DEPARTMENT OF COMMERCE

BUREAU OF FISHERIES

HUGH M. SMITH, Commissioner

THE OYSTER AND THE OYSTER INDUSTRY OF
THE ATLANTIC AND GULF COASTS

By E. P. CHURCHILL, Jr.

Assistant, U. S. Bureau of Fisheries

APPENDIX VIII TO THE REPORT OF THE U. S. COMMISSIONER
OF FISHERIES FOR 1919

Bureau of Fisheries Document No. 890

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BLUE POINTS, FROM NEAR BLUE POINT, LONG ISLAND.

About one-half natural size.

THE OYSTER AND THE OYSTER INDUSTRY OF THE ATLANTIC AND GULF COASTS.

By E. P. CHURCHILL, Jr., *Assistant, U. S. Bureau of Fisheries.*

INTRODUCTION.

The taking of oysters constitutes the most valuable fishery of the United States and one of the most valuable in the world. The annual yield in this country is about 30,000,000 bushels, with a return to the fishermen of nearly \$15,000,000. At least 99 per cent of the oysters of the United States are produced on the Atlantic and Gulf coasts, as shown by the following table:

OYSTER PRODUCT OF THE UNITED STATES.

[From statistics collected by the U. S. Bureau of Fisheries.]

Region.	Private grounds.		Public grounds.		Total.	
	<i>Bushels.</i>	<i>Value.</i>	<i>Bushels.</i>	<i>Value.</i>	<i>Bushels.</i>	<i>Value.</i>
New England States (1910)....	5,549,318	\$3,439,450	92,703	\$157,584	5,942,021	\$3,597,034
Middle Atlantic States* (1911-12).....	7,090,883	5,204,124	11,815,193	4,059,432	18,906,076	9,263,556
South Atlantic States (1910)...	456,194	171,298	1,244,804	192,886	1,700,998	364,184
Gulf States (1918).....	1,227,969	528,123	2,165,526	578,597	3,393,495	1,006,720
Pacific Coast States (1915).....	152,560	548,005	3,544	8,619	156,104	556,624
Total.....	14,476,924	9,891,000	15,301,770	4,997,118	30,038,694	14,788,118

The report of the Commissioner of Fisheries for 1913 stated that the total number of persons engaged in the oyster industry of the United States was 67,257, the yearly wages paid amounting to \$10,876,801, and that the investment in vessels, apparatus, property, etc., was over \$17,000,000.^a

GEOGRAPHICAL DISTRIBUTION.

On the eastern and southern coasts of the United States oysters are found from Wellfleet, Mass., on the inner shore of Cape Cod, to the southern extremity of Texas. The industry on these coasts is bounded by the same limits. Although in past times oysters were found in Maine and New Hampshire, practically none occurs there now, and these two coastal States alone have no oyster industry.

The location of the main oyster beds in each State concerned and the principal towns in which the industry is centered are cited below. The Atlantic and Gulf coast is not lined with a solid bed of oysters along its entire length. Oysters are not found in the open sea, but in coves, bays, estuaries, and mouths of rivers—in a word, in partially

^aReport U. S. Commissioner of Fisheries, 1913, p. 40. Washington.

inclosed waters rendered brackish by drainage from the land. This fact will become more apparent during the reading of the ensuing paragraphs.

MASSACHUSETTS.

The main oyster beds are in Wellfleet Harbor, in the waters in the vicinity of Chatham, in Cotuit Harbor, and in Poponesset Bay. Some oysters are also taken from Centerville Harbor and from the mouths of Wareham and Taunton Rivers. The principal towns concerned are Wellfleet, Chatham, Cotuit, and Falmouth. The oysters are shipped in the shell or shucked, on ice.

RHODE ISLAND.

The main oyster beds are in Narragansett Bay, the industry being centered at Providence, where there are about a half dozen oyster-houses. The oysters are shipped in the shell or shucked, on ice.

CONNECTICUT.

Although oysters are found along practically the entire coast, the principal beds are inside Thimble Islands, in New Haven Harbor, Milford Bay, Bridgeport Harbor, South Norwalk Harbor, around Great Captains Island, and in the deeper water offshore from these places. All the oysters are shipped in the shell or shucked, on ice. There are 6 oyster houses at South Norwalk, 16 at New Haven, and 1 each at Milford, Stony Creek, Guilford, and New London.

NEW YORK.

The oyster beds of New York are in the waters around Long Island. The oysters are shipped in the shell or shucked, on ice. There are 4 oyster houses at Greenport, 1 at Suffolk, and 2 at Northport, on the north side of the island. On the south, West Sayville and Patchogue are the centers of the oyster trade, there being extensive beds in Great South Bay. New York City is the great center of the oyster trade of the State.

NEW JERSEY.

The main oyster beds are in Raritan, Barnegat, and Great Bay, on the eastern coast, the oysters being handled chiefly at Tuckerton and Keysport; and in Delaware Bay, on the west, especially in Maurice Cove and vicinity. The oysters from this region are shipped from Bivalve, where there are several houses handling oysters in the shell or shucked, on ice.

DELAWARE.

The oyster beds are in Delaware Bay, mainly from Bombay Hook to below the mouth of St. James Creek. Most of the oysters are marketed through Bivalve, N. J.

MARYLAND.

The principal oyster beds are in the Chesapeake Bay, there being some, however, in Chincoteague Bay and Potomac River. The number of oyster houses at the main centers of trade are as follows: Crisfield, 40; Baltimore, 28 (15 being oyster canneries); Cambridge, 25; Oxford, 15; Annapolis, 13; Tilghman, 8; and St. Michaels, 6. There are about 160 oyster houses in all in the State. Baltimore is the only city in the State where oysters are steamed and canned, and is the most northerly point on the coast where this process is employed.

VIRGINIA.

The waters covering the main oyster beds of the State are those of Chesapeake Bay, Chincoteague Bay, and the eastern coast of Accomac and Northampton Counties, and the Potomac, Rappahannock, York, and James Rivers. There are about 35 oyster houses, 19 at Norfolk and Portsmouth, 2 at Hampton, 1 at Phoebus, 3 at West Point, 2 at Urbanna, and others scattered about in Northampton, Middlesex, Lancaster, and Accomac Counties. The oysters are shipped in the shell or shucked, on ice, none being canned. One firm prepares an oyster powder from the dried meats.

NORTH CAROLINA.

Four-fifths of the oyster beds of this State are in Pamlico Sound. There is one cannery at each of the following points: Beaufort, Morehead City, Washington, Vandimere, Davis, Bay River, and Sea Level. There is one shucking house, or "raw house," as such a place is termed in the South to distinguish it from a cannery, at Newbern and several at Wilmington.

SOUTH CAROLINA.

Most of the oyster beds are in St. Helena and Port Royal Sounds near the southern extremity of the coast. There are five canneries at Charleston and six at Beaufort, besides two or three at smaller cities.

GEORGIA.

The oyster beds are found along the entire coast line, especially in St. Catherines, Sapelo, Do Boy, Altamaha, St. Simons, St. Andrews, and Cumberland Sounds. There are 18 canneries in the State—four at Savannah, and the rest scattered along the coast. There are five wholesale dealers in raw oysters, besides several retailers at Savannah, Brunswick, and other points.

FLORIDA.

The principal oyster industry of the State is located at Apalachicola, where there are four canneries and nearly a dozen raw houses, the oysters coming from Apalachicola Bay and contiguous waters. There is a small oyster business at Carabelle and some beds at Cedar Keys. A few oysters are canned at Fernandina, on the east coast. There is a small local oyster business at other points in the State.

ALABAMA.

The oysters are found in the lower part of Mobile Bay and the east end of Mississippi Sound. There are 13 dealers in oysters in Mobile, but most of the oysters are opened or reshipped in the shell at Bayou Labatre and small adjacent points on the Mississippi Sound. The only oyster cannery in the State is located at Bayou Labatre.

MISSISSIPPI.

The principal oyster beds in this State are in Mississippi Sound, but 90 per cent of the oysters opened in the State are brought from Louisiana waters, especially from St. Bernard Parish. At Biloxi there are 12 canneries and 6 raw houses, the only city having a larger number of canneries being Baltimore, Md., which has 15. The following Mississippi cities have one cannery and one or two raw houses each: Gulfport, Pass Christian, Bay St. Louis, and Ocean Springs.

LOUISIANA.

The principal oyster beds are in the waters on the east of St. Bernard Parish, although important beds are found on the coast of Terrebonne and Plaquemines Parishes, and others are being developed to the westward. As a result of experiments conducted by the U. S. Bureau of Fisheries between 1906 and 1909, valuable oyster beds were established in Barataria Bay. These were subsequently broken up by a hurricane and the oysters washed about to different parts of the bay. From the natural propagation of the oysters so scattered several beds developed which have grown to be of considerable value. There are about 24 wholesale oyster dealers in New Orleans. One cannery is located near New Orleans, two farther down the river, two or three at Houma in Terrebonne Parish, and a new one is just starting at Franklin.

TEXAS.

The principal oyster beds of this State are in Galveston, West, Matagorda, Lavaca, Espiritu Santo, Aransas, Mesquite, and Corpus Christi Bays. There are from two to six oyster-shucking houses at Corpus Christi, Port Aransas, Rockport, Port O'Connor, Port Lavaca, Seadrift, Palacios, Matagorda, and Galveston. There are no oyster canneries in this State.

OUTPUT OF VARIOUS REGIONS.

Chesapeake Bay produces more oysters than any other body of water in the world.^a Some notion of the size of the industry there may be gained from Plate XVIII, figure 1, showing the oyster fleet operating out of Cambridge, Md., which is only one of the several large oyster centers on this bay. Virginia and Maryland, within whose borders Chesapeake Bay is embraced, lead the United States in oyster production with over 5,000,000 bushels each annually.^b

^aSmith, H. M. Oysters: The World's Most Valuable Water Crop. National Geographic Magazine, March, 1913, p. 231. Washington.

^bReport, U. S. Commissioner of Fisheries, 1913, p. 41. Washington.

OYSTER WITH RIGHT SHELL AND MANTLE REMOVED.

A., anus; A. M., adductor muscle; Au., auricle of heart; D., digestive gland or liver; G., gills; I., intestine; M., mantle; Mo., mouth; O., oesophagus; P., palps; R., reproductive organ; S., stomach; V., ventricle of heart. (Photo from American Museum of Natural History.)

FIG. 1.—SPERMATOOZON OF MALE OYSTER. Magnified 1,700 diameters. (After Stafford.)

FIG. 2.—OYSTER EGG. Magnified 600 diameters.

FIG. 3.—FREE-SWIMMING LARVA OF OYSTER, ABOUT 10 DAYS OLD. Magnified 300 diameters.

FIG. 4.—FREE-SWIMMING OYSTER LARVA WITH VELUM, OR SWIMMING ORGAN EXTENDED. Magnified 300 diameters.

(Figs. 2, 3, and 4 drawn by J. S. Gutsell.)

Connecticut is third with over 4,000,000 bushels. Rhode Island, New York, New Jersey, and Louisiana produce over 1,000,000 bushels annually.

DESCRIPTION AND ANATOMY.^a

CLASSIFICATION.

The oyster of commerce in the United States, with the exception of certain parts of the Pacific coast, is the so-called "eastern oyster," belonging to the species *Ostrea virginica*, Gmelin. It is a member of the group of molluscs popularly known as bivalves, since it has two valves, or shells, which are joined at the narrower ends by a hinge.

EXTERNAL APPEARANCE.

The figures in Plates I, XX, and XXI, though reduced in size, give an idea of the usual shape and appearance of the oyster. The average length of the shells of the marketable size is about 5 inches. Oysters, however, may grow to much greater dimensions, and under certain conditions of growth, such as crowding or development on a mud bottom, are forced into various distorted or elongated shapes.

The shell of the adult oyster varies greatly in thickness, ranging in extreme cases from somewhat less than one-fourth inch to an inch and one-fourth. The usual thickness is from one-fourth to three-eighths inch, decreasing to paperlike thinness on the margins of a rapidly growing shell.

The exterior is marked by laminations and more or less concentric lines of growth; it is often covered by a yellowish cuticle, but is sometimes white and flinty in appearance. The inside of the shell is generally white, somewhat tinged with purple near the margins, and with a more or less pearly luster. The muscular impression is generally nearer to the posterior margin than to the hinge; it is a well-defined scar, kidney-shaped in specimens of ordinary size, but becoming more elongate in very large individuals; in young specimens it is pale, but it afterwards becomes purple or almost black. The left, or lower, valve is deeply concave within, the upper valve being flat or, usually, slightly concave. The animal portions are large, nearly filling the shell, and the mantle border is comparatively narrow.^b

ANATOMICAL FEATURES.

The two valves of the shell of the oyster are held together at the hinge by a dark-colored elastic ligament so placed that it tends to throw the free ends of the valves slightly apart when the large muscle of the oyster is cut or relaxed. The main structures of interest making up the body of the oyster are shown in Plate II and in text figure 1. Plate II represents an oyster lying in the left valve, which is deeper than the right, and more cup-shaped. This is also nearly always the valve by which the oyster is attached to rocks, etc. The flatter right valve is represented as having been removed. The narrow part of the oyster is the anterior or front end, the mouth being located in that region. The broad part is the posterior or rear end. The back or dorsal side is at the top of the picture and the ventral or under side below. The oyster, however, being attached by its left side, may rest in the water in any conceivable position, depending on the surface to which it has fastened itself.

^a The brief account of the anatomy and life history of the oyster is based chiefly on the researches of Brooks (1893), Julius Nelson (1888-1893 and 1900-1915), and Stafford (1913).

^b Moore, H. F. (1897, p. 266.)

Each valve or shell is lined with a thin membrane called the mantle, fringed on the edge and attached to the shell over nearly all its expanse, but free along the margin. The right mantle has been removed with the shell in Plate II. In about the center of the body is the large adductor muscle, by the contraction of which the oyster closes its shell. As stated above, when this muscle is relaxed or cut, the ligament in the hinge forces the valves apart. The main body of the oyster lies between the right and left sides of the mantle and is attached to it and the adductor muscle. It will thus be seen that the oyster is held to the shell by the mantle and the muscle.

In Plate II part of the body wall is represented as having been removed with the right side of the mantle, thus exposing to view the liver or digestive gland and the œsophagus or gullet leading from the mouth to the stomach, which opens into the intestine. This extends downward and backward beneath the muscle, then curves sharply and runs forward on the left of the stomach to the œsophagus, where it again turns to the rear and extends backward to the vent or anus above the muscle.

In a thin-walled sac, the pericardium, immediately in front of the muscle, lies the real heart of the oyster. (The adductor muscle is often erroneously referred to as the "heart," since when it is cut the oyster eventually dies from inability to close its valves.) The circulatory system of the oyster is of the "open" type; that is, the arteries do not terminate in capillaries which lead to the veins, as in man, but deliver the blood, which is colorless, into large spaces, or lacunæ, between the tissues. The blood, as it spreads through these lacunæ, bathes the various cells of the body and is then gathered up by the veins and collected in the auricle or lower chamber of the heart. It then passes into the ventricle, or upper chamber, which contracts and forces the blood through arteries to the different parts of the body. A hinged valve between the two chambers of the heart prevents the blood being driven back into the auricle.

The nervous system of the oyster (not shown in the figures) is very simple, consisting of two ganglia or knots of nervous matter, lying just over the gullet and two nerves passing back from them, one on each side, to another pair of ganglia beneath the adductor muscle. Smaller nerves extend from these two pairs of ganglia to the various parts of the body.

At the anterior end of the body four thin lips or palps hang free in the mantle cavity and extend backward from beneath the mouth for about one-third the length of the body, the posterior ends lapping under the ends of the gills. The latter, four in number, are somewhat similar to the palps in appearance, and extend backward and upward in crescent fashion, as shown in Plate II. Microscopic examination shows that the gills are covered on both sides with very fine hairs or cilia, arranged in rows. These beat back and forth and, when the oyster is lying with the valves open, cause a current of sea water to pass on to the gills. The water is forced through fine openings on the surfaces of the gills into water tubes inside the gills and thence into the cavity above them. As the water passes through the gills the blood is aerated as in the case of a fish. In Plate II the openings of the tubes can be seen on the inner edge of the gills. The right mantle having been removed, the cavity into which the water passes is exposed. It lies in the space just above the inner edge of the gills.

From this cavity the water passes behind the adductor muscle and out between the edges of the valves of the shell around the rear end of the gills, at a point in the upper left of the figure.

The food of the oyster consists entirely of minute animal and vegetable organisms and small particles of organized matter. Ordinary sea water contains an abundance of this sort of food, which is drawn into the gills with the water, but as the water strains through the pores into the water tubes, the food particles are caught on the surface of the gills by a layer of adhesive slime which covers all the soft parts of the body. As soon as they are entangled the cilia strike against them in such a way as to roll or slide them along the gills toward the mouth. When they reach the anterior ends of the gills they are pushed off and fall between the lips, and these again are covered with cilia, which carry the particles forward until they slide into the mouth, which is always wide open and ciliated, so as to draw the food through the œsophagus into the stomach. Whenever the shell is open these cilia are in action, and as long as the oyster is breathing a current of food is sliding into its mouth.^a

The food then passes to the stomach, is acted on by the fluids from the liver, and moves along the intestine. The nutritive portion is

FIG. 1.—Diagram of dissection of oyster to show reproductive organ, consisting of the branching tubules spread over the dotted portion. *au*, auricle of heart; *d*, external opening of reproductive organ; *g*, gills; *M*, adductor muscle; *m*, mouth; *p*, palps; *ve*, ventricle of heart; *y*, posterior end of gills. About natural size. (After Moore.)

absorbed and the feces are thrown out the vent in long, ribbonlike form and carried outside the shell with the stream of water passing out from the chamber over the gills.

The position, form, and general appearance of the reproductive organs of the oyster are the same for both sexes. Really there is but one reproductive organ, which consists of a mass made up of microscopic tubules and connective tissue lying between the folds of the intestine and investing it and the stomach and liver in such a manner as to cover the visceral organs when the opened oyster is viewed from either side. In Plate II most of the reproductive organ has been removed, a small portion being shown about the folds of the intestine. Text figure 1 represents an oyster with the left valve and mantle removed, showing the reproductive organ as it appears from the left side, covering the visceral mass and partially surrounding the heart and adductor muscle. Numerous ducts arise from the organ, unite into one and open at point *d* below the adductor muscle. A view

^a Brooks, W. K. (1880. p. 9.)

of the right side of the organ would present practically the same appearance, there being a similar system of ducts opening on that side beneath the muscle. Through these two openings the genital products are discharged into the water at spawning time.

LIFE HISTORY.

TIME OF SPAWNING.

The oyster may spawn when the water reaches a temperature of 68° F., but spawning proceeds at normal speed only when the water is 70° or above. For this reason the spawning period varies in different regions, depending on the temperature of the water, which is regulated by the depth of the water and the general meteorological conditions. Shallow bodies of water, even though in more northern latitudes, often become warm as early or earlier than deeper waters farther south. In the north, where the season is shorter, the spawning period is relatively short, often lasting only two or three weeks, while in the south oysters may be found in a spawning condition from early spring until fall.

In Long Island Sound, the bulk of the oysters spawn about the last of July; in Great South Bay, spawning occurs from about June 5 until after the Fourth of July. In New Jersey waters spawning begins about June 1. Spawning extends in Chesapeake Bay from May until September. On the Gulf coast, spawning begins in March and spawning oysters may be found as late as November.

REPRODUCTION.

In spite of the fact that the sex of the oyster can not be distinguished by the external appearance of the shell, of the body, or of the reproductive organs, the sexes are separate. Some oysters are male, the reproductive organs developing spermatozoa or milt; other oysters are female and produce ova or eggs. While it has at times been stated that the sex might change from year to year, an oyster being perhaps male one year and female the next, or the reverse, there is no evidence on which to base this belief, except some inconclusive researches made nearly 50 years ago and not borne out by subsequent investigations. It can be almost conclusively stated that the sex of the eastern oyster is permanent and does not change during the life of the individual.

The sexes can be distinguished only by an examination of the products discharged by the reproductive organs. The spermatozoa and eggs are so extremely small that a lens must be employed to distinguish one from the other. The eggs (Pl. III, fig. 2) vary from roughly pear-shaped to oval or nearly spherical and measure about $\frac{1}{500}$ of an inch in diameter. It is estimated that a female oyster will produce over 16,000,000 eggs. The male genital products, or spermatozoa, are many times smaller than the eggs. Each spermatozoon (Pl. III, fig. 1) is made up of a head about $\frac{1}{10,000}$ of an inch in diameter, pointed at one end and flattened at the other. To this flat base is attached a very slender threadlike tail about 20 times the length of the head. This tail lashes about and moves the spermatozoon around in the water after it has been discharged by the male oyster.

Fertilization of the eggs occurs in the water. The oysters, male and female, lying about over the bottom, at spawning time discharge the reproductive elements into the water where they mingle as chance may bring about. The more numerous the oysters on a particular bed, the greater the chance of the actively moving spermatozoa meeting the eggs. The spermatozoa swarm around the eggs, many about each one, until a spermatozoon penetrates the egg membrane, the head only of the spermatozoon passing on in, the tail dropping off. The material of the head unites with that of the egg, and important changes in the latter are thereby initiated.

The single cell of the egg begins to divide into many cells and to change its form and in the course of from 5 to 10 hours develops into a small oyster larva, which swims by means of fine hairs or cilia on the outside of its body. A shell then begins to develop and soon covers the entire body, so that the larva resembles a tiny hard clam. A definite organ of locomotion also appears, consisting of a disk, known as the velum, borne on the end of a thick stalk which is protruded from between the valves of the shell in front. The disk bears cilia which by their movement enable the larva to swim about rapidly (Pl. III, fig. 4). When the velum is retracted the larva settles to the bottom.

The larva is now about two days old and measures about 0.08 mm. in length. As it increases in size certain elevations, the umbones, can be noted on the upper part of the hinge, one on each side. Shortly one valve becomes much deeper than the other, and the umbo on it much more prominent than that on the right side, and by this characteristic the oyster larva may be readily distinguished under the microscope from the larval form of any other bivalve. The deeper valve is the left one and that by which the oyster later becomes attached. During the advanced stages of the larval form, the left umbo is very conspicuous, jutting back in almost the form of a hook (Pl. III, fig. 3).

The period passed through by the oyster larva from the development of the cilia, a few hours after fertilization, until it "sets" or "strikes" is known as the free-swimming stage. Although the larva swims about freely in the water, being so small, its movements and location at any particular time are largely subject to the tides and currents. The free-swimming period lasts from about 14 to 18 days in the more northern waters and a somewhat shorter time in the southern. The warmer the water the more rapidly development occurs and consequently the shorter the free-swimming period.

At the close of the free-swimming period, when the oyster is about one-third of a millimeter (one seventy-fifth of an inch) long, it "sets" if the proper conditions are present. It attaches itself by the left valve to some surface in the water, a rock, shell, stake, in fact almost any object (Pl. IV).

The first essential is that the surface should be clean and that it should remain so a sufficient length of time to enable the young oyster to firmly establish itself. So long as this condition obtains, the nature of the material seems to matter but little. In most bodies of water the spat fixes itself at all levels from the surface to the bottom but in certain parts of the coast its place of attachment is confined to the zone between high and low water, the midtide mark being the place of maximum fixation.^a

^a Moore, H. F. (1897, p. 274.)

Once secured, the swimming organ disappears and the oyster never wanders again of its own volition.

GROWTH.

The shell is secreted by the mantle, the membrane lining the shell. Horny material is first deposited over the outer surface of the mantle and to this is added lime, forming the familiar hard shell. As the mantle increases in size with the general growth of the rest of the body, and as it can be extended somewhat from between the edges of the valves, new shell material is added to the inner surface of the valve and to the outer edge. This makes each valve thick in the central portion, sloping to a condition of extreme thinness at the edges. The outer edges of the valves of a rapidly growing oyster are so thin and knifelike that care must be exercised in handling them to avoid cutting the fingers.

The rate of growth of oysters varies widely, depending on temperature, density and food content of the water, season of the year, and other factors. Its growth is more rapid in the warmer southern waters than in the colder northern. In Long Island Sound about four years are required for an oyster to reach a length of 4 to 5 inches, or marketable size. In southern waters that size is reached in two years. Oysters if left undisturbed may attain a length of 8 to 10 inches or more. While the exact age which an oyster may reach can not be definitely stated, oysters have been found which appeared from the number of layers in the shell to be at least 15 years of age.

Oysters which have unrestricted space for growth acquire the normal shape shown in Plates I, XX, and XXI. When crowded together, the shape becomes modified, even greatly distorted at times. Often numerous set will fasten upon a relatively small piece of cultch, and as growth proceeds a crowded cluster of oysters will result. If broken apart by pressure of growth or by artificial means, their shape will improve.

The crowding of oysters reaches its climax upon the "raccoon" oyster beds. Raccoon oysters are usually found in localities where the bottom is soft and the only firm place which offers itself for the attachment of the spat is upon the shells of its ancestors. Temperature and other conditions are favorable, growth is rapid, the young oysters are crowded into the most irregular shapes, the shells are long, thin, and sharp-edged, and eventually the mass of young is so dense that it crowds out and smothers the preceding generations which produced it and offered means for its attachment. Oysters crowded in this excessive manner are poor-flavored, as well as ill-shaped, but both defects are corrected if they be broken apart, as may be readily done, and planted elsewhere.^a

FACTORS OF ENVIRONMENT.^b

TEMPERATURE OF WATER.

The fact that the oyster is found from Cape Cod to Mexico shows that it can become adapted to living in waters of considerable difference of temperature and in certain regions may withstand wide changes during the course of the seasons. In Long Island Sound

^a Moore, H. F. (1897, p. 275.)

^b The outline of this section, "Factors of Environment," and of the one following, "Natural Beds," and the details of certain topics therein, specifically stated in each such case, are substantially as prepared by Dr. H. F. Moore, Deputy Commissioner of Fisheries, for an uncompleted revision of his "Oysters and Methods of Oyster Culture" (1897).

the temperature over the oyster beds falls in winter nearly to 32° F., the freezing point, and in summer rises to 72° in deep water and 75 to 78° over the inshore beds. In Chesapeake Bay oysters in certain shallow water beds withstand variation from the freezing point, below 32 to 90° F.^a In the Gulf of Mexico the usual range of temperature over the oyster beds is from 50 to 90° F. The relation between temperature and the spawning of oysters has been discussed on page 12.

DENSITY OF WATER.

The higher the proportion of salt contained in sea water the greater the density. Therefore, it is common practice to estimate the proportion of salt by measuring the density of the water with the salinometer. This consists of a glass bulb with a narrow stem at one end on which are gradings reading from 1.000 to 1.031. The bulb is weighted at the end opposite the stem, so that it will sink somewhat below the surface, leaving the stem projecting from the water. The less salt in the water the less the density and the lower the salinometer will sink. Fresh water is arbitrarily considered as 1.000 and the point on the stem of the salinometer to which the water reaches when the instrument is placed in fresh water is so marked. Grades are marked below that on the stem, the bulb rising higher in the water the greater the density. The highest grade is usually 1.031. For convenience three bulbs are usually used, one reading from 1.000 to 1.011, one from 1.010 to 1.021, and one from 1.020 to 1.031. Common sea water usually reads from 1.025 to 1.026 on the salinometer. Oysters are found in water ranging in density from 1.002 to 1.025, but can not withstand densities lower than 1.007 for indefinite periods. In general they seem to thrive best in densities between 1.011 and 1.022.

Oysters are not usually found out in the main body of the seawater, away from the influence of the fresh water from the streams, where the density is 1.025 or more. It will thus be apparent that oysters have become adapted to a certain range of densities, and natural beds have grown up at points fairly close to shore or in inclosed bays where the salinity of the seawater is modified by the inflowing of fresh water.

MUD, SILT, AND SUSPENDED MATTER.^b

A bottom composed of slightly shifting sands or of very soft mud into which the adult oysters will sink and on which the minute spat can gain no firm support is alike unfavorable to oyster culture and to the development of natural beds. If, however, hard objects be distributed on or above such bottoms they will become collectors of spat so long as they remain clean and free from slime or sediment, and if it be desired to produce permanent beds or to catch the floating spat for the purpose of seeding other beds it is manifest that, the scouring action of the currents being equal, waters containing a minimum of sedimentary matter are to be preferred to those more or less laden with mud.

^a Moore, H. F. (1897, p. 280.)

^b Moore, H. F. Proposed revision of "Oysters and Methods of Oyster Culture" (1897).

In this connection a distinction must be drawn between beds used for seed production and those employed in growing and fattening stock for the market. Oysters will frequently grow more rapidly in silt-laden waters, on muddy bottoms, or in their vicinity, than they will elsewhere, as such places are usually more productive of food organisms, owing to the larger amount of dissolved material available for the sustenance of the minute plants which constitute a considerable part of the food of the oyster.

Even adult oysters may be destroyed, however, by heavy deposits of silt such as often result from freshets and crevasses. For the purposes of seed culture or the establishment of self-perpetuating beds the most desirable waters are those which contain an abundance of microscopic vegetation with a minimum of suspended inorganic particles, although an organic slime such as rapidly forms on submerged surfaces in some localities is as effective in preventing the fixation of spat as is inorganic sediment. In many places in Chesapeake Bay and in the bays on the New Jersey coast the sediment, as well as the bottom mud, is largely composed of finely comminuted fragments of seaweeds and other vegetable matter the rapid deposit of which soon covers with a flocculent film the surfaces of all objects exposed to it, excepting when the currents are sufficiently strong to exert a scouring influence. During warm weather this organic deposit is likely to undergo rapid decomposition, the toxic products of which sicken and kill the oysters.

The more or less constant dribbling of fine material upon the bottom has comparatively little effect upon adult oysters, operating mainly to cover the shells and prevent the attachment of spat or to stifle the young oysters after attachment. This rain of fine material occurs almost everywhere but especially where the currents are weak, and it is generally in the latter localities that it is of sufficient volume to be obnoxious.

TIDES AND CURRENTS.

The effects of tides and currents upon the development and growth of oysters are quite important. The genital products, cast directly into the water as previously stated, are moved about so that more opportunity is afforded for the contact of the spermatozoa of the male with the eggs of the female.

The free-swimming larvæ are carried to and fro by the tides and currents, and thus when large enough to set are often some distance from where they were spawned. The importance of this fact in the method of oyster culture by planting cultch is very great and the matter is discussed under a separate section on page 31.

Tides and currents tend to prevent the fouling of material upon which the larvæ set by washing away silt and débris. In still water, as in an inclosed bay, the suspended débris has an opportunity to settle upon the cultch and form a slime and film which prevents the attachment of the larvæ. If the larvæ have attached, the deposit is often sufficient to smother them.

Since the food of oysters consists of microscopic materials found in the water (see p. 19), it follows that currents affect the distribution of the food of the oyster. In still water, nearly all the organisms might settle to the bottom or those in the neighborhood of the

oyster might become exhausted. Currents keep the material agitated and cause a fresh supply to sweep across the oyster beds.

Movement of the water also brings a fresh supply of oxygen to the oyster which aerates the blood by oxygen derived from the water passed through its gills.

DEPTH OF WATER.^a

The known vertical range of oysters under natural conditions is from or near high-water mark to a depth of about 130 feet, the latter extreme occurring over densely stocked and productive beds in Patuxent River, Md. In a large part of the oyster region of South Carolina the natural beds occur almost exclusively between high and low water marks, and some of the beds of Florida are similarly situated, the oysters growing on the aerial roots of mangroves, as they frequently or generally do in Porto Rico and others of the West Indies. In places on the Gulf coast oysters set and grow in limited numbers in the grass on the edges of the marsh prairies above the level reached by many high tides, but in such situations they are frequently killed by freezing.

In the Mississippi delta region a good set is often obtained on cultch planted at or near high-water mark, but the young oysters are removed to deeper water before cold weather arrives.

Elsewhere oysters are rarely planted in this country on bottoms exposed at low water. In most places comparatively shallow depths ranging from 2 to 12 or 15 feet are utilized in oyster culture, but in Long Island Sound the practice has been successfully extended to depths of 60 feet or more.

FRESHETS, STORMS, AND ICE.^a

Freshets occur with more or less frequency in the rivers discharging near the oyster beds of many of the South Atlantic and Gulf Coast States, and with them are to be classed the crevasses or breaks in the levees which sometimes accompany high water in the coastal streams of Louisiana.

The effects of a freshet are twofold. The most immediate effect is that, owing to the vastly increased volume of fresh water discharged, the salinity of the water over the oyster beds is reduced far below the normal and in many cases becomes fresh or practically so for considerable periods. As already stated in another connection, this is often fatal to the oysters already on the beds, and, even when this is not the case, the production of a set is inhibited during the prevalence of the abnormal conditions.

Freshets also carry large quantities of mud and débris scoured from old channels and washed from the land, and as the currents slacken in the bays and estuaries, where the oyster abounds, their carrying power diminishes, and the materials are dropped on the beds. If the deposits so made be deep, the old oysters may be killed, while even a light deposit is sufficient to prevent the attachment of spat until it be again gradually scoured from the shells and other hard bodies on the bottom.

^a Moore, H. F. Proposed revision of "Oysters and Methods of Oyster Culture" (1897).

It sometimes happens that a freshet of unusual severity, while disastrous in its immediate effects, results eventually in an increased productiveness of the beds. If the disaster be due to a prolonged freshening of the water without an undue deposit of silt, the shells are often left in a much-improved condition. This is apparently due in part to the more active scouring action of currents of more than usual velocity, but mainly to the destruction of the organic slime, which often covers the shells in sea water, and the cultch is thereby left in a more favorable condition for the attachment of spat carried from more or less distant beds. The fresh water also exterminates the drills which feed on the little oysters, and, as Dr. Moore's observations of improved sets under the conditions described indicate that sets usually occur in waters of rather high normal salinity, where the drill ordinarily thrives, it is probable that this action of the fresh water is no unimportant beneficial factor. The oysters, from the nature of their reproductive and developmental characteristics, are able to reestablish themselves much more rapidly than their enemies.

Gales, to have an effect on adult oysters in moderately deep water, must be of extraordinary severity, but they frequently do great damage or exterminate beds in shoal water. The waves sometimes pick up the oysters and throw them on the beach, but more frequently they are destroyed by being buried in situ by sand, seaweeds, and débris piled up by the sea. Cases are known of where well-established beds have been overwhelmed by such deposits and others in which thick strata of sand between layers of old shells indicate a succession of such disasters in the more or less remote history of the beds.

Sometimes the eroding effect of currents and waves will uncover the buried oysters and shells, and the beds will again reestablish themselves through the attachment of young; but in other cases the beds are permanently destroyed. The former is the usual result when the reefs rise rather abruptly from the surrounding bottom, and the latter is frequent when they are but little elevated above the general floor of the sea. Planted beds, which usually lie at the general level of the bottom, are usually permanently covered.

Gales are sometimes agents in the establishment of new beds, carrying oysters and shells to surrounding barren bottoms, where they form a nucleus that gradually develops into economic importance. Certain productive beds at the eastern end of Mississippi Sound, by character and by repute, appear to have been so established.

The free-swimming larvæ are more susceptible to the weather conditions than are the adults, and cold rain storms, which would have no effect on the latter, undoubtedly kill large numbers of the swimming young. This was first noticed by Ryder and has been amply corroborated.^a

Ice is occasionally destructive to oyster beds quite independently of the factor of temperature. When heavy ice grounds at extremely low tides, it sometimes crushes the oysters or presses them into

^a The author and J. S. Gutsell, during the study of the occurrence of free-swimming oyster larvæ in Great South Bay, 1919, found that the average number in 50 gallons of water was 8,339 on July 8. A violent squall and rain followed, together with a drop in temperature of 5° F. On July 11, as soon as collections could be made, the average number had dropped to 3,558 larvæ per 50 gallons of water.

the bottom, and occasionally they freeze fast to the underside of the ice and are carried away when it floats.

FOOD OF THE OYSTER.

The food of the oyster consists of microscopic plants and animals and organic detritus growing or found in the water on and above the bottoms on which the oysters lie, or carried to such waters by currents.

A large proportion of the oyster's food is made up of the plant forms which are known as diatoms. There are many species of diatoms, typical forms being shown in text figure 2. Diatoms are found in more or less abundance in almost all waters, varying greatly

FIG. 2.—Typical diatoms, which make up a large part of the food of the oyster. Magnified about 500 times.
(After Moore)

in numbers in different places and at different seasons in the same place or in the same season of different years.

Diatoms derive their sustenance from the various organic materials washed down from the land and held in solution in the water. These organic fertilizers consist of decayed and decaying vegetable and animal matter gathered up from the land by the water resulting from rains and carried down streams and rivers to the sea. The food supply of oysters is thus directly affected by the character of the soil adjoining the tributaries leading to the water over the beds, by the kind and amount of forest or other vegetation and animal life on that soil, by the industries carried on there, and by the amount and seasons of rainfall.

While a large portion of the food of the oyster is made up of diatoms, considerable numbers of microscopic animal forms are

also eaten. The recent work of Dr. T. C. Nelson ^a shows that a larger proportion of the oyster's food is of this nature than was formerly supposed. Copepods, or "water-fleas," the free-swimming larvæ of snails and bivalves (including the oyster), worms, rotifers, and protozoa have been found in the stomach of the oyster. These animals, like the plants, are found in greater or less abundance in all waters. A systematic effort to ascertain the food content available for oysters in any particular water should include the determination of the quantities of the suitable animal as well as plant forms present.

Dr. Nelson kept under observation a number of oysters in water shallow enough for a system of wires and levers to be connected with the shells in such a way that the opening and closing of the valves were recorded on a revolving smoked drum or chimograph in the floating laboratory above. It was found that, during the summer months at least, the oysters remained open, and consequently feeding, for 19 to 20 hours out of 24. Feeding is thus evidently a fairly continuous process during the warmer months.

Organic detritus or débris resulting from the decay and disintegration of plant and animal life undoubtedly contributes to the food of the oyster. As the diatoms and other plant forms become broken up some of their fragments are ingested by the oyster, and a certain amount of nutriment is derived therefrom. After death, animal forms disintegrate and release fats, albumens, etc., into the water. It has been found that the fresh-water mussel may make use of such products, and probably the same is true in the case of the oyster.

NATURAL BEDS. ^b

DEVELOPMENT AND DESCRIPTION.

A natural oyster bed is an area of the bottom on which oysters have become established without the voluntary and intentional agency of man. In law, the term is usually held to include only such bottoms as bear oysters in sufficient quantities to make fishing for them by legitimate methods a means of reasonable livelihood or areas which have formerly been such and whose present character indicates a reasonable likelihood that they may again become productive. The only difference between natural and artificial beds lies in the fact that the latter originate by the intentional act of man, whereas the former arise from natural conditions purely, from accident, or from unintentional human agency incidental to other works and purposes. In most cases the natural beds, and especially the larger ones, have been produced by the operation of factors in which man has no part, and we know nothing of their origin. In a few instances, small beds have been caused by shipwrecks and other accidents; but on the other hand there are many beds, some of them very productive, which have grown on ashes and similar material thrown overboard from vessels and upon shells culled from the live oysters by oystermen and strewn at random over the bottom. Whatever their origins, all oyster beds, if left to

^a Nelson, T. C. Forthcoming report, N. J. Agricultural College Experiment Station.
^b Moore, H. F. Proposed revision of "Oysters and Methods of Oyster Culture" (1897).

themselves will assume the same general physical and biological characters in so far as their environments permit.

The natural beds of the Atlantic and Gulf coast practically all lie like islands in a sea of mud more or less soft. In some places the oysters are in clusters rooted in the mud, in others the substratum is hard to a greater or less depth, but examination will show that this hardness is in most cases superficial, and below it lies mud of a consistency corresponding to that which surrounds the bed. There are a few beds which have grown on rocky bottom, and there is a larger number lying on firm, unshifting sand; but there are few rocky outcrops on the coast south of New England, and most sandy areas tend to shift more or less and engulf such oysters and shells as may be lying on them. The oyster is an inhabitant, par excellence, of the muddy bays, sounds, and lagoons, and in them attains its best development.

In tracing the history of any oyster bed, reference must be made to the nature and characteristics of the young oyster as it develops from the egg. As has been explained on page 13 the embryo oyster is a minute organism endowed with certain feeble powers of locomotion, which are sufficient for awhile to keep it suspended in the water and permit its being carried by the currents. In some cases it may be carried several miles from its parents before the setting stage is attained. The chances are many that when this happens it will lodge on mud and end its story, for so small is the larva at this stage that a mere film of ooze suffices to stifle it. If, however, by rare good fortune it, at this time or just before, comes into contact with a shell, pebble, twig, rocky ridge, or other clean body, whether at the bottom or not, it speedily attaches itself and continues its growth.

So abundant is the supply of larvæ in any prolific oyster region that ordinarily several or many will attach to each square inch of clean surface, and a shell may furnish attachment for a hundred or more. Under such circumstances there soon begins a struggle for existence that is none the less rigorous for being purely passive. As the young oysters grow there is not room for all, and the more vigorous ones, themselves distorted by the crowding, overgrow, stifle, starve, and eventually kill those of slower growth or less advantageously situated. At the end of the first year there has developed a cluster of perhaps from two to a dozen young oysters growing on the original shell, all projecting upward and crowding one another into long, narrow shapes. Upon the projecting mouths of these shells there is another set of spat on the succeeding year, and as this grows some of the survivors of the earlier generation are in their turn crowded and killed. The result of this is that in the course of a few years there is formed a cluster like an inverted pyramid with its apex being gradually driven into the mud by the increasing weight above, while its broad base is made up of several generations of living oysters attached to the dead shells which constitute the middle parts. The oysters around the edge where they have room to grow are often of fair shape and quality, while those more centrally located are irregular, long, narrow, and usually poor, owing to their crowded condition and difficulty in obtaining food.

From the decay of the hinge ligaments of the dead valves, the corroding effect of boring animals, and the solvent action of seawater on the limy shells, these top-heavy clusters tend to break up under their

own weight and under the force of the waves. On hard bottom the disintegrated parts are rolled about and more or less evenly distributed, resulting eventually in the production of other similar clusters scattered at intervals. On soft mud the shells can not roll so readily, and they fall and remain close to the base of the original cluster, where, if not completely engulfed, they form places of attachment for new generations. If the mud be very soft they sink for a short distance and accumulate until they harden the bottom and form a firm support for the shells which fall later, and which in turn are covered with a growth of young.

As these phenomena recur year after year the original single cluster gradually extends around its edges now more or less at the top until it becomes converted into a little bed composed of a dense mass of clusters, with its boundaries sharply defined and limited by the soft mud surrounding it. A number of other clusters have probably been growing simultaneously on the same muddy bottom, and, the areas between becoming narrowed and obliterated, there results a great flat bed made up of a number of smaller patches separated by a muddy network. Where a deep, muddy channel occurs the oyster growth usually stops near the edge of the slope, the shells which would else serve as clutch sinking down into the deep soft ooze. Opposite the mouths of smaller streams, even where there is no such deep channel, the oyster growth is also inhibited, partly by the freshness of the water, but principally and often entirely by the deposit of silt which soon spreads its thin coating over everything lying on the bottom. In some cases the beds may be completely interrupted, but in others they are continuous in their offshore part, passing by and inclosing the unfavorable area as an oval or subtriangular barren, muddy patch surrounded, excepting on its shoreward side, by productive oyster bottom.

It is difficult to say what may have been the condition of the natural beds in Chesapeake Bay before they were disturbed by man, but at the present time they are essentially in the condition so far described, though with their boundaries often ill-defined and the clusters usually smaller and less dense as a result of tonging and dredging. They usually exhibit no great depth of shells, though the bottom is more or less hardened by their accumulation in the underlying mud. They usually extend alongshore, their greatest length in the direction of the currents and their width extending from a couple of feet below low water toward, and often to, the edge of the deep, muddy channels.

In South Carolina and adjacent regions the beds are of essentially the same type, excepting that they are smaller and narrower, and particularly that they are crowded closer to the shores and almost entirely confined to the area between high and low water, a situation impossible in Chesapeake Bay and more northern regions, owing to the killing cold of winter.

Further development in the history of natural oyster beds beyond the stage which has been described results in a gradual thickening of the deposit of shells and the production of a short reef or lump, with a more or less distinct shoaling of water over its top. The living oysters standing vertically in the dense mass, with their growing tips directed upward and kept clean by the currents, present the only available place for spat fixation. Each year the set occurs on preced-

ing generations, raising the living parts of the bed higher above the bottom, while the interstices beneath become filled with old shells, fragments, sand, and mud to form a compact mass. Eventually, in shallow water, the living oysters approach low-water mark or in some parts of the coast rise above it, where their progress is arrested by cold or long periods of exposure to the air.

Each year a set may occur only to be killed in winter, the dead shells, fragments, sand, and mud piling up under wave action, until the crest may become raised to a level several feet above high water, producing a shell island usually surrounded by a more or less dense growth of live oysters. Such islands are not uncommon in the South Atlantic and Gulf States, and they frequently accumulate in time a growth of grass and brush, which more or less obscures their true character. Sometimes the material is thrown up around their edges atoll-like, leaving a depression in the middle in which muddy deposits collect and support a growth of brush. In places where the bottom is composed of very soft mud the sides of these lumps are comparatively steep and soundings will change 1 or 2 feet within a few yards, the difference being due to the depth of shells and oysters.

In open waters, not especially subject to freshets, where the currents are moderate and the silt carried not excessive, such lumps tend to maintain a round or oval outline, with no great difference between the long and short diameters; but where the currents are rapid or the bodies of water constricted, there, as soon as they rear themselves well above the bottom, they show a strong tendency to grow transversely to the tides, especially if the water be silt-laden. Such long, narrow reefs are common in the rivers of North Carolina and in the bays and rivers of Florida, Alabama, Louisiana, and Texas. In James River, Va., and probably in other rivers of the Chesapeake region, the beds, while often showing their greatest extent in the direction of the current, usually have their shoalest parts transversely to it or are made up of a series of transverse shoals and ridges composed of a dense mass of shells and fragments.

The reasons for this transverse development are as follows: The upgrowing reefs form partial dams or obstructions to the flow of the currents, and, in accordance with well-known laws, cause eddies or backwaters on both the side presented to the current and on that sheltered from it, in tidal waters the two being periodically reversed with the reversal of the tide. When the velocity of a silt-laden stream is checked, it deposits part of its load in the slack water, and, under the conditions stated above, mud falls on the upper and lower sides of the reef, while the somewhat accelerated flow around the ends scours the shells and keeps them clean and fit to receive fresh sets of young oysters. These factors operate more energetically the more heavily silt-laden the water, and they would become nonoperative in perfectly clear water. Not only does heavily silt-laden water deposit more mud when its velocity is checked, but it scours more energetically when its velocity is accelerated, the particles of sand and other materials carried in suspension, acting as so many small brushes to rub off such materials as may have previously lodged. The greater volume of water passing the ends of the reef has still two other effects—it brings a large number of swimming larvæ in contact with the shells and it carries more food to the oysters living there. Clean cultch, abundant larvæ, and ample food, three principal factors in

heavy production and rapid growth of oysters, are, therefore, found better fulfilled at the ends of the reef than at the sides lying across the currents. This tendency to transverse growth once established is increased with every increase in the length of the reef, the jetty effect, retarding the flow of water in one place and accelerating it in another, becoming more pronounced.

It frequently happens that reefs similar in general character to those just described begin their development from or close to the shore, usually at projecting points. They grow, of course, principally at their outer ends and extend outward from the shore at right angles to the current, maintaining a nearly uniform width throughout their length.

In the foregoing description of natural beds consideration has been given solely to the oyster itself, but the conditions are always complicated by the presence of other organisms between which and the oyster there are more or less complex biological relations. Some of the minute forms, especially the plants, constitute the oyster food, while many of the larger species either prey actively on the oyster or its young or compete with it in the struggle for food, oxygen, and space in which to grow.

DEPLETION.

Until the last 40 years the majority of the oysters taken from Cape Cod to Mexico came from natural oyster beds which covered an area of such great extent that they were regarded as inexhaustible. That this belief is quite erroneous is shown by the fact that on the northern parts of the coast, where the temperature is about the minimum for the support of oysters, the natural beds have disappeared or have become sadly depleted. Those of Massachusetts are greatly exhausted, and few are found in Narragansett Bay. On the Connecticut coast only two beds of importance remain—one in the mouth of New Haven Harbor and one west of Stratford Lighthouse, near Bridgeport. There are very few in New York waters. Many of the beds of Chesapeake Bay are seriously or quite depleted, although many still remain. From that point southward the depletion has not been nearly so great, as the oyster fishery has not been pursued as vigorously and the environment has been such that the oyster reproduced much more abundantly than in the north, where a failure to obtain set is only too common.

In some cases the depletion or destruction of natural beds is the result of natural causes, such as the cutting off of the inlet to a bay or sound and the reduction of the salinity of the water; the covering of the beds with silt, débris, and fresh water during a freshet; the shifting of sand or mud by storms; or the inroads of living enemies.

The greatest enemy to the oyster, however, is man. Most of the depleted condition of the natural oyster beds is the result of careless overfishing by oystermen. The beds are stripped down so completely that not enough adult oysters are left to furnish sufficient spawn to insure a subsequent crop. Although millions of eggs and spermatozoa are produced, those products are thrown into the water, where many of the eggs fail of fertilization; many eggs and larvæ die or are eaten by enemies; and many fall at setting time on soft bottoms and are smothered. The percentage that finally reaches the adult

stage is relatively small. For that reason too complete removal of the adult oysters from a bed destroys hope for an ensuing generation.

During the past 40 years certain methods of oyster culture have been developed, especially in certain regions, whereby new beds have been built up and a constructive system of increasing the oyster supply has been initiated in addition to the negative one of restrictions on fishing, such as close seasons and the like. Biologists have become concerned in this work, and efforts have been made to promote, by experimentation, methods for the improvement of oyster culture.

CULTIVATION.

From the table on page 5 it will be seen that about half the oysters produced in the United States are taken from private or planted beds, the rest coming from natural or uncultivated areas. It will also be noted that in New England over 90 per cent of the oysters are produced on planted beds, that in the Middle Atlantic States the natural beds are considerably in excess, and that in the South Atlantic and Gulf States the proportion of natural beds is much higher yet. The table shows, however, that the value of the oysters from the planted beds is nearly twice that of those from the natural. This is due largely to the better quality and shape of the oysters produced by cultivation.

It is intended mainly to set forth here the methods of oyster culture which so far have proved to be commercially successful on the Atlantic and Gulf coasts, together with such suggestions concerning their improvement as biological science has to offer. Since there yet occasionally arise false hopes that the so-called artificial propagation, or the hatching and rearing of oysters in tanks or ponds, as is done in the case of fish, is on the verge of practical accomplishment, it may be well to dispose of this matter before proceeding to the treatment of the successful methods mentioned above.

ARTIFICIAL PROPAGATION.

This attempted method of oyster culture can be treated most simply by stating that its perfection and practical application are substantially no nearer solution than when the problem was opened up by Brooks (1880, pp. 10 to 18). He succeeded in artificially fertilizing the oyster eggs with spermatozoa of the male oyster and in rearing some free-swimming larvæ to the age of four or five days. Brooks's methods are in themselves not difficult, and the experiment has been repeated time and again both by biologists and laymen. Owing, however, to the immense practical difficulties of restraining the microscopic larvæ in receptacles or tanks and at the same time providing for a change of water and the introduction of the proper food and removal of waste, no one has succeeded in rearing many of the larvæ until they attach to cultch. It would seem, moreover, impossible to do this on a scale sufficiently large to be of practical application in the oyster industry.

The same statements are true regarding the adaptation of this method, in which attempts were made to substitute for the tanks ponds connected by narrow inlets or ditches with tidewater. While

elaborate designs have been constructed for the manipulation of such ponds and the catching of set on cultch placed in the ponds or the connecting ditches, none has proved to be of any practical value whatever. The principal difficulty seems to have been that, in the effort to confine the set to the pond, too scanty an inlet was provided for the entrance and exit of the tide, and the oysters suffered in consequence. In the cases where efforts were made to catch the set on cultch placed along the connecting canal, if the latter were broad enough to allow sufficient rush of water to keep the cultch clean, most of the set passed out to sea.

Oysters, on the other hand, will reproduce, grow, and fatten in ponds or inlets to which the tide has access in sufficient volume to render the water properly saline, provide the requisite food, and remove the débris. The set from such oysters is at the mercy of the tide; some may be caught in the pond or inlet, and some will be carried outside. In France ponds or "claires" are profitably maintained for the growth and fattening of oysters. The seed oysters placed therein consist of set from outside oyster beds which has been caught on collectors placed in the water along the beach.

While it can not be said that the problem of so-called artificial propagation may not be solved at some future time, for the present it must be emphasized that oyster culturists should base no false hopes on the practical application of this method.

In view of the barren results of 40 years' experiments in this line, it is best to devote attention to the amplification and perfection of methods which have proved to have a certain measure of success and which are applicable to the industry as carried out on such a vast scale in the United States.

LEGAL CONSIDERATIONS.

PROCURING GROUND.

In order to carry on oyster culture either by catching set or planting seed oysters, it must first be ascertained whether ground for that purpose can be leased or otherwise obtained from the State and, if so leased, whether public sentiment is such that the laws will be respected and enforced. In some States ample provision is made for the rental of oyster grounds and the lessee is protected. Oysters are not taken from his beds any more than corn is taken from a man's cornfield. In other States conditions have been in the past such that protection of leased ground, if attempted at all, was an absolute failure. Considerable improvement is noted, however, in this respect within recent years.

In selection of ground for locating oyster beds care must be exercised to avoid waters into which trade wastes are discharged in quantities sufficient to kill either the free-swimming larvæ or the oyster after it has set. It has been found that certain trade wastes from factories are injurious to oysters if present above certain concentrations. Further, the Federal and State health laws must be borne in mind in order to avoid grounds condemned by health authorities because of pollution by sewage. Stringent laws forbid the use of such grounds for raising or fattening oysters.

MARKING BEDS.

Some States employ competent surveyors, and oyster beds are laid out with the aid of ranges, such as important natural objects or special signals set for the purpose. The planters then place stakes or buoys along these lines in such a way that each man knows exactly where his boundary line lies. Such practice is to be highly recommended as tending to avoid disputes and litigation.

METHODS OF OYSTER CULTURE.

Owing to the great size of the oyster beds, to the large number of oysters handled, and to the high price of labor and the relatively low price of the product, it is not practicable in the United States to use the intensive methods of oyster culture employed in European countries, such as France, or in Japan. In those countries, special devices are used for catching the oyster spat and the individual oysters are removed by hand from the collectors and placed on specially prepared bottoms or in ponds for growth and fattening. In the United States, oyster cultivation, in general, is limited to operations which can be carried on by mechanical means on a fairly large scale over areas of considerable size, thousands of bushels of oysters being involved.

Oyster culture in the United States involves two main methods, the catching of spat, or "set," on artificially placed cultch and the planting of "seed" oysters. Where oyster culture is practiced one or the other or both of these processes is carried on, depending on the region and the desires of the planter.

CATCHING OF SPAT, OR "SET."

As stated previously, for some days after hatching the young or larval oyster is free-swimming. At the close of that period, it becomes attached to some fairly smooth, hard surface in the water, usually rocks, shells, etc., on the bottom. Once fixed, it is there for life and never wanders but proceeds to develop and grow. Failing to make such an attachment, it dies. Both while free-swimming and for a time after fixation the oyster larvæ are referred to by oystermen as "set."

Advantage is taken of this habit of the oyster larvæ, and artificial means are employed to increase the area of suitable surface upon which to "catch a set" of young oysters. Various sorts of material are put down to provide a suitable surface upon which the set may become attached. The material used for such a purpose is known as cultch. The most commonly used cultch is oyster shells, although the light thin shells of other bivalves, especially the "jingle" shells, are sometimes employed. Oyster shells, being available in great quantities from the opened oysters, may be returned easily to the bottoms, thus providing the cheapest, most abundant, and most suitable form of cultch for the large beds cultivated by American oyster planters.

After a set is thus obtained on the shells it may be left there to mature into oysters of marketable size, or the shells with the attached set may be taken up and shifted to other beds. This is commonly

done in the fall after setting occurs, but sometimes set is allowed to grow for a year or two and then treated as "seed," which is discussed on page 33.

This method of oyster culture is more extensively practiced in Long Island Sound, Narragansett Bay, on the southern side of Long Island, in New Jersey waters, and in Louisiana than elsewhere. The bottoms are cleaned up by dredging from them the old shells, débris, etc. This is done in May, after the close of the season. The shells are put down during the last half of June or the month of July. In Long Island Sound the old rule was to begin "shelling" the day after the Fourth of July. In Louisiana the shells are put down in June, since the oysters spawn earlier there because of the higher temperature of the water.

For shelling purposes in northern waters, the shells are usually loaded upon large scows (Pl. V, fig. 1) and towed out to the grounds by steamers or gasoline boats. Then while the scow is towed slowly back and forth over the beds, the shells are shoveled overboard by men on the scow (Pl. V, fig. 2). If the ground is new and somewhat soft, sufficient shells are put down to form a firm coating such that the upper layers remain clean and exposed above the mud. In any case, enough shells are put down to form a fairly level continuous layer over the bottom.

In northern waters, examination is made about September 1 to 15 to see whether a set has been obtained. Since many factors—such as time of spawning, condition of the cultch, temperature of the water, storms, currents, etc.—enter in to affect the setting, this is the most critical point in the cultivation of oysters by this method and is the one at which the most failures occur. If no set of consequence has fixed on the shells, sometimes they are left until the following season and "harrowed" just before setting time by dragging over them an oyster dredge with the bag removed. This stirs them up and cleans them somewhat, so that often a fairly suitable surface is provided for the attachment of set. Often, however, they are dredged up and heaped upon the ground beside the oyster house. Here they dry, any oyster enemies upon them dying in the meantime, and may be used over again next season. In case a set (by which the oysterman means a sufficient quantity to be of commercial importance) is found upon the shells, they are either left, in order that oysters may develop on that bed, or are shifted to other beds.

The shifting is accomplished by dredging up the shells, set and all, with ordinary oyster dredges or, rarely, by lifting them with tongs. Sometimes the oysters are moved after attaining the age of one or two years, since growth and fattening proceed more rapidly on some beds than on others, due to differences in food content of the water, etc. In certain places oysters become green, and their sale is hindered by the unsightly appearance. When shifted to certain other beds, this color is thrown off in the course of a few months and the oysters are marketed.

The planting of cultch to catch set is mainly performed on "barren" ground, that is, bottoms practically free from oysters. Such ground is leased from the State or purchased outright by the planters. Some States make ample provisions for such procedure, and the lessee or owner has complete protection for his oysters. In other States public sentiment has not supported efforts to provide for leas-

OYSTER SPAT OR SET TWO OR THREE WEEKS OLD ON INSIDE OF
OYSTER SHELL.

Natural size. (After Moore.)

FIG. 1.—LOADING SHELLS ON BOAT FOR PLANTING.

FIG. 2.—PLANTING OYSTER SHELLS IN LONG ISLAND SOUND IN ORDER TO CATCH SET.

The large scow loads of shells are towed by a gasoline boat or steamer.

ing of ground for this purpose and dependence is placed largely on natural beds for the supply of oysters.

In some few cases a State plants a limited amount of cultch upon certain partially depleted natural beds for public benefit. In general, however, the natural beds are staked off and reserved for general public use by the "natural growther" subject to certain restrictions, mentioned elsewhere.

The principal considerations involved in this method of oyster culture are character of the cultch, character and preparation of the bottom, time for planting cultch, the proper location of cultch beds with respect to tides and currents and the spawning oysters, and the location of beds of spawning oysters.

Cultch.—While formerly limited use was made in the United States of various forms of cultch—such as tin cans, bits of pottery, brush, pebbles, "jingle" shells, and oyster shells—only the last three materials have proved to be of practical value, and at the present time the cultch used consists almost entirely of oyster shells. A few "jingle" shells are known to be employed at one point in Long Island Sound. Oyster shells are large and afford surface for the attachment of quantities of spat (Pl. IV). As this grows, overcrowding is apt to result, since the shells are too heavy to be broken apart by the pressure of the developing set. This is overcome by breaking apart and culling the clusters thus formed.

The advantages of oyster shells as cultch consist largely in their general adaptability, presenting a smooth surface for the attachment of the set, and their abundance and convenience, since an oyster-shucking house has only to turn about and convert its shell pile into spat collectors by the use of its own boats. At the same time the gradual disintegration of the shells provides lime for the succeeding generations.

"Jingle" shells, or silver shells, belonging to the species of *Anomia*, and scallop shells are thinner and more fragile than oyster shells. Consequently, they make a superior form of cultch, since the pressure of the growing young oysters breaks them apart and the formation of clusters is prevented. Unfortunately, the supply of such shells is so limited that very few are now used.

Character and preparation of bottom.—If the bottom at the point where it is desired to plant cultch is sufficiently hard to support it a layer of shells is spread upon it broadcast, as previously described. In case the bottom is soft, it may be prepared by putting down sand or gravel in sufficient quantities to support the shells. Often, however, the bottom is stiffened merely by the use of shells. Sufficient quantities are put down and allowed to sink, until a substratum is formed firm enough to support a layer of cultch several inches or a foot thick above the ground. A bed on which cultch has been placed for several years in succession will gradually be made firmer by the setting of a part of the shells.

Time for planting cultch.—Since sea water always contains more or less suspended débris, which gradually settles upon the bottom or any object thereon it follows that cultch will more or less rapidly become coated with a layer of slime or débris. If this becomes too thick the oyster larvæ are prevented from setting upon it. Movement of the water by tides and currents obviates this difficulty somewhat by washing the débris from the cultch. In bodies of water where there

is little movement, especially in inclosed bays or the like, the deposit accumulates upon the shells rapidly. Such waters, while often very desirable for growing or fattening oysters, are for this reason poorly adapted to catching set.

It early became apparent, then, that it would not suffice merely to spread the cultch at any season of the year most convenient to the planter. Cultch should be put down just as shortly before the bulk of the free-swimming larvæ reaches setting time as it is possible to do it. In general this has been ascertained by experience in the various regions where this method is practiced. For example, in Great South Bay it is planned to complete "shelling" by July 1. In Long Island Sound shelling often begins immediately after the Fourth of July and is completed early in August, individual planters having different ideas as to the best time for planting cultch. In Louisiana cultch is put down in June.

In the case of the large oyster firms, owing to the great quantity of shells handled, it is impossible to concentrate all the shelling into a few days preceding setting time. Such firms often require a month or six weeks in which to complete the process. The best that can be done is to make this period coincide with the weeks immediately preceding setting time.

The proper time of year for planting the cultch has been fixed approximately at certain seasons for each locality, largely by experience derived from the results of some years' practice in this method. The appearance of the adult spawning oysters is noted at intervals each year and the time of planting varied a few days or weeks one way or the other. The aim has mainly been to have the cultch down before any appreciable quantity of spawn has been thrown out by the oysters.

It has been thought until relatively recently that the oyster larvæ set within 3 or 4 days after the spawn was thrown out. It is now known that from 14 to 18 days elapse in New Jersey waters and northward, and a somewhat shorter period in the warmer waters of the Southern States. With this longer period in mind, it will be seen that the time of setting is at least two weeks subsequent to the throwing out of the spawn. In case the spawning period is extended over several weeks, the problem is complicated. In the more northern waters, especially in Long Island Sound, the spawning period has been found to be short, hardly more than two weeks in length, the bulk of the spawn being thrown out in the course of a few days. In such case, keeping in mind the two weeks free-swimming period of the larvæ, it is possible to judge the time of putting down cultch quite accurately.

Since seasonal variations affect the time of spawning, it follows that no exact date which will hold good for each year can be set for planting cultch. As a result of a survey of the free-swimming larvæ made by the Bureau of Fisheries, it was found that the setting time of the bulk of the larvæ in Long Island Sound in 1918 occurred during the week of August 10 to 17. In 1919 there was no setting time in Long Island Sound, since no larvæ developed to setting size, owing, doubtless, to the abnormally low temperature of the water. In 1919, in Great South Bay, setting began about July 1, but the bulk occurred July 15 to 17. These data were secured by following the development and movements of the free-swimming larvæ by

means of examinations of samples of water of definite volume taken in various places from day to day.^a

This method consisted essentially in noting the number and size of free-swimming larvæ found in samples of water taken daily over the oyster beds by pumping 50 gallons through a net or bag of No. 20 bolting silk. By the study of a considerable number of samples taken each day the general abundance and size of the larvæ could be ascertained and the setting time predicted several days ahead.^b As the larvæ approach setting time, with the accompanying increase in size, the left valve of the shell becomes very prominent, as stated on page 13. This renders them readily distinguishable from other bivalve larvæ, and it is easy, after a little practice, to recognize them under the microscope.

It would seem that the advent and development of the larvæ could be noted by this means each season. The State commissions could hire a biologist for a month to make the examinations or train one of their own members to do the work. The development and movement of the larvæ could be followed in a few representative places in the waters of the State and exact information relative to setting time ascertained and imparted to the oyster planters. After a few years it would be found that the time varied within certain fixed limits, and examinations would need to be made only to learn the variation within that period for the particular year.

Location of cultch beds.—The different oyster planters have determined by experience the locations at which beds of cultch are placed. After a term of years each man has found the portion of his ground on which cultch may be placed with what seems the most likelihood of getting a set. Individual planters have their own views as to the proper position of the cultch in relation to the beds of spawning oysters. Sometimes beds of cultch and of oysters are placed side by side; sometimes several are located alternately. Some planters place a certain number of spawning or "mother oysters" about in groups on the cultch bed.

Since the free-swimming larvæ are carried about by the tides and currents, it becomes of importance to follow in each locality the movements of the larvæ in order to ascertain as nearly as possible the place in which they will set. This involves a study of the tides and currents and the directions in which and the distance to which they carry the larvæ in any particular bay, cove, or river mouth. Accurate knowledge of these facts would enable one to state where the cultch should be placed in relation to the spawning oysters. Since the tides and currents depend on the contour of the bottoms and coasts, they are the same from year to year, unless disturbed by storm. The data, once accumulated by perhaps two or three years' study, would have permanent value.

Investigations calculated to ascertain the advantages of such knowledge of the movements and points of aggregation of the free-swimming larvæ were carried on in 1919 by the United States Bureau of Fisheries, using Great South Bay, Long Island, as a testing

^a Churchill, E. P. Jr., and Gutsell, J. S. Reports on Investigation of Oyster Larvæ in Long Island Sound, 1918 and 1919, and Investigation of Oyster Larvæ of Great South Bay. (Contains methods.) Forthcoming reports, U. S. Bureau of Fisheries.

^b Dr. T. C. Nelson (1916), in his study of the occurrence of free-swimming oyster larvæ in Little Egg Harbor, N. J., was able to ascertain the relative abundance of the larvæ in different areas and to predict the setting date about 10 days in advance.

ground.^a The method of examining samples of water for numbers of larvæ described on page 31 was employed. It was found to be possible to ascertain from day to day during the spawning season, lasting, roughly, from June 5 to July 17, the number of larvæ per gallon of water at various representative stations in the bay. In this way the points of aggregation of the greatest numbers of larvæ were determined and charted on the map. Beds of shells had been placed at various points in the bay. The quantity of set caught on the different beds substantiated predictions based on the data derived from the study. The heaviest set was obtained from the beds located at the points in the bay where there had been the greatest accumulation of larvæ. To be specific, it was found that the tide caused the larvæ to accumulate along the channel from about Ocean Beach on Fire Island Beach to the inner United States channel buoy, in the direction of Sayville, Long Island. Cultch beds should be placed along this channel where the bottom is or may be made suitable.

By the use of methods such as just described the distribution of oyster larvæ could be worked out for any particular region. The possibilities of this procedure have been discussed above in connection with the recommendation that such lines of investigation be undertaken for the various oyster waters, perhaps by State authorities.

Location of spawning beds.—Often times the catching of set depends as much on the location of the spawning oysters as on the position of the cultch. Both are important, and sometimes the best results can be accomplished only by the providing of the proper relationship between the two. Spawning beds should be placed where conditions are most favorable for spawning, at the same time putting the cultch at a point where the larvæ from the bed will be carried back and forth across it by the tides or be accumulated over it by eddies or cross currents.

For example, in Great South Bay, Long Island, which is large and shallow, the oysters are placed about over the bay at various points where they grow and fatten best, the catching of set from them being a matter of rather secondary importance in this locality. As a matter of fact one place is as favorable as another for the spawning of the oysters, the bay being of fairly uniform depth and salinity. As stated above, the larvæ accumulate in the channel, and cultch should be placed there.

In Long Island Sound a different condition prevails. The catching of set has been a large feature of the oyster industry there. Cultch beds were planted at greater or lesser distances offshore or in the lower part of the mouths of rivers. Owing to a recent failure of the set there, investigations have been made by the United States Bureau of Fisheries during 1917, 1918, and 1919. It has been found that in the past the bulk of the set consisted of larvæ from natural oyster beds in the shallow waters of bays, coves, and river mouths, where the water became warm relatively early in the season and the spawning occurred early enough for the larvæ, carried out by the currents to shell beds in deeper waters, to develop, set, and acquire a fair size before the close of the short summer season

^a Churchill, E. P. Jr., and Gutsell, J. S. Investigation of Oyster Larvæ in Great South Bay. Forthcoming report, U. S. Bureau of Fisheries.

of that locality. These inshore beds are practically exhausted now, and dependence is being placed for set upon the oysters planted in deeper water offshore. The deeper water warms up slowly, and the oysters spawn so late that the crest of the warm season is over before setting occurs and very little set is obtained from them. In Long Island Sound spawning beds should be placed in the shallow inshore waters to take the place of the original natural beds. Cultch beds should be placed where they have been heretofore, outside or in the lower part of the mouths of rivers outside or alongside the oyster beds.

In this connection, as stated earlier, the fact that certain waters are contaminated with factory trade wastes must be borne in mind. It has been found that the upper waters of certain harbors in Long Island Sound contain such a concentration of trade wastes that oyster larvæ are at once killed by it. No adult oysters are now found in such waters. As these wastes are carried out nearer to the mouths of the harbors they are diluted and are at least not so immediately fatal to the oysters, but ultimately the effect is certainly harmful. Some of the wastes also probably contribute to the green discoloration of the meats of oysters found in certain beds. Vigorous efforts should be made to require the reclamation of trade wastes by the factories and to prevent their discharge into waters otherwise fitted for the maintenance of sea-foods.

General desirability of planting cultch.—The method of oyster culture by means of catching set on planted cultch is the most promising one at present. Small seed oysters may be placed on bottoms where, due to improved conditions, they will grow faster, acquire a more desirable shape, and thus bring a better price. But by putting down cultch in places where there was none before set may be caught which otherwise would have perished. By this method the actual number of oysters is increased. This method should be developed further in some such manner as suggested above and brought into more general use.

At several points on the Atlantic and Gulf coasts no cultch is planted, the shells being burned for lime or used in building roads. In some of these places the oyster beds are becoming seriously depleted. This is especially true of Chesapeake Bay. Investigations carried on there by the United States Bureau of Fisheries during 1919 showed that, while there were abundant free-swimming larvæ during the spawning season, the vast majority of these perished from lack of cultch upon which to attach themselves. It would seem highly desirable to cease disposing of the shells for lime or road building and to clean up the oyster bottoms and plant the shells on them to catch set. The general improvement of the oyster beds and the consequent increase in revenue from them would far outweigh the relatively small amount now received for the shells as at present handled.

PLANTING SEED OYSTERS.

In the method of oyster culture by planting seed the start is made with small or "seed" oysters instead of shells. Such seed oysters may vary in size from set of a few months' growth, about the size of one's finger nail, to oysters of nearly marketable size in some cases.

They are usually, however, small oysters attached to old shells or other material upon which they originally caught. Sometimes, if fairly large, the individual oysters are removed from the old shells or the clusters broken up before planting. Seed may be bought or taken by the planter from his own or natural beds.

Very little seed is now taken from Chesapeake Bay and planted in Long Island Sound, although the importation of "southern" oysters and seed was formerly an extensive practice. The oyster beds of Maurice Cove in Delaware Bay are kept up by the planting of seed taken from the natural beds in the bay. Seed oysters are planted in Chesapeake Bay to some extent and in York River, Va. To a lesser extent the planting of seed oysters is carried on in other States. In many of the Southern States the clusters of small "coon" oysters are broken apart and used for seed. Such coon oysters grow in abundance along the shores and naturally are so thickly crowded together that they acquire a long, narrow shape and are quite indifferent oysters. If the clusters are broken apart and the oysters put down on suitable beds when an inch or two long, they grow into fair-shaped, marketable oysters in about a year in southern waters. Seed oysters are planted at various times of the year, depending on the local conditions, in some places in the fall, in others in the spring.

A number of oystermen make a business of taking shells bearing set from natural beds and selling it to the large planters to be placed on their leased beds as seed. No shells are planted upon natural beds, except by the State in certain cases, the set attaching to shells left by the death of adult oysters, or to rocks, débris, etc. The material bearing the set is taken from such natural beds by the use of tongs (Pl. XI) or by light dredges lifted by hand or hand windlasses on a sailboat (Pl. XV, fig. 1).

In nearly all States it is illegal to use other than a sailing vessel on natural beds and in most instances the dredge must be lifted by hand or by a hand windlass, although sometimes it is lawful to lift the dredge with a donkey engine on deck of a sailing boat. The purpose of restrictions on the use of steam and power in dredging is to limit dredging on natural beds to the use of the less efficient apparatus in order to conserve the supply of oysters. In most States such "natural growth" may not be taken from the beds during certain of the summer months, the purpose being not to disturb the beds during spawning and setting time.

In northern waters it requires from four to five years for an oyster to reach marketable size (a length of from 4 to 5 inches, measured in the shell). In Chesapeake Bay three years is sufficient, while in the South marketable size may be attained in two years. Oysters grow more rapidly in the warmer waters.

In oyster culture by the method of planting seed the main considerations are the kind of seed, character of the water, food supply, bottom, sowing the seed, and caring for the beds.

Seed.—Seed oysters vary in size from the set just caught that season and taken up in the fall, when it is about the size of a finger nail, to oysters which will attain marketable size within a few months after planting. The majority of the seed, however, is not more than 1½ inches long. It is obtained from "natural growers" who make a business, as stated above, of taking seed oysters from natural beds and selling them to planters, or by the planter himself gather-

ing them directly from the beds. In many places the larger planters buy of the "natural growers", since steam vessels and heavy dredges, such as are owned by the large oyster companies, are not allowed to work on the natural beds. The "natural grower," with less capital, can afford to maintain a vessel and some hand dredges and profitably sell to the large oyster company, which in turn obtains seed more cheaply than it could by supporting its own sailing vessels and crews. In States where such a system is practiced, the natural beds are set aside by the State for the "natural grower" with limited capital.

The material dredged from the natural beds usually contains old shells, rocks, and debris, in addition to the oysters. Sometimes the whole is bought at a reduced price, but usually the desirable material is culled out and the clustered oysters broken apart as far as possible.

Water.—As a general rule seed oysters should not be obtained from warm waters and put down in those excessively colder. If this be done, it will usually be found that their growth is checked for some time and that a certain percentage die. After a time, however, they become accustomed to the reduced temperature and renew their growth.

In general, the warmer the water the more rapid the growth of the oysters. This is due both to the greater abundance of food material and to the fact that the bodily activities of the oyster proceed more rapidly when the organism is warmed to a relatively high temperature.

The density of the water should be between 1.007 and 1.023. Although oysters are found both in water of lesser and of greater densities, they do best within the limits stated.

Food.—The character of the food of the oyster is discussed on page 19. In order to profit by planting oysters, a sufficient quantity of food for them must be assured. Often certain waters and bottoms are suitable for catching set on cultch, but do not possess a sufficient food supply to enable the oysters to grow and fatten rapidly. Other grounds furnish an abundant food supply, but the water is so loaded with debris that cultch and set are soon covered. Hence in many cases cultch beds are placed in waters of the former character, and the set is caught and later transferred to waters containing more food.

Care must be exercised not to place more oysters on the ground than can be supported by the supply of food present. On the average about 500 bushels of seed are sowed per acre. The food content of the water varies greatly from place to place and from time to time in the same place. It is affected to some extent by the amount of material brought from the land by the streams and rivers. This again is dependent on the rainfall. As previously stated, diatoms make up a considerable part of the oyster's food and diatom growth is affected by materials washed down from the land. A period of excessive drought causes a falling off in the diatom content of the water.

It would be well if a systematic biological study could be made of the food content of the water over prospective oyster grounds. In order to do this samples of water of definite amounts should be strained through No. 20 silk bolting cloth and the number and

amount of food organisms and material ascertained microscopically.^a Estimate is usually made per liter, which is about equal to a quart. If it were found from a series of examinations that the food content of the water were conspicuously low, it is obvious that the grounds in question would not be desirable for the planting of oysters.

Bottom.—The bottom is cleaned of débris by dredging. If firm enough to support the oysters, no further preparation is needed. If soft, the surface is hardened by putting down shells, sand, or gravel, deposited uniformly so that there are no holes in the surface as finally prepared.

Sowing the seed.—The seed oysters are removed from the original bed by the use of tongs or dredges and are planted in much the same manner as shells by being shoveled from boats or scows (Pl. V, fig. 2) towed back and forth over the grounds. About 500 bushels per acre are usually planted, though the amounts vary widely with local conditions. The oysters are spread uniformly, so that they may not lie in heaps and cause some to fail to receive the proper amount of food or to be crowded and thus grow irregularly.

Care of beds.—The beds are generally left untouched after planting, except for combating enemies in some cases (see below) and shifting certain of the oysters, if desired, to other grounds for final preparation for market. The oysters to be shifted or sold directly are taken up by the use of tongs and dredges. After the oysters have been removed from the beds the grounds are cleaned up by dredging, when they may be used again for planting cultch or seed.

PROTECTION AGAINST ENEMIES.

The more important enemies of the oyster will be described briefly and the methods, if any, of combating each set forth.

STARFISH.

There are two species of starfish which may be classed as oyster enemies. These are the common star, *Asterias forbesi*, and the purple star, *Asterias vulgaris*. The starfish opens an oyster by inclosing it with the arms or rays (Pl. VI, fig. 1), which are provided with rows of suckerlike feet on the lower side, and exerting a constant outward pull on the valves of the shell, until the oyster is exhausted and the valves are allowed to gape at the ends. The starfish then protrudes its stomach from the mouth, which is on the lower side of the central disk, inserts it between the valves of the oyster shell, and sucks in and digests the meat. The set and 1 and 2 year old oysters are more subject to the inroads of the starfish, because of their smaller size and weaker adductor muscle: but the larger starfish prey on oysters as much as 3 years old.

In certain waters the starfish are very destructive to oysters, often invading and cleaning out a whole bed before the planter is aware of their presence. This is true of New England waters and those immediately to the southward. They are unknown in Chesapeake Bay and constitute a menace to oysters only in the regions mentioned in the preceding sentence. In Narragansett Bay and Long Island Sound it has been necessary to fight them very vigorously.

^a This method will suffice to determine the great bulk of the food available in the water and is usually sufficient for practical purposes. The material in actual solution in the water, which probably contributes only a small percentage of the food of the oyster, can be determined only by chemical analysis.

FIG. 1.—STARFISH ATTACKING AN OYSTER.

(Photo from Dr. H. M. Smith.)

FIG. 2.—PHOTOGRAPH OF OYSTER SHOWING THE TURBELLARIAN WORM
KNOWN AS THE WAFER OR "LEECH."

The worm has fastened itself upon the oyster and appears as a dark wrinkled body in about the center of the oyster meat. Natural size. (After Danglede.)

FIG. 1.—USUAL STYLE OF "STAR MOP" USED FOR EXTERMINATING STARFISH IN LONG ISLAND SOUND.

The stars become entangled in the brushes as they are dragged over the bottom. The mops are then raised and plunged into vats of hot water on deck to kill the starfish.

FIG. 2.—"DISH-PAN" FORM OF STAR MOP, USED IN LONG ISLAND SOUND.

The only practical method of destroying the starfish so far devised is by the use of the "star mop" (Pl. VII, fig. 1). This usually consists of an iron bar about 10 feet long, to which are attached 8 or 10 large mops or brushes of heavy rope-yarn about 4 feet long. The bar moves on small wooden iron-tired wheels as it is dragged over the bottom by a chain attached by three drag bars arranged as shown in the figure. The chain passes through a pulley attached to a stout post amidships, and the mop is raised and lowered in the same way as a dredge. The starfish cling to or become entangled in the mops and are brought to the surface when the apparatus is lifted. Two mops are usually used, one on each side of the boat. A long narrow vat is generally placed inside the gunwale on each side of the boat. These vats are kept filled with water which is heated by steam from the boiler circulated through pipes in the vats. Each mop with its burden of "stars" is dropped into the hot water. This is the most rapid and efficient method of killing the starfish and removing them from the mops. Sometimes only one vat is used, placed across the deck before the cabin, and each mop is swung around and lowered into it by means of a small crane.

In Plate VII, figure 2, is shown a special form of star mop, the "dishpan," devised for use on a rocky bottom. The toboggan-shaped body consists of two pieces of boiler iron, the larger one $4\frac{1}{2}$ by 2 feet and attached to the triangular smaller one by four rings bolted on as seen in the figure. This allows some independence of movement of the two parts. The mops are the same as used with the other form of apparatus. This mop slides over the rocks more readily than the wheeled bar, the brushes falling down between the rocks and catching the stars. This style of mop, however, is heavy and awkward to handle and is not extensively used.

"Starring" must be kept up whenever any considerable number of the enemy appears and should be of a cooperative nature. It is of little avail for a planter to attempt to keep his beds free from starfish, unless his neighbor does likewise.

DRILL.

There are at least four species of snail-like molluscs known to oystermen as drills or screw borers. One of these, *Urosalpinx cinereus* (text fig. 3), attaining a length of about an inch, is found abundantly from Massachusetts to the east coast of Florida. The eggs are laid in small, yellowish, vase-shaped, leathery capsules,^a deposited in clusters on objects in the water. Another species is *Thais lapillus*, about the size of the preceding. It is found from the east end of Long Island northward. Other species of drills (often called borers, snails, whelks, or conchs) are *Thais hæmastoma* (Pl. VIII, top) and *Thais hæmastoma floridana*. These sometimes reach a length of 3 inches. They are found on the Gulf coast, where they are often very destructive to oyster beds. The eggs are laid in tubular capsules about a half inch long, attached by the ends to

FIG. 3.—*Urosalpinx cinereus*, the oyster drill of the Atlantic coast. Natural size. (After Moore.)

^a Moore, H. F. Proposed revision of "Oysters and Methods of Oyster Culture" (1897).

shells and other objects in the water (Pl. VIII, center). Masses of these capsules are often found covering oyster shells so thickly that there is danger of smothering the oysters. From their reddish-purple color these masses are often referred to as "red grass."

The various species of drill possess a rasplike apparatus which can be protruded from the mouth. With this they bore a hole through the shell of the oyster (Pl. VIII, bottom) and suck out the contents. Drills destroy many young oysters, their thin shells being relatively easily penetrated. After the oyster becomes older its shell is heavy enough to resist the effort of the drill.

In Long Island Sound it has been found that about the most practical method of lessening the numbers of this enemy is the following: The teeth are removed from an ordinary oyster dredge, and a bag with meshes of an inch or less is put on in place of the usual coarser one. After the oysters have been taken off the bed for market or shifting, the specially equipped dredge is used and everything left—shells, drills, débris, etc.—is dredged up

FIG. 4.—*Pogonias cromis*, or drum fish. At times this fish destroys large numbers of oysters. (After Jordan and Evermann.)

and dumped ashore to dry. The drills die, and a good deal of the material may then be used as cultch.

DRUMFISH.

The fish known as the "black drum," *Pogonias cromis* (text fig. 4), is found at intervals of time and place from New Jersey to Texas and is often very destructive to oyster beds. It attains a length of several feet and has a heavy body with large stout teeth. The oysters are crushed, shell and all, by these strong teeth, the younger thin-shelled ones being, of course, especially subject to the depredations of the drumfish. These fish go in schools and their attacks are spasmodic, often whole oyster beds being cleaned out in a short time and then, again, no drumfish being seen for several months or years.

Efforts have been made to kill or frighten away such fish by the explosion of dynamite, but no particular success has been achieved. In southern waters, especially in Louisiana, where oyster beds lie in shallow water and there is not much tide, it has been found practi-

TOP, BORERS OR "DRILLS" (*THAIS HAEMASTOMA*) OF THE GULF COAST;
CENTER, SO-CALLED "RED GRASS," THE EGG CASES OF THE BORERS;
BOTTOM, OYSTER SPAT DRILLED BY BORERS.

Natural size. (After Moore and Pope.)

CONCHS. TOP, CHANNELLED CONCH OR WHELK, *BUSYCON CANALICULATUM*;
CENTER, STRING OF CAPSULES CONTAINING EGGS OF KNOBBED CONCH;
BOTTOM, KNOBBED CONCH OR WHELK, *BUSYCON CARICA*.

cable to fence the beds with chicken wire strung on posts set in the bottom.

CONCH.

This is also a snail-like mollusc, comprising several species, some of which attain a length of from 5 to 6 inches. *Busycon carica* and *Busycon canaliculatum* (Pl. IX) are the most common. The eggs are deposited in flat parchmentlike capsules about an inch in diameter and strung together by a cord along the side to form a loosely spiral chain a foot to a foot and a half in length. This is cast free from the animal and left to the mercy of the waves. It has been found^a that the conch opens an oyster by inserting the edges of its own shell between the valves of the oyster when it gapes (text fig. 5) and then introducing its proboscis and eating the meat. Conchs do not occur, however, in sufficient quantities to destroy many oysters. No definite means of combating them are employed, although those taken when dredging are usually killed.

MUSSEL.

Mussels, the common edible species, *Mytilus edulis*, and other species, of the Atlantic waters, and *Mytilus hamatus* (Pl. X, fig. 1), of the Gulf coast, are bivalves which, shortly after hatching from the egg, attach themselves to material on the bottom by a slender thread or hair called the byssus. As development goes on the number of hairs is multiplied and they become shorter and stouter until the adult mussel, at a length of 4 or 5 inches, is very firmly attached by these threads. The mussels multiply rapidly, and dense beds are sometimes formed over the oysters, tending to smother the latter. Since the mussels feed upon essentially the same materials as do the oysters, there is always danger of a greater or less exhaustion of the food supply.

In Long Island Sound the mussel is attacked in the following manner: The mussel spawns and "sets"—that is, attaches by the byssus—perhaps a month or more before the oyster. Advantage is taken of this fact, and when evidences are found of an alarming number of young mussels on the oyster beds, they are "harrowed" by dragging over them an ordinary dredge with the bag removed or open at the back. This process crushes and destroys the majority of the tiny mussels without injury to the adult oysters. If this process is carried out on a bed planted with shells to catch a set, no harm is done, as the oysters have not yet spawned, and there is consequently no oyster set on the shells.

FIG. 5.—Conch opening an oyster. About one-half natural size. (After Colton.)

^a Colton, H. S. How Fulgur and Sycotypus eat Oysters, Mussels, and Clams. Proceedings, Academy of Natural Sciences, Philadelphia, Vol. LX, 1908, pp. 3-10, 5 pls. Philadelphia.

BORING SPONGE.

Boring sponge (*Cliona celata*) is the term applied to a yellow sponge which begins its existence by boring (Pl. XXI, lower left figure) in the shell of the oyster, where it forms small tunnels, in which it lives. The shell is gradually honeycombed, and the oyster becomes weak and thin from the effort to seal up the openings where the tunnels penetrate the shell completely. The sponge also spreads over the outside of the shell and often smothers the oyster by its very size. No means of protection against the sponge can be suggested, but fortunately it does not occur in sufficient numbers in most regions to prove a serious menace.

BORING CLAM.

The boring clam (*Martesia cuneiformis*, *M. smithii*, and *M. corticaria*) is a species of clam which enters the shell of the oyster by boring a small round hole and excavating in the substance of the shell, at the inner end of the hole, a hemispherical cavity (Pl. X, fig. 2) in which it then spends its life, often attaining a length of three-eighths of an inch. The clam usually does not penetrate the shell entirely and does not feed upon the oyster. It attains its food through the external opening. It does comparatively little damage to the oyster.

WAFER OR "LEECH."

This is a turbellarian worm (Pl. VI, fig. 2) of undetermined species which on several occasions has destroyed large numbers of oysters in the vicinity of Cedar Keys, Port Inglis, and Tampa, Fla. This worm is nearly flat, more or less circular in outline, and is about three-fourths of an inch long. It finds its way between the valves of the oyster and feeds upon the meat, eventually killing the oyster. It flourishes in water of fairly high salinity, and its ravages are checked by lowered temperatures. No method of combating it can be suggested other than a careful working of the beds and the use of new air-dried cultch and fresh seed stock.

TAKING OYSTERS FROM THE BEDS.

Oysters are commonly taken by the use of hand tongs, patent tongs, dredges lifted by hand or hand windlasses, or dredges raised by engines or hoisters turned by the engine of the boat. These forms of apparatus and the boats on which they are used are described below.

TONGS.

Ordinary hand oyster tongs are shown in Plate XI, figures 1 and 2. There are two long, flat, smooth, wooden handles about 3 inches wide and nearly 1 inch thick, bolted, riveted, or pinned together with a wooden pin, scissors fashion, about 4½ feet from one end (see figures), leaving the long ends for handles. To the short end of each shaft is secured at right angles a light iron bar, about 3½ feet long, bearing teeth, while above this bar are five or six still lighter bars or heavy wires parallel to the bar and attached to the shaft. The ends of the bars or wires are fastened together by short wires. The arrange-

FIG. 1.—MASS OF MUSSELS ATTACHED TO OYSTERS.
(After Moore.)

FIG. 2.—OYSTER SHELLS SHOWING PITS AND CHAMBERS MADE BY BORING CLAM.
(After Moore.)

FIG. 1.—TONGING OYSTERS, WORKING THE TONGS ON THE BOTTOM.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 2.—TONGING OYSTERS, LIFTING AND EMPTYING THE TONGS.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 1.—PATENT TONGS, USED TO SOME EXTENT IN TAKING OYSTERS
IN THE LOWER PART OF CHESAPEAKE BAY.

FIG. 2.—UNLOADING OYSTERS BY MEANS OF A CRANE OPERATED BY A
DONKEY ENGINE IN THE SMALL BUILDING AT THE RIGHT.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 1.—SMALL SAILING BOAT USED IN TONGING OYSTERS IN QUINNIPIAC RIVER, CONN.

FIG. 2.—SMALL SAILING BOAT USED IN TONGING OYSTERS IN RIVERS ON THE COAST OF ALABAMA.

ment on each shaft is made with the teeth sloping inward, and when the handles are closed the two are brought together, the whole forming a basketlike affair, $3\frac{1}{2}$ feet long by about 8 or 10 inches deep. In operation (Pl. XI, fig. 1), the handles are worked scissors fashion, and the teeth forced under the oysters retained in the basket, which is then lifted (Pl. XI, fig. 2). Oyster tongs vary in length with the depth of water in different localities. In some places, as in the Rappahannock River, oysters are tonged with such apparatus from a depth of at least 20 feet.

PATENT TONGS.

Patent tongs are used quite extensively in Virginia and but very little elsewhere. From Plate XII, figure 1, it will be seen that their general construction is similar to that of hand tongs, except that the handles are of iron, about 6 feet long and provided with an eye at the end for the attachment of ropes for lowering and raising the tongs. The basket of the tongs is of considerably heavier material than in case of the hand tongs. Patent tongs are employed in water too deep to admit of the use of ordinary tongs and are raised and lowered by a spool or windlass, as in Plate XII, figure 1. While being lowered the tongs are locked open by the short hook seen on one of the handles just above the center pin. When they strike bottom, the consequent release of the weight of the baskets on the handles allows the hook to become disengaged. The tongs are then "jigged" by jerking upon the rope several times, causing the teeth to sink more deeply, and then lifted by the windlass.

SMALL TONGS AND NIPPERS.

In very shallow water of perhaps 2 to 4 feet in depth small tongs are often used. These consist of two wooden handles about 7 feet long, arranged as in the case of the ordinary tongs, but with only a single bar on each about 10 inches long, each bar being provided with teeth. This instrument is much lighter and more convenient to use in shallow water than ordinary tongs, especially where only a few barrels of oysters are desired. Such tongs are sometimes called "nippers." In other regions the term "nipper" is applied to a device of a similar nature, except that, instead of ending in a toothed bar, each handle terminates in a narrow blunt blade, thus forming true pincers or nippers, with which single oysters can be taken or dislodged from rocks or pilings.

TONGING BOATS.

In Plate XIII, figures 1 and 2, and Plate XIV, figure 1, are shown various styles of tonging boats. Plate XIII, figure 1, shows a small boat used on Long Island Sound; and Plate XIII, figure 2, a small tonging boat at Bayou Labatre, Ala. Plate XIV, figure 1, shows the type of tonging boat used at Apalachicola, Fla. These boats often carry an auxiliary gasoline engine besides the sails. Such a boat with engine is seen in the figure, returning with a load of oysters which have been obtained by tonging. Boats of this sort often have a shallow hold into which oysters are piled until full, after which they are heaped on deck. Plate XII, figure 1, shows a boat equipped with patent tongs.

On the small boats, in compliance with State law, the oysters are culled on a board placed across the boat, as in Plate XI.

DREDGES AND DREDGING BOATS.

The hand dredge is shown in Plate XV, figure 1. It consists essentially of two triangles made of three-fourths inch iron bar, joined at the apices, and the bases separated about 18 inches by curved bars, as seen in the figure at left. It usually measures 4 or 5 feet in width. The base of the lower triangle consists of a bar about 1½ inches thick, to which are welded teeth about 3 inches long, set about 3 inches apart. To a ring at the apex of the dredge a rope or wire cable is attached, by which the dredge is lowered and raised, either by hand or by the hand windlass. Plate XVI, figure 1, shows a small dredging sloop or "skipjack" under sail on Chesapeake Bay, the dredge on the port side being lifted and the hand windlass visible beyond it. In some States, as Maryland, somewhat heavier dredges than this are operated by the use of a donkey engine placed on the deck of a sailing vessel (Pl. XVII, fig. 2). Plate XVI, figure 2, shows such a dredging schooner at work. These vessels are propelled entirely by sails, it being illegal to dredge with other than sails as motive power; the engine merely operates the dredge.

From one to three dredges are usually operated from each side of the boat, each dredge being raised and emptied in turn. Plate XVII, figure 1, shows the dredge being thrown overboard and the roller over which the chain moves in lowering and raising it. After the full dredge is lifted it is allowed to rest on the roller and is emptied by pulling the bag forward (Pl. XVII, fig. 2), thus turning it wrong side out and dumping the oysters on deck. The dredge is then dropped overboard again. The oysters are culled on deck and then shoveled into the hold or onto the pile on deck.

A yet heavier and stouter form of dredge (Pl. XV, fig. 2) is used where dredging with power boats is allowed. It will be seen to resemble the other patterns, except that it is largely made of heavy, flat, iron bars, about 2 inches wide and nearly 1 inch thick and firmly braced. The lower part of the bag is of iron mesh instead of cotton. Dredges of this sort measure from 5 to 7 feet in width and hold 12 to 15 bushels of oysters (one oyster company uses larger ones holding nearly 30 bushels; these are emptied by mechanical means). These dredges are raised and lowered by a heavy chain which passes through a pulley on a stout post in the midline forward and then down to the hoister in the hold. The hoister is turned by the engine of the boat. Plate XIV, figure 2, shows the arrangement of rollers, pulleys, post, and dredges on a gasoline power dredging boat. In Long Island Sound large steamers are often used for dredging on leased beds. One company has two steamers each carrying three dredges on a side, six in all, each with a capacity of nearly 30 bushels. These two steamers are each about twice as large as any other oyster steamer in the world, having a capacity of 8,000 bushels (Pl. XVIII, fig. 2).

FIG. 1.—SMALL SLOOP USED IN TONGING OYSTERS NEAR APALACHICOLA, FLA., RETURNING WITH LOAD OF OYSTERS. SHOWING OYSTER CANNERIES IN BACKGROUND.

FIG. 2.—GASOLINE BOAT USED IN DREDGING OYSTERS IN LONG ISLAND SOUND.

In the center is the post to which are attached the pulleys through which pass the chains leading to the dredges on each side. When the dredges are being raised and lowered, the chains move over the rollers on the gunwale.

FIG. 1.—HAND DREDGES AND WINCHES FOR HOISTING THEM.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 2.—MACHINE-HOISTED DREDGE USED IN TAKING OYSTERS.

FIG. 1.—SMALL SLOOP OR "SKIP-JACK" USED IN DREDGING OYSTERS IN CHESAPEAKE BAY.

The dredge shown lying on the roller is raised and lowered by the hand windlass over which the man is stooping. (Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 2.—OYSTER-DREDGING SCHOONER IN CHESAPEAKE BAY.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 1.—LOWERING THE DREDGE.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 2.—EMPTYING THE DREDGE.

In this case the dredge has been lifted by a donkey engine, part of which may be seen at the right.
(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 1.—OYSTER FLEET OPERATING FROM CAMBRIDGE, MD., LYING IN HARBOR. Cambridge is only one of the several important oyster centers on Chesapeake Bay. (Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 2.—ONE OF THE TWO LARGEST OYSTER STEAMERS IN THE WORLD, BOTH OWNED BY A NEW ENGLAND COMPANY.

Three dredges lifting 30 bushels each are operated on each side. The capacity of the steamer is 8,000 bushels per day. (Photo from H. C. Rowe Co.)

FIG. 1.—LARGE OYSTER HOUSE AT PROVIDENCE, R. I., SHOWING DREDGE BOAT UNLOADING OYSTERS AT RIGHT AND ELEVATOR TO SHELL PILE AT LEFT.

FIG. 2.—UNLOADING OYSTERS FROM THE BOAT AT ONE OF THE LARGE OYSTER HOUSES BY MEANS OF A BELT CONVEYER.

UNLOADING AT WHARF.

In most cases the oysters are shoveled from the hold or deck into large measures or buckets and hoisted to the wharf by a rope passing over a pulley and operated by hand or by a crane with a donkey engine as motive power, as in Plate XII, figure 2. The buckets are emptied onto the wharf and the oysters removed later in wheelbarrows; or into wheelbarrows and the oysters rolled into the shucking room on a level with the wharf, or sometimes to a storage room on an upper floor (Pl. XII, fig. 2). Some large oyster companies have arrangements whereby the buckets are lifted directly into the storage room, and some have an elevator, the end of which may be lowered into the boat and the oysters shoveled onto an endless belt or other carrying device (Pl. XIX, fig. 2).

This carrier transports the oysters directly to the storage room or drops them into another endless bucket-chain carrier which does so. In case the oysters are to be canned they are dumped from the buckets, which have lifted them from the boat, directly into cars, which are then pushed into the steamers inside the cannery.

FLOATING.

Brief mention may be made of the practice whereby, in some localities, oysters, after being taken from the beds, are "floated" for a time before being used. This process is accomplished by spreading the oysters out in a large shallow barge or float so constructed that, while resting at the surface, water may freely circulate through it, the oysters thereby being covered at all times. Such floats vary considerably in structure, often consisting of a rectangular framework some 12 or 15 feet wide by 20 to 30 feet long, made of four large timbers 15 or 18 inches in diameter, with a bottom of boards laid so that cracks are left between them. The float may be towed to the desired point and anchored either before or after the oysters are placed in it.

The floating is usually undertaken for one of two purposes—purification and cleaning of the oysters or temporary storage. In certain regions oysters from beds which are exposed to sewage are floated in waters of a certain degree of saltiness designated by the health authorities until any possible impurities contained are thrown off. In such salt water the oysters do not become bloated, as they would if floated in fresh. Oysters are also sometimes floated in order that they may free themselves from sand or dirt contained in the intestinal tract.

Some companies maintain floats such as described in which a temporary stock of oysters may be kept a day or two in order to have a supply on hand to fill extra orders or to tide over a shortage caused by failure to obtain sufficient stock directly from the beds, for any cause, such as the breakdown of a boat or formation of heavy ice over the beds. In this case the floats are placed by the oyster house in water of about the saltiness of that over the beds.

The practice of floating oysters in fresh water of creeks and rivers for the purpose of "fattening" has largely died out or been suppressed by health authorities. The oyster did not fatten in such circumstances, but merely enlarged itself by absorbing creek water which the consumer paid for at oyster prices.

PREPARATION FOR MARKET OR SHIPMENT.

Oysters are usually shipped in three general conditions—in the shell; shucked, on ice; and canned.^a The building where oysters are handled in either or both of the first two conditions is referred to as an oyster house or, in some sections, especially to distinguish it from a cannery, as a “raw house” or “raw-oyster house.” If oysters are canned, the plant is known as a cannery. Plate XIX, figure 1, shows the front view of a large oyster house. Oyster houses are provided with a wharf of some sort, so that the boats may be unloaded directly, as described above.

IN THE SHELL.

Oysters are shipped in the shell usually in barrels, sometimes in sacks, without ice, although for long distances a refrigerator car is often used. In many cases, especially for shorter hauls or transportation by river boats, the barrels are not headed, a piece of heavy gunny-sack being fastened over the top of the barrel. A considerable export trade in oysters to England is carried on from the waters of New York and New England. These oysters go in barrels holding 3 bushels and one-half peck, headed up. Only the best-shaped, selected oysters are used for the export trade.

A large number of oysters are thus handled in the shell, since oysters on the half shell have found a place on the menu of the leading hotels and restaurants. For this purpose oysters from certain beds have come to be esteemed as most desirable. These have acquired trade names by which they are universally known and which are derived from the locality from which the oysters are taken. The best-known examples are the Blue Points from beds near Blue Point, a cape on the south side of Long Island; Cotuits, from Cotuit Harbor, Mass., and Lynnhavens, from Lynnhaven Bay, Va. There is a growing tendency to look upon these terms merely as trade names and to employ them to designate any oyster answering the requirements of size and shape of these oysters, regardless of the waters from which they were taken.

Blue Points (Pl. I) are small oysters, about 3 to 4 inches long by 2 to 2½ inches in width. They are rather rounded in form and the shells are fairly smooth. The meats are small and of very delicate flavor, making these oysters very acceptable when served raw on the half shell. For this reason Blue Points have acquired a wide reputation. Lynnhavens (Pl. XX) and Cotuits (Pl. XXI) are larger oysters than Blue Points and of more angular shape. Because of their fatness and flavor they have become highly esteemed.

Oysters are shipped in the shell to points on the Pacific coast both for the market and for planting as seed or for fattening. In 1915, over two-thirds of the 156,104 bushels of oysters produced on the Pacific coast were raised from transplanted eastern oysters.^b

^a One firm puts out an oyster powder made by extracting in a vacuum the moisture from oyster meats. This powder is sold in small vials packed in pasteboard cartons and is used in making broths and soups. So far as the writer is aware, only one firm puts such a product on the market.

^b Radcliffe, L. Fishery Industries of the United States. Report of the Division of Statistics and Methods of the Fisheries for 1918. Appendix X, Report, U. S. Commissioner of Fisheries, 1918, 167 pp. Washington, 1919.

"LYNNHAVENS," FROM LYNNHAVEN BAY, VA.

About one-half natural size.

"COTUITS," FROM COTUIT HARBOR, MASS.

About one-half natural size.

FIG. 1.—SHUCKING TABLE IN LARGE OYSTER HOUSE.

The oysters come down from the storage room above and out the bottom of the V-shaped chute. The worker stands on the bench and places the oyster to be opened on the small block on the edge of the table.

FIG. 2.—WASHING FRESH OYSTER MEATS ON "SKIMMING BOARD."

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 1.—"RIFFLE" OYSTER WASHER, ON WHICH FRESH OYSTER MEATS ARE WASHED PREPARATORY TO BEING PACKED ON ICE.

FIG. 2.—SEVERAL STYLES OF CONTAINERS USED IN SHIPPING OYSTERS. Shucked oysters are placed in metal or glass containers, which are packed in the boxes or tubs with cracked ice about them.

FIG. 3.—FIFTEEN CARS OF OYSTERS READY TO BE RUN INTO THE OYSTER CANNERY. Each car holds 20 bushels, making 300 bushels in all. The capacity of this cannery is 1,500 bushels per day.

SHUCKED, ON ICE.

The process of opening an oyster and removing the "meat" is known generally as "shucking." For this purpose the oysters are conveyed to tables or stalls of various sorts in the oyster house. In the smaller establishments this is done by wheelbarrow and shovel; in the larger, the oysters are first taken to a storage room, as described above, and then let down through chutes to the individual stalls of the shuckers. Plate XXII, figure 1, represents a shucking table in one of the large oyster houses. The shucker stands on the bench before the table. The oysters fall down the slanting chute to the narrow table along the edge of which are seen the blocks on which the shucker places the oyster to open it. The shells are thrown through small chutes in the table and fall into the trough seen below, whence they are removed by a mechanical carrier.

The process of shucking requires considerable skill and strength of hand and wrist. Various methods are employed and several slightly differing styles of opening knives. Some shuckers first break off the "bill" or tip of the shell with a small hammer, insert the knife into the opening thus made, and cut the large muscle holding the shell together. Others scorn such aid, since it takes longer, and by steady pressure force the knife between the shells at the tips or the side. A skilled shucker moves his hands so rapidly the eye can hardly follow the movements. A heavy mitten is worn on the left hand, which grasps the oyster, the shell being very sharp on the edges. A fair day's shucking is 10 to 12 gallons.^a If the oysters are in good condition, "fat," 12 gallons or a little more may be shucked. The average yield of shucked oysters from a bushel in the shell varies greatly with the condition and quality of the oysters. If the oyster meats are full and plump, they are spoken of as "fat" and the yield is greater than when "poor"; that is, the meat thin, watery, often semitransparent. A fair average yield is from 6 to 8 pints per bushel.

The "meats" are thrown into a galvanized-iron measure, which in some cases is perforated to allow the drainage of excess liquor. In some houses, however, the measures are not perforated and are partially filled with water into which the oysters are placed as shucked. When the measure is full it is taken to the measuring window and the oysters measured or weighed. The shucker sometimes receives a ticket, but in many cases the individual scores are marked up on a board by the weighing window and payment made weekly. In the smaller oyster houses the shells are thrown by the shucker to the floor and later removed in wheelbarrows. In many such houses each shucker stands in a sort of movable wooden stall placed before the table. This stall is 18 or 20 inches wide and about waist-high, being open at the rear so that the shucker may step in and out readily. Such stalls keep the accumulating piles of shells from encroaching on the space where the worker stands and also afford something against which he may lean while working. In some of the larger houses, where the shells are not thrown on the floor, the stalls are used merely to satisfy the shuckers who have

^a Many, however, shuck more than this amount. The author knows of one man in particular, at Hampton, Va., who opened 26 gallons a day. Since his score was marked up and pay given for this amount, this record is authentic.

become accustomed to their use in smaller places and find it less tiring to work while standing in such a stall.

Shuckers are paid by the gallon; during the winter of 1919-20 the price was \$0.35 to \$0.40 per gallon. Some large firms in New England employ Portuguese for shucking; in places farther south many Negroes are used for this work. Both men and women are often employed; especially is this true where colored labor is used.

After being shucked the oysters are spread out on washing tables. These are usually comparatively simple in form, as seen in Plate XXII, figure 2, are made of galvanized iron, and measure about 5 feet long by $2\frac{1}{2}$ wide, the bottom being perforated to allow the water to drain off and supported on a wooden framework, as shown in the figure. Some of the larger firms use more or less elaborate washing tables, some being of the "riffle" style (Pl. XXIII, fig. 1). This consists essentially of a sloping zinc platform with ridges or elevations across it which retard the oysters as they are washed down it. The oysters receive several washings, usually in fresh water from the tap. In some States, however, the law requires that the washing be done with salt water of a certain strength in order that the oysters may not be bloated by the absorption of fresh water. In the larger houses, after receiving a preliminary washing on tables similar to that in Plate XXIII, figure 1, they are carried by a gentle stream of water down narrow runways to tanks on a lower floor (Pl. XXIV, fig. 1). These are made of galvanized iron and are about 5 feet square by 15 inches deep. Here they receive two washings, in some cases compressed air being blown from pipes through the water in which the oysters are standing. This is thought by those using it to remove more thoroughly the fine particles of dirt or bits of shell. The excess water is allowed to drain off in the last tank, and the oysters are then packed in various sorts of containers, as the tin cans in the figure, which are then packed in ice.

Usually the oysters are divided, according to size, into three grades: Standards, the smallest; Selects, the next; and Counts, or Extra Selects, the largest. The usual containers are tin cans, as shown in Plate XXIII, figure 2, of a capacity of 1, 3, or 5 gallons. The oysters are packed into these without any other liquor than that remaining after the excess has been drained off, as stated above. The cover is put on, often secured by a string passed over the top and attached to lugs on each side. The cans are packed in ice singly in boxes (Pl. XXIV, fig. 2), or several together in a barrel. Sometimes metal containers, shown at right in Plate XXIII, figure 2, are used. These are packed in a bucket carrier with ice about them. The figure also shows the 5-gallon size tin can, the bucket carrier, the short boxes containing tin cans, and a bottle container with paste-board cap, holding one-tenth gallon. Thirty bottles are packed in a flat, wide box (see figure), with ice over their tops, and a wooden cover is nailed on.

CANNING OYSTERS.

Oysters were first canned at Baltimore in 1820, and the expression "cove oyster," which now seems synonymous with canned oysters, was originally given to the small oysters found in the coves on the west bank of Chesapeake Bay between Baltimore and the mouth of the Potomac.^a The industry has spread rapidly in the last 20 years.

^a Smith, H. M. Oysters: The World's Most Valuable Water Crop. National Geographic Magazine, March, 1913, p. 258. Washington.

FIG. 1.—TANKS FOR WASHING SHUCKED OYSTERS.

The oyster meats come down the metal trough from the floor above. After washing they are placed in the tin cans.

FIG. 2.—PACKING FRESH OYSTER MEATS IN ICE FOR SHIPMENT.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 1.—CAR OF OYSTERS READY TO BE RUN INTO STEAMER.

FIG. 2.—INTERIOR OF OYSTER CANNERY; OPENING STEAMED OYSTERS.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 1.—INTERIOR OF OYSTER CANNERY, SHOWING TABLE ON WHICH THE OYSTERS ARE PUT INTO THE CANS.

FIG. 2.—INTERIOR OF OYSTER CANNERY, SHOWING PACKING TABLE, CAPPING MACHINE, AND BASKET IN WHICH THE FILLED CANS ARE "PROCESSED."

FIG. 1.—LOWERING A BASKET OF CANNED OYSTERS INTO THE KETTLE OR STEAMER TO BE "PROCESSED."
(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 2.—BASKET OF CANNED OYSTERS, AFTER HAVING BEEN "PROCESSED," READY TO BE LOWERED INTO THE "COOLER," AT RIGHT, WHERE RUNNING WATER IS PASSED ABOUT THE CANS.

There are now 15 canneries in Baltimore, which city still leads in number of canneries; 16 in Mississippi, 12 being at Biloxi; 18 in Georgia, 4 at Savannah, 4 in and about Brunswick, and others at smaller points; about 12 in South Carolina; 7 in North Carolina; 6 or 7 in Louisiana; and 4 or 5 in Florida.

Oyster canneries, like raw houses, are located on the water front with a wharf at which the oysters are unloaded from the boats. Plate XIV, figure 1, shows a view of an oyster cannery. At most canneries the oysters are unloaded from the boat in large tubs or buckets, as previously described, and dumped directly into cars 10 or 12 feet long, made of iron strips, basket-fashion, as in Plates XXIII and XXV. The cars are then pushed on a track into the building. Plate XXIII, figure 3, shows a line of 15 loaded cars, 20 bushels in each car, 300 bushels in all. The capacity of this particular cannery is 1,500 bushels per day.

The cars of oysters are run into rectangular iron steamers, which are often long enough to accommodate 3 cars at once. Steam is passed through for from 3 to 10 minutes, depending on the thickness of the shells. The cars are then pushed on out the other end of the steamer, sometimes being afterwards switched to another track or another room by the aid of the device shown in Plate XXV, figure 1. The short piece of track upon which the car rests is also provided with wheels, and the whole is rolled onto a lower track running at right angles to the first.

The steamed oysters are then opened directly from the cars by shuckers or openers standing alongside (Pl. XXV, fig. 2). Each worker has a metal bucket, which is suspended by a hook to the side of the car. The buckets are perforated to allow the escape of excess liquor. A knife is used, but no such skill or strength is required as is necessary in the case of raw oysters, since the steamed oysters have been killed by the process and the shells are gaping and easily separated. When a worker's bucket is filled, it is taken to the weighing window, payment being by weight, where either the money or a ticket is received. Both men and women, and often children over the legal age, do this work. In Alabama and Mississippi the workers are largely of the Slavic races. In those States many of the canning firms furnish quarters for their labor, often wood and water being included.

After being weighed, the oysters are washed two or three times with tap water in vats or on tables and then carried in buckets to the packing table (Pl. XXVI, fig. 1). The general construction of such a table is shown in the figure; it is made of wood, of convenient height, and about 12 feet long by 6 wide in the wider part and 3 in the narrower. The packing is usually done by women or girls, who stand along the sides of the table. The empty cans are supplied the packers from boxes behind them, or often a supply is placed along the edge of the table on which the oysters are piled. The packers at the farther end (see figure) of the table fill the cans almost full, placing the oysters in with the hands. They then put the cans in the rack or trough extending along over the table. The bottom of this is an endless belt which moves the cans forward until they are stopped by the crossbar at the nearer end of the trough. One packer stands on each side of the table, which is narrower here, takes the partially filled cans from the trough, one at a time, places them on the balances

seen in the figure, and fills them up until the correct weight is reached. So far in the process there is practically no liquor in the can. Cans varying in capacity from 3 to 10 ounces are usually packed. The cans are then placed on another belt, which carries them along the trough to the left under a length of perforated pipe from which hot brine drops into the cans.

The belt then takes them to the capping machine (Pl. XXVI, fig. 2), where the cover is put on. This is commonly done by the crimping process, although some firms still use the method of sealing the cover on with solder. The machine shown in the figure crimps the covers on 58 cans per minute.

After leaving the capping machine the cans are placed in large circular iron baskets, about 4 feet across, and lowered into a cylindrical metal processing tank (Pl. XXVII, fig. 1). In these tanks the cans are heated by steam to a high temperature for a short time, after which they are removed and lowered into a circular wooden tank or cooler (Pl. XXVII, fig. 2), and cooled with running water. The baskets of cans are then wheeled on tracks to the labeling and packing room (Pl. XXVIII, fig. 1), where the labels are pasted on by girls or women. The finished product is then packed in boxes, this work being done by men (Pl. XXVIII, fig. 1).

DISPOSITION OF OYSTER SHELLS.

In the larger oyster houses the shells are usually dropped by the shucker through a chute leading from the table down to a wide endless belt or a trough through which passes an endless scrape carrier. These devices carry the shells outside and up an elevator (Pl. XXIX, fig. 1) or an inclined plane (Pl. XXVIII, fig. 2). The carrier continues over the shell heap, sometimes being inclosed, and drops the shells at certain points, which may be varied as the pile grows (Pl. XXVIII, fig. 2). In other oyster houses, especially the smaller ones, the shells are removed in wheelbarrows, which are rolled on planks up the side or across the top of the pile (Pl. XXIX, fig. 2).

The shells are used for culch, as previously described; for making lime, which is placed on soil as a fertilizer; for poultry grit; for making shell roads; and for ballast for railroad track beds. In Plate XXIX, figure 1, is shown a kiln in which the shells are being burned to make lime, a pile of the burned shells appearing in the foreground. The interior of the kiln is cone-shaped at the bottom. The shells are deposited in the kiln by the elevator, a certain amount of fine coal being mixed in as fuel. The fire in the lower part of the kiln is kept burning constantly, and the burned shells are shaken out through the grate at the bottom. The shells are then allowed to air-slake, and the lime is sold for fertilizer. The burned shells bring about \$8 per ton. About a ton is put on an acre. A ton of burned shells increases in bulk to about a ton and a half during the slaking process. A ton of the slaked lime sells for \$6.50.

Crushed shells are used for poultry grit. The shells are first dried in a direct-heat rotary drier similar to that used in factories where fertilizer is made from menhaden. The degree of heat applied depends entirely on the percentage of moisture in the shells; the greater the moisture the higher the temperature required. It is essential that a close observance be kept during the drying process, in order to regulate the temperature, as shells may be damaged by too much

FIG. 1.—INTERIOR OF OYSTER CANNERY; LABELING AND BOXING CANS OF OYSTERS.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 2.—SHELL PILE OF A LARGE OYSTER COMPANY, SHOWING CONVEYER FOR CARRYING SHELLS FROM SHUCKING TABLE TO THE PILE.

(Photo from J. S. Darling and Son.)

FIG. 1.—KILN FOR BURNING OYSTER SHELLS TO MAKE LIME, SHOWING SHELL HEAP IN BACKGROUND AND PILE OF LIME IN FOREGROUND.

(Photo from Prof. E. N. Cory, Maryland State University.)

FIG. 2.—LOADING OYSTER SHELLS INTO CAR FOR USE IN BUILDING ROADS.

heat. If the temperature is too high, the shells are likely to turn yellow, and if they are not sufficiently dried they may become soft. If they have been sheltered from the weather and are thoroughly dry the drying process may be dispensed with. After passing through the drier they are carried by a conveyer to the crusher and from there to the screen, which is usually of the revolving type and made of various-sized mesh to separate the crushed shells into several grades or sizes.

In Plate XXIX, figure 2, shells are being loaded on cars for road making. In some cases the shells are partially crushed before being put on the roads; in other cases they are put on whole and are worn down by the traffic. Plate V, figure 1, shows shells being loaded on a scow for planting to catch set.

The shell heaps are cleaned up annually. Most of the shells are used for one of the above purposes. The shell piles shown in the figures convey but a faint notion of the actual vast bulk of the oyster crop taken annually from the waters of the United States.

LEGAL REGULATIONS.

In each State in which there is an oyster industry there are certain regulations for its conduct, provided by State law and administered by officers and inspectors, appointed in nearly all cases by a State fish or oyster commissioner or president of a State conservation commission.

The regulations, while necessarily differing widely to meet the varying conditions, usually provide for a system of surveying and staking off with conspicuous buoys or markers the various beds leased or owned by the planters and the "natural" beds, the latter being those which have grown up naturally and which are open to the public. In some States, where there are many leased or privately owned beds, this surveying is very carefully attended to, and accurate maps of the oyster beds are provided. In others, especially those in which there are few or no leased beds, the surveys are poorly cared for, and no maps are kept.

The legal season in which oysters may be taken for market is usually restricted to the months of September to April, inclusive. The oyster is thus not interfered with during the spawning season, which occurs in the summer.

A cull law is usually provided by which oysters under a certain size—2½ or 3 inches generally—may not be taken except for seed, but must be thrown back on the beds from which lifted. Some States allow only sailboats and hand dredges to work on natural beds, as in Long Island Sound; some forbid dredging of any sort, all oysters being taken with tongs; some allow dredging only on leased beds; some, only in water of a certain depth; and some allow engine-driven dredges to be used on boats propelled by sails.

In most States only a legal resident may take oysters from the waters, and a license fee must usually be paid. In some cases oysters can not be shipped from the State in the shell, except for seed. This compels the establishment of oyster houses within the State and the retention of capital in that State. In others, as Louisiana, the oysters may be shipped out in the shell, but a tax per bushel must be

paid to the State by the shipper. Some States require no license fee, but the dealer pays a tax per bushel or gallon for oysters sold. This nominally throws the tax on the dealer instead of the oysterman.

Most States make provision for leasing bottoms for the cultivation of oysters at a small rental, \$0.25 to \$1 or \$2 per acre, for a term of years, the number of acres per person being limited. Provision is usually made that the natural beds may not be leased, but must be left open to the public. In some of the southern States there is very little interest in leasing beds, there being sufficient oysters found on the natural beds. In such States there is little or no planting done, except a limited amount by the State in the effort to build up certain natural beds.

The health authorities of most of the States provide certain regulations requiring that oyster beds be located at safe distances from sources of contamination, such as sewers, etc., and that oysters must pass certain rigid inspection tests for bacterial content before being placed on the market. The Federal Government also inspects oysters which enter into interstate commerce.

There are many other minor regulations peculiar to the different States and growing out of special conditions prevailing in each. The details of these may be secured from the State shellfish commissions of the various States.

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