds drive the water from this part of the Sound toward the broad lower region, while southerly winds bank the water in this upper region. Pains Bay, as will be seen from maps 1 and 4, is somewhat protected from the direct effect of such winds, but as the level of the water in that part of the Sound rises or falls, a current must flow in or out of the mouth of the bay. From the extent of the bay and its relative narrowness, I would infer that the currents are of fair rate. On the few occasions when I have taken the current with a satisfactory meter the water has been either "slack," or with a current of .11 to .15 nautical miles per hour.

Fresh water is received into this portion of the Sound from Albemarle Sound, through Currituck and Roanoke sounds, and from the creeks and rivers of the western shores. Oregon and New Inlets contribute salt water, and Hatteras Inlet is not too far south to affect this region. In consequence, the density in this region is well adapted for the production

[10] *Explanation of Plate X.*—Representative clusters of oysters taken from Pains Bay natural beds July 19, 1905, a little over three months after the close of the season for oystering on natural beds. These oysters are not, therefore, quite representative of the natural oysters of the bay, but illustrate the elongated form of the natural oysters growing in the softer bottom. The oysters of Pains Bay are large and highly valued.



OYSTERS TAKEN FROM PAINS BAY, NATURAL BEDS.

of oysters though it is relatively low on the mainland side. The densities I have observed in Pains Bay range from 1.0060 to 1.0090.

In planning the experiments it was desired not only to try the firmer bottoms, where the probabilities were in favor of success, but to test the soft middle bottoms, where the appearances would suggest failure. A moderately favorable result from experiments so located would be of greater value than complete success from the other beds, as indicating the possibility of greatly extending the area available for the cultivation of the oyster.

Experimental Plants.—Locations.—Four beds were made: "A," "B," and "C," placed June 27, 1904 and each consisting of 2 plants, and "D," placed on the following day and consisting of 3 plants. (See fig. 5.)

Bed "A" was situated nearly opposite the thoroughfare, and in 5 feet of water. The firm bottom was composed of sand with some blue mud. It was hard to drive a pole through the first 8-12 inches, after which it would go easily for 3 to 3½ feet through soft blue mud to strike again a very resistant stratum. The nature of the bottom might suggest that the formation of the inlet had changed its character by causing sand to drift in over the mud, and that the bottom might not now be in a stable condition. The history of a plant located here for 2 years should offer a fair test, and the result of this trial, as will be seen below, gives no suggestion of want of stability.

Bed "B" was situated not far from "A" but nearer to the marsh and farther out of the direct current from the thoroughfare. It was designed to test a portion of bottom that was less under the direct influence of the thoroughfare, and therefore more representative of the firm reef on the south side of the bay. The depth of water was 5 feet. The bottom was softer than that at "A," but firm enough to support the weight of a man; it was muddy sand, slightly shelly, and was presumably well adapted for oyster beds. A pole could be thrust with some difficulty through 20 inches of mud, when a more resistant layer was felt.

Bed "C" was located well out toward the middle of the bay. The depth was 7 feet and the bottom was soft mud, through which the pole would go easily for 3 to 6 inches, striking then in most places a shelly layer. Below this there was about 2 feet of soft mud supported by a hard stratum. The top layer seemed very soft for the support of planted shells, and the results at this place were watched with much interest, though without great hope. As will be seen below, the results were more favorable than was expected.

Bed "D" was placed on the north side of the bay, but well out on the reef. The depth was 5½ feet and the bottom was tougher than at any

other plant in the bay. It was difficult to work the pole down for a foot in the blue soapy mud.

Methods.—Bed "A" is composed of plants 17 and 18. (See fig. 6, A.) No. 17 covers 2,000 square feet, dimensions 40 x 50, and is planted with shells evenly distributed, 5 bushels to 100 square feet, or with a quantity of shells sufficient to make one uniform layer. On No. 18, area 2,200 square feet, dimensions 40 x 55, only 2½ bushels of shells

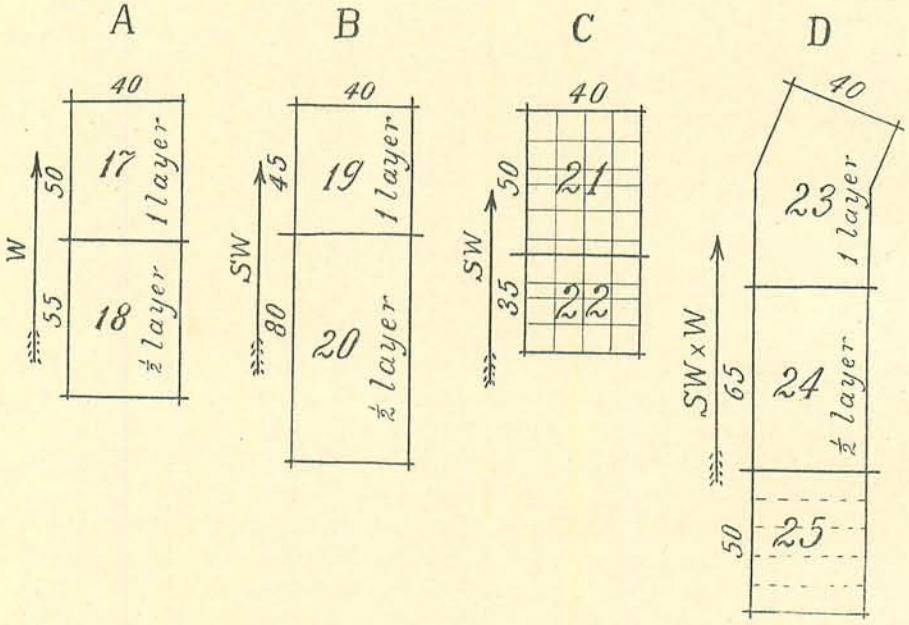


FIG. 6.—Experimental oyster plants in Pains Bay.

per 100 square feet were used. This is just half the quantity required to make a solid layer. The two plants are placed end to end to make one continuous bed, 40 x 105 feet, with the long dimensions in an E. and W. direction. One hundred bushels were used on the one plant, 55 on the other.

Plants 19 and 20 together constitute bed "B," which has a width of 40 feet and a length of 125 feet. (See fig. 6, B.) The same methods were used as for the plants of "A," but the lighter plant, No. 20, is considerably larger than the heavier, No. 19. No. 19 embraces 1,800 square feet, dimensions 40 x 45 feet, No. 20, 3200 square feet, dimensions 40 x 80. The long dimension of the bed has a N. E. and S. W. direction.

As bed "C" was located on very soft mud a light plant such as No. 18 or No. 20 was not attempted. (See fig. 6, C.) Plant 21, area 2,000 square feet, was made with 5 bushels to each 100 square feet, or a quantity sufficient to make one even layer; but, instead of planting evenly, the shells were placed in lumps. In each square, 10 feet on the side, 5 bushels of shells were planted, but they were placed in such a way as to pile up toward the center of the square. The same method was followed on No. 22, area 1,400 square feet, except that a double quantity of shells per 100 square feet was used. The entire bed is 40 x 85 feet, there being a gap of 5 feet in No. 22, and the long dimension is in a N. E. and S. W. direction.

Bed "D" is composed of 3 plants, Nos. 23, 24 and 25. (See fig. 6, D.) No. 23 was planted like Nos. 17 and 19, with shells sufficient to make one even layer. Its area is a little more than 2,400 square feet. Its dimensions are 40 feet in width, with a length of 60 feet on one side and about 70 on the other, a change in the direction of its long axis having been made convenient by a change of the wind while the planting was in process. No. 24, area 2,600 square feet, was planted with 2½ bushels per 100 square feet. On No. 25, dimensions 40 x 50 feet, a quantity of shells sufficient to make an even layer was used, but they were placed in 5 ridges each 40 feet long. The entire bed is 175 feet long and 40 feet wide, with the long dimensions in a S. W. x W. and N. E. x E. direction, except that at one end it bends towards the west.

History of Plants.—The plants were made June 27 and 28, 1904. A few shells, taken by a local oysterman, August 12, and mailed to me, indicated a good set of spat. (See Pl. IX, *C*, and "explanation.") The bed was visited *September 26,* when the plants were 12 weeks old. There had not only been an excellent set, but the rate of growth was particularly good, as the record which follows shows:

Pains Bay, Sept. 26, 1904.

Length of Oysters.	No. per 100 Shells. A	B
Less than ½ inch	87	96
½ inch	207	320
1 "	193	108
1½ inches	53	..
2 "	3	..
Totals	543	524
Average lengths in inches	.95	.76

Records were not made at this time for beds C and D. The more rapid growth of the oysters on bed A, as compared with B, was quite noticeable, and was attributed to the location of this bed, opposite the thoroughfare, and in a position to benefit by the currents flowing through this opening. (See Pl. IX, *C*.)

A second visit was made *July 18-21, 1905,* when the plants were examined and staked off with some care. There had been no sanding at A, and practically none at B, and D. It was expected to find much mudding at C, but, on the whole, this bed was in good condition. Perhaps one-fourth or, at the outside, one-third, of No. 21, the lighter plant at this place, had mudded.

On most of the beds over 70 per cent of the shells taken up with the tongs bore young oysters of the set of 1904.

Pains Bay Plants.

Per cent of Shells with Oysters of the Set of the First Years.

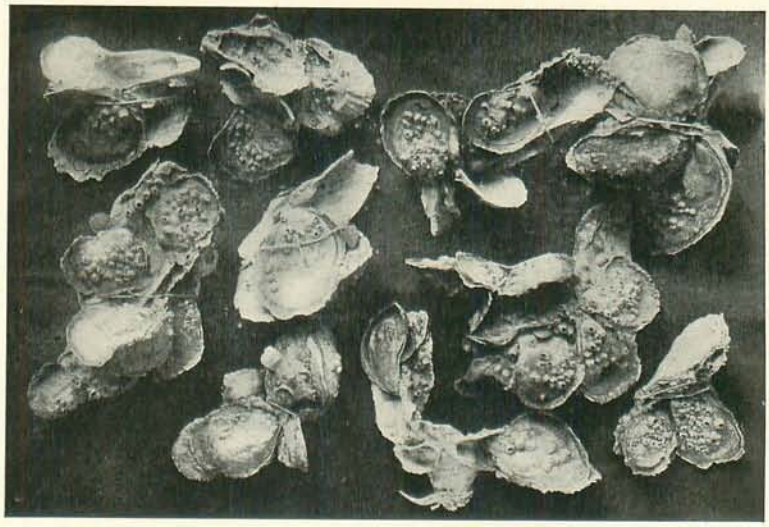
	A.		B.		C.		D.		
	17	18	19	20	21	22	23	24	25
Heavier plants.....	Nearly all.		75	.....	.....	74	72	.....	50
Lighter plants.....	....do		.....	26	71	.....	.....	71	.....

For some reason, not apparent, the proportion of shells on plant 20 that took a set was comparatively small, a condition that has been favorable for the growth of the oysters. That the proportion of shells on No. 25 that caught is as low as 50 is explained by the fact that the shells were planted in ridges and the tongs of course take up many that were above the mud, but beneath the top shells, and therefore not exposed.

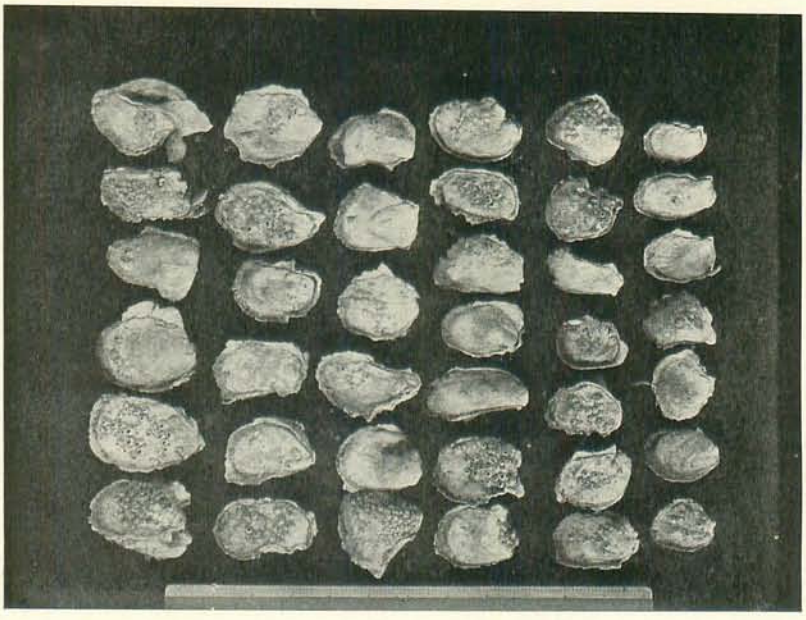
A considerable number of the exposed shells that had not caught in 1904 bore the new set of 1905.

The following record will give some idea of the relative abundance and growth of the oysters on the different plants (see Pl. XI,[11] *A* and *B*).

[11] *Explanation of Plate XI.*—*A* represents clusters of oysters taken from bed "A," experimental plant at Pains Bay, July 19, 1905, 12⅔ months after planting bed. *B*, oysters from bed "A" of Pains Bay experimental plant culled from the shells and representing the run of the bay. These were taken July 19, 1905, after about one year.



A. REPRESENTATIVE CLUSTERS OF OYSTERS FROM EXPERIMENTAL PLANT IN PAINS BAY AFTER ONE YEAR.



B. OYSTERS REPRESENTING RUN OF BED FROM EXPERIMENTAL PLANT IN PAINS BAY AFTER ONE YEAR.

Pains Bay, July 18-21, 1905.

Length of Oysters.	Number per 100 shells.							
	A.		B.		C.		D.	
	17	18	19	20	21	22	23	25
Less than 1 inch	6	3	10	7	10	19	4	3
1 inch	44	19	52	..	46	56	29	12
1½ inches	118	69	105	93	98	93	68	70
2 "	138	147	93	80	54	36	98	115
2½ "	47	69	14	33	8	9	34	24
3 "	..	11	2	20	..	1	7	..
3½ "	..	3	..	..	..	..	..	..
Totals	353	321	276	233	216	214	240	224
Average sizes in inches	1.5	2.3	1.6	2.2	1.75	1.6	2.1	2.1

Several interesting facts are shown by this record.

(1) The set at A has been much more abundant than elsewhere, and this may be attributed to its being in the line of the currents through the small inlet.

(2) The plants made with the lighter sowing of shells—No. 18 at A, No. 20 at B, No. 21 at C (No. 24 at D not given)—show a faster growth

No. of Oysters Exceeding 2 inches in Length, per 100 Shells.

	A.		B.		C.		D.	
Heavier plants	185	.....	109	.....	.....	46	139	139
Lighter plants	.....	230	.....	133	62	.....	Not counted	

of the oysters, and, at A and B a slightly smaller number of oysters. The crowding on the heavier plants has retarded the growth to some extent.

(3) The growth at A and D has been, on the whole, better than at the other plants. This is not so well seen in the averages which are reduced, at A, for example, by the large number of small oysters present. Comparing the number of oysters that, at the end of this period of two years exceed 2 inches in length, the advantage of the position of A and D, as well as that of the method of lighter planting is well shown.

When one considers that 70 per cent of the shells taken bore oysters and that on each 100 such shells there were from 46 to 230 oysters over 2 inches long, one gets some idea of how many oysters over 2 inches in length there were on the beds.

(4) The least growth was shown by the oysters on bed C. This bed is perhaps less in the line of direct currents than the others, and the water is deeper, which would tend to make the current slower. However, if no greater growth had been shown at any of the plants than at C, the condition would have been considered good.

Another visit was made *August 9 and 10, 1906.* It was intended to make a final examination of the beds later in the season, but the weather condition and shortness of time available prevented my doing so. However, the observations made at this time indicated that the conditions were essentially as in July, 1905, except for the further growth of the oysters, and for the new set of 1906 (see Pl. XII, *A* [12]).

Some observations made at this time are included in the two following sections:

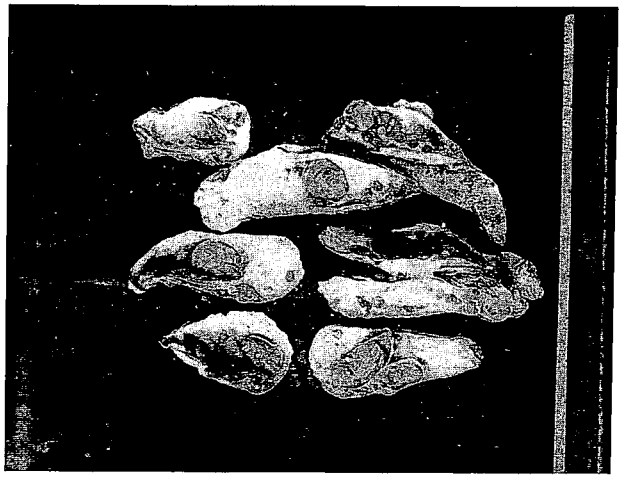
Set of Spat.—The following table, giving the record of the set of spat for 1904, 1905 and 1906, shows that the set has been ample each year.

Pains Bay.

Length of Oyster	Number per 100 shells.				
	Sept. 20, 1904.		July 18, 1905.		Aug. 9, 1906.
	A.	B.	A, No. 18	D.	A, No. 17
Less than ⅛ inch	87	96	105	268	396
⅛ inch			93		
¼ "			5		
½ "	207	320	...	...	8
1 "	193	108	...	...	. .
1½ inches	53	...	...	...	...
2 "	3	...	...	...	...
Totals	543	524	203	268	404

[12] *Explanation of Plate XII, A.*—Oysters from bed "D" of Pains Bay experimental plant illustrating the run of the bay. These were taken August 10, 1906, after 25½ months.

A. OYSTERS TAKEN FROM PLANTS IN PAINS BAY, AUGUST 10, 1906, AFTER 2 YEARS.



B. OYSTERS TAKEN FROM CUNNING HARBOR EXPERIMENTAL PLANT, NOVEMBER, 1903, AFTER 3 MONTHS.

C. OYSTERS TAKEN FROM CUNNING HARBOR EXPERIMENTAL PLANT, MAY, 1904, AFTER 8½ MONTHS.

It may be observed that on July 18, 1905, a very few measured over ¼ of an inch, that on August 9, 1906, some, but very few exceeded ½ of an inch, and that on September 20, 1904, a large number were longer than 1 inch, and several at A exceeded 1½ and 2 inches. As the totals form a series corresponding to the lateness in the season of the time of count, one would infer that the total set for each year was about the same.

Summary.—The hard reef on each side of the bay is well adapted for the support of planted shells. There has been practically no mudding in the six plants made on these reefs. The lighter method of planting is more satisfactory than the heavier, both because it is more economical, and because the oysters have a better chance for growth. The softer bottom in the middle region of the bay will also support shells, properly planted. While less mudding has occurred on the heavier plant at C, the lighter would seem the more satisfactory. Even though a small portion of such a plant should be lost in the mud; there would be left a much larger bed than could have been made at the same expense if the method of thicker planting had been employed. The lumping of the shells in small lumps is to be recommended for such a bottom.

During each of the past three years, there has been an abundant set of spat on the planted shells.

Growth is rapid, especially during the first year. It would be a distinct advantage to break up and scatter the oysters, at least those of the heavier plants, as, on accouut of the abundance of spat, the oysters become too crowded to grow to the best advantage or in the best form. This work should be done at some time between 6 and 18 months after the making of the plant.

Since the set occurs so abundantly each year on the old shells and oysters, it follows that it will not be necessary to make new plants of shells on the same ground. The discarded small oysters and shells, returned to the bottom, should form the basis for future growth, and make the bed permanent.

No enemies have been noted as doing any serious injury. There are a few ascidians and a few mussels, but these have worked no serious harm. A few dead oysters have been observed each time, but the number has been proportionately very small and, in view of the abundance of the oysters, a larger death rate could be endured without injury, and even with benefit to the bed.

The last examination of these plants was made when they were but little over two years old. Some marketable oysters could be obtained during the coming season, but it would be 15 months before the beds should be regularly worked for market. They were, however, at that

time showing the need of cultivation, or breaking up, that they should have received during the preceding winter, and which a regularly established private plant would ordinarily receive each winter as they are worked over for the purpose of marketing the available oysters. It is this sort of cultivation which the public beds receive annually, except that, on public grounds, the cultivation is done without thought or care, and with the object of marketing everything possible—not simply those oysters which can not remain another year to advantage.

THE OFF-SHORE PLANTS.

The experimental plants so far described have all been located within bays or near the land. There are a large number of these bays, many of which embrace some thousands of acres each, and they offer an important field for investigation. There can be learned, too, from observations made in them much that will throw light on the problem of the cultivation of the bottoms in the open sound. In this latter regard, however, the value of the experiments described is limited. The bays, as a rule, present conditions different from those that prevail out in the sound. The positions are somewhat protected, the depths are less and the currents probably better than in the open sound; the areas of available bottom are more limited and oysters of the natural growth are in fairly close proximity.

It is the off-shore region of the Sound that not only offers the largest areas of available bottom, but is the least well supplied with natural beds. The investigations would be incomplete indeed without experimental plants located and designed especially to test the possibilities of the off-shore bottoms.

In the prosecution of such experiments some practical difficulties present themselves, and chief of these is the problem of marking the beds so that they may be found again with little loss of time. The task of finding a small and unmarked bed at some distance off-shore is a more difficult one than might at first be imagined. Compass bearings have been found to be quite unsatisfactory as a sole dependence, though quite useful, or even essential, to use in connection with other marks. On small boats there seem to be too many factors to cause an error in the reading of the compass or in the compass itself. The same compass does not always give the same reading on different boats. When a position is reached that gives the proper bearings for the bed that is sought, the boat may prove to be several hundred yards from the bed. By placing a temporary buoy and describing circles about it, and using a sounding pole, the bed will in time be found; but, if there are other rocks in the neigh-

borhood, each one found must be tonged for examination. It may require half a day or more to find the bed with certainty. Then, when the plant is located, another half a day may be required to measure and stake off the bed so that the several plants may be distinguished. Such delays prove very expensive, especially when, as is not infrequently the case, only one or two days of the week offer weather suitable for such work.

The most satisfactory marks are stakes, provided the stakes can be replaced at least twice a year. The time spent not only in finding but in measuring and distinguishing the different plants may thus be saved. Sometimes, however, a year or a little more has elapsed before it was possible to return to certain beds, and the stakes would meantime have been worm-eaten and lost. In July, 1905, very large green pine stakes were placed on the bed in the Bight of Royal Shoal, fig. 8. The stakes were so heavy that it required at least two men to handle them in putting them down. On my return in September, 1906, the stakes had disappeared. I was reluctant to believe that they had been destroyed by worms in such a period of time. However, after a day and a half spent in locating the bed from compass bearings and by the methods referred to above, and in marking off the several plants, the lower parts of two of these stakes were found in proper positions, and thoroughly worm-eaten.

The most convenient and satisfactory method of locating some of the beds was attained by getting two objects on shore in line with a house or a tree near the shore and a tree in the woods behind, or a point of marsh and some characteristic mark on the distant forest. Such marks when properly recorded by drawings and descriptive notes proved invaluable. In cases where cross bearings of this kind could be made, the plants could always be found within a short time; but this would apply only to beds at no great distance from the shore.

Of several types of buoys that were tried, two were made that, it was believed, should be satisfactory. The first type of buoy was made from an oak keg of 10-gallons capacity, re-enforced with hoops of $\frac{1}{2}$ inch galvanized iron rod (see Pl. I). The keg was securely harnessed with $\frac{3}{8}$ inch galvanized wire rope encircling the keg tightly near each end and forming a bight below to which was attached a long cable of $\frac{5}{8}$ inch wire rigging. For anchors iron disks or rails of 150 to 400 pounds weight were used. A row-lock socket was screwed to the side of the keg with short screws, and in this was placed an iron flag-staff, 3 to 4 feet in length, and supported by wire stays. Many precautions were taken to ensure security of attachment and as little friction as practicable. The keg was then copper-painted, and just sufficient ballast was attached

below to keep the keg from rolling over under the weight of the flagstaff.

Some of these buoys remained in place in very exposed positions for considerable periods of time. The most exposed position of any plant was at Long Shoal (see fig. 5). A buoy was placed there August 18, 1903. In November it was replaced by a freshly painted buoy, and this one was replaced by another in April, 1904. The cable and anchor were examined and found to be in good condition. By the 25th of June the buoy had disappeared. In view of the history of the buoys used at other places it was surprising only that this one should have remained as long as it did. Usually they were lost within a short time. In one instance a buoy in a comparatively protected position disappeared within three weeks. The cable, with the anchor, was found intact. Attached to it was a part of the wire that had been fastened to the keg. This wire had been parted at *two* places where there could not possibly have been friction and the appearance of the ends showed that the wire had been hacked in two with a hatchet or other instrument.

Believing that the kegs were a temptation to some unscrupulous boatmen who would value them as water kegs, a spar buoy was devised. On the lower end of a spar 4 inches in diameter a conical iron cap was fitted and securely nailed. In the end of the cap there was an eye for use in attaching the spar to the anchor—a 550-pound car wheel. The attachment was effected with the use of $\frac{5}{8}$ and $1\frac{1}{4}$ inch galvanized wire rope. The spar was well coated with hot coal tar. This buoy, placed in the water in August, was in position in November, but had been lost before the following May.

The first two trial plants of ridges placed December, 1902, at considerable distances off-shore, were lost on account of dependence in buoys and compass bearings. After this experience it was decided that, with the conditions under which the work must be prosecuted as they were, it would be best for the time to locate the experimental plants at no great distance from the shore, and with reference to finding them again without being dependent upon buoys or stakes.

It would be advisable in time to conduct experiments in the central regions of the sound, but it was not feasible to test all regions within a few years, and the beds to be described in the following pages are, it is believed, as representative as could have been made under the circumstances. The beds, or sets of the plants, to be described are those near Cunning Harbor, near Long Shoal, and in the Bight of Royal Shoal (see figs. 8, 5, and 7, respectively).

A few leading questions may be kept in mind in following the history

of these plants. It has been seen that the set of spat in the bays has proven abundant. Is the set equally abundant, or sufficiently abundant, on the off-shore plants? Is the rate of growth equally good or satisfactory? What are the conditions in the off-shore regions as regards stability of the bottom?

The three beds are widely removed from one another (see map, Pl. II), are on bottoms of different character, and are under very different conditions in other respects.

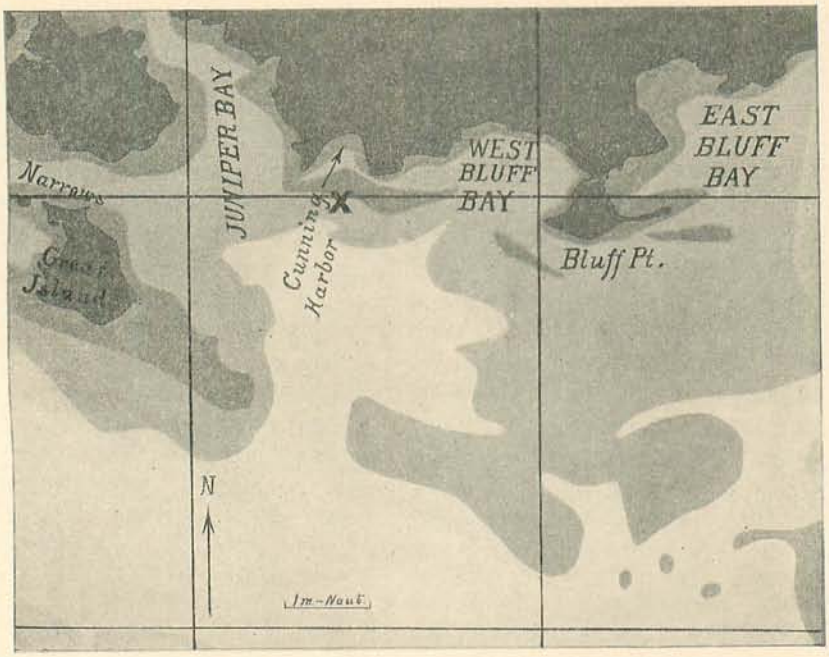


FIG. 7.—Chart of the region around Cunning Harbor. Depth of water less than 12 feet and more than 6 feet indicated by light shading; less than 6 feet, by darker shading. Oyster plants are indicated by X marks.

CUNNING HARBOR PLANTS.

Location.—Bluff Point juts out as the southeast extremity of the mainland portion of Hyde County. Going west from this point one passes the wide mouth of West Bluff Bay, a smaller bay unnamed on the usual charts, then the wide and long Juniper Bay, and beyond this enters the strait between Great Island and the mainland. This strait, indicated on the Coast and Geodetic Survey charts as Swan Quarter Narrows, is better known to the oystermen as Great Island Narrows. The smaller bay

between Juniper and West Bluff is known as Little Juniper Bay, or as Cunning Harbor (see Pl. II and fig. 7), a name that it well deserves from the fact that a long shoal reaching a short distance south from Juniper Bay Point bends at right angles to extend westward entirely across the mouth of the little bay and one-third of the way across West Bluff Bay. South of this high shoal, there is a reef between the one and two fathom lines, at one end continuous with a similar reef extending around Great Island, at the other end broadening out into the deep shoal around Bluff Point. On this reef, south of the high shoal, and opposite the western part of Cunning Harbor are located our plants 14 and 15, referred to as the Cunning Harbor plants. This bed is about half a mile off-shore, and in 10½ feet of water. The bottom may be described by saying that it feels to the pole, applied lightly, like a carpeted floor, hard but with a softish layer on top. The pole can, however, with one arm be driven in for several inches. Samples scraped from the bottom with pole and cup show sand, a little blue mud and a few small pieces of shell.

Natural Oysters.—In Great Island Narrows and, in fact, all about the island, there are natural rocks that are worked by the oystermen. They have described a natural rock a mile long as lying somewhere between the location of our plant and Bluff Point. Along the reef are scattered clusters, but probably not in sufficient abundance to constitute a natural bottom. Over half a dozen hauls with the dredge near Juniper Bay Point August 19, 1903 brought up less than half a tub of oysters, large, fat, and of good flavor, and a slightly greater quantity of shells. Other hauls were made near the plant and with similar results. A fair proportion of young oysters was noted, as shown in the record below:

Juniper Bay Point Natural Beds, August 19, 1903.

Length of Oysters.	Per 100 Shells, Near Juniper Bay Pt.	Near Plants.
Less than 1 inch	92	36 [13]
1 inch	60	28
1½ inches	4	0
2 "	4	20
Total young oysters	160	84
Per cent of shells with oysters	64	44

It was desired to make here three plants one of which should be a very thin sowing of shells, for it was believed that the set of spat would be sufficient, and that the character of the bottom was such as to support

[13] As some of the better clusters had been removed from this lot, the record is not representative.

single shells or clusters. At the time the plant was made, it was necessary to modify this plan, because the shells available were not suitable for very light plants. The load contained originally too large a proportion of small thin shells that could not be expected to take a set on a bottom with even a superficial layer of sediment. This plant was the last made from this boat-load and, as most of the smaller shells had found their way to the bottom, the shells then in hand had a particularly large proportion of the wafer-like top shells. (See above p. 8. Description of cultch, in Sec. on "Methods of Planting," and Pl. III, *A*). The location is, however, a very desirable one in which to experiment with a planting of about 25 bushels to 1,000 square feet.

Experimental Plant.—The planting was done August 19, 1903. On No. 14, containing over 4,000 square feet, 500 bushels of shells were evenly scattered. This was sufficient to make a flooring of 2½ thickness of shells. The plant is rectangular in shape, 100 x 40 feet, with its long dimensions in a N. W. and S. E. direction. Plant No. 15 is continuous at its end with 14, and of the same size, shape and direction, but only a little over 200 bushels of shell were used. The method of planting is illustrated in fig. 9. This quantity of good shells should make an even flooring, and is as economical a plant as it was advisable to make with the shells then available. On account of the character of the shells, the method of placing the cultch was slightly modified toward the outer N. W. end of the plant. Instead of scattering the shells each shovelfull was thrown so as to fall as nearly as possible in one mass. The beneficial result of this method seems to appear in the subsequent history of plant 15.

History of Plants.—The first visit to the plants was on *November 13* of the same year. The record of plant 14 for that date is as follows: (See Pl. XII, *B*.)

Cunning Harbor Plants, November, 1903.

Length of Oysters.	Per 100 Shells.
Less than 1 inch	218
1 inch	43
1½ inches	4
Total oysters	265
Per cent of shells with oysters	76
Average No. of oysters per shell with oysters	3.5
" size " " " "	.64 inches.

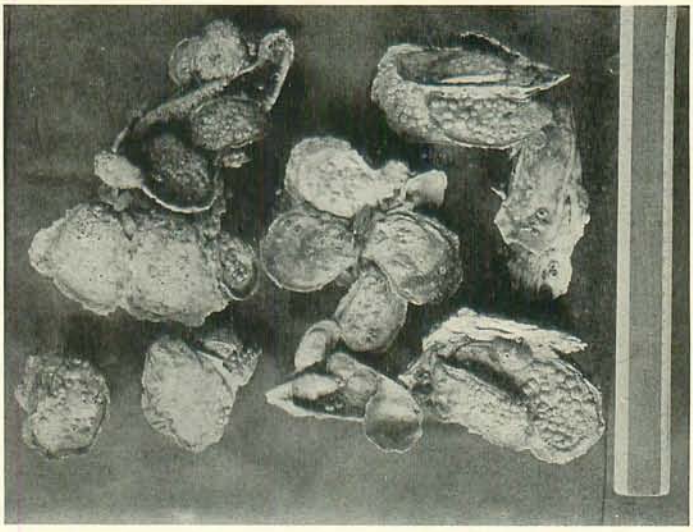
Only 3 dead oysters were noted, but there may have been others very small that were not counted. Many of the shells were encrusted with a polyzoan, but this had apparently not interfered with the set of spat. A few small mussels and ascidians were noted. In regard to the size of the oysters, it must be recalled that the plant was made about seven weeks after the first set of spat in Pamlico Sound.

April 2, 1904.—This was less than five months after the preceding visit and before the set of the second season. The record, therefore, shows the number that had survived the preceding winter, and indicates the growth during the winter season, a period of comparatively slow growth. In number of oysters, these records compare very favorably with that of the preceding November. As shells taken from the mud were disregarded in making the April records, the comparison of number must be made, not between total numbers of young oysters, but between the average numbers of oysters "per shell *with* oysters"; November 3.5; April 2.7, 3.2, and 2.2.

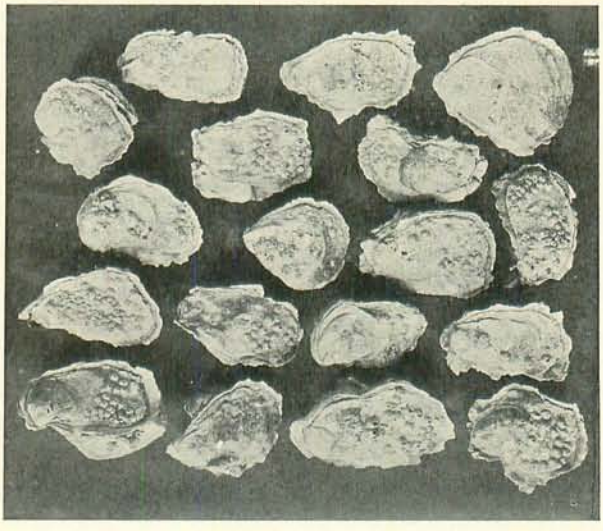
Cunning Harbor Plants, November, '03 and April, '04.

	Per 100 Shells. April 2, '04.			Nov. '03.
	14 S. E. Part.	14 N. W. Part.	15	14
No. shells with young oysters....	92	92	88	..
" oysters less than 1 inch.....	114	136	102	218
" " 1 inch	106	112	66	43
" " 1½ inches	30	36	26	4
" " 2 "	..	12	2	..
Total young oysters.....	250	296	196	265
Average No. oysters per shell with oysters	2.7	3.2	2.2	3.5
Average size of oysters.....	.99	.97	.94	.64

The average number of young oysters per shell with oysters for plant 14 is 2.95, the mean of 2.7 and 3.2; this is 13% less than the corresponding average found in November. However, this difference is not greater than the difference between the two counts for No. 14 made in April, and may be attributable in part to the unavoidable error of average based on small numbers. At any rate, the loss during the winter season was slight and without practical significance. It was readily to be seen that the larger shell clusters caught spat better than the smaller shells, and that the set on the heavier plant 14 was greater than on plant 15. From the table it may be seen that the increase in length during the period from November to April was about 50% (see Pl. XII, *C*).



A. REPRESENTATIVE CLUSTERS.



B. REPRESENTATIVE OYSTERS.

OYSTERS FROM CUNNING HARBOR EXPERIMENTAL PLANT (14) TAKEN JULY 22, 1905, AFTER 23 MONTHS.

The bed was not visited again until *July 22, 1905,* 23 months after the shells were planted. At this time the shells bore the later set of 1903, the set of 1904, and the early set of 1905. While the skiff was rowed over the bed I felt the bottom with a pole. The shells felt thick over the whole of No. 14 but rather scattering over No. 15. It was evident that some mudding had occurred on 15. At various points of the S. E. half of No. 14, about a tub of oysters and shells were tonged up. When counted, there were found to be 259 shells; 64 of these had mudded, but of this 64, 49 were thin wafer-like top-shells that can be discarded for practical purposes; 15 were good shells. Considering that the shells were planted thickly it was to be expected that some of the lower shells would sand or mud. Of the 195 exposed shells, 168 or 86% bore young oysters of the sets of 1903 and 1904. Of the 27 without oysters, 12 were the practically useless thin shells.

Similar counts for plant 15 indicated that about one-half the shells at the S. E. end had mudded, and at the opposite end, where the shells were less scattered, about one-fifth.

A count of the oysters on 100 shells from No. 14 gave the following record:

Less than 1 inch	34
1 inch	134
2 inches	120
3 "	64
4 "	4
Total	356

This shows 68 oysters over 3 inches in length on 100 shells with oysters. Reducing this number on the basis of computations given above, there would be 59 oysters over 3 inches in length on every 100 exposed shells, or 57 on every good shell taken up with the tongs. Of course, the tongs take up largely the top shells, but, assuming that only about two-fifths of the shells planted are exposed, there would be at this time about 60 oysters over 3 inches on every 250 shells of the plant—almost one to every 4 shells.

From about one tub of shells and oysters there were culled an even bucketful over the legal cull-limit, 2½ inches, length of top shell. The bucket, just one-fifth of an oyster tub or bushel, contained 113 oysters. Most of them were small, little above the cull-limit, and they had been carefully culled of shells and small oysters. After throwing out the oysters, undesirable on account of size or shape, 70 were left, one-fourth of which, taken at random, are shown in Pl. XIII, *A* and *B*.

At this time, let it be recalled, (1) the bed was only 23 months old, (2) it was 18 months before the bed should be expected to yield a profitable return, (3) when the bed should be worked, and the good removed for market, the smaller would be thrown back to perpetuate the bed.

A very few ascidians were noted on the oysters, and there were some mussels but not a sufficient number to be of serious detriment. The clusters shown in Pl. XIII, *A*, are representative in this and other respects. There was no weed and, except for barnacles, the oysters were very clean. Oyster crabs, two or more other species of crabs, some annelids, and a flat worm are the more common inhabitants of the bed.

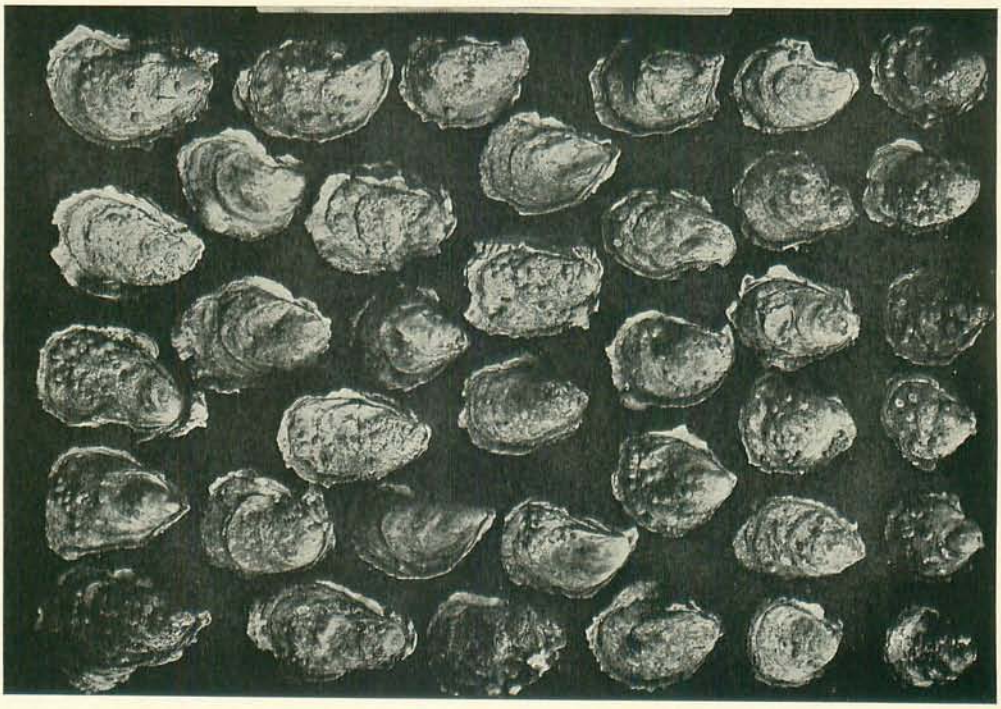
It was too early in the season for a very good set of 1905 spat, but there was noted on plant 14 a set of 64, less than one-fourth inch, 52 one-fourth inch, and 4 one-half inch oysters.

The results at this time were encouraging. The indication was that the planter who wished to work his bed over during the following winter, as it would be almost necessary to do, could cull out enough marketable oysters to pay the cost of this work. It would be better, however, to replant all the oysters on the same or other bottoms.

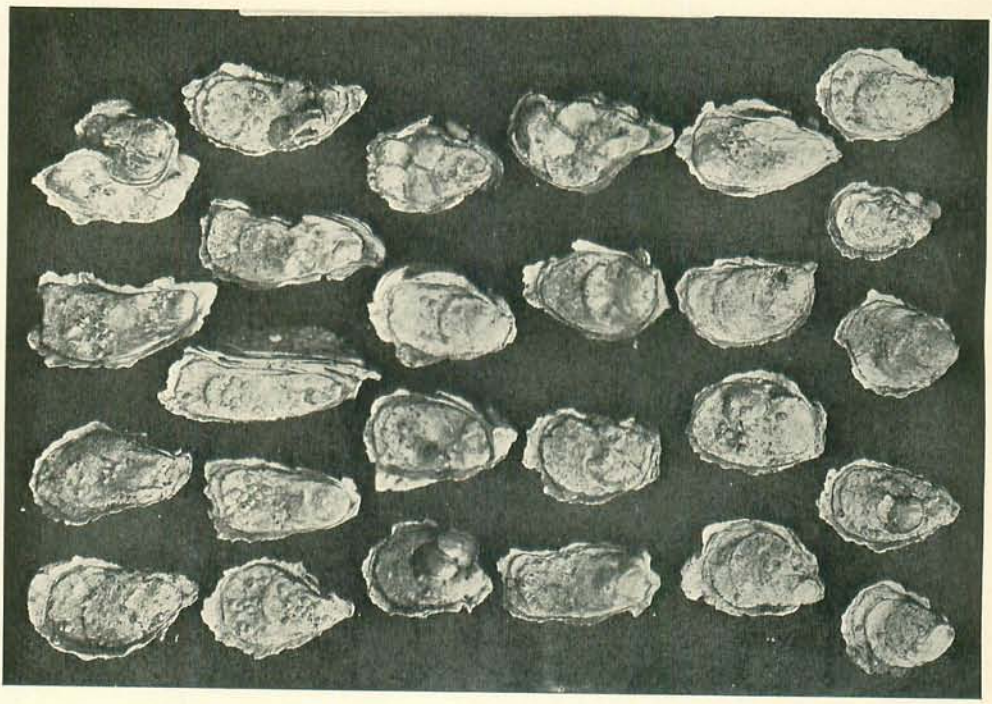
It is just at this stage that the history of our experimental plants deviates from that of farms conducted for commercial purposes. Unavoidable circumstances prevented our giving the cultivation that a commercial planter could not neglect, that, in fact, on established plants would come in in connection with the annual harvesting.

A final visit to this bed was made *September 15-18, 1906*. The condition of plant 14 was very much as anticipated, but the observation on plant 15 was more interesting. Plant 14 is somewhat "rank." It shows the want of that cultivation it should have received during the preceding winter. The early oysters have been rather overcrowded by the oysters of subsequent years. Many of the oysters, therefore, are too narrow to be of desirable shape; yet there are many that are comparatively well-rounded and deep. Those illustrated in Pl. XIV, *A*, may be taken to illustrate the run of the bed. Out of a large box-full of oysters and shells tonged from this bed, there were culled out a quantity of marketable [14] oysters sufficient to fill the box nearly half-full. As the breaking up of the clusters in culling made them pack more compactly, there was probably at least bulk for bulk of marketable oysters as compared with shells and small oysters. The same test was made again, and both oysters and shells were measured in ten-quart buckets, with the result that there was

[14] In this paragraph, the term "marketable" is applied to all oysters over 2½ inches, hinge to mouth.



B. FROM PLANT 15.



A. FROM PLANT 14.

found to be 4½ buckets of marketable oysters to 3½ buckets of cullings. The oysters on 167 shells were measured and gave the following record:

Cunning Harbor Plant, No. 14, September, 1906.

Per cent of shells with oysters 84

	No. per 100 Shells. Live.	Dead.
1 inch in length.....	195	5
2 inches in length.....	58	3
3 " "	41	1
4 " "	14	..
5 " "	1	..
Total oysters	309	9

Average No. of oysters per shell with oysters.. 3.7

While the condition of No. 14 was very much as expected, No. 15 showed more interesting results. Feeling over this bed with a pole indicated the same condition as in the previous year: The oysters were felt only in a scattering way and the bed seemed to be largely mudded. When the tongs were used the oysters were, indeed, taken up scatteringly, but the beneficial result of such a condition for the growth of the oysters was quite apparent. Many of them were quite good in shape, of the deep "cup-shelled" form (see Pl. XIV,[15] *B*). A test measurement indicated that the marketable oysters formed about one-third of the total bulk tonged up, including the mudded shells; and the larger part of the mudded cultch consisted of the thin useless shells already mentioned. The oysters seemed abundant enough to make it profitable to tong for them. That the oysters were more abundant at the N. W. end was quite evident. The difference in method of planting employed at this end has been referred to above, p. 49.

The bed is not large enough for the use of a dredge, but the present condition of this plant seems to indicate that the proper method of planting in this locality is to make a plant of large area with the shells thinly scattered. The oysters from such a plant could be taken up more economically with a dredge.

[15] *Explanation of Plate XIV.*—Oysters taken from Cunning Harbor experimental plants. *A* are representative oysters from plant 14 after three years. Some have a good shape, but in consequence of over-crowding and want of cultivation, the large proportion are unduly elongated. These were taken September 18, 1906. *B* are representative oysters from plant 15. The better formed of the oysters from this thinner plant as compared with those from plant 14 is very apparent. *C*, see Plate XI, *B*. This illustration does not show the depth of the oysters, but a good proportion are of the deep, "cup-shelled" form. These were taken September 18, 1906.

Comparing No. 14 with No. 15, it is seen that, while on 14 there are a great many more oysters, those obtained from 15 are more desirable in shape and size. Just what, however, would have been the condition of 14 had it been worked over during the past winter cannot be said, but it is reasonable to suppose that such cultivation would have greatly improved the quality of the oysters so that the difference between the two plants would be less than as they now stand.

That the set of spat in 1906 has been quite abundant is shown by the following record:

Per cent of shells with spat..... 96

Length of Oyster.	Per 100 Shells.[16] Live.	Dead.
Less than ½ inch.....	1704	16
½ inch	116	20
Total young oysters.....	1820	36

Possibly some of the new set were more than one inch in length, but only the smaller ones could be counted with certainty.

Remarks on Physical Condition of the Region.—The *currents* in such a locality are naturally not rapid, but the meter has at different times indicated currents of:

Currents at Cunning Harbor Plants.

.23	nautical	miles	per	hour	in a N. W.	direction.
.10	"	"	"	"	S. E.	"
.17	"	"	"	"	S. W.	"
.17	"	"	"	"	S. W.	"
.07	"	"	"	"	NxW	"
.00	"	"	"			
.00	"	"	"			

The *density* is, perhaps, not so high as might be desired for the best flavor of oysters, but, if anything is lost in this way, the loss may be more than compensated in the prevention of the growth of enemies of the oyster. The lowest density noted was 1.0040 surface, and 1.0048 bottom after the remarkably prolonged rainy season of 1906. I have not sufficient records for an average, but the density notes follow:

[16] The term shell in such records applies to any single piece, whether an oyster, a shell or a cluster, small or large.

Density of Water at Cunning Harbor Plants.

	Surface.	Bottom.
Aug. 19, 1903	1.0072	1.0074
Nov. 13, "	1.0096	1.0102
Apr. 4, "	1.0096	..
July 22, 1905	1.0050	1.0054
Aug. 27, "	1.0098	1.0010
Sept. 15, "	1.0040	1.0048

Character of Bottom.—The bottom at the plant has been described as of sand with a little blue mud and bits of shell, and the depth is 10-11 feet. Going off shore the depth increases gradually, while the bottom remains of the same general character, except that the proportion of mud increases. At a distance of about a half a mile off-shore from the bed the depth is 14 feet, the bottom is of sandy mud, and a little shelly, but still sufficiently resistant to support single shells. All of this bottom should be excellent for planting. Going inshore, the water soon begins to shoal up. At a depth of about 9 feet a little blue clay is found. Further inshore on the slope of the shoal there is a surface layer of soft sand, through which the pole may easily be thrust into a brown, muddy clay. The shoal does not seem, therefore, to be of a character that would permit its shifting, even if it were not protected from northerly winds by its position. Our bed was purposely located rather close to the shoal. If the bottom at the position of the bed is trustworthy, that offshore from the bed should be even safer. Inshore from the bed is hardly to be recommended, because of possible disturbance from the beating of the waves; for this southern side of the shoal is fully exposed to the force of the sea in southerly winds.

Summary and Inferences.—The conditions in this region seem, in the main, distinctly favorable for the cultivation of oysters. The currents are not rapid but are satisfactory, the density is rather low for the best flavor of oysters, but serves to prevent the growth of weed and other forms detrimental to oyster beds. Enemies are practically absent; there have been few deaths on the bed. A few mussels are present, but they are not abundant enough to be a practical obstacle. The bottom is firm, apparently hard enough to support single scattered shells, and well adapted for oyster culture. The depth is great enough to make injury from the effect of waves highly improbable, while not too great to permit working a bed with either tongs or dredge.

The set of spat was good each year 1903-1906, inclusive, though no new cultch was planted after the first year. The planter in such a locality is

relieved of the necessity of purchasing seed oysters; a bed once started may supply the seed for its own replenishment.

Two plants were made, each of 4,000 square feet. On one the shells were placed in about 2½ layers. The character of cultch used was comparatively poor, and the extent of mudding on No. 15 is not more than was to be expected on this account. There is a noticeable difference between the products of the two beds. Oysters are more abundant on the heavier plant, but those from the lighter plant are distinctly superior in form. The former plant is not only impractical on account of expense, but is undesirable on account of its product. Such a method of planting would probably be followed only for the purpose of obtaining a set for the seeding of surrounding bottoms.

The results of the experiments, as well as the natural conditions, suggest the advisability of trying a plant of not over 25 bushels of shells per 1,000 square feet, with shells of fair size. If such a plant should not prove satisfactory, a series of small beds could be made throughout a large area. With subsequent working of these beds, their area would be extended to cover as much of the ground as is desired.

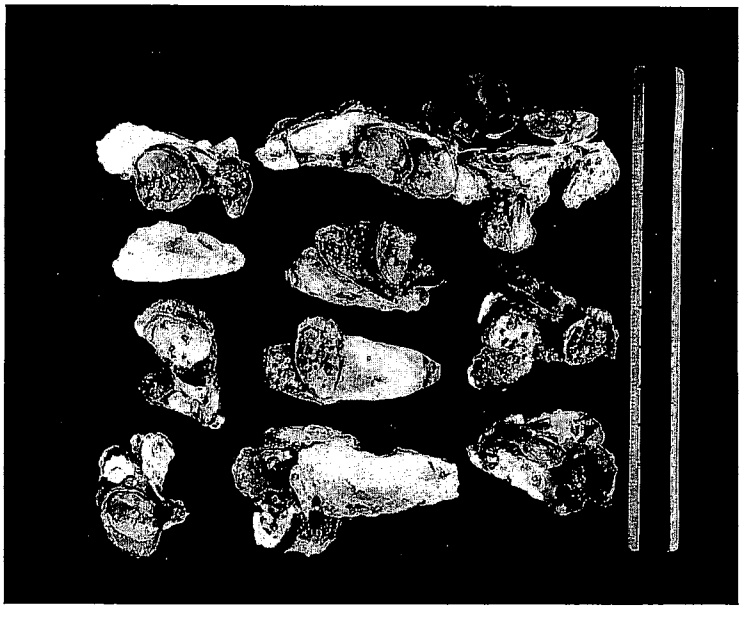
After 23 months there were a small proportion of oysters that could be marketed, but it is believed that it would be advantageous to keep nearly all of the oysters on the bottom for 40 months or more. In that event, it would, at least on heavy plants, be advisable to work over and extend the beds between the 18th and 24th months.

The bottom tested by the experimental plants is not a circumscribed region but is representative of a considerable area that seems almost or quite barren.

LONG SHOAL PLANTS.

Location.—From the region of Parched Corn Bay, and about 5 miles east of Long Shoal River, Long Shoal extends out into the Sound in a S. E. direction for 5 miles (see fig. 5 and Pl. II). A part of this shoal is high, depth 1 to 6 feet, but it is without islands. At a distance of a mile from Long Shoal Point, the high part of the shoal makes a sharp bend, changing its course from east to southeast (see map, fig. 5, of the Pains Bay region). South of this bend and in 12 feet of water the experimental bed was located. The bottom was of the character described as "sticky" —a stiff mud that would support the weight of a long sounding rod resting on its small end. When the rod was pushed through a few inches of mud it struck a more resistant layer, through which it could be forced into stiff mud again. The pole could be worked with one hand to a depth of 4 feet.

A. OYSTERS TAKEN FROM LONG SHOAL EXPERIMENTAL PLANT, NOVEMBER 12, 1903, AFTER 3 MONTHS.



B. OYSTERS TAKEN FROM LONG SHOAL PLANT, APRIL 11, 1904, AFTER 8 MONTHS.

There is hardly a more exposed position in the sound. The shoal and the mainland afford protection from northerly and west winds, but southwest gales have the full sweep of the sound from Harbor Island, a distance of 45 miles, while south and southeast winds are interrupted only by the low and narrow strip of banks 20 to 25 miles distant. In addition, the shoaling up as the high shoal is approached causes the sea to shorten and become more choppy. In consequence, at no place has it been found more difficult to find days when the sea was smooth enough to work satisfactorily on the bed with the small boats that must be used in staking off the bed for identification of the several plants.

From the nature of the position it would be inferred that the currents would be fairly good; that, while dependent on the wind, their direction would be subject to some deflection on account of the shoal. I have taken the current only once with a satisfactory meter. The rate was then .18 nautical miles per hour. The density in this general region is comparatively low, but not unfavorable for the growth of oysters. The lowest I have noticed was 1.0040 surface, and 1.0056 bottom. This was after several days of strong northerly winds, when the density here, especially at the surface, had doubtless been affected by fresh water driven before the wind from Albemarle and Croatan sounds. The highest was 1.0120 surface and 1.0122 bottom.

Experimental Plants.—A bed 40 x 200 feet was made August 18, 1903. It was composed of four plants, Nos. 10, 11, 12 and 13, which had the lengths, respectively, of 60, 60, 40 and 40 feet (see fig. 10).

On No. 10, area 2,400 square feet, the shells were planted to make one even layer.

On No. 11, same area, the same quality of shells was used but they were planted in low lumps, the shells being thrown so as to pile up just a little in each square 10 feet on the side. There were 24 lumps in this plant 40 x 60 feet in extent.

Nos. 12 and 13, area of each 1,600 square feet, were planted like Nos. 10 and 11, respectively, except that the shells were placed twice as thickly.

At this stage of the work I had, I believe, an undue fear of mudding or sanding on ordinary bottoms. With the experience subsequently gained from observations of this and other plants, I should have made at least one of the plants a lighter one than No. 10.

History of Plants.—The bed was planted a month and a half after the time for the appearance of the first set of spat. By November there had been a satisfactory set and good growth, as appears from the following record, made November 12, or 2 months and 25 days after the date of planting. The young oysters were of good shape (see Pl. XV, *A*).

Long Shoal, Nov. 12, 1903

Length of Oysters.	No. per 100 Shells.		
	No. 11	No. 12	No. 13.
Less than 1 inch.....	172	92	147
1 inch	136	172	117
1½ inches	24	40	80
Total No. of oysters.....	332	304	344
Per cent of shells with oysters	80	88	73
Average length in inches....	.9	1.01	1.05

The plants were examined again April 11, 1904. None of the plants had suffered from "mudding." It was clear that the lighter plants promised as good results as the heavier and more expensive (see Pl. XV, *B*).

Long Shoal, April 11, 1904.

Length of Oysters.	No. per 100 Exposed Shells.			
	No. 10	No. 11	No. 12	No. 13
Less than 1 inch.....	44	72	72	32
1 inch	80	126	118	66
1½ inches	101	106	123	94
2 "	30	6	20	32
2½ "	2	..	2	..
Total No. of oysters,	257	310	335	224
Per cent of exposed shells with oysters..	86	96	90	90
Average size of oysters in inches	1.44	1.27	1.34	1.5

The average size indicated a rapid growth for an off-shore plant. The Long Shoal plants were not only leading the off-shore in rate of growth, it was one of the very best beds, being excelled in rate of growth only by Chain Shot and Harbor Island. A very low death rate is indicated by the fact that the record shows almost as many oysters per 100 shells as were present in November preceding, as well as by the observation that there were only from 5 to 18 empty shells to be noted on the several plants respectively.

A later visit was made *September 25, 1904*. The plants seemed in as good a condition as at the time of the examination in April. The record given below shows that the rapid growth had continued, and that there had been a good set of spat in 1905. I could not distinguish with certainty between the larger oysters of 1905 and the smaller oysters of 1904.

But, from observations made on shells that had been placed here in the preceding July (see below), it is pretty certain that nearly all of the oysters under 1½ inches in length were of the new set. Assuming this to be the case, the average length of the remainder, or the oysters of 1904, would be about 2 inches. The number of oysters per 100 shells that were 2 inches or more in length, 155, was significant, as the plant was at this time but a few days more than 13 months old.

Long Shoal, Sept. 25, 1904.

Length of Oysters.	No. per 100 Shells.
Less than ½ inch	160
½ inch	111
1 "	43
1½ inches	54
2 "	106
2½ "	46
3 "	3
Total No. oysters	523
Per cent of shells with oysters	86

The bed was at this time in very promising condition as regards the number of oysters, the rate of growth and the fair shape of the oysters. No further observations have been made on the bed. In July, 1905, I made a short visit to this region, but owing to difficulty in locating the position, could make no observations upon it at that time. In 1906, it was intended to make another visit to this place, but conditions made it impossible to do so.

Plant No. 26.—A light plant of ¼ of the quantity of shells necessary to make an even layer was made July 5, 1904. Some of these shells were taken up in the following September and the spat record is given in the next section. Nothing further can be said as to the condition of this plant since, for the reasons given above, no further observations were made upon it.

Following is the record of the set of spat on the shells of plant No. 26, taken September 25, 1904. The plant was then 2⅔ months old.

Length of Oysters.	No. per 100 Shells.
Less than ½ inch	183
½ inch	189
1 "	67
Total	439
No. of shells with oysters	50

Summary.—There was a good set of spat in 1904 and in 1905, the only years in which observations were made. The rate of growth was quite good. No mudding had occurred at the end of 13 months and it is improbable that mudding would occur on plants made as these were. It is probable that a much lighter plant would be adapted to the conditions on this bottom.

PLANTS IN THE BIGHT OF ROYAL SHOAL.

Natural Conditions.—Royal Shoal is a large shoal with somewhat the form of a horseshoe, connected with the southern end of Bluff Shoal, and continuous on the southeast with the shoals extending out from the

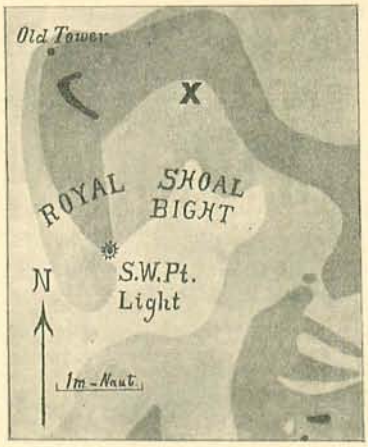
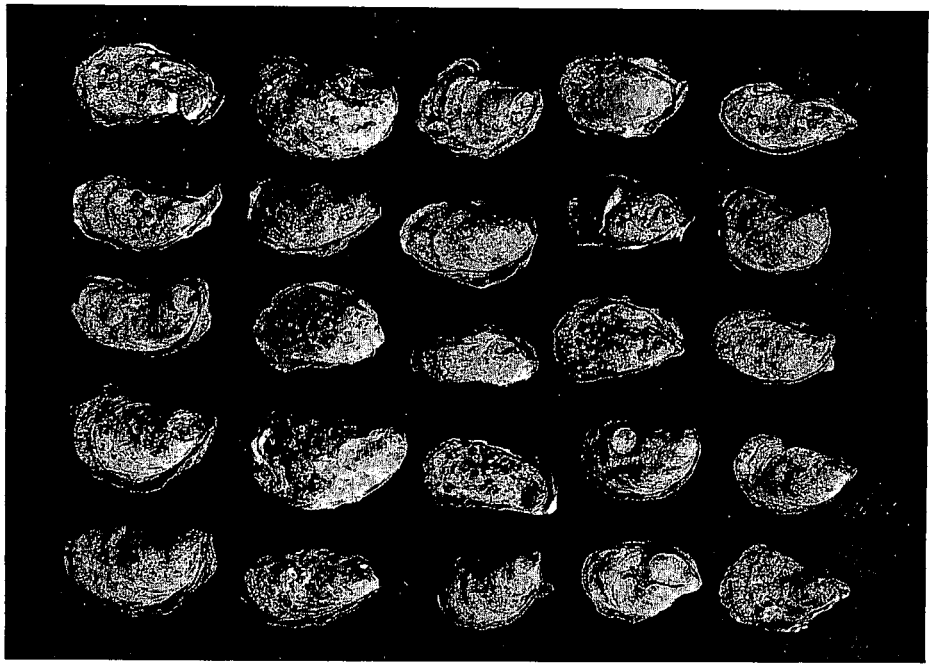
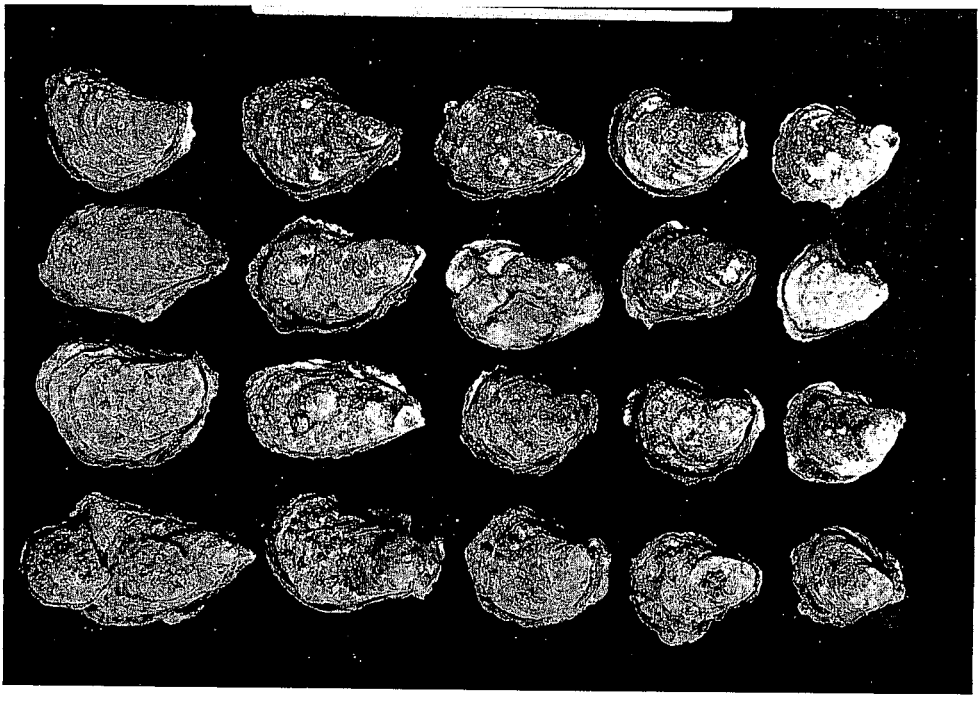


FIG. 8.—Chart of Bight of Royal Shoal. Depth of water less than 12 feet and more than 6 feet indicated by light shading; less than 6 feet, by darker shading. Oyster plants are indicated by X marks.

bank. The shoal is comparatively high on the west; in fact, it leads up to a long low island, the Royal Shoal "Rock." The loop of the horseshoe, or as it is commonly known, the "Bight of Royal Shoal," embraces a large region with a depth of water up to 12 feet or a little more (see map, fig. 8). The place is much frequented by vessels seeking a harbor from northerly winds, by pound-net fishermen, and by oystermen who tong on the numerous small beds. It is said by oystermen that these rocks were discovered some years after oystering had begun on the other beds of the sound, and the opinion is often expressed that they owe their origin to the throwing over of ballast or of clinkers by vessels at anchor in the Bight. Whatever their origin, most of these rocks are exceedingly small, usually not large enough for more than one tonging boat to work on the



B. OYSTERS TAKEN FROM BIGHT OF ROYAL SHOAL EXPERIMENTAL PLANT, SEPTEMBER 21, 1906, AFTER 2 YEARS



A. OYSTERS TAKEN AT BIGHT OF ROYAL SHOAL FROM NATURAL ROCK.

bed at one time. I have not made a careful examination of the bottom in the Bight, except in the region of the plants, where there are many small "rocks"—but oystermen state that there are large areas that are barren.

The oysters that are taken from the rocks are of fair size and shape, and of good flavor (see Pl. XVI,[17] *A*).

The Bight is about 8 miles from Ocracoke Inlet, not so far but that the flow of currents is decidedly influenced by the lunar tides. There is a regular ebb and flow corresponding to the ocean tides at the inlet. At the same time, the currents caused by the winds are felt here as elsewhere. Owing to the depth of the water and the distance from the inlet, the currents are probably not more rapid than those that prevail at other places, but with the combination of currents from two causes, they are more constant and change in direction more frequently. The currents that I have noted were .25, .20, .36, .25, and .09 nautical miles per hour, respectively.

I have not on the occasion of any visit found the bottom density to be higher than 1.0160, nor lower than 1.0060. The following observations have been made:

Density of Water at Royal Shoal Plant.

	Surface.	Bottom.
June 30, 1903	1.0055	1.0060
Aug. 4, 1903	1.0090	1.0092
Nov. 14, 1903	1.0110	1.0160
April 29, 1904	..	1.0120
July 25, 1905	1.0100	1.0102
" 26, 1905	1.0098	1.0114
Sept. 20, 1906	1.0070	1.0071

The last observation was made after the exceptionally prolonged rainy season of 1906. The others, excepting the first, have not a wide range, but from the fact of the proximity to Ocracoke Inlet, I would suspect that the density, at least in times of easterly winds, would sometimes be higher than any of my observations indicate.

The position of the planted bed is in the northern part of the Bight, where the depth is generally about 12 feet. The bottom is of a rather soft but sticky mud, in which a small sounding rod may readily be forced with one arm to a depth of 3 feet or more in the mud.

[17] *Explanation of Plate XVI, B.*—Oysters from plant C of Royal Shoal experimental plant show the run of the bed after three years. The lack of working the bed during the preceding year is shown in the poor shape of many of the oysters. These oysters were taken September 23, 1906.

Experimental Plants.—The location of this experimental bed differs from that of the other off-shore plants described above in several respects. (1) It is at a greater distance from mainland or banks. (2) It is in comparative proximity to an inlet from the ocean, and subject to the consequent conditions as regards currents and density. (3) The bottom is not firm but is of a rather soft mud. (4) Its location amidst the small natural rocks insures much the same conditions of development for the oysters on the planted and natural beds, except that while the planted

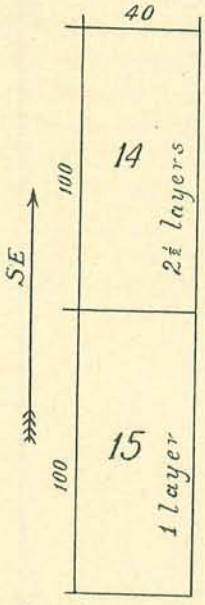


FIG. 9.—Experimental oyster plants opposite Cunning Harbor.

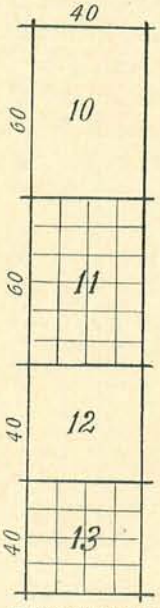


FIG. 10.—Experimental oyster plants near Long Shoal.

shells have been undisturbed for some years, the natural beds are annually worked by tongers.

This bed, planted August 5, 1903, was the first made on soft bottom. In fact, although several trial plants for specific tests had been made some months earlier, this was the first bed to be planted. It was desired not only to see if a plant economically made would endure, but also to ascertain just how thickly it would be necessary to plant shells on such a bottom to prevent a serious degree of mudding. Accordingly, 3 plants were made with quantities of shells sufficient to make beds of, respectively, 1, 3 and 5 layers of shells. Five bushels per 100 square feet were counted as sufficient to form one uniform layer. Each plant embraces 4,000 square feet, being 100 feet in length by 40 feet in width (see

fig. 11). As the several plants have their long axes parallel, and as spaces of 10 feet separate consecutive plants, the three taken together constitute a bed 100 x 140 feet. The heaviest plant is "A" (5 layers), the next "B" (3 layers), the lightest "C" (1 layer). Furthermore, it was at this time doubtful if there would be an adequate set of spat, and it was advisable to try a high ridge with the object of ascertaining if ridges of shells in such a locality would be more successful in taking spat than shells planted as an even flooring. Two hundred and fifty bushels were, therefore, planted as a ridge 100 feet long, and this is referred to as plant "D." The methods used for "A" and "D" could not be supposed

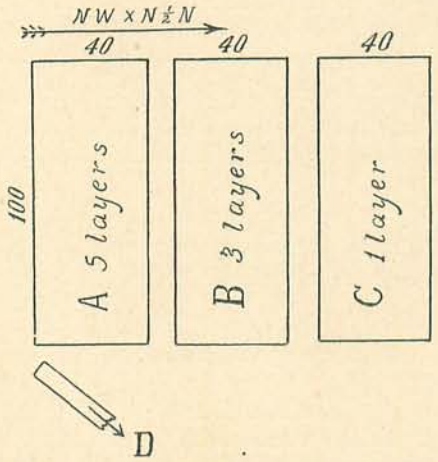


FIG. 11.—Experimental oyster plants in the Bight of Royal Shoal.

to be adopted for commercial planting, but the plants might serve a purpose in supplying answers to important questions.

History of Plants.—The plants were examined in November, 1903. There had been a very fair set of spat, not too abundant as is frequently the case. As may be seen from the record, the rate of growth was rather slow, as compared with the rate at other beds previously described.

Royal Shoal, November 14, 1903.

Length of Oysters.	No. per 100 Shells. A	B	C
Less than 1 inch.....	130	94	129
1 inch	30	18	42
1½ inches	..	2	..
Totals	160	114	171
Per cent of shells with oysters	68	60	70
Average size of oysters in inches	.73	.64	.65

Only a few dead oysters were noted and these were, chiefly, small ones.

A second visit was made, April 29, 1904, following, and the record for plant A indicates continued slow growth during the winter season, and practically no loss of oysters. In fact, a slightly greater number of oysters were counted, but this may be attributed to the fact that a larger number of shells without oysters were included in the earlier count as a comparison of the per cents shows.

Royal Shoal "A", April 29, 1904.

Length of Oysters.	Number per 100 Shells.
Less than 1 inch	87
1 inch	70
1½ inches	10
2 "	5
Total	172
Per cent of shells with oysters	80
Average size of oysters	.93 inches.

Observations were made September 27, 1904, to gain an idea of the set of spat in 1904, and the amount of growth of the older oysters, but the bed was not staked off to ascertain from which plant the shells were taken.

Royal Shoal, September 27, 1904.

Length of Oysters.	Number per 100 Shells.
Less than ½ inch	324
½ inch	108
1 "	96
1½ inches	128
2 "	60
2½ "	4
Total	720

Evidently there had been a good set of spat this year, and it might be anticipated that it would be necessary to break up the bed during the following winter in order to get the best results in growth and good form of the oysters. However, there was no opportunity to do this.

A careful examination of these plants was made July 26, 1905, two years after the time of planting.

Plant A felt very thick and "rank," and showed no sign of mudding, except in a few small spots.

Plant B also felt rank, but the growth of oysters is hardly as good as on A. It had mudded a little at the eastern end. Probably ¼ of the plant was partially mudded.

Plant C, where the shells had been placed in only one layer showed more mudding, but oysters were taken up in all parts. Even if half mudded, it would show a better return for the cost of planting than either A or B.

The record shows that the rate of growth is not so rapid as at other places. There was a fair number of oysters over 3 inches in length but too great a number of smaller oysters attached with the larger. This, in part, is the harmful effect of leaving the bed undisturbed during the preceding winter.

Royal Shoal, July 26, 1905.

Length of Oysters.	Number per 100 Shells.		
	A.	B.	D.
Less than 1 inch	30	6	8
1 inch	140	86	108
2 inches	130	98	102
3 "	26	24	34
4 "	6	..	8
Totals	332	214	260
Per cent of exposed shells with oysters	93	86	..

That the new set was abundant appears from the record of oysters assumed to be of the set of 1905:

Royal Shoal, July 26, 1905.

Length of Oysters.	Number per 100 Shells.
Less than ¼ inch	20
¼ inch	32
½ "	164
1 "	(48?)
Total	216 (+ ?)

No forms were noted that would work serious injury to the oyster. Planarians (flat worms), ascidians, mussels and weed were present in very small quantity. Sponge, barnacles, serpula, anomia, annelids, and other indifferent forms could be found, but, on the whole, the shells and oysters were in a clean condition.

A final examination of the Royal Shoal plants was made, September 20 and 21, 1906. The conditions as regards mudding were essentially as noted in 1905, except that, with the further growth of oysters and the attachment of new spat, the plants all felt thicker, and, therefore, gave

a better impression when tested for mudding. On the other hand, the want of cultivation had shown itself in the crowded condition of the oysters on all of the beds, and the consequent retarding of the good growth. The oysters were, therefore, not of the most desirable form, nor so large as might otherwise have been expected. It is not impossible that the beds were worked some during the preceding winter. There was no direct evidence of this, but some observations led me to suspect it. These were the facts that the proximal part of ridge D seemed considerably widened, that the gap between B and C was partially filled, that while there were some well-known thick oysters (see Pl. XVI, *B*) these occurred so scatteringly as to suggest that the average size of the oysters present was not representative of the real growth that had occurred.

That the bed had been molested is not to be assumed in the absence of better evidence, and the small proportion of large oysters must be attributed in part to the fact that the region is not one of particularly rapid growth, in part to the overcrowded condition of the bed; for these two causes, especially the latter, have operated to a considerable degree.

Tests were made of each plant in the following way. Oysters and shells were tonged up from various parts of each plant to fill a box of about 2 tubs capacity. The oysters that would "pass inspection" were then culled out, and both oysters and culling measured in 10-quart buckets. It was not attempted to cull out oysters that should be marketed, for the bed was not yet a good marketing bed, but simply to cull out the oysters that would exceed the cull limit of 2½ inches from hinge to mouth.

A box of shells and oysters from A, yielded 1¼ buckets of oysters and 4½ buckets of shells, or 1 bucket of oysters to 3.6 buckets of shells.

From B were obtained 1 bucket of oysters to 3 of shells.

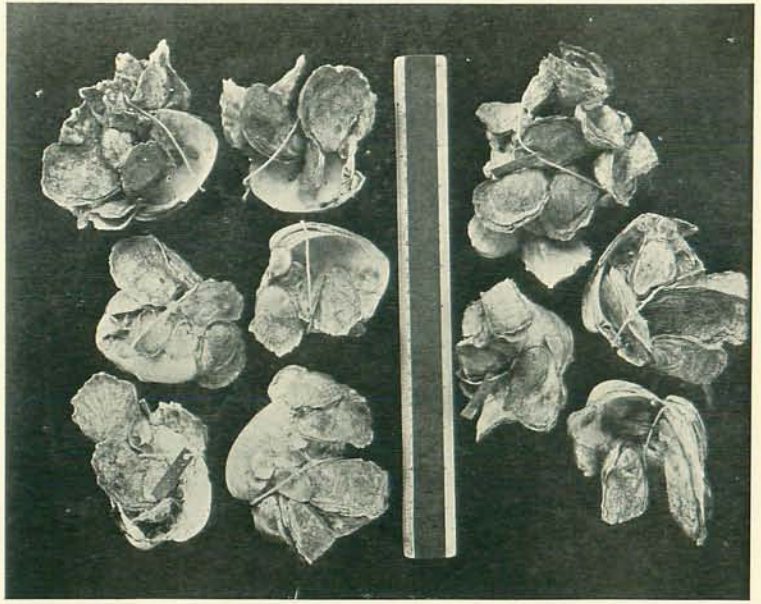
The result of C was 1 bucket of oysters to 5 of shells.

The same operation was tried again, but this time for each test tonging was done on all three beds, with the following result:

N. E. end, plants A, B, and C,	1	of	oysters	to	4.3	of	cullings.
Middle region,	"	"	1	"	"	3.75	"
S. W. end,	"	"	1	"	"	3.	"

(See Pls. XVI, *B*, and XVII, *A*, and the explanations.)

The new spat was remarkably abundant. Although the number of dead spat less than ½ inch in length appeared as abundant as the live spat, the following record of live spat could be made:



B. YOUNG OYSTERS FROM PLANT OF H. S. DOXSEE, IN SILVER CREEK AT OCRACOKE.

The shells were planted in June 1903; "A" being about 10 months old

Royal Shoal "B", September 21, 1906.

Length of Oysters.	Number per 100 Shells.
Less than ½ inch	6,824
½ inch	60
1 "	52
Total	6,936

Set of Spat.—The set of spat has been observed each year for four years. In 1903, the number of oysters attached to the shells was very favorable, neither too few nor too many for shells planted thickly. In 1904, the set was much heavier, and it was evident that with such a set each year, the breaking up or cultivation of the bed would be necessary. In 1905, the observations were made comparatively early in the season, but it appeared that the set of that season would be comparable to that of the preceding year. In 1906, the set was, as wherever observations were made that season, exceptionally abundant. It was much greater than was desirable, but, undoubtedly with so large a number of small oysters, a large proportion would, of necessity, die during the following winter.

Summary and Inferences.—The location is such that fairly regular currents prevail. The bottom is of such a character that comparatively heavy planting is required. The oysters of the natural beds are of good quality.

The set of spat each year has been adequate and generally quite abundant. The beds, if undisturbed, become overcrowded and cannot produce a fair proportion of oysters of good shape. This difficulty would doubtless solve itself, in large degree, in beds that are worked each year for market. The natural rocks all about the planted bed are subject to practically the same conditions as the planted bed, but, with the working which they receive each season from the oystermen, they produce a large proportion of very desirable oysters.

The loss by death has been very small and there seems to be no forms present that are seriously inimical to the oysters.

Mudding has not occurred to as great a degree as might have been expected. The heavier plants have mudded least but the expense of such methods of planting would probably be prohibitive. It would seem advisable to try on such a bottom a quantity of shells such as was used on plant C, but to place the shells in small lumps. In the subsequent working of the beds, the small unit rocks would become enlarged to meet each other, and form a continuous rock.

The rate of growth has been slower than at the other off-shore plants, in spite of the favorable currents. The explanation for this is not evident. One suggestive difference between the conditions at this place and those at other locations where, with less favorable conditions as to currents, the rate of growth is better, is found in the remoteness of this locality from the rivers and estuaries contributing to the sound the drainage of rich lands and swamps. It may be that the conditions at this place are consequently less favorable for the rapid multiplication of the diatoms that constitute the food of the oyster.

There is found no reason for believing that such a locality may not be adapted for planted beds that would be subject to yearly working, but one would naturally choose first regions that are more favorable in rate of growth and in character of bottom.

GENERAL SUMMARY.

Quite a variety of bottoms have been tested by plants. The bottoms off Cunning Harbor, at four places in Pains Bay, near Long Shoal and in the Bight of Royal Shoal, are not unfavorable for planted beds, though the soft bottoms at plant C in Pains Bay and in the Bight of Royal Shoal would not be chosen for commercial plants as long as other more favorable bottoms were available. Chain Shot Shoal is probably representative of large areas of shoal in this and other regions that are well adapted for gardens for the production of seed oysters. I do not know if there are regions in Pamlico Sound where it would be necessary to make plants with seed oysters; but, if not, there remains the potential value of such localities for the production of seed oysters for exportation. This is a point which has been treated more fully in my previous report.[15] The trial plants in Wyesocking Bay and the bed at Harbor Island failed because of the shifting of the bottom, a contingency that must be guarded against by taking into account the direction and strength of currents and the proximity of shoals that may be liable to shift.

Nowhere have we had too light a set of spat on the planted shells. This fact has a double significance. In the first place, it means a saving of expense in the making of plants. The necessity of purchasing seed oysters is obviated, and it is not likely that it would often be necessary to plant new shells on ground once established. In the second place, it follows that the planted beds cannot be left to take care of themselves, but that annual cultivation will be necessary. This point will be referred to again below.

[15] Oyster Culture in North Carolina, Economic Paper No. 10, N. C. Geological and Economic Survey, 1905, pp. 15-17.

No important set has been observed prior to July. As the young oysters are attached some days before they become visible, shells should be planted at least by the early part of June in order to get the full set of the season. It was found that shells planted in December at Chain Shot and Wyesocking caught abundantly in the following summer, and that the old shells and oysters that had been in the water for one or more years received abundant sets. Shells might well be planted, then, as much earlier than June as might be desired. By the following November, there was a good set on shells planted so late as August 18 and 19, 1903, at Long Shoal and Cunning Harbor.

Average rates of growth of one and one-half to two inches were noted during the first years. After two years a number of oysters of "marketable" size were present, but it is not believed that oysters would be marketed to advantage before the fourth winter (after 3½ years).

One of the most striking features of the oyster bottoms in Pamlico Sound is the practical absence of enemies that work serious injury. None of our plants seem to have suffered from drills, skates, or other destructive forms. Weed seems to present difficulty only in certain regions on the east side. Mussels have not taken hold on the planted shells to any serious degree, and, while there are localities in Pamlico Sound where mussels thrive, it does not appear that they do serious harm on beds that are worked yearly. Ascidians rather overcrowded the shells in Wyesocking but have not been injurious elsewhere.

LIMITATION OF EXPERIMENTS.

There is this significant difference between the methods employed in the experiments and those that would be used in commercial planting, and there is a corresponding difference between the results to be expected. The beds have been absolutely without cultivation; the plants have been made and the results that followed have been observed and recorded; but the conditions under which the work has been prosecuted have rendered it impossible to attempt to alter the natural results by working over the beds or transplanting. The cultivator of oysters will not rest after making his plant, but, if conditions demand it, he will work over his plants, break up clusters, replant on adjacent bottoms or transplant into other waters, as may be necessary to obtain oysters of the desired shape and quality. It has been seen above that conditions at each plant do demand such cultivation. There is not now a single plant, except it be plant 15 at Cunning Harbor, that does not suffer seriously from overcrowding. The oyster planter in North Carolina may expect to have serious problems, but if the conditions of the past four years are typical,

he will not, at least in such regions as we have tested, have before him any problem in getting new seed on his plants. If the bottom holds so that the discarded shells remain clear of sand and mud, the new set should usually be more than sufficient. The difficulty he will have is that the new set each year may be so abundant that annual cultivation will be necessary in order to prevent the plants from becoming "rank." This problem may be expected to solve itself in considerable measure in practice. Each season the planter will, naturally, work over his beds to gather such oysters as it is desired to market, and this working may answer the purpose, if it is done with a little care and with proper attention to the replanting of the cullings. He may, perhaps, find it advisable to replant everything taken, looking to the increased value of the product to compensate for the expense.

The expense of careful initial planting and of subsequent cultivation will be counterbalanced to some extent by the fact that it can barely be necessary to plant new shells on the same bottoms.

The natural beds are instructive in this respect. It is the common verdict of oystermen that, where the natural beds were first worked, the growth was thick and the oysters comparatively long and narrow, but that, after they have been worked, the yield in subsequent years has shown marked improvement. It is true that many, if not all, of the natural beds are being exhausted, but this may be attributed to the facts that culling is often half neglected and that, when the culling is properly done, the cullings are simply dumped overboard without regard to the proper method of planting on the particular bottom in question. These facts should not apply to the working of private plants.

Summing up, the experiments here described show what results have been obtained without work subsequent to the making of the plant; they do not show, though they may suggest, what results may and should be obtained in the hands of a judicious cultivation.

It is the belief of the writer that the future of the oyster industry in North Carolina is dependent on the development of the industry of oyster culture, and that, with the natural conditions in Pamlico Sound and elsewhere as they are, the cultivation of oysters is quite practicable. The problem is before the State. Will it allow the oyster industry to continue to decline until its value is negligible? Or, will it pass such simple and practical laws providing for the leasing of bottoms, that enterprising and intelligent planters may proceed to take up bottoms and lay the foundations of an industry which should increase ten-fold the value of the oyster to the State?