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A TECHNOLOGICAL STUDY OF THE OCEAN QUAHOG FISHERY

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ABSTRACT

The ocean quahog (Arctica islandica) offers an excellent source of food and the industry developed around this mollusk during the recent war appears to be sufficiently stabilized to make it an integral part of the Atlantic Coast fisheries. The technological aspects of the ocean quahog are discussed in this report. This includes methods of catching, processing and marketing, along with certain economic considerations.

The sanitation problems of the industry have been carefully investigated. The bacteriological data are presented in detail in order to indicate the major sources of difficulty. It was found that methods of storage, lack of adequate refrigeration and certain plant practices were responsible for most of the losses in sanitary quality which have been reported. Methods for eliminating these difficulties are indicated at the end of the report.

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The presence of the ocean quahog, Arctica islandica, in the waters of Rhode Island and adjacent areas has been known for some time. It was not until May 1943, however, that this shellfish was exploited as a food resource. At that time, under the impetus of the war food program, commercial utilization of this clam was initiated. Although a newcomer in the shellfish field, it has already established itself commercially and it may continue to be found in the market for years to come. Because of its abundance, large size, and fine flavor, it has found a ready acceptance among processors of chowders and related shellfish products. On the other hand, its texture limits its possibilities to this restricted field.

In order that the industry which was developing around this shellfish might produce a safe, wholesome product, the U. S. Fish and Wildlife Service in cooperation with the State of Rhode Island, from October 1943 to November 1944, undertook an investigation which included technological and bacteriological studies. From the results, it has been possible to indicate the sources of potential difficulties and to permit the industry to produce a first-class product.

The technical findings of the ocean quahog investigation are presented in this report. A previous publication by the Rhode Island Division of Fish and Game, (1945) presents, in a more popular form, a survey of the industry based on the findings of the same investigation.

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PART I

The ocean quahog[1]/ belongs to the family Pleurophoridae (Pratt, 1935) which includes all bivalves with the mantle lobes united posteriorly by a curtain pierced with two siphonal orifices. All of the species in this group have a foot which is thick and tongue-shaped. There are two large unequal gills on each side which are united behind, forming a complete partition (Tryon, 1873).

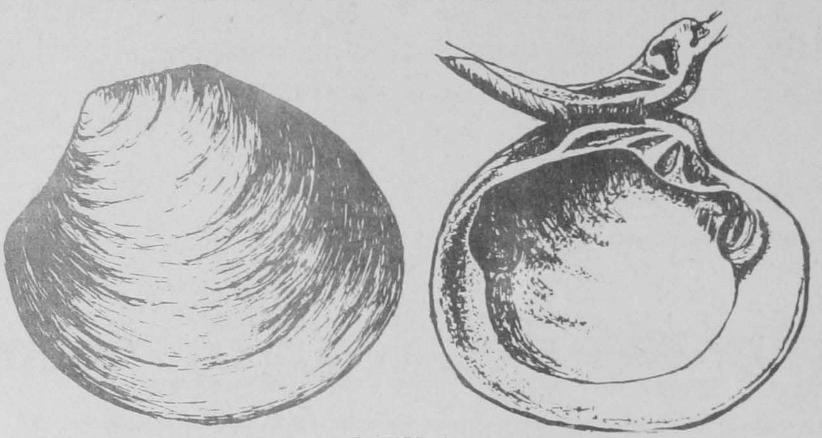


FIGURE I

The distinguishing anatomical features of Arctica islandica have been described by Adams and Adams (1858) and Tryon (1873). The shellfish has a large, thick, ponderous shell with incurved, contiguous, prominent beaks. Tryon gives the average dimensions of the shell as 3.3 inches in length and 2.8 inches in width. The shell is covered with a coarse, wrinkled epidermis which is black but shades into an olive-brown towards the margin (Fig. 1 and 1A). The umbo occupies a central position, and the hinge contains three

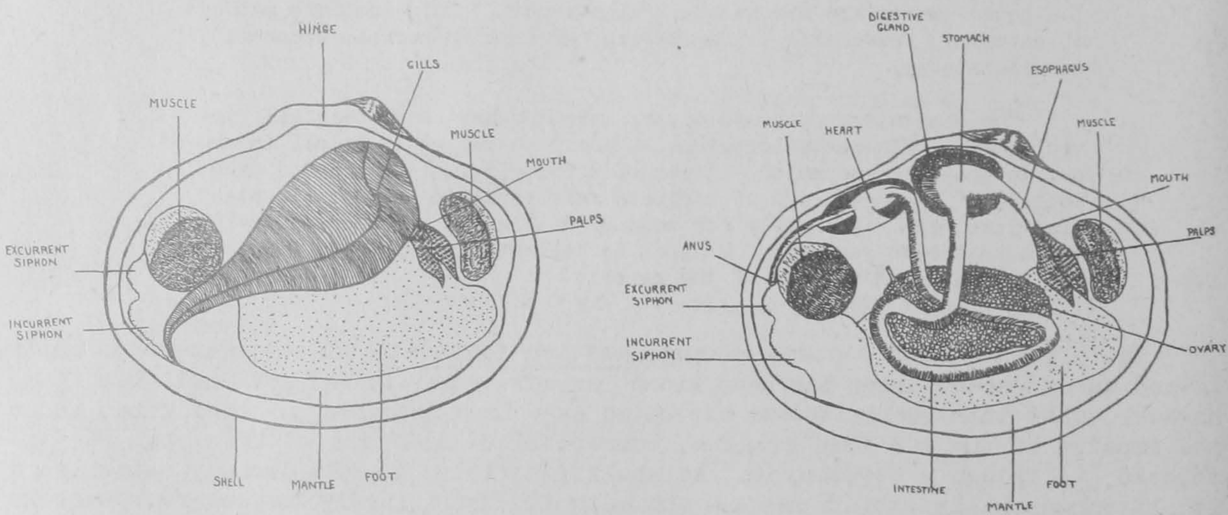


FIGURE IA

diverging cardinal teeth. There is also one posterior tooth in each valve. The mantle is open in front and beneath, but is united behind by a curtain. The siphons are short and compressed with ciliated orifices. The anal orifice is narrow and conical with short cilia crowning the apex. The gills are large and quadrangular, unequal in size and are united posteriorly. The foot is thick and linguiform.

Although originally believed to be a strictly European species (Adams and Adams, 1858) it is now known that the ocean quahog is widely distributed in the

1/Common name accepted by the U. S. Food and Drug Administration, 1944. Letter to the Chief of the Division of Commercial Fisheries authorizing the use of the name "ocean quahog."

waters of the North Atlantic. It has been reported from the Scandinavian coast, Greenland, and North America. In general, it has been found to inhabit the muddy bottoms of the colder areas of the Atlantic Ocean, but the north-south limits of its distribution have not yet been determined.

Commercial fishing operations have been limited thus far to the off-shore waters of Rhode Island and southern Massachusetts (Fig. 2). The Rhode Island State College and commercial interests have located several areas which are of

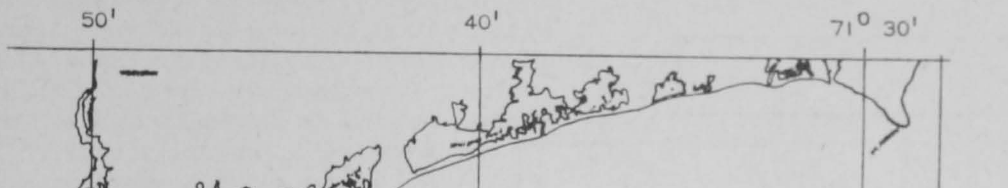


FIGURE 2

commercial importance. Originally, only two areas were fished, one of approximately $8\frac{1}{4}$ million square yards, located three miles southwest of Point Judith, and another of about $4\frac{1}{2}$ million square yards, southeast of the Point Judith Whistling Buoy. These beds are found at depths ranging from 80 to 120 feet. During 1943, these two beds yielded about 50,000 bushels of ocean quahogs and can still yield catches of commercial importance. However, the dredging operations have left considerable shell debris and so these beds are not being used extensively at present. Since January 1944, new areas of commercial significance have been located near Newport, Sakonnet Light, Vineyard Light, and Block Island. An extensive bed has been located between Gay Head and Cutty Hunk Island.

The Rhode Island State College has made surveys of several potential production areas using a reconstructed quahog dredge of two bushels capacity. The data analyzed by type of bottom are indicated graphically in Figure 3 (see p. 4). The smallest average yields were obtained on stony or rocky and hard sand bottoms, the average catches being 6 and 5 specimens, respectively, for a 4-minute dredge. Loose sand, sand and mud, and clay and mud bottoms gave average yields of 16, 31, and 27 quahogs for the same length of time. The highest average yield was obtained on "sticky" mud bottoms where 41 specimens were caught on a 4-minute drag.

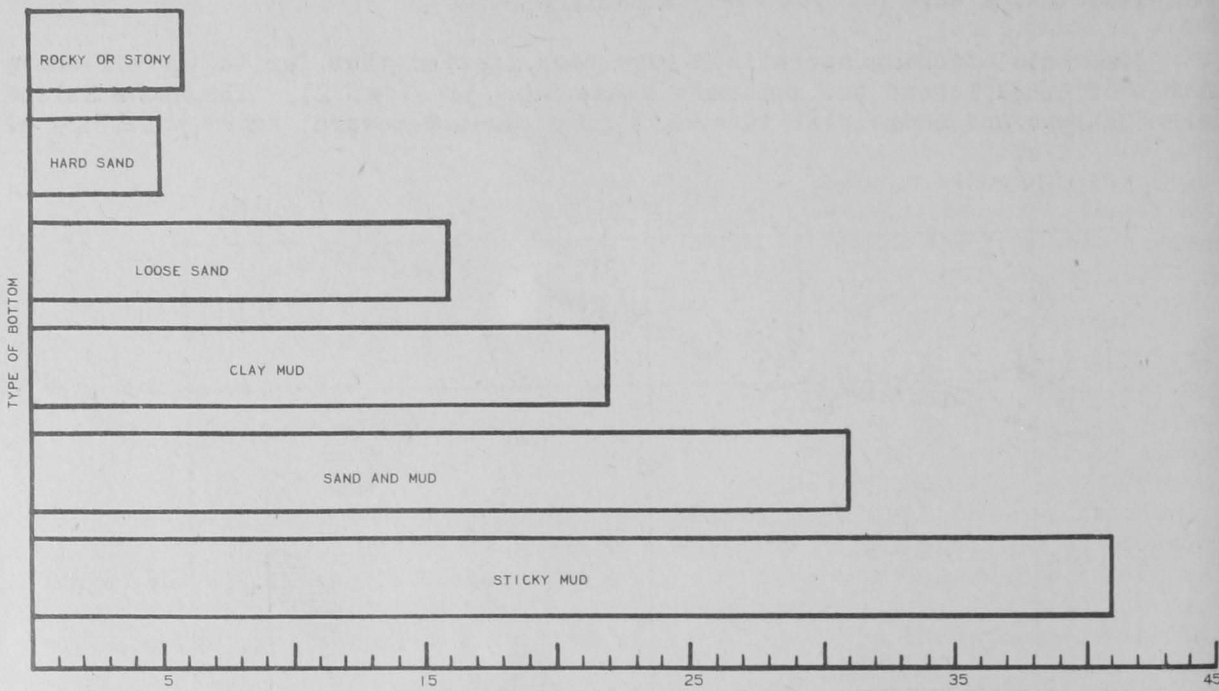


FIGURE 3 - AVERAGE NUMBER OF QUAHOGS CAUGHT IN 4 MINUTES OF DREDGING

In Figure 4, the same data are indicated in relation to the water depth. Very few specimens were caught in waters less than 80 feet in depth, the average hauls

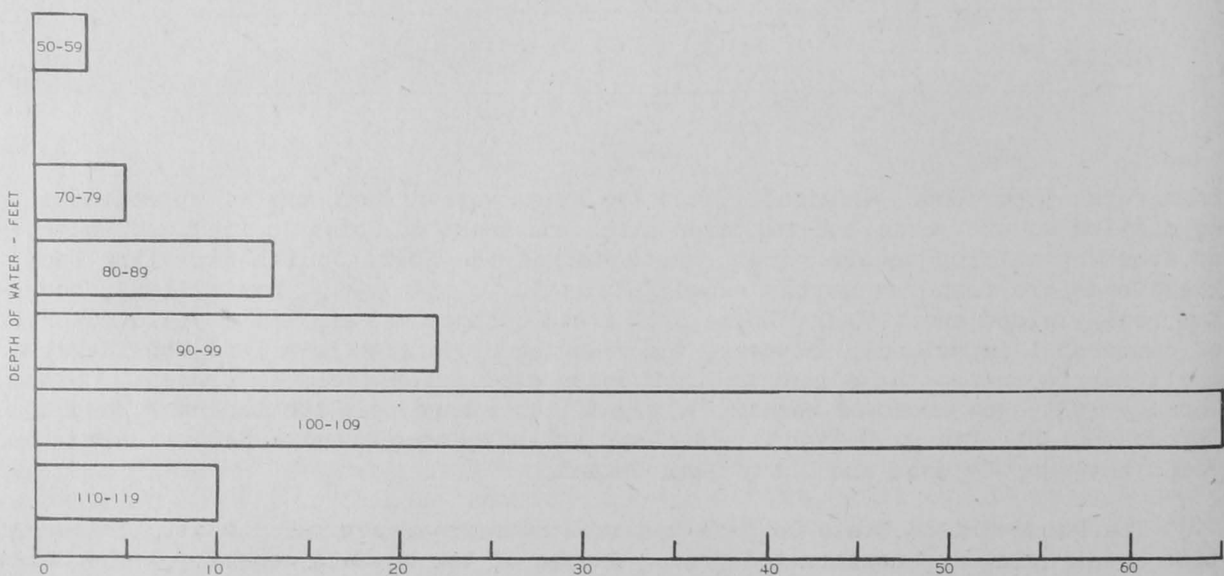


FIGURE 4 - AVERAGE NUMBER OF QUAHOGS CAUGHT IN 4 MINUTES OF DREDGING

being 3 per 50-60 feet of water and 5 per 70-80 feet. Between depths of 80 and 90 feet, an average of 13 specimens was taken and an average of 22 was obtained in 90-100 feet. The largest haul was made between 100-110 feet, the average number of specimens being 65. Beyond this depth, the average dropped to 10 quahogs (110-120 feet) per 4-minute drag of the dredge.

Dredging for ocean quahogs is similar to the power dredging of the bay quahog as practiced in the inshore waters of Rhode Island and Massachusetts. The only difference is that the ocean quahog is taken in 80-120 feet of water instead of 18-30 feet. The boats used are regular fishing vessels of the dragger type (Fig. 5), being 40-50 feet long. A few 60-65-foot oyster boats also have been converted for ocean quahog operations. The boats are powered with gasoline or Diesel engines of 40 or more horsepower. The strain put on the vessel by dredging is severe and the masts have to be sound and well stayed. The smaller boats are usually manned by a captain and a crew of two men. The larger boats usually have a crew of three in addition to the captain.

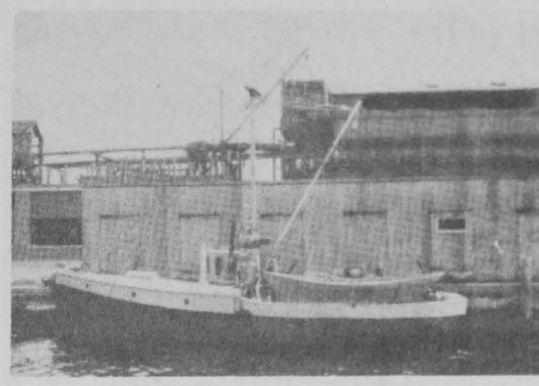
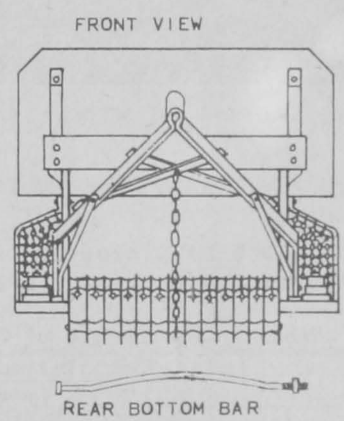


FIGURE 5 - TYPICAL OCEAN QUAHOG DREDGER

The dredges used are of the Nantucket type and are known as "rocking-chair" or "queer" dredges. In operation, they act as a multi-toothed plow which digs through the bottom and scoops the animals into an attached chain bag. These are custom-built and cost from $100 for a 12-toothed dredge to $130 for a 20-toothed instrument, complete with chain bag. The teeth are 7 inches long and are spaced 1½-2 inches apart. The bottom of the dredge has two channels which are weighted with about 100 pounds of lead. The bag, made of steel



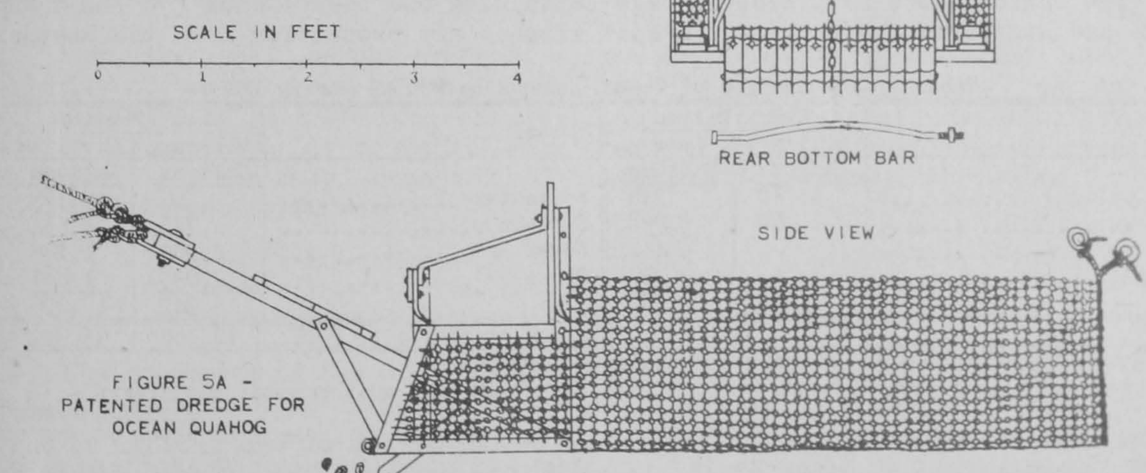


FIGURE 5A - PATENTED DREDGE FOR OCEAN QUAHOG

rings, 2 inches in diameter, is attached to the dredge and is equipped with a purse-string arrangement (Fig. 5A).

The dredge is operated from a power winch driven by the boat engine. The winch has a single cable drum equipped with either a hand or foot brake. The drum houses 50 fathoms of 7/16-inch cable which is used for raising and lowering the dredge. The cable is fed from the drum through a block secured to the mast. It then runs through another block on the boom and thence to the towing arm of the dredge. The dredge is towed by a rope attached to the towing arm and fastened to the Sampson post of the boat.

FIGURE 5B - LOWERING THE DREDGE

In operation, the dredge is lowered over the side and dropped to the bottom. It is then towed for 15 minutes. At the end of this time, it is raised and the mud removed by rinsing the loaded dredge in the water several times. The dredge is then lowered on the deck and the catch is dumped by releasing the purse string. The dredging is repeated while the catch is being culled and bagged (Fig. 5B).

Since these quahogs are found outside of the 3-mile limit, the State statutes regarding inshore dredging do not apply and so the length of the season and size of catch are not legally restricted. Because of poor weather, however, the actual dredging time is limited to an average of about 17 days per month. The annual average catch per boat is about 71 bushels per day. The monthly and daily records of the dredging operations are shown in Tables 1 and 2.

The culled catch is placed in bags containing one bushel each (90 lbs.) and these are stored on the deck of the boat without any protection from the weather

Table 1 - Production of Ocean Quahogs by Months During 1943

Month	Distribution		Month	Distribution	
	Military	Civilian		Military	Civilian
	Gallons	Gallons		Gallons	Gallons
May	1,238	248	September	60	9,329
June	80	5,798	October	1,745	4,534
July	-	8,441	November	4,204	1,275
August	-	3,810	December	7,033	1,887
	1,318	18,297		13,042	17,025
			Grand total	14,360*	35,322**

*Frozen in 1 gallon metal containers containing 8 pounds.
**Frozen in 5-pound paper cartons - 5,625 gallons; fresh in 1 gallon metal containers - 29,697 gallons.

and without refrigeration. The bags are stacked on top of one another so that there is little opportunity for air to circulate between them. Upon arrival at the dock, the bagged catch is transferred to a closed truck. No refrigeration is employed[2] and in warm weather this operation is equivalent to placing the quahogs in an incubator. The period of truck transportation varies with the distance to the plant. Occasionally, the catch is kept in the truck for as long as 2 or 3

2/Since this paper was written, one of the leading producers has started using refrigerated trucks for hauling.

days. The quahogs are without refrigeration throughout this time and no ventilation is provided. Because of this, many specimens have to be discarded when the bags are finally opened.

Table 2 - Data on Daily Dredging Operations by Months During 1943 and 1944

Month	Days Fishing	Average Boats Per Day	C A T C H		
			Average		Total
			Per Day	Per Boat	
1943	Number	Number	Bushels	Bushels	Bushels
June	16	4	273	77	4,385
July	16	5	300	58	4,809
August	18	6	371	66	6,681
September	14	6	391	70	5,487
October	18	3	254	75	4,576
November	18	4	258	70	4,659
December	23	4	382	81	8,804
1944					
January	20	4	568	189	11,359
February	19	3	291	102	5,643

Storage at the processing plants may not be much better than that on the vessel or truck. The bags are frequently piled on the floor of the warm or heated shucking house and are kept without ventilation or refrigeration until shucked.

The shucking operations are very similar to those employed with other shellfish. The shuckers supply themselves with shellstock by carrying a bag over to the bench. The quahogs are dumped out and are washed free of mud and detritus with running water. The meats are shucked into gallon containers. In some plants, the shell liquor is saved, but this is not common practice. (A 90-pound bushel of ocean quahogs yields about 1½ gallons of drained meats, or about 12 pounds.)

The shucked meats are delivered to a packing room where they are dumped onto a perforated metal platform and washed with fresh water before being packaged. After packaging, they are refrigerated.

Very few ocean quahogs are sold as shellstock (1,043 bushels in 1943). The majority of the catch is sold as either fresh or frozen meats. The fresh quahogs are usually sold in 1-gallon, single-service, or returnable metal containers. Gallon packages usually contain 8 pounds of meats. The frozen stock is packaged in either 1-gallon metal cans or in 5-pound paper packages. The sales for 1943 of the different types were:

Fresh - 1-gallon containers - 15,687 gallons
Frozen - 1-gallon containers - 36,360 gallons
Frozen - 5-pound paper cartons - 5,625 gallons or 45,000 pounds

The economics of the ocean quahog industry, at the time this report was written, are summarized in Table 3. The catch of the smaller boats (40-50 feet) averages between 100 and 150 bushels per day of actual dredging; that of the larger boats averages between 200 and 250 bushels. The price per 90-pound bushel varied between $1.00 and $1.40 with an average, in 1943, of $1.25. A bushel of shellstock yields 1½ gallons of meats and the cost of shucking is 35 cents per gallon. An average shucker can produce an average of 32 gallons per day. The price of the final product, whether fresh or frozen, has varied from $3.00 per gallon in 1943 to a price of $1.75-$1.85 to large consumers and $2.50 per gallon to small consumers. The number of processors has varied but only two have succeeded in maintaining high production. Ocean quahog production is seasonal for two reasons.

Generally speaking, the best weather for dredging occurs during the summer months and secondly, at this time the oyster shuckers are available to the ocean quahog industry.

Table 3 - Commercial Statistics on Ocean Quahog Industry 1943-44

Average number of fishing days per month	17
Average number of boats fishing each month	4
Average catch per boat per day of fishing	71 bushels
Weight of one bushel of shellstock	90 pounds
Weight of one gallon of shucked meats	8 pounds
Average yield of meats per bushel of shellstock	1½ gallons or 12 pounds
Average cost of shellstock per bushel	$1.25
Average cost of shucking per gallon of meat	$0.35
Average selling price per gallon of meat	$1.85-$2.50
Average number of gallons shucked per worker per day	32

Chemical analysis (Lee, 1944--see Table 4) and feeding tests (Darling, 1944--see Table 5) indicate that the ocean quahog is nutritious. On a dry weight basis, it is higher in protein and ash than the bay quahog but lower in glycogen. Its

Table 4 - Proximate Analysis of Ocean Quahogs1/

Condition	Water	Protein (Nx6.25)	Fat (Petroleum ether extract)	Ash	Difference from 100
	Percent	Percent	Percent	Percent	Percent
Simmered	75.2	18.20	0.26	2.17	4.17
Fresh shucked	82.0	-	-	-	-
Dry basis	-	83.4	1.09	8.73	16.8

1/Analysis made by Charles F. Lee, Chemist, Fishery Technological Laboratory, Division of Commercial Fisheries, College Park, Maryland.

riboflavin content was 266 micrograms per 100 grams of ocean quahog meat. In feeding tests using young rats, a comparison of the proteins of ocean quahogs and beef was made at levels of 11 and 12.5 percent, respectively. The proteins were of equal growth-promoting value. Thus, it can be seen that this shellfish offers a wholesome, nutritious source of food.

Table 5 - Average Gain in Live Weight of White Rats and Protein Intake Per Group for an Eight-Week Period1/

Source of Protein	Number of Rats	Av. Gain in live weight	Coefficient of Variation	Average Protein Intake	Standard Error
		Grams	Percent	Grams	Grams
Ocean Quahogs	10	117.3	12.5	55.6	0.12
Beef	4	115.3	9.9	55.3	0.19

1/Data from report by Dorothy B. Darling, formerly Pharmacologist with the Fishery Technological Laboratory, Division of Commercial Fisheries, College Park, Maryland.

There is no reason why the ocean quahog should not be one of the finest shellfish obtainable. Its habitat is clean, deep ocean water and with proper handling it can be made an important addition to the group of edible shellfish. In the section of this report which follows, detailed information is given to indicate the current pitfalls in the methods of handling which detract from its wholesomeness. By eliminating these basic difficulties in the industry, the ocean quahog can be made one of the safest and most wholesome forms of seafood.

PART II

The major difficulty in the ocean quahog industry, as now practiced, is the production of a commodity which can meet the bacteriological standards established for shellfish by the U. S. Public Health Service (1946). The presence of coliform bacteria in commercial packs of ocean quahogs had been reported by the Rhode Island State Health Department and excessively high bacterial counts had been obtained. When consideration was given to the environment of the shellfish, it seemed unreasonable to believe that any coliform bacteria found in the waters or mud from which the ocean quahogs were being taken could have any sanitary significance. It was equally doubtful if any such organisms present in the animal at the time of removal from the sea could be construed as evidence of domestic sewage pollution. For these reasons, a bacteriological investigation was initiated to determine the sources and types of coliform bacteria and to locate the place in handling and processing where large numbers of bacteria were introduced.

The initial investigations began in December 1943. Sampling stations were established in each of three production areas which were then being worked by the dredgers. A station was established at the approximate center of each bed and four satellite stations radiating due north, east, south, and west were established at a distance of one-half mile from the center. These satellite stations were generally located at the approximate edges of the beds. However, in the case of Bed No. 2, the north and south stations had to be established one mile distant from the center in order to be on the periphery of the production area. By this arrangement of five stations at each bed, it was possible to detect any pollution which might be tide or current-borne. Since these areas were located in ocean shipping lanes, it was impossible to use buoys to mark exact locations. Land ranges, compass bearing, and running time were used to locate the stations on sampling trips.

The locations of the sampling stations are given below and are shown on the accompanying map (see Fig. 6, p. 10). (U. S. Coast and Geodetic Chart #1210, Jan. 1944.)

Bed No. 1: This was designated as the Newport Grounds station. The center of the bed (Station No. 1) was located 1.5 miles SW. by S. $\frac{3}{4}$ S. from Brenton Lightship. The satellite stations were each located 0.5 mile from the central one. The water depths ranged from 97 to 102 feet.

Bed No. 2: This bed was SSE. of Point Judith Whistling Buoy. The center of the bed (Station No. 2) was located 2-1/8 miles SSE. of Point Judith Whistling Buoy. Station No. 2a was one mile due north, and Station No. 2b, one mile due south of the central station. The other two satellite stations were 0.5 mile from the central station. The water depths ranged from 80 to 117 feet.

Bed No. 3: This bed was SW. by S. of the west entrance of the Point Judith Breakwater. The center of the bed (Station No. 3) was 3 miles SW. by W. from the west entrance of Point Judith Breakwater. The satellite stations were each located 0.5 mile from the central station. The water depths ranged from 80 to 120 feet.

Two types of investigations were made. The first dealt with the bacteriology of water, mud, quahogs, etc., as separate materials. The results of this work indicated that process studies would be desirable. These were made by making bacteriological tests of the water, mud, and quahogs from the same area and then testing samples of the catch throughout the handling and processing to the final

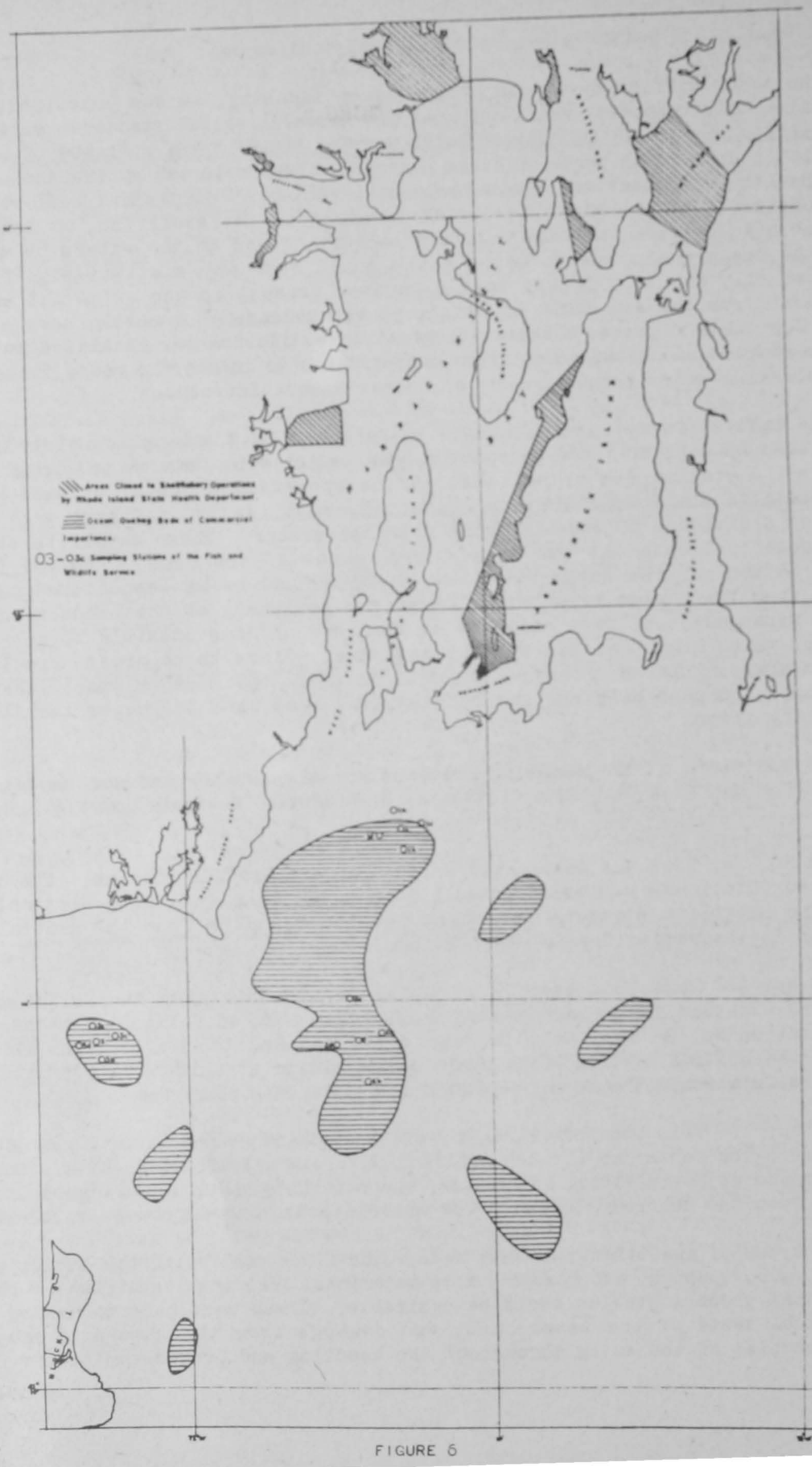

Areas Closed to Shellfishery Operations by Rhode Island State Health Department
Ocean Quahog Beds of Commercial Importance
O3 - O3c Sampling Stations of the Fish and Wildlife Service

FIGURE 6

consumer product. In all of the work, pertinent, supplementary field data were obtained, such as air and water temperatures, state of tides, etc.

Surface and bottom water samples were collected with a suitable sampling device. Mud samples were obtained from the dredges. Except in the case of the process samples, where separate lots of quahogs were earmarked, quahogs were taken at random from the catch as it was dumped on the deck of the vessel.

Throughout the study, methods given in Standard Methods for the Bacteriological Examination of Shellfish (1944) were employed. Presumptive tests for coliform bacteria were made with lactose broth and these were confirmed with brilliant green lactose bile broth and eosin-methylene blue agar. The plate counts were made with tryptone-glucose agar. Isolates were made from the eosin-methylene blue agar and sent to the Fish and Wildlife Service Laboratory at College Park, Md., for taxonomic studies.

If the presence of coliform bacteria in ocean quahogs represents pollution at the source of the shellfish catch, then the waters of the area should also contain these micro-organisms. This should be particularly true in the case of the bottom water in which the quahog feeds. High total bacterial counts in the ocean quahog might also have their origin in the surrounding waters. One might also expect that the bacterial content of the waters might alter appreciably with the

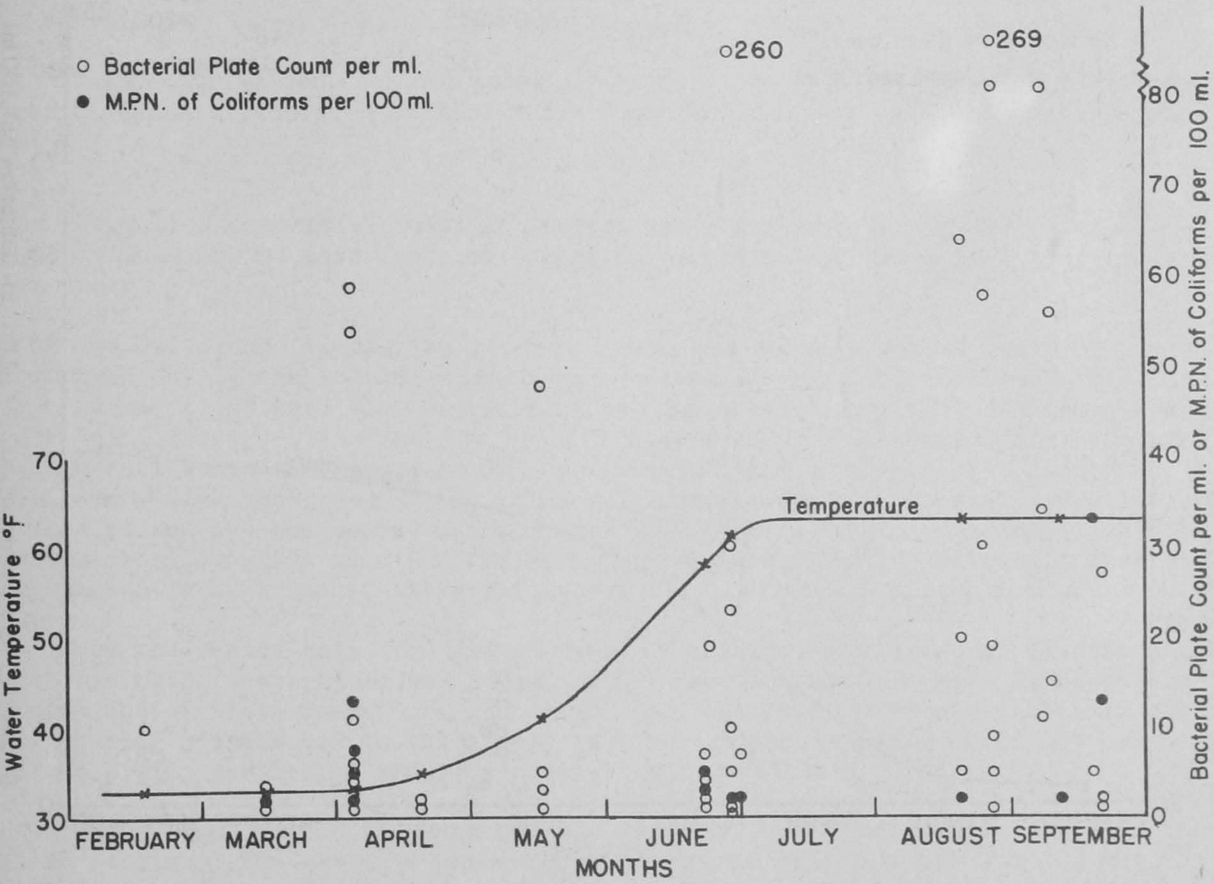


FIGURE 7 - DISTRIBUTION OF STANDARD PLATE COUNTS AND MOST PROBABLE NUMBER OF COLIFORM BACTERIA OF BOTTOM WATER SAMPLES

temperature of the water, higher counts and coliform scores being obtained during the warmer weather. It was necessary, therefore, to make quantitative bacteriological studies of the waters at each station in order to determine the role of the natural environment in regard to the findings with the ocean quahog per se.

In all, 53 samples of bottom water from all three stations were examined during the period of sampling (February through September). The water temperature varied from 35.9° to 63° F. The distribution of the standard plate counts and the coliform scores in relation to the water temperature are shown in Fig. 7, (see p. 11). The average bacterial count per ml. for each respective month was as follows:

February - 2   April - 6.72   May - 10   June - 6.29   August - 55.6   September - 28.4

The average bacterial count per ml. for each station was:

No. 1 - 7.0   No. 2 - 28.0   No. 3 - 50.0

The average Most Probable Number of coliform bacteria per 100 ml. for each month was:

February - 4.7   April - 0   May - 0   June - 7.0   August - 0   September - 0

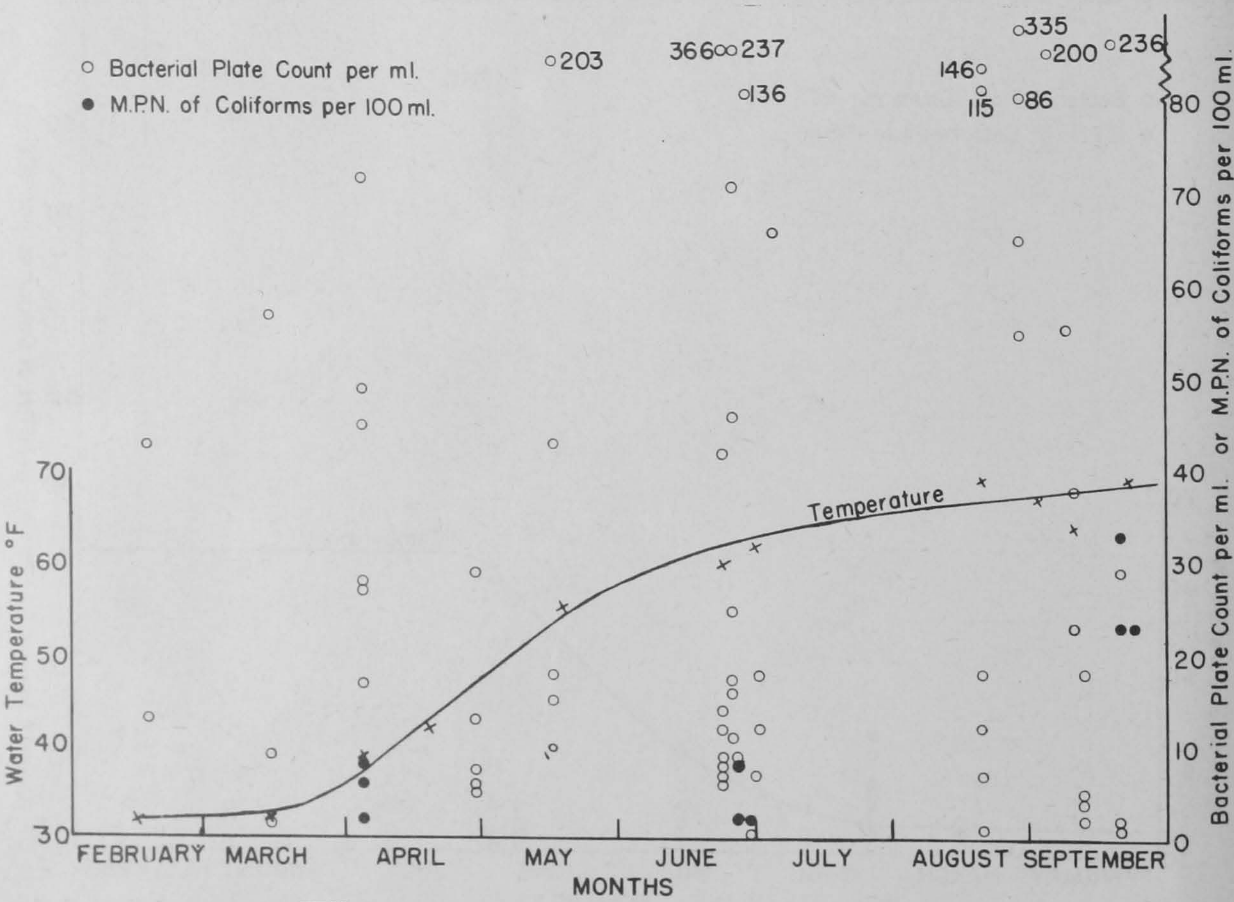


FIGURE 8 - DISTRIBUTION OF STANDARD PLATE COUNTS AND MOST PROBABLE NUMBER OF COLIFORM BACTERIA OF SURFACE WATER SAMPLES

The percent of samples positive for coliform bacteria for each station was:

No. 1 - 38 No. 2 - 5 No. 3 - 6

In the case of Station No. 1, the coliforms were found throughout the sampling period; at the other two stations they occurred only during July.

The bacterial counts on 53 samples of surface waters showed wider variations than those of bottom waters (Fig. 8, see p. 12). The average bacterial plate count per ml. for each respective month was as follows:

February - 28 April - 27 May - 58 June - 61 August - 20 September - 78

In general, these averages are consistently higher than those for bottom water samples. The average bacterial count per ml. for each station was:

No. 1 - 45.8 No. 2 - 64.8 No. 3 - 28.3

In the case of the first two stations, these average counts are considerably higher than in the case of bottom water counts from the same areas.

The average Most Probable Number of coliform bacteria per 100 ml. by month was:

February - 0 April - 2.1 May - 0 June - 2.5 August - 0.2 September - 0.3

This distribution does not parallel the findings with bottom water. The percent of samples from each station which were positive for coliform bacteria was:

No. 1 - 39 No. 2 - 17 No. 3 - 12.5

Most of the positive tests at Station No. 1 occurred during April; the other two stations showed this group of organisms sporadically during June, August, and September.

The difference in results between bottom and surface waters can probably be accounted for by the location of the production areas. All three were situated in main shipping lanes and in addition to the normal ship traffic, these areas were being traversed continually by mine sweepers. The discharge of refuse and sewage from boats and the continual churning of the water probably maintained a relatively high bacterial flora which was diminished by dispersal and dilution before it reached the depths at which the quahogs were taken. Possibly, the high values obtained which made for the wide fluctuations shown in the result were due to samples taken in zones where refuse recently had been dumped overboard.

Mud was tested only for the presence of coliform bacteria, no quantitative bacteriological determinations being made. Fourteen samples were examined over the period of field operations. Of these, only one gave evidence of coliform bacteria being present and in this instance, the presumptive test could not be confirmed. This particular sample was obtained from Station No. 3.

Thirty-two samples of ocean quahogs were collected during the course of the field studies. The average bacterial plate count of the meats was 322 per ml. This is about 12 times as high as the average for the bottom water which was 28 per ml. The plate count average by months was as follows:

February - 165 April - 35 May - 1,214 June - 45 August - 506 September - 371

The average plate counts for each station were distributed as follows:

No. 1 - 125 per ml. No. 2 - 438 per ml. No. 3 - 39 per ml.

The counts varied from a low of 6 per ml. in one sample taken at Station No. 1 in February, to a high of 3,530 per ml. in a single sample taken at Station No. 2 in May.

The Most Probable Number of coliform bacteria per 100 ml. averaged 74 for all samples but only 5 out of the 32 samples yielded positive tests for these organisms. The average Most Probable Number by months was as follows:

February - 22 April - 0 June - 4 August - 303 September - 0

The high score for August was due to a single sample having a Most Probable Number of 2,400 per 100 ml. The average for each respective station was:

No. 1 - 17 No. 2 - 0 No. 3 - 240

Four samples from Station No. 1 were coliform positive; one was positive from No. 3; and none of the samples from No. 2 showed the presence of this organism. The high average Most Probable Number value for Station No. 3 was due to the same high-score sample responsible for the August average.

The average Most Probable Number of coliform bacteria in ocean quahogs was exactly 100 times greater than that of the bottom water which was 0.74 per 100 ml. The percent of ocean quahog samples which were positive for coliform were in agreement with what was found in bottom water, the percent of positives being 16 for the former and 17 for the latter. There was no agreement, however, between the distributions by months or stations. The results probably indicate what the expected frequency of coliform bacteria may be in production areas.

The higher bacterial plate counts and Most Probable Number of coliform bacteria in the shellfish is an expected finding since the ocean quahog undoubtedly concentrates micro-organisms within itself by filtering them out of large quantities of sea water. The data indicate that the bacterial content of the quahog is about 10 to 12 times that of the surrounding water. Should this ratio prove to be correct over a period of several years in various types of producing waters, it would be possible to evaluate the bacterial quality of the shellfish on the basis of data obtained on bottom water samples alone.

From January through September, quantitative tests were run on shellstock taken from the shucking houses. The specimens were treated in exactly the same manner as those taken in the field. In all, 42 composite samples were examined. Of these, 7 had a bacterial content so high that the plates could not be counted, and the plates had to be discarded because of an excessive number of spreading colonies. The average standard plate count of the remaining 34 samples was 3,140,460 bacteria per ml. of quahog meat. This is almost 10,000 times greater than the average value per shellfish taken directly from the water.

The average Most Probable Number of coliform bacteria for the 42 samples was 3,669 per 100 ml. This is over 400 times the average Most Probable Number per 100 ml. for the freshly-caught shellstock. The percent of samples yielding positive tests for coliform bacteria was 40.5, which is over twice the value for the field samples.

There was no correlation between the magnitude of the plate counts or coliform scores and the season of the year, the original source or the shucking plant from which the specimens were taken. The data indicated that either methods of handling or a period of incubation was increasing the bacterial content of the shellstock. Another possibility was that the ocean quahogs were being grossly contaminated from some external source. Whatever the cause, however, it was apparent that from a bacteriological viewpoint, the shellstock was usually of very poor quality by the time it reached the shucker.

Bacteriological determinations on 30 samples of shucked ocean quahog meats examined over the same period of time and from the same plants as the shellstock showed a further increase in both the standard plate count and the coliform content. The plate count increased about one-third over that of the shellstock in the plant, the value for the average being 124,751 per ml. Whereas, only 40.5 percent of the unshucked quahogs in the plants contained coliform bacteria, 83.3 percent of the shucked samples yielded positive tests for this group of bacteria. The average Most Probable Number of coliform in the shucked stock was 7,191 per 100 ml. This is roughly twice as many as were found in the unshucked specimens.

During April 1944, one plant began saving the liquor from the ocean quahogs by shucking into collanders which were placed in pans to catch the juice. Recovered liquor was strained through cheesecloth into a storage tank and after settling, all but the lower few inches was decanted into suitable containers and frozen. This made it possible to obtain bacteriological data on the fresh shell liquor. The average standard plate count for 18 samples was 16,404 bacteria per ml. and the average Most Probable Number of coliform bacteria was 2,174 per 100 ml. Forty-four percent of the samples gave positive tests for this group of organisms.

In considering the possible sources of coliform bacteria which might be responsible for the post-catch contamination, the most obvious source appeared to be the bags in which the shellfish are stored. These were being re-used without being cleaned. The wet bags were dumped in large piles on the floor of the shucking house where they remained for a day or more. When a sufficient number accumulated, the bags were hung out on lines or were spread over shell piles or on the ground where they became contaminated with sea gull droppings. The bags are 18 inches wide and 34 inches long and each bag contained an average of 696,968 coliform bacteria. Ordinary washing failed to reduce this number appreciably but 5 thorough washings with soap and hot water and equally thorough rinsing in clean hot water reduced the average coliform content to 29,364 per bag.

Treatment of the washed, clean bags with a solution containing 100 p.p.m. of free chlorine for 10 minutes failed to eliminate these bacteria. By subjecting the clean bags to live steam for 10 minutes, it was possible to rid them completely of coliform bacteria. This could also be accomplished by commercial laundry practice which was found to be the most satisfactory and least costly method. The elimination of coliform bacteria from cotton or jute fibers is difficult and unless great care is taken to keep the bags clean, and properly sterilized, they offer a serious menace to the bacteriological quality of the shellfish.

A second source of contamination was bilge water. The water from the holds of the ocean quahog dredgers was usually pumped out on the dock where it was permitted to run over the shellstock stored thereon. This bilge water contained on the average of about 16,000 coliform bacteria per 100 ml. The practice of permitting this grossly contaminated water to contact the shellstock can easily be eliminated by the use of overboard bilge pumps.

During and immediately following a spell of extremely hot weather in August, a series of "process" samples were examined bacteriologically. The temperature of the bottom water at this time varied from 51° to 63° F. This period represented a time when one would expect maximum coliform scores and plate counts in field samples. Since the samples were homologous; i.e., taken at the same time from the same source in each sampling series, it was also possible to evaluate bacteriologically, the influence of handling, transportation, and processing.

The technic employed was as follows. A specimen of mud was taken from the dredge at the time of the first haul. Samples of surface and bottom waters were taken before dredging began, after the sixth dredge haul, and after the last haul. Samples of ocean quahogs were taken from the first and last hauls of the dredge, upon arrival at the dock, upon arrival at the shop, after overnight storage at the shop, immediately after shucking, and at the time of packing. Field samples were adequately refrigerated until examined in the laboratory. Specimens from the shop were taken directly to the laboratory and the bacteriological tests were begun immediately. Every effort was made to get the laboratory tests accomplished as soon as possible in order to obtain data which would be representative of the specimens.

The bacteriological findings are summarized in Table 6 (see p. 17). The data indicate that even under conditions of expected high bacterial counts, the mud, water, and ocean quahogs initially are of good sanitary quality. It is not until the shellstock has been out of water for some time that the bacterial count of the ocean quahog increases. From the time of arrival at the dock until the final product is ready for packing, the bacterial content, including the coliforms, increases. In some instances, there was a slight decrease in plate counts after the meats had been washed, but the coliform content usually remained high. One sample of ocean quahogs failed to give any indication of coliform bacteria throughout the entire transportation-processing period, although the plate counts showed some increase.

From these data, it is evident that the bacteriological difficulties originate at the time the ocean quahogs are first stored on the deck of the vessel in bags. From this point on, the problem is aggravated by the methods of transportation and processing. Modifications in the present handling technics are necessary if the excellent quality of the shellstock as it comes from the water is to be maintained until the final product reaches the consumer.

In order to determine the predominant types of coliform bacteria present in each phase of sampling, 223 isolates from confirmatory media were studied taxonomically. Detailed taxonomy was not done but the cultures were classified into 5 types with the idea of designating the probability of their ultimate source, the assumption being made that typical Escherichia members and related form were of fecal origin and that the typical Aerobacter members and related types were of soil, plant, or water origin. Such designations are purely arbitrary and may have no real significance in this particular case.

The coliform group and each of its 5 types were defined as follows: Coliform Group: This included only asporogenuous, Gram negative, aerobic rods which fermented lactose aerogenically within 48 hours.

Type I: All organisms of this type were characteristic Escherichia members. Acetylmethylcarbinol was not produced from dextrose. Citrate was not utilized as a sole source of carbon and cellobiose and alphamethylglucoside were not fermented. Hydrogen sulfide was not formed. Indole was produced. Organisms showing these characteristics were considered to be typical of the fecal coliform bacteria.

Table 6 - Bacteriological Data Obtained on Process Samples

Type of Sample	Time of Sampling	I Aug. 20-21 M.P.N. Coliform per 100 ml.	I Aug. 20-21 Standard plate count per ml.	II Aug. 22-23 M.P.N. Coliform per 100 ml.	II Aug. 22-23 Standard plate count per ml.	III Aug. 25-26 M.P.N. Coliform per 100 ml.	III Aug. 25-26 Standard plate count per ml.	IV Aug. 27-28 M.P.N. Coliform per 100 ml.	IV Aug. 27-28 Standard plate count per ml.	V Aug. 29-30 M.P.N. Coliform per 100 ml.	V Aug. 29-30 Standard plate count per ml.
Mud	First haul	0	*	0	*	0	*	0	*	0	*
Surface water	Before dredging	0	18	0	7	0	115	0	86	0	200
Bottom water	Before dredging	2	5	*	*	0	30	0	9	0	19
Surface water	After sixth haul	0	2	*	*	0	146	0	65	0	55
Bottom water	After sixth haul	0	10	*	*	58	5	0	5	0	91
Surface water	Last haul	0	12	*	*	0	0	0	338	0	*
Bottom water	Last haul	0	64	*	*	0	1	0	1	0	*
Quahogs	First haul	0	265	0	232	0	3,100	2,400	1,080	0	800
Quahogs	Last haul	20	117	0	280	0	1,720	0	1,300	0	760
Quahogs	Arrival on dock	*	*	45	3,540	9,200	572,000	0	1,560	490	T.N.C.
Quahogs	Arrival on dock	20	*	1,400	3,280	16,000	299,000	0	640	2,400	1,560,000
Quahogs	Shop - next morning	0	16,260	16,000	76,000	16,000	306,000	0	11,400	16,000	110,000
Quahogs	Freshly shucked	13,000	338,000	16,000	430,000	16,000	106,000	0	7,000	16,000	188,000
Quahogs	Washed meats	*	*	16,000	566,000	16,000	540,000	0	4,400	3,500	61,800

Type of Sample	Time of Sampling	VI Sept. 9-10 M.P.N. Coliform per 100 ml.	VI Sept. 9-10 Standard plate count per ml.	VII Sept. 11-12 M.P.N. Coliform per 100 ml.	VII Sept. 11-12 Standard plate count per ml.	VIII Sept. 18-19 M.P.N. Coliform per 100 ml.	VIII Sept. 18-19 Standard plate count per ml.	IX Sept. 21-22 M.P.N. Coliform per 100 ml.	IX Sept. 21-22 Standard plate count per ml.
Mud	First haul	0	*	0	*	0	*	0	*
Surface water	Before dredging	0	23	0	18	0	2	23	5
Bottom water	Before dredging	0	81	2	15	*	*	13	27
Surface water	After sixth haul	*	55	0	5	0	29	23	5
Bottom water	After sixth haul	0	269	0	34	0	5	0	2
Surface water	Last haul	0	37	0	4	33	236	0	5
Bottom water	Last haul	0	11	0	56	33	*	0	1
Quahogs	First haul	0	130	0	640	0	1,200	*	*
Quahogs	Last haul	0	138	0	820	0	1,520	*	*
Quahogs	Arrival on dock	170	6,600	5,400	T.N.C.	490	*	*	*
Quahogs	Arrival on dock	220	760	3,500	6,400	790	*	*	*
Quahogs	Shop - next morning	490	7,400	2,400	124,000	1,300	508,000	*	*
Quahogs	Freshly shucked	5,400	78,000	5,400	152,000	790	310,000	*	*
Quahogs	Washed meats	330	20,000	16,000	72,000	16,000	23,400	*	*

*No test made

T.N.C. - Too numerous to count

Type II: Cultures of this type belonged in the group of Escherichia-Aerobacter intermediates. They had the same general characteristics of Type I but were irregular regarding either citrate utilization or the fermentation of cellobiose and alphamethylglucoside or else they produced hydrogen sulfide. All cultures of this type produced indole. They were considered as being probably of fecal origin.

Type III: The cultures of this group were characteristically Aerobacter cloacae types. They produced acetylmethylcarbinol from dextrose, fermented cellobiose and alphamethylglucoside, and utilized citrate. They were non-encapsulated and produced flat, gray colonies on eosin-methylene blue agar. The possibility that such cultures might be of fecal origin was considered.

Type IV: These organisms possessed the same characteristics as Type I but were atypical in colonial appearance on eosin-methylene blue agar and failed to produce indole. These were classified as atypical Escherichia members, probably not of fecal origin.

Type V: This group was composed of typical Aerobacter members. They all produced acetylmethylcarbinol from dextrose, were active fermenters of cellobiose and alphamethylglucoside and utilized citrate as a sole source of carbon. They were hydrogen sulfide negative. The organisms were all encapsulated and produced raised, mucoid colonies on eosin-methylene blue agar. They were indole negative. Most of them were Aerobacter oxytocum except for this last characteristic. All cultures of this type were considered to be non-fecal in origin.

The distribution of the various coliform types is indicated in Table 7. Characteristic fecal Escherichia cultures (Type I) occurred the least frequently, only

Table 7 - Types of Coliform Bacteria Isolated From Various Sources

Type of Sample	TYPE OF COLIFORM BACTERIA[1] Cultures Isolated				
	I	II	III	IV	V
	Number	Number	Number	Number	Number
Mud	2	0	2	0	0
Bottom Water	7	5	5	2	4
Surface Water	8	5	5	2	4
Ocean Quahogs (from water)	3	10	6	5	5
Ocean Quahogs (at shop)	0	15	13	14	13
Ocean Quahogs (meats)	6	20	8	19	8
Ocean Quahog Liquor	0	1	3	6	3
Bags	1	3	3	1	4
Bilge Water	1	0	1	0	0
Total Cultures	28	59	46	48	42
Percent of Total	12.5	26.0	21.0	21.5	19.0

1/Coliform bacteria were classified as follows:
Type I: Typical Escherichia
Type II: Escherichia - Aerobacter Intermediates
Type III: Aerobacter cloacae
Type V: Typical Aerobacter

12.5 percent being of this type. The other four types were about equally divided, the respective percent of each being as follows:

Type II - 26 Type III - 21 Type IV - 21.5 Type V - 19

Since there was practically no opportunity for either the water or the ocean quahogs to be initially contaminated from any sewage source except the water traffic in the production areas, it may be that the only coliform bacteria of any sanitary significance were those of Type I. The largest single source of the typical *Escherichia* members was the water (surface and bottom), 15 of the 28 cultures having come from this source. The other four types were predominantly from ocean quahogs. In the case of Type II cultures, 45 out of 59 were from ocean quahogs, with 30 of the 45 coming from the stored shellstock and shucked meats. Of the Type II cultures, 27 out of 46 were from the shellstock but the largest single source (13 cultures) was the stored shellstock. The same general picture also characterizes the other two types, 38 out of 48 Type IV cultures coming from the ocean quahogs and 26 out of 42 Type V cultures having the same origin. The outstanding single source of Type IV cultures was shucked meats and of Type V, the stored shellstock. The low incidence of Type I organisms in the ocean quahog would seem to indicate that most of the coliform bacteria found may not have been of fecal origin at all but represented strains of bacteria which are indigenous to the shellfish and which had had an opportunity to multiply. While admitting the undesirability of coliform bacteria in the final product, there is a reasonable doubt regarding the sanitary significance of their presence in the materials examined in this investigation. True fecal pollution during storage and shucking would probably yield a much higher percentage of typical *Escherichia coli*.

Recommended Practices

The bacteriological data presented in this study leaves little doubt concerning the necessity of modifying current trade practices if the initial high quality of the ocean quahog is to be maintained until the final product reaches the consumer. It should be neither too costly nor too troublesome to produce a seafood of excellence from this shellfish. With the aim of accomplishing this, the following practices are recommended:

1. Bags: The bags used for storing the shellstock should not be re-used without having been laundered. They should be stored in such a manner as to prevent exposure to external contamination.

2. Aboard the Vessel: The bagged catch should be protected from direct exposure to the sun and heat. Preferably, the shellstock should be thoroughly iced as soon as possible after removal from the water.

   The ocean quahogs should be stored in a manner which will protect them from exposure to bilge water or other sources of contamination.

   Upon return to port, the ocean quahogs should be re-iced, if necessary, or transferred to a refrigerator. If further hauling is necessary, they should be transferred immediately to a pre-cooled truck or other vehicle. Shellstock should not be permitted to stand unprotected for any length of time on the dock or on the deck of the vessel.

3. Transportation: The trucks used for transporting shellstock should be designed to prevent contamination of the ocean quahogs from dust and dirt. The trucks should be pre-cooled before loading and the load should be thoroughly iced. Upon arrival at the plant the load should be re-iced, if necessary, if it is not removed immediately.

4. Storage: Throughout the period of storage, the ocean quahogs should be kept at a temperature not higher than 40° F. It is recommended that the shellstock be held no longer than 24 hours before shucking and that 48 hours should be the maximum period of storage for the shellstock.

5. Shucking Room: Shucking room cleanliness is essential for the production of high quality food. At the end of each day, the benches should be cleared of all materials and utensils and thoroughly cleaned. The floors should

be swept and scrubbed daily. Platforms upon which the shuckers stand should never be placed on the shucking benches. They should be stood on end on the floor, thoroughly washed and left in this position until used again.

Shellstock should not be washed free of mud on the benches while shucking is in progress. It would be desirable to have a separate bench for this purpose and to have only clean quahogs on the shucking benches.

6. Utensils: All shucking knives, buckets, and other utensils should be thoroughly cleaned at the end of each day's operations and should be sterilized in accordance with the recommendations of the State health authorities. Only utensils which are in good repair and which are free of rust or other corrosion should be employed.

7. Packing Rooms: The packing room should be immaculately clean at all times. The equipment should be sterilized by the use of suitable antiseptic agents. The receptacles into which the ocean quahogs are packed must be kept free of dirt and stored in a manner which will keep contamination at a minimum. In the case of metal containers, a rinse with chlorine solution prior to packing will effectively eliminate contamination from dust and handling. The lids should be similarly treated. Under no circumstances should the packer's hands come in direct contact with the inside of the containers.

8. Storage of Packaged Meats: As soon as the ocean quahogs are packaged they should be refrigerated. The lag between the packaging and refrigeration should not exceed 30 minutes at any time. When friction-top metal cans are used, care should be taken to prevent over-filling so that the lids will not be forced off during refrigeration. Any lids which do come off during storage should be replaced with new, clean ones and the originals returned to the packing room for cleaning and sterilization before they are re-used.

9. Shipment: Ocean quahogs must be kept at a temperature not exceeding 40° F. at all times until used. Shipments must be kept properly refrigerated throughout the period of transit. This applies to shellstock as well as shucked meats.

10. Personnel: All workers should remove their aprons, rubber gloves, etc., before entering the toilet and should wash their hands thoroughly with soap and water before resuming work.

Shuckers should not enter the packing room at any time.

Lunches, overcoats, and other personal property should be stored elsewhere than in the shucking or packing room. If winter outer-clothing is necessary for persons working in the freezers, this should be special clothing and used only for this purpose and it should be kept clean and in good repair.

The above suggestions are supplementary to any requirements of the U. S. Public Health Service, the U. S. Food and Drug Administration, the State regulatory authority, or local food agency. These recommendations are based upon observations of the ocean quahog operations and indicate methods of eliminating some of the chief obstacles in the way of maintaining high quality production. The ocean quahog offers a food source of very high quality; it is ridiculous to sacrifice the quality through failure to follow these relatively simple and inexpensive practices.

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