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SEASONAL VARIATIONS OF COLIFORMS AND ENTEROCOCCI IN A CLOSED SHELLFISH AREA

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Many valuable shellfish resources cannot be utilized because they exist in polluted waters near seashore communities. Some of these communities have a stable population contributing a uniform yearly pollution. Others, such as summer resorts, have widely fluctuating populations, and contribute varying amounts of pollution to the receiving waters. A vital question is raised concerning restriction of shellfish gathering after the summer population has gone and the pollution is materially reduced.

The purpose of this study was to determine, (1) the year-round variability of the quality of both water and shellfish from an area with such a seasonal fluctuation in population, and (2) the ratio of pollutional organisms present in the overlying water and in the shellfish. The study consisted of a sanitary and bacteriological survey.

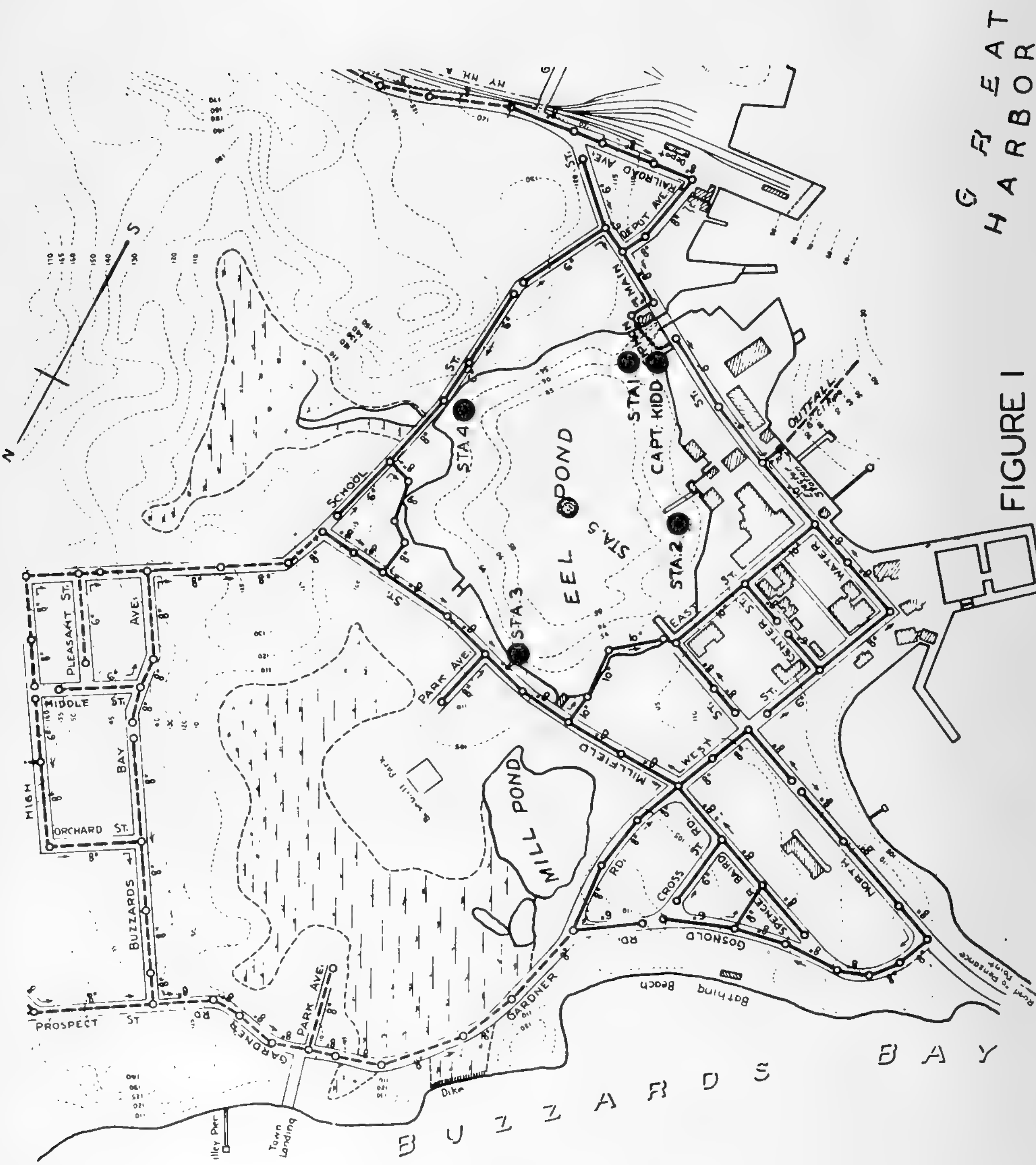
Sanitary Survey of Eel Pond

Description

Eel Pond (see Figure 1), situated in the center of Woods Hole, Massachusetts, has an area of approximately 0.025 sq. mi., and a watershed area of approximately 0.28 sq. mi. The pond, varying in depth from about two feet at the shore to 20 feet in the center, has about 80 percent of the shore line well defined by vertical stone walls. Three fresh water inlets, one on the east side, two on the north side, numerous surface drains, and some private sewers, discharge into the pond.

The land immediately surrounding Eel Pond is fully developed. On the immediate shores are located domestic dwellings, stores, bakeries, restaurants and biological laboratories. The pond provides an excellent harborage for large and small pleasure carft, and is used as such all year round; naturally, the numbers of such craft increase greatly during the summer.

Eel pond is directly connected to Great Harbor by a boat channel about 500 feet long and 75 feet wide. Current observations made at the Eel Pond outlet to this channel during a 6-hour period revealed 18 cyclic changes of current flow with a maximum velocity of about one foot per second. This fluctuation of current, coupled with the mean range of tide which is 1.8 feet, indicates that the pond seldom gets a thorough flushing. Thus, it appears that the pollution in the pond has a tendency to be maintained at a high level.



GREAT HARBOR
BUZZARDS BAY
EEL POND
MILL POND
STA. 1
STA. 2
STA. 3
STA. 4
STA. 5
CAPT. KIDD
OUTFALL
N
S
SCHOOL ST.
MAIN ST.
WATER ST.
NORTH ST.
EAST ST.
WEST ST.
CENTER ST.
MILLFIELD ST.
PARK AVE.
RAILROAD AVE.
DEPOT AVE.
GOSNOLD RD.
CROSS RD.
BAIRD ST.
SPENCER
GARDNER RD.
PROSPECT ST.
BUZZARDS BAY AVE.
HIGH
MIDDLE ST.
ORCHARD ST.
PLEASANT ST.
Bathing Beach
Dike
Town Landing

FIGURE I

Sanitary Survey

A sanitary survey of the immediate vicinity of Eel Pond shows that there are 90 homes and establishments which contribute pollution either directly or indirectly into the pond. There is an increase in the pollution load in the summer due to summer residents. It is estimated that the population in the immediate vicinity of Eel Pond increases to 2,200 during the months of June, July and August, as compared to 400 year-round residents. Although most of the homes bordering on the pond have cesspools, there are a few which discharge their sewage directly into the pond. Seepage and overflow from a number of the cesspools cause some pollution of the pond. The waters of Great Harbor near the Eel Pond boat channel receive considerable pollution from commercial establishments and dwellings along the channel. Some of this pollution probably enters Eel Pond during the flood tide.

On the basis of the sanitary survey, it would appear that Eel Pond is subject to moderate pollution throughout the year with a marked increase during the months of June, July and August.

Bacteriological Survey

A series of six stations (Figure 1) was established in Eel Pond; one in the approximate center, one at the entrance of the boat channel, and four at approximately equidistant points along the periphery of the pond. Surface water samples were collected at these stations at least once a month from August 1948 through July 1950. Additional samples were collected for salinity determinations. At one station (Captain Kidd's), in addition to the water samples, a shellfish sample consisting of six or more quahogs (*Venus mercenaria*) was collected for bacteriological examination. The temperature of the water was determined at each collection.

Laboratory Methods

Samples of shellfish and water were collected and prepared for analysis, except for a few minor deviations, in accordance with the methods described in "Recommended Procedure for the Bacteriological Examination of Shellfish and Shellfish Waters".(1)

Phosphate dilution water(2) was used instead of one percent saline. Shellfish were prepared for disintegration in a Waring Blendor by weighing the contents of six shellfish and adding an equal amount by weight of sterile phosphate buffered diluent instead of the recommended 200 ml. of one percent saline to 200 ml. of meats and liquor.

Suitable aliquot portions of samples were planted in at least three decimal dilutions using five tubes per dilution. Parallel plantings were made into standard lactose broth and Winter and Sandholzer[5] enterococcus presumptive broth. The presumptive lactose broth tubes were incubated at 37° C. (air incubator) and examined for the presence of gas at 24 and 48 hours. All lactose broth tubes showing gas were confirmed by transferring a 3 mm. loopful to brilliant green lactose bile broth 2% (B.G.B.). The presence of gas in any amount in B.G.B. after 24 or 48 hours of incubation at 37° C. was considered a positive test for the coliform group.

The enterococcus presumptive broth tubes were incubated for 24 hours in a 45° C. (water bath) and examined for turbidity and acid which indicate a positive presumptive test. Positive presumptive tubes were checked by transferring two loopfuls (3mm. loop) to confirmatory agar-broth slants for incubation at 37° C. for 18 to 24 hours. The confirmed test consisted of: (1) pin-point colonies on the agar slant, (2) sedimented growth in the broth portion, and (3) the demonstrations of gram positive streptococci. The results were recorded in terms of the "Most Probable Number" (MPN)[3] per 100 ml. for members of the coliform and enterococcus groups.

Results

In Figure 2, the average MPN values for coliforms and enterococci and the average monthly temperatures for Stations 1 through 5 are presented.

In general, the coliform content of the waters follows the temperature fluctuations, however, this condition is not constant. The sharp rise of coliforms and enterococci in April as compared to March and May might be due to a temporary increase in population. Summer residents often come to Woods Hole in April to inspect their homes and to make the necessary preparations for reopening them in June. During June, July and August, when the population of Woods Hole is at its peak, the coliform content of the water increases. Since the recovery of enterococci, with one exception, is low (not more than 10 organisms per 100 ml.), it seems that no conclusions regarding the effect of temperature on the numbers of organisms of this group of bacteria can be made.

Figure 3 shows the average coliform and enterococcus values of waters and quahogs from the Captain Kidd station.

In December, January, February, March and April the coliform content of quahogs was considerably below the 2400 per 100 ml., Public Health Service's tentative coliform standard for shellfish other than oysters. For the most part, however, the overlying water during the period is in grossly polluted range, having a coliform content of 700 or more per 100 ml. Quahogs are inactive at temperatures of 5° C. or

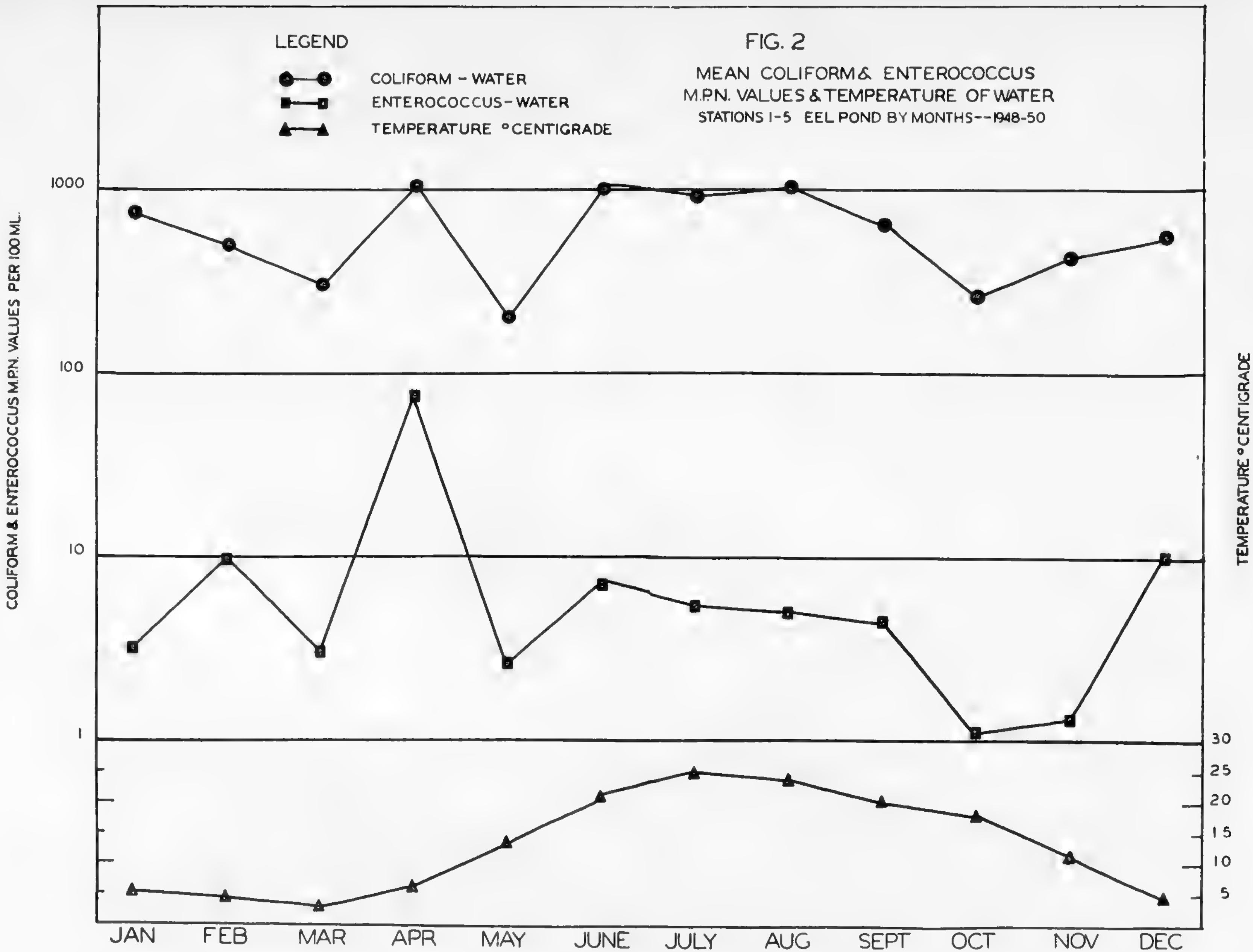


FIG. 2
MEAN COLIFORM & ENTEROCOCCUS
M.P.N. VALUES & TEMPERATURE OF WATER
STATIONS 1-5 EEL POND BY MONTHS--1948-50

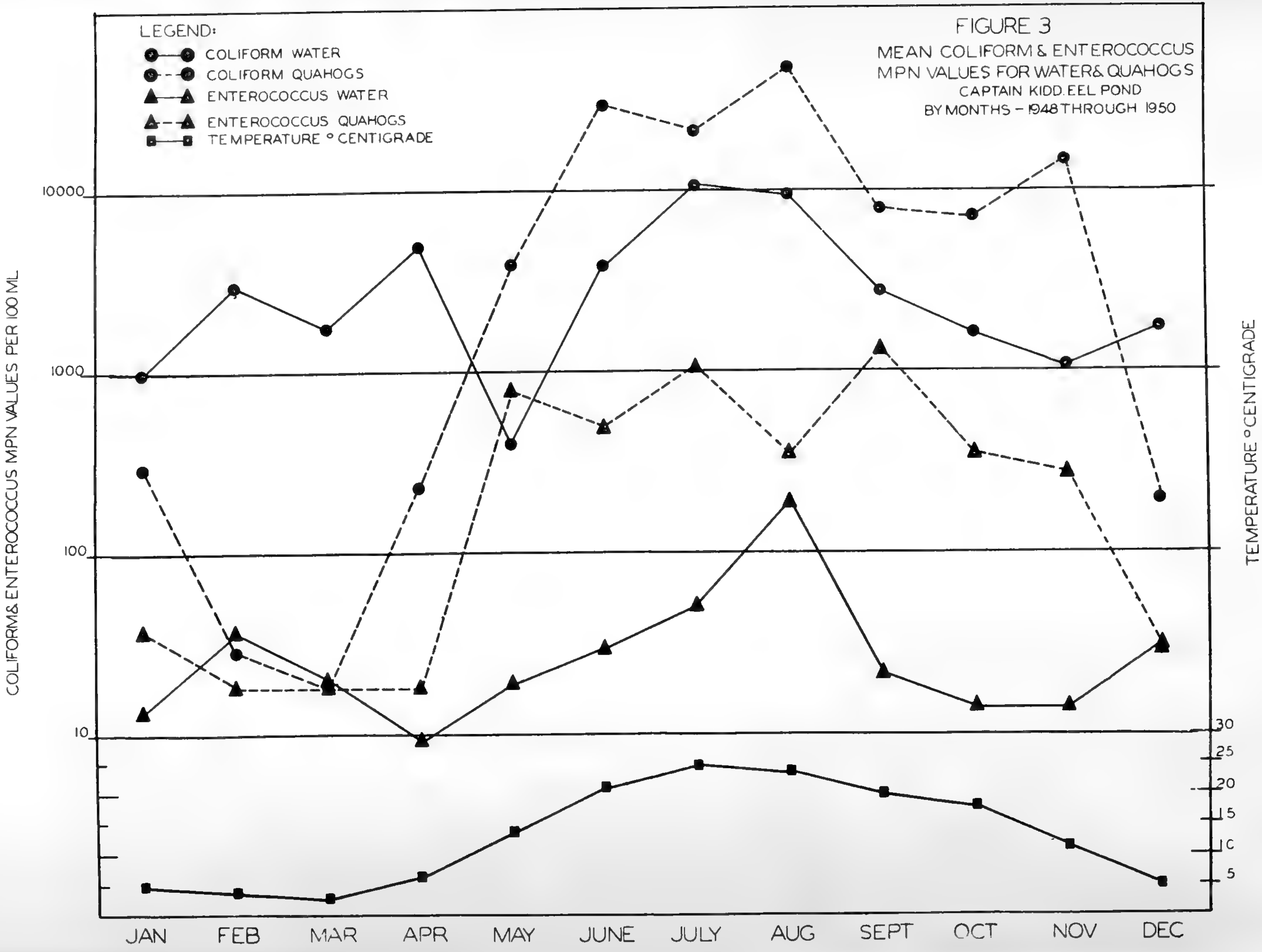


FIGURE 3
MEAN COLIFORM & ENTEROCOCCUS
MPN VALUES FOR WATER & QUAHOGS
CAPTAIN KIDD. EEL POND
BY MONTHS – 1948 THROUGH 1950
LEGEND:
COLIFORM WATER
COLIFORM QUAHOGS
ENTEROCOCCUS WATER
ENTEROCOCCUS QUAHOGS
TEMPERATURE ° CENTIGRADE
COLIFORM & ENTEROCOCCUS MPN VALUES PER 100 ML
10000
1000
100
10
TEMPERATURE ° CENTIGRADE
30
25
20
15
10
5
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC

lower and it is interesting to note that, during the cold months, the coliform content of these shellfish was significantly low.

With the advent of higher temperatures an increase in the coliform and enterococcus content of the quahog was observed. A simultaneous rise and fall of the coliform content and the temperature is noted. These data are in agreement with Loosanoff's[4] observations. Using "shell openness" as a measure of activity he found that hibernation, for a majority of quahogs examined, began at 5.0° to 6.0° C. At temperatures of 3.9° to 10.0° C. he found there was a correlation with period of openness and the rise in mean temperature. He found no correlation when the temperature of the overlying water was in the range of 11° to 27.9° C. However, he did find that the animals were open 69 to 90 percent of the time; the highest percentage of openness, 90%, occurred at temperatures between 21 and 22° C. These observations are borne out in Figure 3.

A rise in temperature and an increase in population is reflected in the coliform and enterococcus densities of water and quahog samples. The maximum numbers of these bacteria occur in June, July and August when Woods Hole has its maximum population. Although the coliform and enterococcus groups of organisms follow a similar pattern, no constant ratio exists between them.

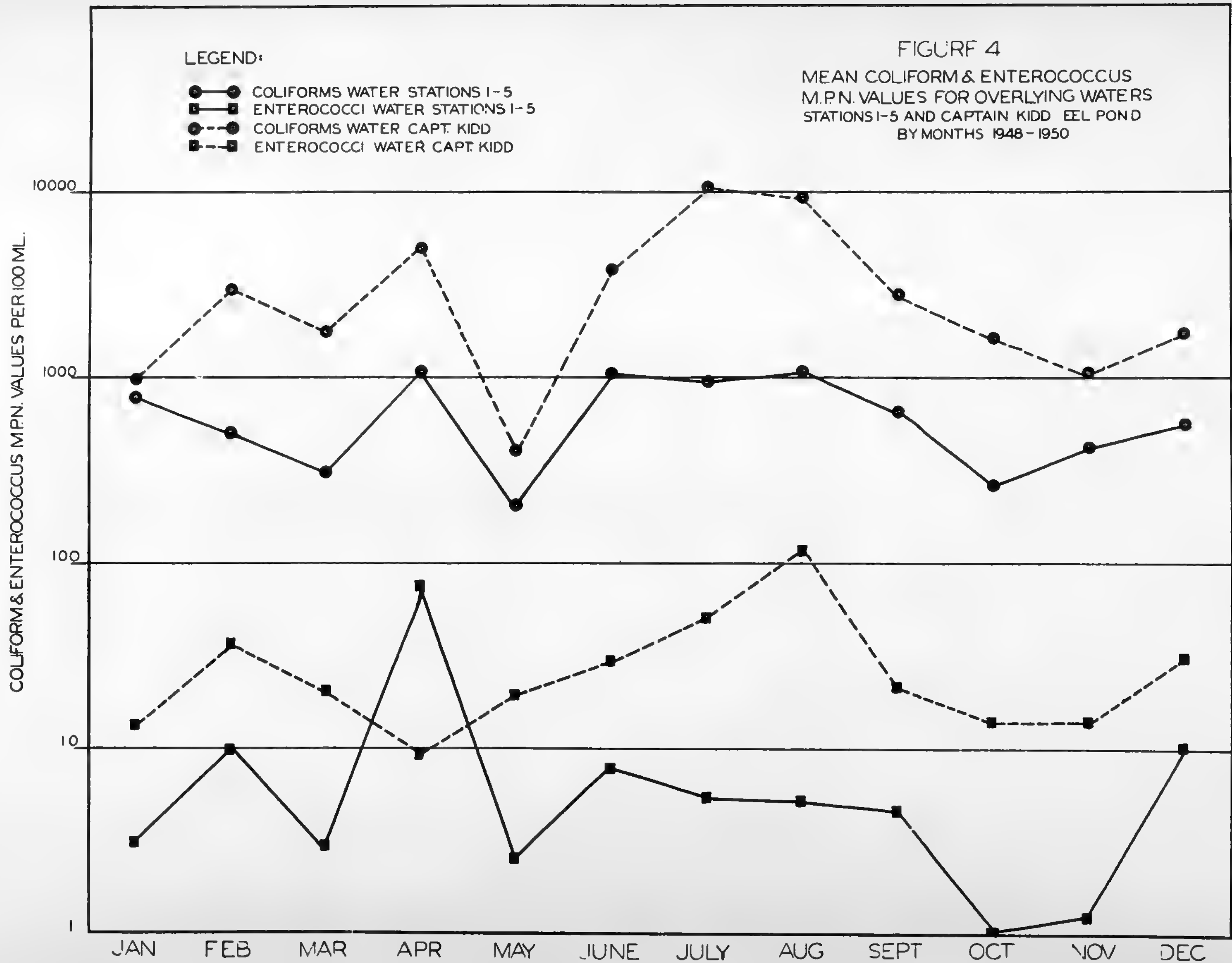
In Figure 4, the mean monthly coliform and enterococcus content of waters from Stations 1 through 5 are compared with those from Captain Kidd's. The rise and fall of coliforms at both sampling areas show a similar pattern. However, the above trend is not apparent in the enterococcus results.

The average salinities and coliform and enterococcus numbers from Stations 1 through 5 and Captain Kidd's are presented in Table I. There is no marked variation of salinity during the course of the year. The salinity of the pond is slightly less than that of Vineyard Sound, the outer boundary of Great Harbor. The salinity of Eel Pond has no apparent effect on the bacteriological population.

In Figure 5, the effect of population on the coliform and enterococcus densities in samples from the Captain Kidd station is shown. During the summer months of June, July and August the approximate population discharging wastes in the immediate area of this station is 1,000, as compared to 75 during the remainder of the year. The population density increases in an approximate ratio of 13 to 1; the coliform and enterococcus ratios increase only three to one.

Discussion and Conclusions

The data indicate that when the population contributing pollutions increases, the coliform and enterococcus organisms in quahogs also increase. Quahogs (Venus mercenaria) are quiescent at temperatures of 5°C. or less. The results show that the bacterial content of the



FIGURF 4
MEAN COLIFORM & ENTEROCOCCUS
M.P.N. VALUES FOR OVERLYING WATERS
STATIONS 1-5 AND CAPTAIN KIDD EEL POND
BY MONTHS 1948-1950

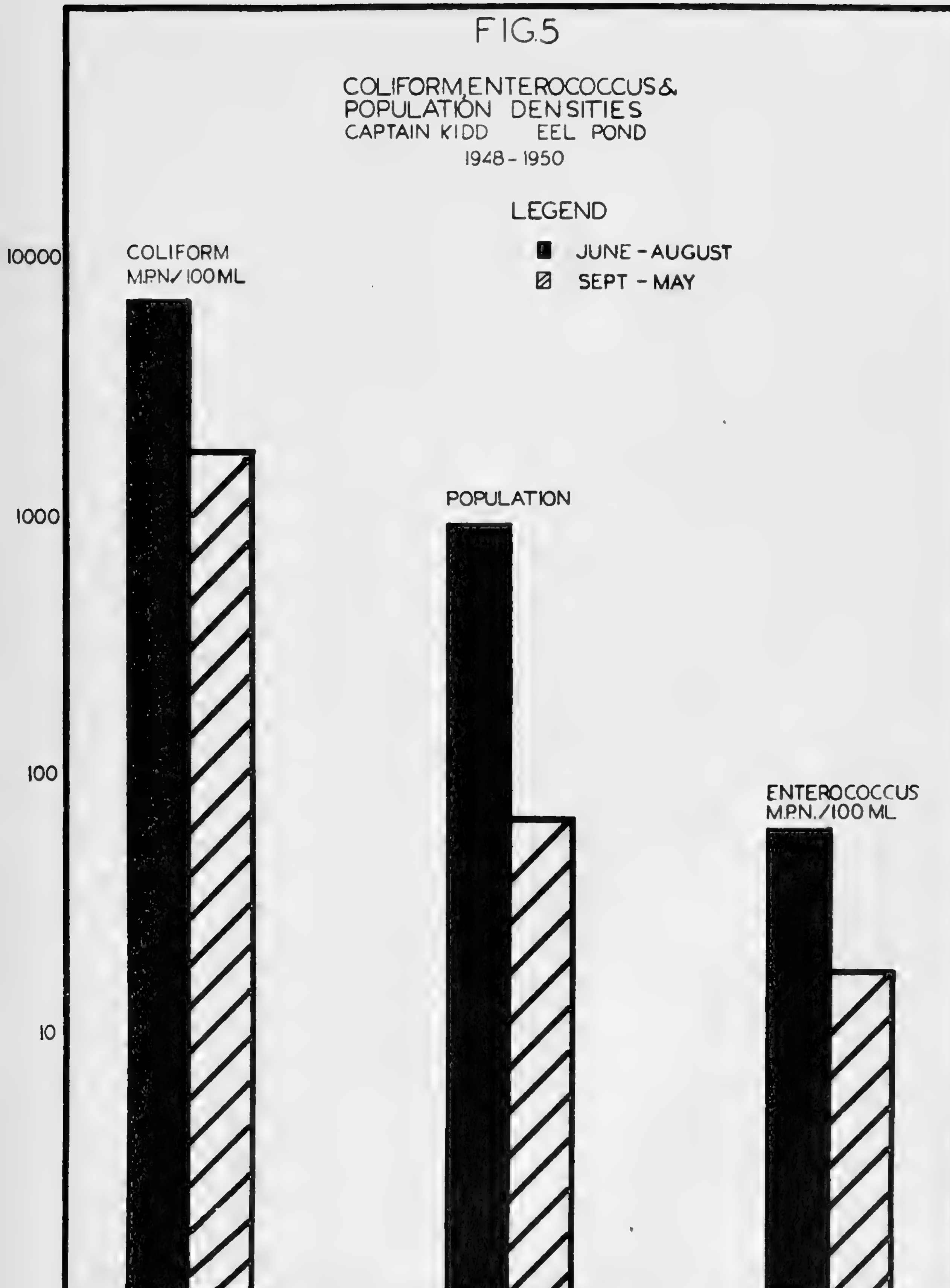


FIG.5
COLIFORM, ENTEROCOCCUS & POPULATION DENSITIES
CAPTAIN KIDD EEL POND
1948 - 1950
LEGEND
JUNE - AUGUST
SEPT - MAY
10000
1000
100
10
COLIFORM M.P.N./100 ML
POPULATION
ENTEROCOCCUS M.P.N./100 ML

Table I

Average Salinities, Coliforms and Enterococci from Eel Pond Water Samples

	Salinity P.P.T.	Coliforms MPN/100 ml	Enterococci MPN/100 ml	Salinity P.P.T.	Coliforms MPN/100 ml	Enterococci MPN/100 ml
Jan	30.867	750	3.1	31.333	965	13.1
Feb	29.972	499	9.8	30.840	2,940	36.6
Mar	28.251	298	2.9	27.850	1,730	20.6
Apr	30.429	1,048	75.1	31.770	4,900	9.3
May	29.632	208	2.5	30.820	402	19.0
June	31.133	1,016	7.8	31.550	3,820	29.7
July	30.926	931	5.5	31.620	10,500	51.0
Aug	31.099	1,075	5.2	31.236	9,300	119.0
Sept	31.565	644	4.6	31.400	2,720	21.6
Oct	32.280	263	1.0	31.790	1,610	14.0
Nov	31.172	415	1.2	30.925	1,060	14.0
Dec	31.022	558	10.2	31.330	1,700	31.0

shellfish is not affected under such conditions by the quality of the overlying waters. As soon as the temperature rises and the quahogs become active, their coliform and enterococcus contents are affected by the coliform and enterococcus density of the overlying water.

The salinity of the waters in Eel Pond, ranging from a low of 27 parts per thousand to a high of 32 parts per thousand, indicate that comparatively little fresh water enters Eel Pond.

From the available data there is an indication that no ratio exists between the coliform and enterococcus groups of organisms. The findings of the sanitary survey also indicate that Eel Pond is seldom flushed.

The results of the sanitary and the bacteriological survey show that although Eel Pond is polluted at all seasons of the year, the pollution is greatest during June, July and August when the population of the community increases. However, when the population decreases, the pollution does not decrease sufficiently to permit harvesting or marketing of shellfish.

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NOTES ON GROWTH OF *THAIS HAEMASTOMA FLORIDANA* AND *THAIS (STRAMONITA) RUSTICA*

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In order to wage successful campaigns against predators, it is usually advantageous to know as much as possible about the bio-ecological backgrounds of such pests. Many times, weaknesses in the survival fitness are found which, if properly exploited, result in diminished numbers of the harmful organism and a reduction in its activity. Such considerations provided the motivation for a study of the growth rates of two of Florida's most voracious gastropod predators.

The location for these studies was the area surrounding the mouth of the local waterway, Coral Gables, Florida.

From February 22 to February 26, 1950, 257 snails of the genus *Thais* were notched on the lip and released. Of these, 181 were *Thais haemastoma floridana* and 76 were *Thais (Stramonita) rustica*.

On May 15 and 16, 1950, all marked animals that could be found were brought to the laboratory for measurement. Ten of these were *Thais rustica* and fourteen were *Thais floridana*, making a total of twenty-four recovered. Lip increment was then determined.

As shown by Moore (6-7), the relation between the amount of growth measured in a spiral direction on the lip of a shell and the corresponding increase in the height of the shell is dependent on two fundamental shell angles, theta, the half apical angle, and alpha, the spiral angle. Theta may be obtained by direct measurement, but alpha is usually obtained from the formula:

$$\tan \text{alpha} = \frac{2.72 \sin \text{theta},}{\log R} \text{ where}$$

R is the ratio of the diameters of two successive whorls. The formula for determining the length of a plain logarithmic spiral is $\frac{l}{r} = \sec \text{alpha}$.

If this spiral is projected upon a cone (as it is in the case of the two snails studied), the formula becomes:

$$\frac{l'}{r} = \sec \text{alpha} \cdot \sec \text{beta}$$

where l' = the spirally measured length, and beta is an angle derived from alpha and theta, but more easily taken by direct measurement.

Table 1

Growth of *Thais rustica*
(all figures given in mm)

No.	Calculated Original Height 2-25-50	Whorl Inc. mm	Final Height Measured 5-16-50	Height Inc.	Weekly Height Inc.
1.	25.8	16.0	35.2	9.4	.8
2.	33.6	10.5	38.7	5.1	.4
3.	26.4	7.0	29.0	2.6	.2
4.	28.2	15.0	35.5	7.3	.6
5.	26.0	20.0	35.5	9.5	.8
6.	25.6	15.0	37.5	11.9	1.0
7.	25.2	16.0	36.2	11.0	.9
8.	26.6	16.0	34.0	7.4	.6
9.	29.1	8.0	33.7	4.6	.4
10.	26.5	11.0	31.8	5.3	.4
Ave.	27.3	13.4	34.7	7.4	.6

Growth of *Thais floridana*

No.	Calculated Original Height 2-25-50	Whorl Inc.	Final Height Measured 5-16-50	Height Inc.	Weekly Height Inc.
1.	46.2	6.0	48.5	2.3	.2
2.	42.0	16.5	50.0	9.0	.6
3.	38.0	13.0	44.5	6.5	.5
4.	45.0	12.5	50.5	5.5	.4
5.	31.9	25.0	43.0	11.1	.9
6.	34.3	15.0	40.5	6.2	.5
7.	35.8	11.0	41.0	5.2	.4
8.	33.8	8.0	37.5	3.7	.3
9.	36.0	9.0	40.0	4.0	.3
10.	35.8	9.5	40.0	4.2	.3
11.	31.0	20.0	40.0	9.0	.7
12.	27.8	35.0	40.0	12.2	1.0
13.	33.2	11.0	39.0	5.8	.5
14.	25.2	19.0	35.0	9.8	.8
Ave.	35.4	15.0	42.1	6.7	.5

Frequently during the entire period of this study, females were noted laying eggs. It may be presumed that the growth recorded here takes place during the times of normal reproductive processes.

Results of growth rate sudies are given in Table 1. It will be seen that the average height increment for the ten Thais rustica was slightly greater (7.4 mm) than the average increase shown for Thais floridana (6.7 mm). This slight difference is very likely the result of the smaller size of individuals making up the Thais rustica sample. More rapid lineal growth is a common feature of younger, smaller individuals.

In a period of 82 days maximum height increment for Thais floridana was 12.2 mm (approximately 1/2 inch). In the same length of time, the maximum recorded height growth for Thais rustica was 11.9 mm.

The faster rate of living, and growing, in warmer waters has been reported often by investigators of other poikilothermous animals. Oysters, in particular, have been shown by Ingle (3-4), Gunter (2), and Menzel (5) to have a very rapid growth in the Gulf of Mexico.

Experiments are being conducted at the present time to ascertain growth rate during the other seasons of the year.

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A METHOD OF REDUCING WINTER MORTALITIES OF *VENUS MERCENARIA* IN MAINE WATERS

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This paper is primarily concerned with efforts to reduce winter mortalities of *Venus mercenaria* in Maine waters. During the last five years some work has been done on this problem, but the following discussion is of our more intensive efforts during the last year.

Maine does not have a very large hard-shell clam fishery in comparison with other Atlantic states; but, despite the annual take of only about half a million pounds of meats, or 50,000 bushels, at a value of approximately $100,000, it is an important part of the economy of towns that border on Casco Bay. It is primarily an intertidal fishery.

Our industry relies upon natural seed sets to support the fishery between periods of natural setting. From what information is available it appears that these intermittent sets have extended back into the 20's in this area, and how much longer we do not know. The last good set that we received in the upper portion of Casco Bay was in 1947, and the bulk of this *Venus* population is just getting to littleneck size this summer. In some of the best growing sections, cherries of this same age class can be found.

Although the sets are infrequent, heavy concentrations of quahogs have, in the past, occurred in small areas. Under certain conditions these quahogs have grown relatively slow, and mortalities have been high. Transplanting of these quahogs has, for the most part, proved to be economically desirable because of high survivals and good growth of the relayed seed. Last summer we moved 3012 bushels from two areas of heavy concentration in Maquoit Bay.

Moving any numbers of quahogs of this size presented financial and other problems. Our own Department did not have funds and could only supply personnel to aid in the organization and transplanting operations. Meetings were held with the diggers, town officials and dealers; and the diggers contributed their efforts for several tides. A special town meeting ear-marked town license money for some equipment used in moving the seed. Dealers in the area made $200 available; the Bount Seafood Corporation of Warren, Rhode Island contributed $500; and a $1000 contribution from the Campbell Soup people was added to pay for the transplanting of the seed. The operation extended from July 8 to December 6 and was terminated because of the cold weather. Quahogs were, for the most part, spread onto the flats near or below the mean low tideline.

Concentrations were found to run as high as 167 per square foot with Venus ranging from 27 - 59 mm. having a mean of 43 mm. Slide #1 illustrates the concentration of quahogs as does Slide #2 and Slide #3. In Slide #3 a pile has been made of quahogs from the area shown. Slide #4 illustrates one of the methods of gathering. Quahogs were raked into windrows shoveled with the use of rock forks into wire baskets and then loaded into boats as shown in Slide #5 or bagged as shown in Slide #6. Quahogs were spread directly from the boats onto the flats or sifted out of bags from boats towed by outboard motors as shown in Slide #7. Slide #8 is a photograph of a chart showing the relative locations of the seed beds and the sections into which the quahogs were planted. Figures indicate the number of bushels relaid into the various areas. In order to record the population numbers and distribution of the Venus in these concentrations a planimetric map was made of the two principal seed areas.

Slide #9 shows the telescopic alidade, plane table and surveyor's rod used in making the planimetric map. Slide #10 is a convenient rock in the seed bed area that was used as a survey station. A map of the 1950 fall survey is shown in Slide #11. The dots on the map indicate where square-foot samples of Venus were taken, counted and measured. Boundaries of the area are shown.

Throughout the summer and at the time of the last transplanting on November 18 from Seed Bed #2, we observed that many quahogs were exposed, or partially so, because of excessive crowding and their inability to burrow to a normal depth in the flats. Slide #12 shows how sandy-clayey silt partially covered the quahogs in the depressions and how quahogs in the higher portions of the flats were completely covered by sediment. The edge of one of these higher portions of flats can be seen in the top left corner of the slide.

On November 25 and 26 of 1950, the Casco Bay area was lashed by a violent wind and rain storm with peak gusts of wind of 76 m.p.h. occurring near the time of low water on the twenty-sixth. Shortly after this storm we observed that most of the silt over and around the quahogs had been removed, and thousands of live quahogs were almost completely exposed to the elements. This was the condition when observed on December 24.

This area was again visited on February 4. Excessive mortalities had occurred and a closeup of these empty valves is shown by Slide #13, with a view out across the flats shown by slide #14.

We cannot be positive of the exact time and reason for the heavy mortalities of the sediment free, exposed quahogs in the seed beds found in the intertidal zone of Maquoit Bay, but we do feel that combinations of factors, including the water, tide and weather, as shown on Slide #15, have important bearing upon these mortalities. The amount of ice over the beds, the rate of freezing and thawing, concerning which we have no information, may have had great significance.

At the bottom of the chart are the sea water temperatures in Fahrenheit degrees recorded by the Coast Guard Station at Portland Headlight in outer Casco Bay. They may be indicative of fluctuations in the temperature of water that covered the quahog beds in the inner portion of the bay. All weather data shown were obtained from the U. S. Weather Bureau office eighteen miles southwest of Bunganuc Point in Portland. At the top of the graph are the dates, heights of the tides, the atmospheric pressures, and wind speeds and directions. On the left margin are shown the air temperatures in Fahrenheit degrees.

We considered that weather factors at the time of low water were most critical, so we selected the Weather Bureau's temperature, wind and atmospheric pressure recordings that were made nearest to the time of each low water. Taking into consideration the observations of the local diggers as to the length of time that Seed Bed #2 is uncovered by the water on each low tide, it appeared that it would be best to compute all information on the basis of the *Venus* being exposed to the elements for an average time of four hours per low tide. The length of the bars or lines indicates the range of temperature for each four-hour low water period.

Considering the observations of local diggers, as to the length of time that Seed Bed #2 is uncovered by the water on each low tide, it appeared that it would be best to compute all information on the basis of the quahogs being exposed to the elements for an average time of four hours per low tide. The length of the lines or bars in the body of the graph indicates the range of temperature for each 4 hour-low water period. To give the range of temperature during this period we recorded the temperature reading nearest the time of each low water, and plotted this, along with the temperatures two hours before and two hours after the initial reading.

Barometric pressures and wind speeds and directions are included in the data because of their effect upon the length of time the quahogs would be exposed by the water. Onshore winds, or a low barometer, means that both the high and low tides will be higher than predicted; while with offshore winds, or a high barometer, they will be lower.

You will notice that the lowest air temperature of the period occurred January 30 and 31, 1951, with air temperatures of -6° F. The warmest period was during the p.m. tide of January 4 with air temperatures reading 52° F. The greatest degree of change during any one 4-hour period occurred on January 14 with the temperature ranging from +10° to +34°. Wide differences can be noted in making comparisons of the temperatures during consecutive tides. Some of these rapid temperatures may well have been lethal to the exposed quahogs in Seed Bed #2. For instance, on December 24 the temperature in the afternoon ranged from 38° to 40° and the next morning had fallen to a range of 28° to 19°. Other instances of rapid fluctuation and a wide range of temperatures within this period can be readily seen.

In order to record and evaluate the changes that had occurred in Seed Bed #2 since our fall survey, another planimetric survey was made in the spring. Slide #16 is a combination of the map previously shown and the survey map made in the spring. With fall and spring surveys it was possible to make comparisons of the concentration and distribution of the living quahogs. We were also able to show, by counting both living and dead Venus in sample plots, the numbers and locations of the mortalities. It was not possible to make a topographic survey of the seed area because the extreme range of elevations within the area were less than one foot. We observed that elevations and depressions in the seed bed, as well as the position of the seed in relation to high water, had an important bearing upon the percentages of mortalities. In general, the sample plots indicated that the quahogs survived best in the depressions where silt or water covered them during the low tide. Mortalities were also greater near the low than the high watermark. We observed here as we had in other parts of Casco Bay that, where portions of the flat surface were elevated above the surrounding surface, Venus mortalities were high. Differences in elevation are shown by Slide #17. In this photo can be seen two stakes of equal length, with both driven into the flats the same distance. In the depression as shown by stake 3, 55 percent were dead; and in the elevated portion shown by stake 4, 92 percent were dead. In the entire Seed Area #2, considering depressions and elevated portions from near low to high water, average mortalities were 40.3 percent. The seed bed was spotted with these small depressions, and in some instances they joined to form extended depressions.

The average mortality rate for areas where depressions permitted the quahogs to remain covered at low tide was 14 percent, while in areas where elevations were higher and the flats were completely drained at low tide the average mortality was 53.5 percent. In some cases mortalities ranged as high as 100 percent. On the other hand, some of the depressions had practically no mortalities.

The spring resurvey of Area #2 emphasized two very important changes that took place between October, 1950, and Mar.- April, 1951. First was the extremely high mortality in the entire area. In Seed Bed #2 average mortalities of all samples was 40.3 percent. The other fact was the dispersion and displacement of live quahogs as was shown on our planimetric map of the area.

We feel that clam populations can be evaluated in terms of actual production within a reasonable range of error by using surveying instruments, making a planimetric map, and then considering the acreage involved and the size and densities of the clam population.

In the fall planimetric survey of Seed Bed #1, 6586 bushels were shown in the flats. This survey was completed after 2406 bushels had been transplanted from this area. In Seed Bed #2, illustrated by the slides, we found 6637 bushels of quahogs after 568 bushels had been transplanted from the area. In the two seed areas, we therefore, estimated a Venus population of 13,223 bushels. In the spring we were able to resurvey Seed Area #2 and found 4160 bushels of live and 2,727 bushels of dead Venus. Mortalities in the upper seed bed were 30.3 percent and in the lower seed bed 40.3 percent.

Insofar as the plantings in Maquoit and Middle Bays were made intermittently from July 8 to December 6, it is impossible to determine the exact time that any particular quahog was transplanted in considering the growth increments; but it is sufficient to say that growths in some of those quahogs transplanted in the early part of June having a median size of 43 mm. added 12 mm. in growth in one year. Translated into volume increase this means a median increase of 2.21 bushels for each bushel taken from the seed bed.

Had we been able to transplant in the spring of 1950 the Venus that were lost in these two seed beds and assuming survivals equal to those that were transplanted, with comparable growth rates figured to mid summer 1951, the loss to the town of Brunswick in terms of today's prices was approximately $55,000. The loss in Seed Bed #2 alone would be $37,000.

In the spring of 1951 we checked the areas into which we had transplanted the 3,012 bushels of small quahogs. Because of the small number of quahogs of this size class in these areas, it was not difficult to determine just where the seed had been scattered from the boats. We found that mortalities ranged from less than 1 percent to 13 percent in these seed islands with the heavier mortalities occurring in places where many quahogs had been dumped in one small area. In several such isolated spots the quahogs were seeded so thick that those in the top layers were unable to burrow into the flats and mortalities occurred.

SUMMARY

In a brief summary of our findings and recommendations for future efforts it appears that:

1. Conditions favorable to high mortalities are created when sediment cover over quahogs is scoured or eroded and quahogs are fully exposed at low water during the winter.

2. Conditions favorable to high survival and better growth are created when seed stocks are removed from areas of high density to sparsely populated flats of normal gradient where quahogs are able to burrow their normal depth below the surface.

3. Density of quahog population is not per se, a direct cause of mortality.

Exception:

a. Where density is great enough to contribute to changes of elevation in relation to the normal gradient of the flat. (This proposition has not been established, and there is no definite data even indicating such a condition except where planted stocks had been dumped in large concentrations in a small spot and created a mound on the flats).

4. Conditions favorable to high mortalitites in seed concentrations (even of comparatively low density) are created where portions of the flats are more elevated than would be anticipated from the normal gradient of the flat surface.

5. Portions of a seed concentration near the low watermark have a higher percentage of survival than do corresponding portions near the high watermark.

6. Where quahogs are located in mounds or bars above the normal gradient of the flat, 100 percent or nearly 100 percent winter mortalities may be anticipated.

7. Conditions favorable to high survival are created when water filled or sediment covered depressions remain during low tide.

8. Considerable displacement and dispersion of living and dead quahogs on Area #2 took place between October, 1950 and March-April,1951.

9. Sediments covering the quahogs at the time of the October 1950 survey had been removed from the seed concentration by March 1951.

10. The question has been raised - is a seed concentration of high density the result of natural setting in the area or is it the result of transportation of seed by tide, storm or other normal or abnormal conditions from the point of original set to the place of concentration?

Concerning Area #2 this information is available:

a. The presence of a seed concentration in the immediate vicinity of Area #2 was reported by commercial fishermen prior to January, 1949.

b. That considerable displacement and dispersion occurred between October 1950 and March - April has been established.

It is likely that the original setting of these quahogs took place somewhere within the immediate vicinity of the present location of Seed Area #2, but it is further likely that considerable displacement of a local nature has since taken place either continuously or periodically.

RECOMMENDATIONS

As the result of our study of, and experience with, quahog seed concentrations of high density during the past several years we make the following recommendations:

1. Any concentrations resulting from future sets or from the collection and displacement of future sets should be transplanted before growth has created stratification of the population.

2. Transplanting should be made as early as possible after concentrations have been discovered. (If the 3000 bushels of quahogs transplanted during 1950 had been transplanted during the late summer and fall of 1948 they would have occupied a volume of some 75 to 80 bushels and the work effort could have been reduced by about 200 man hours.)

3. In order to reduce mortalities of transplanted stocks improved methods of planting the quahogs should be carried out whereby concentrations of seed which result in creating points of elevation in the planted area are avoided. The planting should be uniform and spread out well over the area to be seeded.

INCIDENCE OF INFECTION OF OYSTERS BY DERMOCYSTIDIUM IN THE BARATARIA BAY AREA OF LOUISIANA

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Basic to any study of disease is investigation of the epidemiology (or epizootiology if the organism infected is not man). In the case of Dermocystidium disease of oysters every effort has been made to accumulate data which would throw light on the problems of distribution, sources of infection, relation of environmental factors to rates of infection, and relation of intensity and incidence to mortality. It is intended to present in this paper the data from several studies which it is believed are fairly representative, and which will assist in forming conclusions concerning the nature and pathogenicity of Dermocystidium disease of oysters.

The general nature of the disease organism has been reported (Mackin, Owen, and Collier, 1950). It will be sufficient here to recall that it consists of a single cell which reproduces in the oyster tissues by a schizogony-like multiplication of nuclei. Studies on the histopathology of infection have also been reported (Mackin, 1951). These latter studies demonstrated (1) that light infections develop into heavy infections involving the major part of all tissues, (2) that extensive and obvious damage results from heavy infections, involving all connective tissues, muscle, digestive epithelia, ganglia, and others, (3) final stages include development of multiple abscesses, especially in the mantle, and consequent loss of mantle epithelia.

A primary purpose of this paper is to present data clarifying the matter of incidence in gapers as well as in live oysters. From the standpoint of epidemiology it must be established that intensity of infection in gapers is constantly greater than it is in surviving oysters, and that, furthermore, these survivors should show intensities ranging from none through light, moderate and up to heavy, if it be maintained that progressive development of disease results in death. Conversely, the fulfillment of these con-

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Note.--The Author is indebted to members of the Grand Isle Laboratory staff for collaboration in these studies. Mr. Louis Boswell has been responsible for most experimental work and slide techniques, Mr. Fred Cauthron for photomicrography and Mr. Dan Wray for management of field studies. Dr. Sewell H. Hopkins has assisted materially in many ways. The work of the Research Foundation has been sponsored by The Texas Company, Humble Oil & Refining Company, The California Company, Tide Water Associated Oil Company, Phillips Petroleum Company, Shell Oil Company, and Gulf Oil Company, and this sponsorship is gratefully acknowledged.

ditions must be regarded as strong evidence of lethality. As time permits, the data from several studies which bear upon these matters will be presented, and will be clarified as necessary for each study.

STUDY NUMBER I

Mortality pattern in Barataria Bay

It will be necessary first to present a general picture of the mortality pattern in the Barataria Bay area as well as a brief explanation of the methods of taking data. One study has been selected as representative. This one was initiated in July of 1948 and ended in September of 1949. Five stations were set up for data-taking purposes. These consisted of wooden racks placed under low tide level on which were placed Sea-rac trays containing approximately 1000 oysters to a station. One station should be regarded as a control. This one was located in Bayou Wilkinson at Bay Chene Fleur and was known as the Chene Fleur station. Mortality had been established as light at this station, showing that the factors responsible for lethality were largely absent. Varying somewhat in degree, the other four stations contrasted sharply with the control station in the matter of yearly mortality, having from two to three times as heavy losses. All of these stations are in higher salinity waters and had been established as representing typical high mortality areas.

All stations were stocked in July 1948 with oysters from Chene Fleur Bay. All stations therefore started out with equivalent oysters. Whatever variations in mortality as occurred at the various stations must necessarily have been imposed by factors present at the various stations. Stations were visited at bi-weekly periods until September, 1949 and the rates of mortality computed for each bi-weekly period in percent mortality per day. These data were plotted in the form of a graph.

The major features of the mortality pattern at the five stations are as follows.

1. Oysters at the Chene Fleur station maintained a low death rate through-out the year contrasting strikingly with the death rates at the other stations. Exact total mortalities will be presented later.

2. Mortalities at all stations were low and roughly equal through the late summer and fall of 1948 and winter of 1948-49. The first few months of this period were high temperature months (22° to 32° C to the middle of October). Generally lower temperatures prevailed through the winter and it is obvious from the graph that these lower temperatures depressed mortality rates and held them at a low point until returning warm weather of the following spring.

3. Mortality rates accelerated rapidly, during May and June of 1949 at all stations excepting the control.

4. Rates at the Bassa Bassa station abruptly dropped and continued downward in the middle of the hottest part of the summer. Less positive and drastic drops were recorded at the other stations all of which, however, maintained a high death rate throughout the summer to the end of the studies.

STUDY NUMBER II

Incidence of Dermocystidium recorded for oysters used in Study Number I

During the progress of the preceding mortality study efforts were made to collect, fix, and section as many gapers from the stations as possible. Slides made from these gapers were analyzed for intensity and incidence of infection by Dermocystidium marinum. A total of 69 (about 2%) of the oysters dying at all stations were recovered in sufficiently good state of preservation for study. Most of these were recovered during the spring period of acceleration of mortality.

Additionally, at the end of the study a group of surviving oysters from each station were fixed, sectioned and also studied for incidence and intensity of infection. This group totaled 112 oysters.

Before presenting the data, in order that they be meaningful, it is necessary to define the categories of intensity of infection. These definitions are taken from a previous paper (Mackin, 1951) and are quoted verbatim. "Light infections are defined as those in which the distribution of parasitic cells is such that search is necessary to confirm infection. A moderate infection is defined as one in which the local foci of infection have developed to the point where a number of parasitic cells are concentrated in localized areas of tissue, producing obvious histologic changes, but in which a large part of the host tissue has not been infiltrated. A heavy infection is one where the major part of all tissues excepting certain epithelia are more or less heavily infiltrated, and at least some areas contain massive infections."

Table 1 contains data on intensity and incidence of infection of gapers collected at the various stations. Contained in this table also are total mortalities for the 14-month period, and the stations are arranged in the order of mortality level. Recovery of gapers from the Chene Fleur station was negligible and the data are included only for the sake of completeness and to show that Dermocystidium disease exists even here although the incidence from live oysters shows a quite low level. Taking all stations together 85.5% of the gapers had infections in the heavy classification.

Incidences of heavy, moderate, light, and negative infections in survivors of the study are shown in Table 2. Survivors from the Chene Fleur station showed to be 100% negative, while those at the Bayou Rigaud

TABLE 1

INCIDENCE OF HEAVY, MODERATE, AND LIGHT INFECTIONS OF DERMOCYSTIDIUM IN GAPERS RECOVERED FROM FIVE STATIONS IN THE BARATARIA BAY AREA JULY 21, 1948 TO SEPTEMBER 14, 1949

Station	% Mort. over 14 Month Period	No. Gapers Recovered	Per cent of Infection			
			H	M	L	N
Chene Fleur	29.7	3	33.3	0.0	0.0	66.7
Bassa Bassa	61.4	17	64.7	5.9	17.7	11.7
Grande Ecaille	76.6	13	100.0	0.0	0.0	0.0
Sugar House	82.5	15	100.0	0.0	0.0	0.0
Bayou Rigaud	84.2	21	90.5	0.0	4.8	4.8

H - Heavy infection
M - Moderate infection
L - Light infection
N - Negative

TABLE 2

INCIDENCE OF DERMOCYSTIDIUM IN SURVIVORS OF THE 1948-49 MORTALITY STUDIES IN THE BARATARIA BAY AREA

Station	% Mort. over 14 Month Period	Number Sectioned	Per Cent of Infection				
			H	M	L	Tot.	Neg.
Chene Fleur	29.7	26	0.0	0.0	0.0	0.0	100.0
Bassa Bassa	61.4	21	9.5	14.3	14.3	38.1	61.9
Grande Ecaille	76.6	21	0.0	9.5	42.9	52.4	47.6
Sugar House	82.5	23	4.3	8.7	39.1	52.1	47.7
Bayou Rigaud	84.2	21	4.8	14.3	47.6	66.7	33.3

station with highest mortality had a total incidence of 66.7% of infection. Most pertinent to the study are the comparative incidences of heavy, moderate and light intensities and additionally the number of negative oysters. Heavy infections were found in only 4.7% (compare with incidence in gapers) of these live oysters, moderately intense infections were found in 11.7%, light infections in 35.9% and 47.6% were negative.

The data from this study reveal several facts of interest. These may be listed as follows:

1. Low incidence of Dermocystidium at the Chene Fleur station was evidently due to poor environmental conditions at that station. Since the only major environmental difference is salinity, it is inferred that low salinities are in some manner a controlling agency for the parasite.

2. Oysters grown at the Chene Fleur station had relatively low incidence but this low incidence could not have been due to any capacity for resistance to disease since they became infected in large numbers when removed to areas of high incidence. The percentage of infected oysters having increased from near zero (in live oysters) to an average of approximately 50% at the four experimental stations.

3. Increase in incidence of Dermocystidium disease when oysters were removed to the experimental stations was paralleled by increase in mortality rate from approximately 30% at Chene Fleur to an average of about 75% at the four experimental stations.

4. The requirement that intensity of infection be sensibly greater in gapers than in survivors was fulfilled. The incidence of heavy infections in gapers was nearly 86%, in live oysters only about 5%.

STUDY NUMBER III

Dermocystidium incidence in winter months

In connection with another study in Barataria Bay came an opportunity to answer certain questions relating to causes of mortality during winter months. The data show that mortality rates fall to a comparatively low ebb when the water is cool or cold and it was questionable whether or not cool water brings Dermocystidium development to a complete halt, or whether or not low temperatures may not destroy all but some overwintering stage as yet unknown. The answers are still only partial because the effects of very low temperatures have not been studied. However, those in the normal range of Barataria Bay winters have been studied to the extent that effects of average winters can be confidently predicted.

Field data were procured from oysters kept at an experimental station at Bay Baptiste at its junction with upper Barataria, and at Station 51 which is located in mid-lower Barataria. Gapers were collected at bi-weekly or monthly intervals at these stations from November, 1949 to April, 1950. A total of 27 of these were picked up at the Bay Baptiste station and 15 at Station 51, a good record for winter, when mortalities are low. All gapers recovered were sectioned and the slides studied for incidence and intensity of infection by Dermocystidium. The data for the Bay Baptiste station are presented in Table 3 and Table 4 contains those for Station 51.

These winter and early spring collections of gapers showed that Dermocystidium in heavy concentration appeared in even higher percentage than in summer, and that early spring deaths as well as those in summer are in high percentage a result of Dermocystidium disease. Combining the two stations, nearly 93% of gapers recovered had heavy infections of Dermocystidium. It should be noted that few of the gapers were recovered in mid-winter although an effort was made to procure more complete information during December, January and February. March, however, actually is the period of least mortality and temperatures were quite low during that month, ranging from 13° to 25° C with an average less than 18°.

Perhaps more enlightening is a laboratory study on effect of low temperatures. In this study, carried on in the spring and summer when normal water temperatures are in the high twenties and low thirties, water for one aquarium was cooled to 18° C by refrigeration equipment, the other received no treatment, the temperature ranging from 25° to 32° C. Oysters used in the study had high infection rates as established by previous sectioning (over 50% infected). Twenty-five were placed in each aquarium and the study continued until approximately 50% of deaths had occurred in the control aquarium (warm water). The study was begun on May 18, 1950 and terminated on July 19, 1950, two months later. Mortality of oysters in the warm water was just six times as great as in those in the cooled water. Data on incidences of Dermocystidium are presented in Table 5.

These data reveal several very interesting facts. These are as follows.

1. The total incidence of Dermocystidium including gapers and survivors was approximately the same in the two aquaria at termination of the study. This is what would be expected if the cooled water slowed the metabolic rate of the parasites without destroying them.

2. The incidences of heavy, moderate and light infections in cooled water were 1, 5, and 10 respectively, while in the warm water the incidences were 8, 4, and 4. Thus eight times as many oysters in warm water progressed in disease to the acute stage as attained that stage in cooled water.

3. Every oyster reaching the stage of heavy infection died. Two out of nine which had attained a moderate infection died and both of these were in warm water. Two oysters with light infections died but it is not probable that cause of death in these cases was Dermocystidium.

TABLE 3

INCIDENCE OF HEAVY, MODERATE, AND LIGHT INFECTIONS OF DERMOCYSTIDIUM IN GAPERS RECOVERED FROM THE BAY BAPTISTE STATION, BARATARIA BAY AREA, LOUISIANA

Date of Collection	No. Gapers Recovered	Per Cent Recovery	Intensity of Infection, Number			Number Negative
			H	M	L	
11- 9-49	0	0.0	-	-	-	-
11-23-49	3	12.0	3	0	0	0
12- 7-49	0	0.0	-	-	-	-
1- 6-50	0	0.0	-	-	-	-
2- 5-50	5	4.0	5	0	0	0
3- 7-50	0	0.0	-	-	-	-
3-22-50	5	20.0	5	0	0	0
4- 6-50	11	22.4	9	0	2	0
4-21-50	3	15.8	3	0	0	0
Totals	27	7.2	25	0	2	0

TABLE 4

INCIDENCE OF HEAVY, MODERATE, AND LIGHT INFECTIONS OF DERMOCYSTIDIUM IN GAPERS RECOVERED FROM STATION 51 IN BARATARIA BAY, LOUISIANA

Date of Collection	No. Gapers Recovered	Per Cent Recovered	Intensity of Infection, Number			Number Negative
			H	M	L	
11- 8-49	0					
11-22-49	0					
12- 6-49	0					
1- 5-50	0					
2- 4-50	0					
3- 6-50	3	4.4	3	0	0	0
3-21-50	2	8.0	2	0	0	0
4- 7-50	4	9.5	3	0	0	1
4-22-50	6	11.3	6	0	0	0
Totals	15	3.6	14	0	0	1

4. The laboratory data exactly support tentative conclusions from field data, namely that low rates of mortality in winter are due to decreased metabolic rates of Dermocystidium marinum and not to elimination of the parasite.

STUDY NUMBER IV

Water-borne nature of the infective element of Dermocystidium marinum

The wide distribution of D. marinum infection in Louisiana oysters has suggested that the infective cell is water-borne. There are no conclusive data indicating the nature of the infective cell. Several observed stages are suspect, but to date the only reasonable certain fact is that the stages ordinarily observed in oyster tissues, i.e. the spherical vacuolated stage and the cells resulting from reproduction by multiple fission cannot produce disease by direct inoculation into a new host. This failure to effect direct transfer suggests that either a saprophytic stage, or a parasitic stage in an alternate host, may exist, which hypothetical stages may produce the as-yet-unknown infective stage for the oyster.

All that as it may be, the fact remains that oysters do become infected on a wholesale basis. It may prove to be that the matter of the presence or absence of intermediate saprophytic or parasitic stages could become a matter of considerable practical concern. Because of the very large number of possibilities, so far as available intermediate hosts are concerned, it seemed desirable to limit the field of study, if possible, by attempting infection in the absence of most normal ecological associates of the oyster. Also it would be helpful to determine whether or not it is true that the infective elements are water-borne, even if it should not turn out to be possible to determine whether the infective element was free, or parasitic in some water-borne intermediate host.

After considerable study of the type of experimental equipment best suited to the problem, a technique was worked out which, on the basis of the data derived, answered some of the questions involved. The study was carried through as follows.

Sea water at the laboratory was run into an overhead constant head tank which also served as a settling tank for silt. The water from the constant head tank was passed into two aquaria below. One of these, called the experimental tank, contained 20 oysters from a known high infection group. By previous sectioning the infection level of D. marinum was known to be not less than 50%. In the control tank were placed 20 oysters, known to have a low level of incidence, established at probably less than 5%. From each of these tanks a tube led to a rubber manifold which distributed water to 16 finger bowls each containing one oyster. These oysters also had a low infection incidence. The objective in isolating the second group of experimental and control oysters in finger bowls was to exclude the possibility of infecting each other.

TABLE 5

INCIDENCE OF HEAVY MODERATE, AND LIGHT INFECTIONS OF DERMOCYSTIDIUM IN OYSTERS USED IN A LABORATORY STUDY OF THE EFFECT OF COOLED WATER ON OYSTER MORTALITY

MAY 18, 1950 TO JULY 19, 1950

		Intensity of Infections				
		Heavy	Moderate	Light	Negative	Total
Oysters in Cooled Water	Gapers	1	0	1	0	2
	Survivors	0	5	9	9	23
Oysters in Warm Water	Gapers[1]	8	2	1	0	12
	Survivors	9	2	3	8	13

[1]One gaper not recovered.

Total percent infection in cooled water 64%
Total percent infection in warm water 64%

TABLE 6

INCIDENCE OF HEAVY, MODERATE, AND LIGHT INFECTIONS OF D. MARINUM IN GAPERS AND SURVIVORS OF STUDY OF MANNER OF TRANSFER OF INFECTIVE ELEMENTS OF THE DISEASE

JULY 31, 1950 TO OCTOBER 16, 1950

			Tot. No.	Int. of Inf. H.	M	L	N	Not Recovered
Experimental Oysters	20 oysters with high infection incidence in Tank 1	Gapers	15	12	0	0	1	2
		Survivors	5	0	3	0	2	0
	16 oysters with low infection incidence in finger bowls	Gapers	8	7	0	0	0	1
		Survivors	8	0	0	1	7	0
Control Oysters	20 oysters with low infection incidence in Tank 2	Gapers	3	2	0	0	1	0
		Survivors	17	1	1	5	10	0
	16 oysters with low infection incidence in finger bowls	Gapers	4	2	0	0	2	0
		Survivors	12	0	0	1	11	0

Note: 76.7 percent of gapers from all aquaria with heavy infections of Dermocystidium marinum.
2.4 percent of survivors with heavy infections of D. marinum.

As completed the set up consisted of two units receiving water from a common source. In one of these units (experimental) water passed through a tank containing oysters known to have high incidence of D. marinum and was delivered to 16 low-level incidence oysters in individual finger bowls. The other unit (control) was precisely the same excepting that the intermediate tank contained low-level incidence oysters rather than high level. The experiment was carried on in high mortality territory where the water necessarily contained infective elements and infection of control oysters was considered unavoidable. However, it was reasoned that placement of infected oysters in the flow stream of the experimental group should produce greater incidence of disease in these latter than occurred in the controls, provided the infective element was water-borne and the aquarium contained all necessary elements for completion of the life cycle.

The data derived from this study are presented in Table 6. Since mortality of the experimental oysters in finger bowls exactly doubled that of the controls, it may be inferred that some of the infective elements came from the infected oysters in the experimental tank. This eliminates the possibility that any animals of large size such as crabs, etc. are intermediate hosts, but does not eliminate shell inhabitants such as Polydora, Martesia, or others, and does not certainly eliminate such forms as were in the plankton. Nor does the study eliminate the possibility of a saprophytic stage developing on the bottom or in the water. It does emphasize the water-borne nature of the infective element, whatever it may be.

Of perhaps more importance is the establishment of the fact that proximity of disease carriers influences the incidence of disease in an imported susceptible population. There is an indication of contagiousness in the data, i.e., direct oyster to oyster transmission, but there are data contradictory to this in the fact that attempts at direct artifical transfer have failed heretofore. This failure may have been due to employment of improper technique.

Of considerable interest is the distribution of deaths in time. Deaths from Dermocystidium in the large experimental tank started almost immediately, the first mortality occurring just 10 days after the initiation of the study. Oysters in the experimental finger bowls receiving water from this tank started dying almost a month later. Oysters in the control tank had their first Dermocystidium death more than a month after initiation of the study, and the first Dermocystidium death in the control finger bowls did not occur until 4 days prior to the termination of the study. These relationships are shown in Table 7.

STUDY NUMBER V

A study of the relationships of spawning to infection with D. marinum

It has frequently been noted that the acceleration of mortalities in the spring months, which has already been discussed, corresponds closely

TABLE 7

DATES OF DEATH OF OYSTERS DYING WITH HEAVY INFECTIONS WITH DERMOCYSTIDIUM IN EXPERIMENTAL AND CONTROL TANKS AND FINGER BOWLS OF INFECTION STUDY

	Exp. tank	Exp. Finger Bowls	Control Tank	Control Finger Bowls
July 31	Study begun			
10	X			
	X			
Aug. 20				
	X			
31				
	X	X	X	
	X	X		
10	X			
	X			
Sept.				
20				
	X	X		
	X	X		
		X		
30				
	X			
	X			
	X	X		
10				
Oct.				X
			X	X
		X		
16	Study ended			

with the normal peak spawning period. Actual observation of spawning at some stations has been followed closely with extraordinary increases in mortality rate. It was considered necessary, therefore, to study the apparent relation and to determine whether or not it extended to a cause and effect sequence.

It seemed likely that if production of gonadal products and subsequent spawning had a weakening and ultimately lethal effect on the oysters that a histological study of those dying during the peak spawning period would establish it as fact, or provide some data bearing on the cause of death if it was not a fact. To provide material for such a study a number of oysters were placed on trays and these in turn placed on underwater racks at the Grand Isle Laboratory of the Texas A. & M. Research Foundation. Here they could be examined daily and the gapers recovered, fixed, sectioned and the slides studied. At intervals live oysters from the same group were also fixed and sectioned, and subsequently studied, to provide control observations.

The data are presented in Table 8. A study of these data does not support the thesis that weakening by spawning had anything to do with mortality. In the first place but few of the gapers had spawned. More than half of them showed that the gonadal tissue was either resorbed under conditions of parasitism or was directly destroyed by occupation of the gonads by Dermocystidium cells. Among the controls most of the light and moderately infected oysters developed normal gonads, showing that resorption and destruction of gonadal tissue probably occurred after relatively heavy infections had developed.

It appears probable from these data that the correlation of spawning period and period of accelerating mortality is due to the fact that optimum temperature for Dermocystidium development corresponds very closely to optimum spawning temperatures, *i.e.*, about 22° to 25° C in Louisiana.

SUMMARY

By way of summary it is interesting to see how incidences in all oysters in the small group of studies discussed are distributed. Table 9 presents a summary uniting these studies and reduced to percentages of each category of intensity.

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TABLE 8

GONADAL CONDITION AND INTENSITY OF DERMOCYSTIDIUM INFECTION IN GAPERS AND LIVE CONTROL OYSTERS DURING THE GONADAL DEVELOPMENT PERIOD AND SPAWNING PERIOD IN THE SPRING OF 1950

	Controls (live oysters)			Gapers		
Gonadal Development	Partially mature or mature unspawned	Spawned out	Undeveloped	Partially mature or mature unspawned	Spawned out	Undeveloped or destroyed
Heavy Infections	0	0	1	11	5	25
Moderate Infections	2	1	1	0	0	1
Light Infections	8	0	1	0	0	3
Negative	9	0	1	0	0	2
	Total sectioned: 25			Total sectioned: 47		

TABLE 9

COMBINED INCIDENCES OF DERMOCYSTIDIUM OF STUDIES 2 TO 5 OF THIS PAPER

Intensity of Infection	Total No. Studied		Number with: Heavy Infections	Moderate Infections	Light Infections	Negative
Gapers	198	No.	171	4	11	12
		%	86.4	2.0	5.6	6.1
Live Oysters	214	No.	6	25	59	124
		%	2.8	11.7	27.6	58.0

A REPORT ON THE INTERRELATIONSHIP BETWEEN THE GROWTH AND MORTALITY OF OYSTERS

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Abstract

Volumetric yield (Louisiana sacks) is derived theoretically from selected experimental oyster transplantations in Louisiana. Theoretical derivation of volumetric yield values rests on the assumption that volumetric yield results from the interrelationship of oyster growth and oyster mortality. Oyster growth and oyster mortality are determined, respectively, by length measurements and counts of random tonged oyster samples. Observations were continuous at subsequent intervals of time for a period of approximately eleven months from November, 1947, through October 1948.

THE EFFECTS OF PREDATION ON SOFT CLAMS, *MYA ARENARIA*

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During the two summers and the intervening winter of 1949 and 1950, observations were made on the survival of native and planted soft clams (*Mya arenaria*) in natural clam flats and in sections of the same flats which were fenced or covered with chicken wire to protect the clams from some of their natural enemies.

These observations were made on two different types of flats in the northern or upper part of Plum Island Sound, near Newburyport, Massachusetts. One, Hales Cove, was composed of moderately firm sandy mud. The other, Horseshoe Flat, was a slightly ripple-marked flat of firm sand, bonded with a little dark silt. The clam population of these flats was at a low ebb, producing almost no commercial digging, though in the past a man could dig three bushels in a tide, according to local residents.

Observations on Predators

The disastrous effect of natural predation on small plots of transplanted clams was first noticed in the summer of 1949. On May 26 and June 2, sixteen bushels of clams were distributed in eleven plots on the Horseshoe Flat and at Hales Cove. All were planted by broadcasting the clams on the exposed flat and allowing them to dig in. The average length of these clams was 39mm. and there were about 3700 per bushel. At Hales Cove, six 8-foot x 10-foot plots were planted at a concentration of 20 clams per square foot. On the Horseshoe Flat, two 10-foot x 10-foot and three 10-foot x 20-foot plots were planted at a concentration of 38 clams per square foot. The plots on both flats covered a total area of only 1280 square feet and were, therefore, small in relation to the size of the flats.

The clams dug in well, judging by counts of the holes one day later. Within a week, however, the horseshoe crabs (*Limulus polyphemus*) had located the plots. On June 7, 31 crabs were found in the three 10-foot x 20-foot plots on the Horseshoe Flat. They had dug into all plots so thoroughly that the surface was covered with depressions. At Hales Cove the entire surface of the planted areas was lowered so that square pools of water marked the plots at low tide. When these plots at Hales Cove were dug in November 1949, 92 percent of the clams had disappeared. Field observations and occasional trial digging in the plots indicated that most of this loss was caused by horseshoe crab predation within a week or two after the clams were transplanted.

As a result of this experience, another transplanting experiment was attempted on August 26, 1949. This plot, No. 13, was 20 x 20-foot, and was seeded with 32.4 mm. clams at about 32 per square foot. This time, however, a fence was built around the plot, following the then unpublished work of Turner (1949). The fence was made of three-foot wide chicken wire of two-inch mesh. The lower edge was buried about six inches, making a fence two and a half feet high. This fence effectively barred the horseshoe crabs which were still plentiful in the surrounding area. About three weeks after the fence was built, the crabs disappeared, on their annual fall migration from the Sound. This fence was destroyed by ice during the winter, but it was rebuilt in the spring before the horseshoe crabs reappeared.

In November 1949, after the horsehose crabs had migrated, two more series of plantings were set out on the Horseshoe Flat and at Hales Cove. These clams were of two size groups: Group I averaging 46.2 mm. in length and 1680 per bushel, and Group II averaging 16.1 mm. in length and 34,560 per bushel. A total of 21 plots was established on both flats. The larger clams were planted at concentrations of 38 and 21 per square foot, the smaller clams in concentrations of about 200, 100 and 75 per square foot.

Both groups dug in well, although the smaller sized Group II dug in much faster. Inasmuch as the smaller clams seemed more likely to be susceptible to bird predation, half of each plot of small clams was covered with chicken wire soon after planting.

In the spring when the first fence which had been destroyed by ice was rebuilt (plot No. 13), fences were also built around four of the eight 5-foot x 10-foot plots. The fences were designed to protect a light and a dense planting of each of the two size groups of clams. The other four similar plots were left as controls. The chicken wire covering half of the 10-foot x 20-foot plots had been left down during the winter and the ice had either destroyed or rendered useless all but a small 6-foot x 8-foot strip on plot No. 24. This small strip supplied all the samples of protected clams. It had been planted with 100 per square foot.

All fences were completed on May 9, 1950, which proved to be just ten days before the horseshoe crabs reappeared. Soon after the first horseshoe crabs were seen, they swarmed over the Hales Cove flats, and depressions from their digging literally covered the area. Fragments of *Mya*, *Macoma* and whole or crushed *Gemma* were found in horseshoe crab guts and in their capsule-like droppings. No horseshoe crabs were found inside the fenced areas all summer, so we feel safe in saying that this clam predator can be barred from any area enclosed by a fence such as described above.

However, with one predator controlled, it soon became obvious that something else was causing heavy losses. Every time the planted area was visited, new sharp-edged depressions, unlike those made by the horseshoe crabs, were found inside the fence as well as outside. Freshly cleaned-out clam shells with the hinge ligament still intact but with the edges chipped were plentiful in the area.

This predation was not due to birds as was first suspected. Gulls and ducks had been seen puddling for small clams in other areas much as described by Medcof (1949), but they were never seen bothering our planted stock, and their tracks were not often seen in the area.

The boring snail, Polinices heros, which is fairly common in Plum Island Sound, was also eliminated as the predator causing the heavy losses. Although snails were sometimes found with drilled or partly drilled clams enclosed in the foot, there was no indication of a concentration of them in the planted plots, either inside or outside the fences. Drilled clam shells were seldom found in our square-foot samples. However, this is not to pass lightly over the importance of the boring snail as a clam predator. Small snails one-half to one inch in diameter have been found on Horseshoe Flat in concentrations of one per 25 square feet, and Turner (1949) reports that they can be very destructive.

All the above-named predators must take their toll, but we finally learned that the Green crab, Carcinedes maenas, was doing most of the damage inside our fences. These crabs are very abundant in Plum Island Sound and they were found inside the fences and sometimes in the pits. Definite proof was obtained on August 16, 1950, when a crab was caught in the act while we watched at high tide, using a swimmer's face plate. This crab was at the edge of a very fresh and well-defined pit, chewing on a freshly cracked clam. Both crab and victim were collected, the crab measuring 64 mm. wide and the clam 50 mm. long.

The crabs generally were wary of a swimmer, but they frequently were seen scuttling away from an excavation. They could be seen going both through and over the fence. One-inch mesh chicken wire was tacked over the bottom two feet, but it did not reduce the number of green crab holes inside the fenced area.

A typical green crab excavation is about three to six inches in diameter and sometimes six inches deep. Generally, they are undercut on one side and the low surrounding mound of fresh dirt is highest on the side opposite the undercutting. The sharp edges and the undercutting clearly distinguish them from the shallower and wider depressions left by horseshoe crabs or where ducks and gulls have paddled with their feet.

Square-foot samples revealed a much greater production of clams in protected than in unprotected areas. As might be expected, protection was more important for the survival of the smaller Group II clams than of the larger Group I clams which were able to dig deeper in the flats. Table I shows the results from Group I clams in fenced and unfenced plots.

The horseshoe crabs, arriving about the middle of May 1950, had had a little over two months to feed on the clams, and in that time they had eaten about half the clams outside the fence. Since we have seen that a two-inch mesh fence is not a barrier to green crabs, most of this difference must be attributed to horseshoe crabs. However, it may be noted that these clams were nearly legal size (2 inches) when planted. This enabled them to survive inside a fence, but it effectively rules them out as subjects for profitable clam transplanting. Transplanting always involves losses from breakage and the failure of some clams to dig in, as well as the expense of collecting them in the first place. Therefore, the transplanted clams must be relatively small and produce an increase in total volume; or else they must be harvested by cheap mechanical means, which is illegal in most clam-producing areas. Because of this situation, the large clams were not sampled further.

As may be seen in Table I, the recoveries inside the fences were actually greater than the estimated density at planting. Obviously, the planting density was underestimated, and the survival was something less than the percentages given.

In Plot 13 (the first trial fence) survival was about 12 percent one year after planting, which is lower than for the large Group I clams but greater than for the small Group II clams. Their average size at planting was 32 mm., which also was about midway between the two groups.

Sampling of the small Group II clams in October showed less than 2 percent survival inside the fence and no survival outside. Under the chicken wire, however, survival was high, considering the small size at planting. Individual samples ranged from 20 to 70 percent during the summer.

Figure I illustrates the great contrast in length frequencies and survival between unprotected native clams and natives protected for one year by one-inch mesh chicken wire staked down flat on the surface. By following the peaks in the length frequency polygons for the protected clams in Fig. 1, it may be seen that the series starts with one size group. These are the 1949 year-class clams, wintering at a modal length of about 3 mm. There is indication of some growth in March and April. After May, the protected and unprotected clams fared quite differently. In the protected plot the 1949 year-class survived and grew from May to August. After August, they stopped growing but continued to survive. By contrast, the 1949 clams in the unprotected areas were completely wiped out. While this was going on, a second group of small clams appeared. This group, probably mostly 1950 year-class, continued to receive recruitments from larvae settling down or from wandering byssus stage clams so that it was highest in November. Whatever growth may have occurred in this group was masked in the histogram by the continuous recruitment of small individuals. The large number of 1 mm. clams collected in September under the chicken wire (Figure 1) does not necessarily indicate an unusually great abundance of this size class, because that particular sample was taken with a finer screen than all other samples. One mm. clams might have been abundant in some other samples, but our screens were not fine enough to collect them.

TABLE I: RECOVERIES FROM FENCED AND UNFENCED PLOTS, SET OUT NOVEMBER 16, 1949, JULY 18 - 25, 1950. SAMPLED BY DIGGING A FOUR-SQUARE-FOOT AREA IN EACH PLOT. AVERAGE SIZE AT PLANTING 46 MM. (GROUP I CLAMS)

Area	Plot No.	FENCED PLOTS			UNPROTECTED PLOTS		
		Est. No. Planted Per sq. ft.	No. Recovered Per sq. ft.	Aver. Length	Est. No. Planted Per sq. ft.	No. Recovered Per Sq. Ft.	Aver. Length
Hales Cove	15	(21)	20.5	52.4			
" "	16				(38)	23.5	57.9
" "	17				(21)	9.0	55.6
Horseshoe	18	(38)	45.5	57.2			
"	19	(21)	21.3	55.1			
"	20				(21)	15.0	58.5
"	21				(38)	14.3	57.7
	TOTAL	(80)	87.3		(118)	61.8	
	SURVIVAL		Nearly 100%			About 52%	

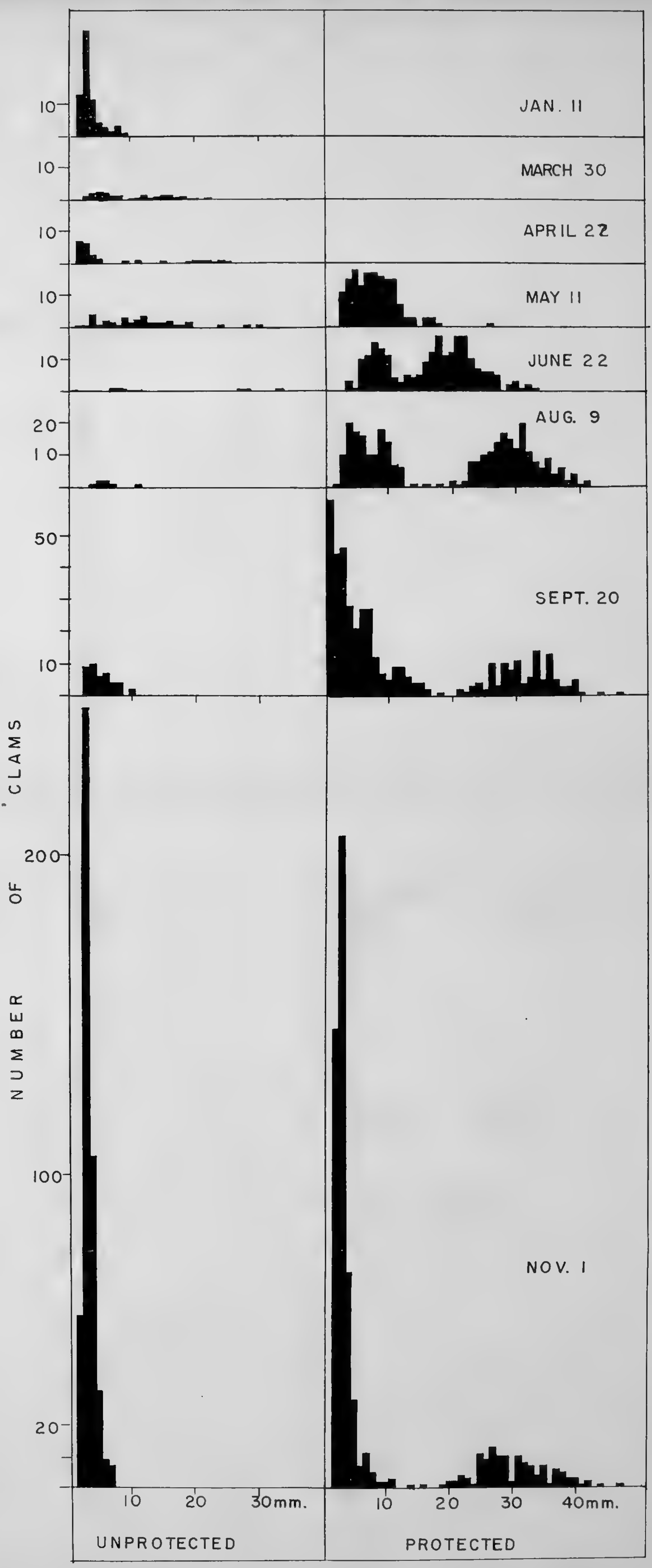

Fig. 1.--Length frequencies of native clams, in square foot samples, from unprotected plots and from plots protected by one-inch mesh chicken wire staked down on surface of flat.

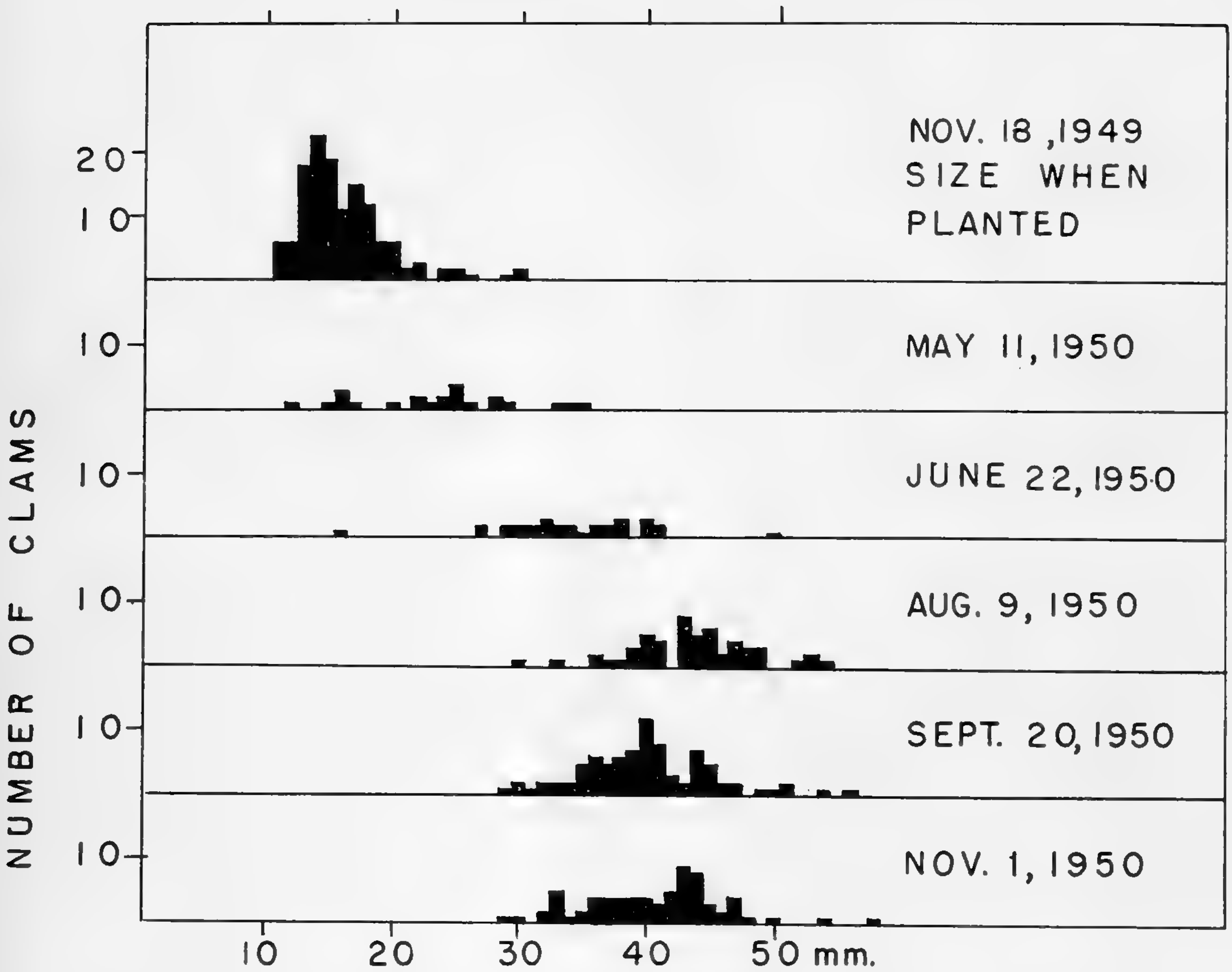

Fig. 2.--Length frequencies of planted clams protected by one-inch mesh chicken wire staked down on surface of flat. May 11 to November 1 histograms represent one-square-foot samples. Size at planting determined from sample at time of planting, on November 18.

Figure 2 illustrates the growth and survival of planted clams under the same small piece of one-inch mesh chicken wire protecting the native clams of Figure 1. The unprotected planted clams completely disappeared in May and June. As in Figure 1, it may be seen that growth was relatively rapid in the spring, but stopped in mid-summer. In fact, there was an apparent shrinkage, a phenomenon that may warrant further investigation. Both native and planted stock were taken in the same samples, hence the numbers of protected clams in Figs. 1 and 2 may be added to show the total numbers of clams per square foot under the chicken wire.

The shells of the transplanted clams were more rough and chalky-looking than the relatively smooth native clams, but the new growth took on the smooth appearance of the native stock. Hence they could be readily distinguished from the natives under the same screen. For the same reasons the winter or planting check and the new growth were clearly marked. Measurements of lengths at the annulus coincided with the length frequency at planting.

Conclusions

From the above observations it would seem that during periods of clam scarcity, the young clams in the open flats will not survive the combined predation of the horseshoe crabs and green crabs. Clams can be protected from the horseshoe crabs by a fence but only the legal or nearly legal sized clams go deep enough to survive green crab predation. Some large clams will survive inside a fence, but they will show little or no increase in volume per unit area and hence no economic gain. Under chicken wire, however, both native and transplanted clams will survive well and grow. We have yet to learn what the clam and predator relationships are during periods of clam abundance.

Those experiments clearly demonstrate that clams would return in numbers to these flats if it were not for the predators, and so the present scarcity cannot be blamed entirely on overdigging and not at all on changes in climate or unfavorable soil, except as these changes might affect the abundance of predators.

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VARIATIONS IN SIZES AND RATE OF GROWTH OF LAMELLIBRANCH LARVAE OF THE SAME PARENTS

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Abstract

The larvae obtained from the eggs of a single female of *Venus mercenaria* and fertilized with the sperm of a single male of the same species, and a similar culture of the larvae of *Mytilus edulis*, were grown to metamorphosis. Examination and measurement of the samples collected at two-day intervals indicated that the larvae originating from the same parents and kept under identical conditions showed great variations in rate of growth, size and time of beginning of setting.

THE BONNET CARRÉ SPILLWAY AND THE OYSTER BEDS OF MISSISSIPPI SOUND

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The Bonnet Carré Spillway was constructed thirty-three miles above Canal Street of New Orleans by the Crops of Engineers, U. S. Army as a part of the project to control floods in the Mississippi Valley. An Act of Congress directs the Engineers to open the spillway when the water height is 20 feet on the New Orleans flood gauge. The spillway discharges a little more than 250,000 second feet of water into a floodway leading into Lake Pontchartrain and thence out through Lake Borgne to Mississippi Sound, where the flood waters affect oyster beds of the states of Louisiana and Mississippi. Since its completion in 1932 the spillway was opened in 1937, 1945 and 1950. The periods of flow were February 4-March 15, March 24-May 17, and February 11-March 17, respectively. The respective flows in acre feet were 12,400,000, 24,500,000 and 10,900,000.

The 1937 opening was generally conceded to be beneficial and increased crops of oysters, shrimp and fish followed. The 1945 opening did considerable damage to oysters in Mississippi Sound and the Louisiana Marsh, killing them out in proportions ranging from 50 to 100 percent. The 1950 opening caused a maximum mortality of about 15 percent on the inmost beds, lying near the mouth of Lake Borgne, as shown by independent checks by the writer and biologists of the Louisiana Department of Wild Life and Fisheries. Prior to the opening of this spillway the oysters in this whole region had been subjected to low salinity from rainfall in the area and drainage from the Pearl River. It was noted that oysters in the low salinity areas survived the Mississippi flood waters better than those in salinities which had previously been higher. No silting on the oyster beds was observed although the muddy river water could be traced far out into Chandeleur Sound. As a whole, the 1950 opening was beneficial and it may be said that there is a beneficial aspect to all spillway openings, even those which cause heavy mortality, because various oyster enemies, such as Thais, are killed out and nutrient salts are brought into the area.

The effect of fresh water upon oysters and other marine organisms depend in part upon temperature, the previous salinity to which the animals were subjected, the rapidity of the onslaught of fresh water and the length of its stay. The factors are complex and each opening of the spillway will doubtless differ in certain respects. It is significant that the 1945 opening, which caused damage, came later in the year, was longer extended, and flowed twice as much water as the other two.

At the present time the Bonnet Carré Spillway is operated purely as a flood control measure. In certain years the waters of Mississippi Sound become too saline for oysters and the possibility of operating the spillway so as to allow river water to flow into the floodway in high salinity years is worthy of consideration. This would utilize the spillway positively in a phase of biological engineering and such an operation would doubtless necessitate certain changes. The feasibility of utilizing the existing structure for increased benefits should be determined.

BIOLOGICAL EFFECTS OF BULLRAKING VS. POWER DREDGING ON A POPULATION OF HARD SHELL CLAMS, VENUS MERCENARIA

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Narragansett Bay, Rhode Island has supported an intensive commercial fishery for hard shell clams or quahaugs for many years. Hand diggers using tongs or bullrakes are allowed to fish in any unpolluted waters in the state. Power dredges have been restricted to the southern half of the Sakonnet River except for a short time during World War II when additional areas were opened to increase food production. Locations of quahaug fishing areas are shown in Figure 1.

Controversies continually arise between fishermen using power methods and those who harvest the clams by hand. Rakers and tongers claim that they are using the only methods which do not harm the bottom or destroy young clams. They claim the dredges tear up the bottom, breaking many of the clams which are caught as well as those which go through the bag of the dredge and are left to die. They also believe the dredges bury the small clams so deeply that they are smothered, and that the bottom is sometimes plowed to such an extent that current action causes scouring which prevents a new "set" from surviving.

Dredgers claim they are merely cultivating the bottom and preventing it from becoming too compact for the clams to live. Dredging, they state, really improves the bottom, inducing new sets and increasing the growth rate of those clams which are left.

The Division of Fish and Game of the Rhode Island Department of Agriculture and Conservation has the responsibility of enforcing laws regulating areas which may be fished by dredging as well as the dredging catch limit of 30 bushels per day. Difficulties in enforcing these laws, the dredgers demands for additional areas, and controversies between power and hand diggers resulted in a request by the Division of Fish and Game that the Fish and Wildlife Service investigate the problem. Since this controversy

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Note.--The authors wish to acknowledge the valuable assistance of Dr. Charles J. Fish in planning the experiment, and the cooperation of the Narragannsett Marine Laboratory in providing equipment and laboratory space. Louis D. Stringer, Fishery Biologist, U. S. Fish and Wildlife Service, prepared most of the illustrations for this paper. Thomas F. Kane, Fishery Aid, U. S. Fish and Wildlife Service, collected much of the field data used in this report.

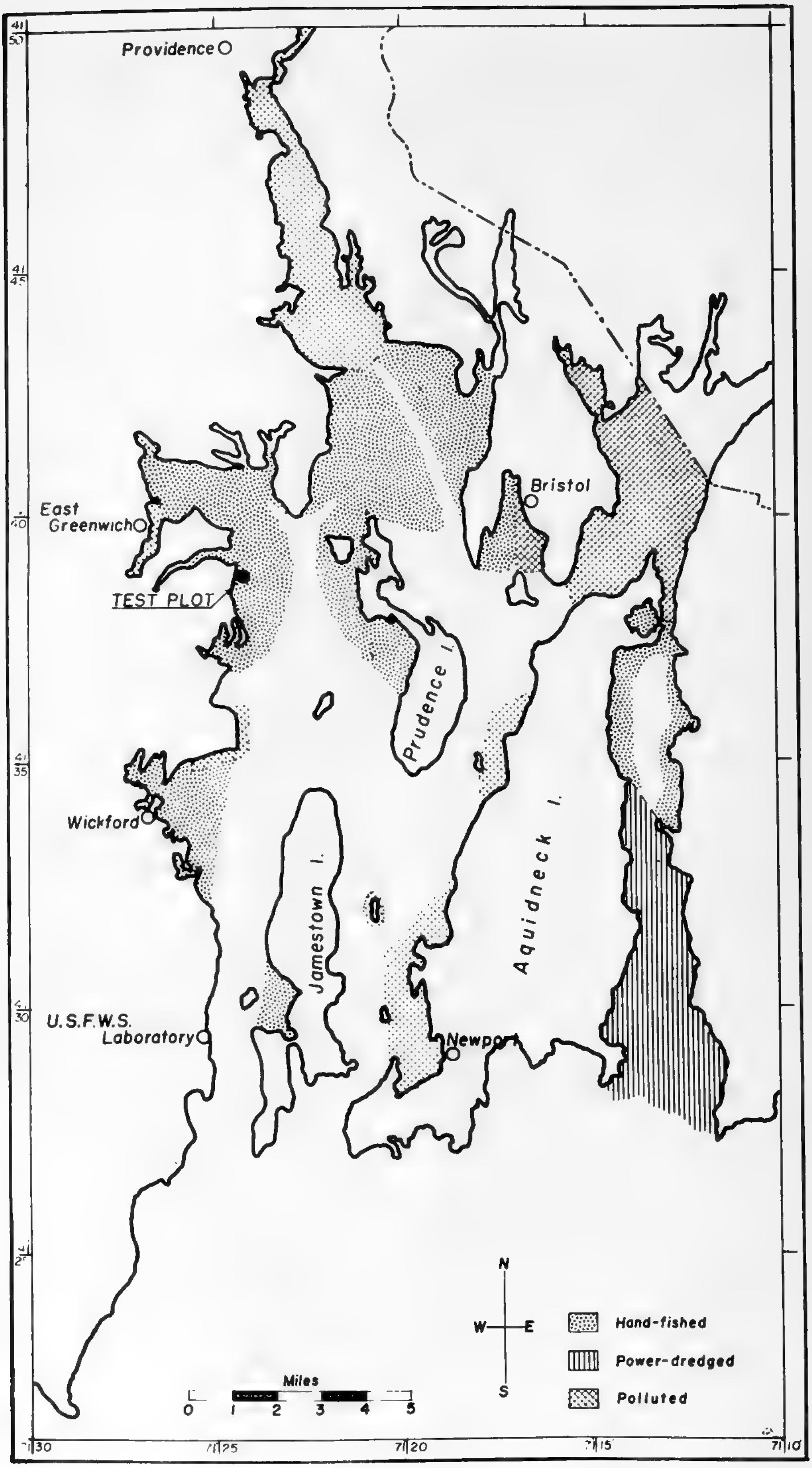

Fig. 1--Narragansett Bay, R. I. showing location of hard clam fishery and test plot.

has been encountered in other states, it was decided that the Service should undertake an experiment to determine the relative biological effect of power dredging and hand raking upon a population of quahaugs. The Division of Fish and Game agreed to close an experimental area and to patrol it to prevent illegal fishing. The Narragansett Marine Laboratory of the University of Rhode Island agreed to furnish office and laboratory space and to share the expenses of operating a research boat. The Fish and Wildlife Service agreed to conduct the experiment, analyze, and publish the results.

FISHING METHODS

Fishermen bullrake from flat-bottomed skiffs about 16 feet long. The rake, sometimes called a Shinnecock Rake, is about 36 inches wide and has about 30 teeth with 7/8-inch spaces between. The teeth are curved on about a 4-inch radius so the rake will dig about 8 inches deep. (Figure 2). The handle or stale is in sections and may be increased to about a 36-foot length for digging in waters 25 feet deep. Although the maximum depth for raking is about 40 feet, most is done at less than 20 feet. The fisherman pulls the rake through the bottom in a series of short jerks, occasionally bringing it to the surface to empty the catch into the boat. About 1,400 fishermen are licensed in Rhode Island to catch quahaugs by hand digging methods, and about half of these use bullrakes. The maximum catch per day for rakers is about ten 80-pound bushels, but the average is only about four bushels. The price depends upon the size composition of the catch. Rakes will efficiently catch clams as small as 46 mm. length which is just under the legal length of 47-48 mm. (1-1/2-inch width). Therefore, their catch represents fairly well the size composition of clams above 45 mm. A few smaller clams are trapped in the mud, shells and debris brought up by the rake, but most of these pass between the teeth. Rakers prefer to catch "little necks" which range in size from 1-1/2-inch width (47-48 mm. length) to 2-inch width (60 mm. length) since the price for these averages $5.00 to $6.00 per bushel compared to $2.50 to $3.50 per bushel for larger clams. Clams over 2-inch width are known to the fishermen as "mediums", "large", or "chowders", although dealers establish additional size groups.

Fishermen tong from flat-bottomed boats similar to those used in raking. The tongs are similar to those used for oysters but are modified to dig through the bottom to remove the clams. Stales (Handles) are usually no longer than 15 feet, which allows digging in water about 12 feet deep, although 18 to 20 foot stales are sometimes used in water 15-16 feet deep. Because this type of fishing is less strenuous than bullraking it is the method used by the older fishermen, although most men use tongs where the water is shallow. The tongs catch clams of the same size range as rakes. The maximum catch per fisherman in 80-pound bushels is about five per day, and the average is about three.

Fig. 2.--Bullrakes are used by about half of Rhode Island's 1,400 "hand" diggers.

The quahaug dredge, sometimes called the "Fall River" or "Nantucket" dredge, consists of an iron frame with a row of teeth spaced 2 inches apart which dig the clams from the bottom. The bag which holds the catch is made of 2-inch iron rings which allow clams under 2-inch width (60 mm. length) to pass through. (Figure 3.) The dredge is used primarily for catching quahaugs of the large or chowder size. Dredge boats which range from 30 to 45 feet in length require masts, booms, winches and powerful engines for dragging the dredge through the bottom. A crew of two is normally required. Boats dredge in water as deep as quahaugs occur and as shallow as the draft of the boat will permit. They can operate in weather which would be too rough for hand digging. The daily catch in Rhode Island is limited to 30 bushels per boat, but this amount can only be attained for a short time after the opening of the season in the southern part of the Sakonnet River. The dredging season is from December 1 to March 31. Rhode Island has about 24 licensed quahaug dredge boats, although at the maximum of the fishery in 1943-1945, 46 boats were engaged.

METHODS FOR CONDUCTING THE EXPERIMENT

After dredging quahaugs at stations throughout Narragansett Bay we decided that the Highbanks area between Quonset Naval Air Station and Greenwich Bay was suitable for the experiment. The depth of the plot selected is about 20 feet and the bottom is firm sandy mud. Samples dredged with a small mesh liner inside the bag showed quahaugs of all sizes to be present (Figure 4).

We held meetings with the dredgers and with the hand diggers to discuss the proposed experiment and both groups gave their approval. The Division of Fish and Game then closed the 3-acre test area to commercial fishing. This area included three parts as shown in Figure 5, with the plots to be dredged and bull raked during two summers separated by a control tract. The dredged plot was placed downstream in relation to the non-tidal drift so silt would not be deposited upon the control and bullraked plots as the hand fishermen claimed that silting or scouring was one of the bad effects of dredging. The hand digging method chosen for the experiment was bullraking since the depth was too great for tonging. We divided each test plot into quarters to determine the effect of the fishing upon a new set of clams in relation to the length of time before or after setting. A different arrangement of the quarters was necessary in the two areas since dredging required a long tract, whereas a square plot was more suitable for raking. Unfished corridors 25 feet wide were left on both sides of the control plot to prevent overlapping.

Bullraking Operations

We employed two commercial bullrakers to fish Area B. Each digger sold his catch and in addition received enough remuneration to make his wages equal to those he would have received had he fished wherever he desired. This total wage was based upon catch records from commercial bull-

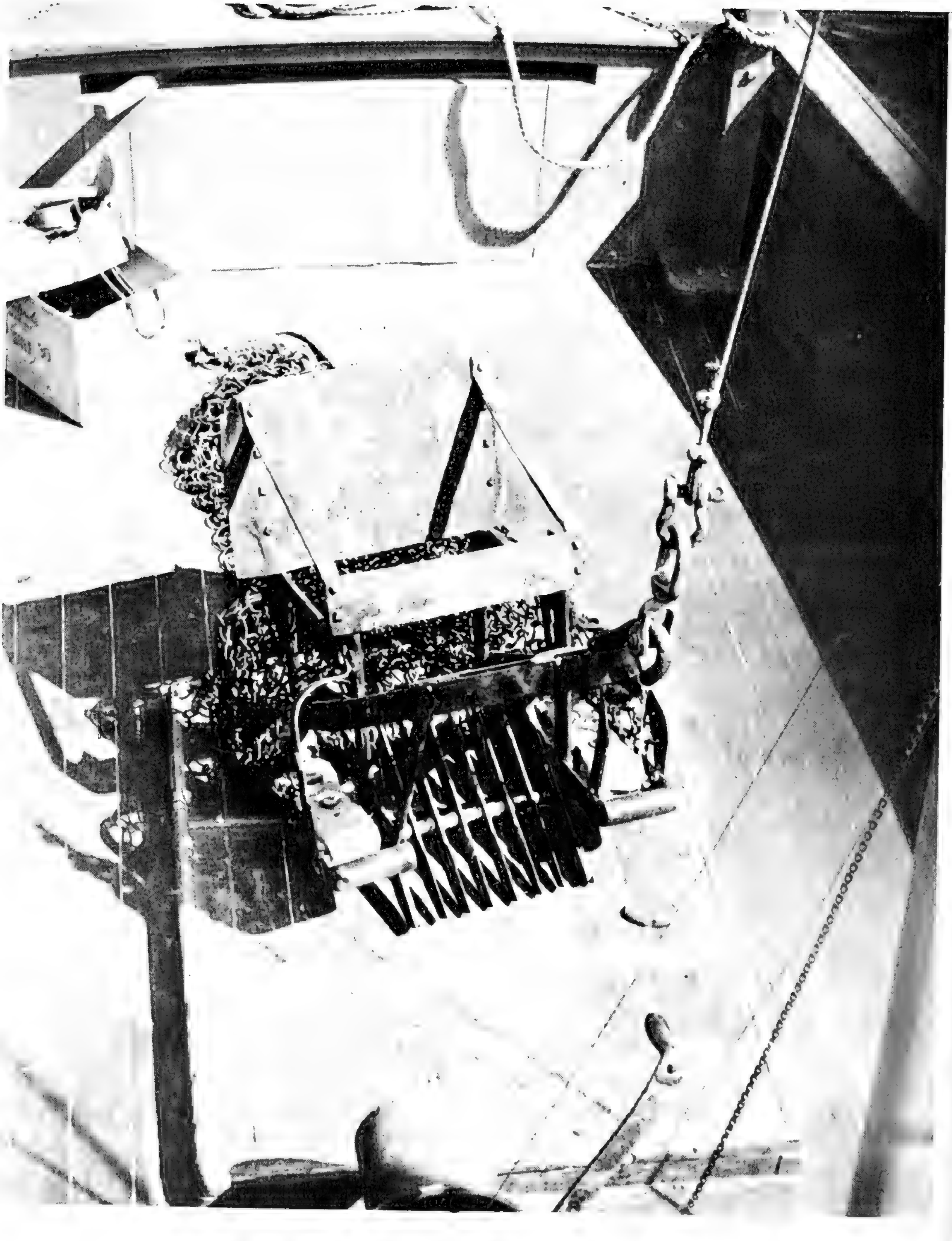

Fig. 3.--Hard clam dredges are operated from 30-45 foot power boats in the southern half of the Sakonnet River.

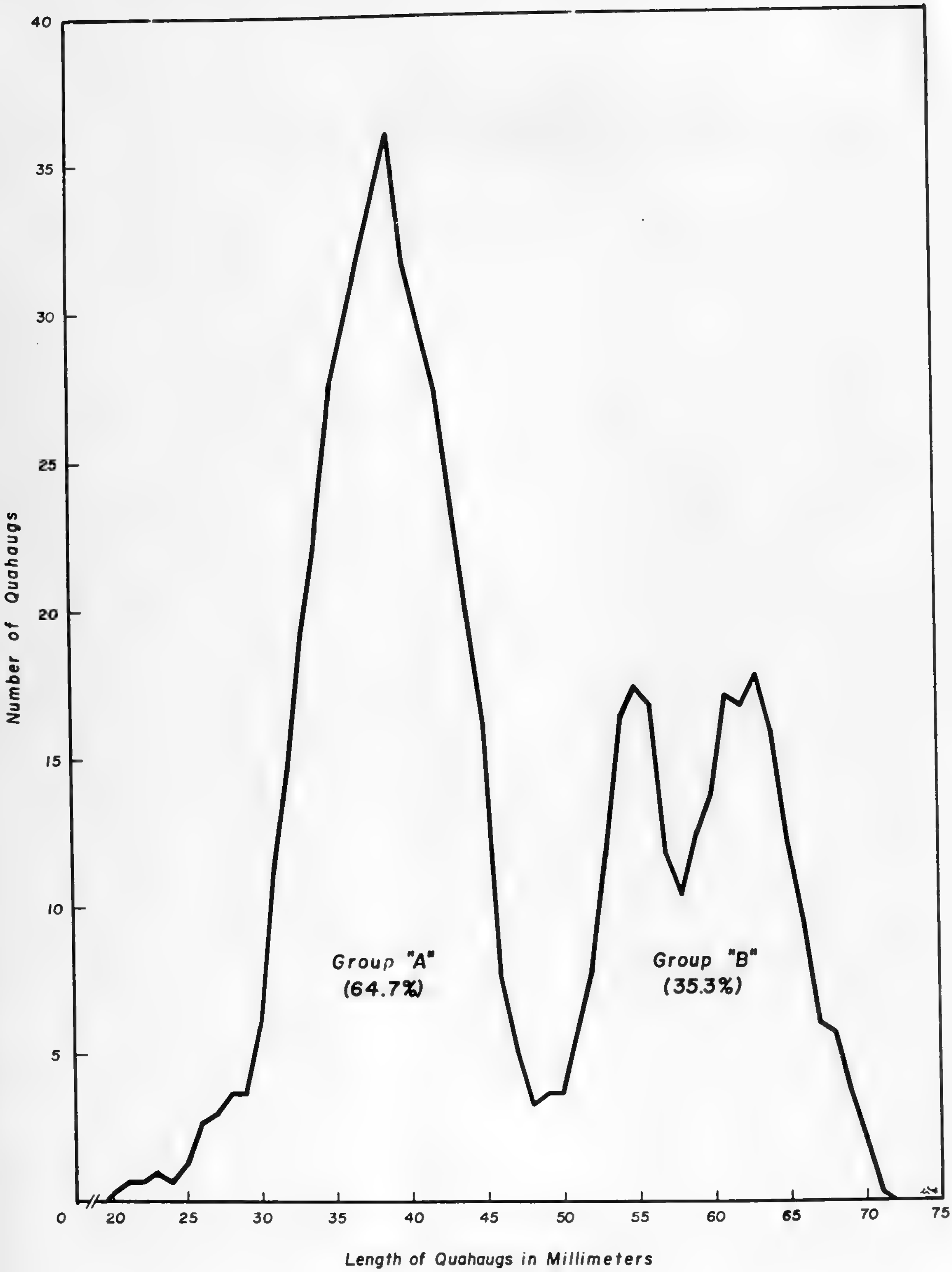

Fig. 4.--Size distribution of 640 quahaugs from test plot May 1949--before experiment. Data smoothed by moving average of 3's.

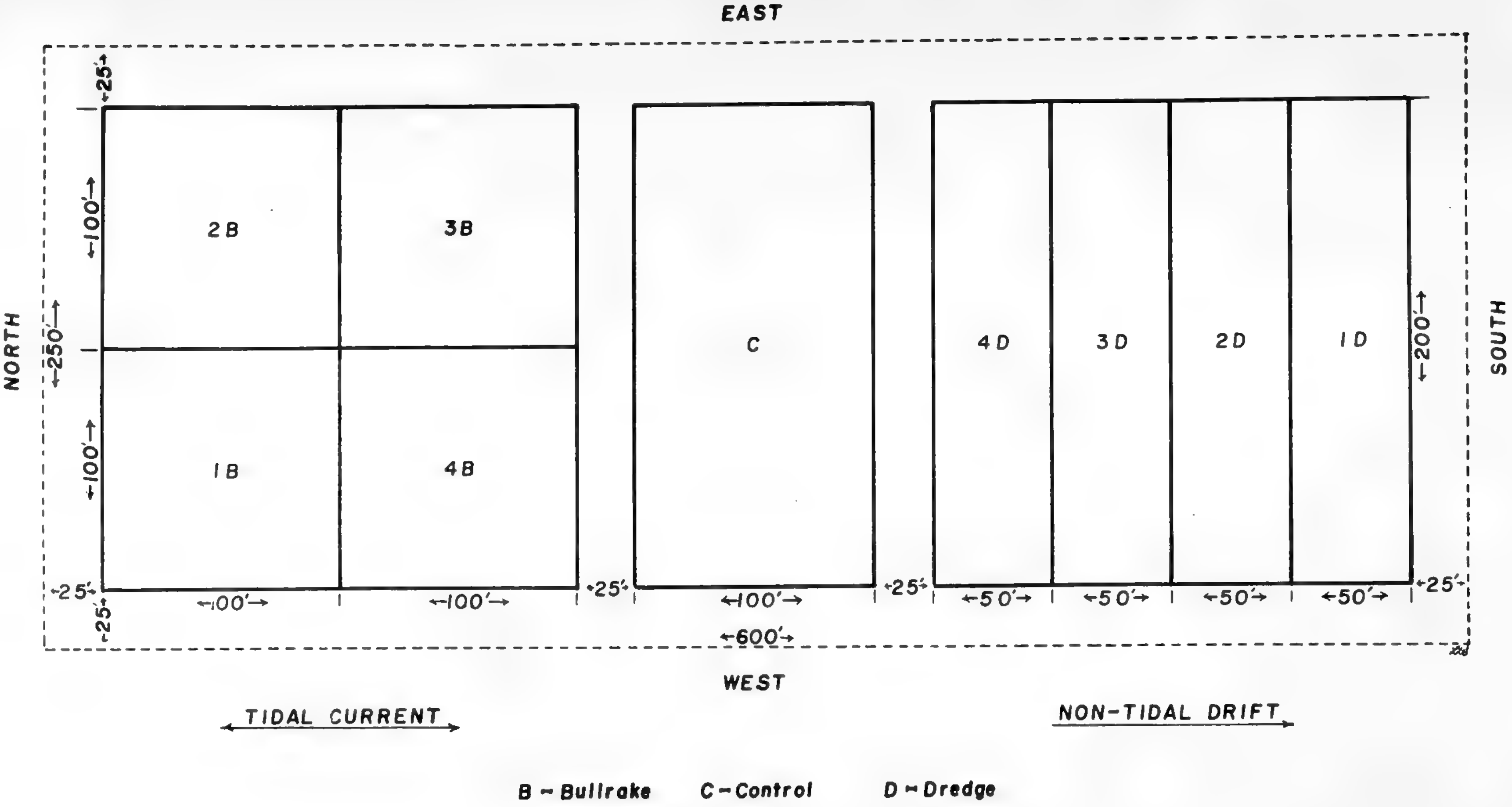

Fig. 5.--Plan of dredging vs. raking test plot.

rakers in the area. The diggers raked in each quarter in 1949 until their individual daily catch fell to a pre-established minimum value of $5.00; then they began a new quarter. In 1950 the catch of larger clams per day began at a lower level than in 1949. Termination of fishing in each quarter could not be based on the minimum catch value used in 1949. Bullraking was therefore continued in each quarter for approximately a two-week period. Digging occurred during the periods from July 14 to September 30, 1949 and July 5 to September 7, 1950. A biologist was always present to obtain records of catch, size and breakage of clams.

Dredging Operations

The boat Lil-Joy chartered by the Narragansett Marine Laboratory dredged Area D in 1949, using an 8-tooth commercial dredge. In 1950 the Fish and Wildlife Service chartered the boat Marie with a 12-tooth dredge to fish the experimental area. The size and shape of the quarters of the test plot made it impossible to dredge in circles as is done commercially. In the experiment the dredge was dropped at the border of the tract, pulled the length of the quarter, and then lifted clear of the bottom. The boat then turned to make another pass across the area. After several drags the dredge was lifted aboard, the catch removed, counted, and measured, and the breakage recorded. Dredging continued in each quarter until the same quantity of clams over 60 mm. in length had been obtained from the corresponding quarter of the bullrake area (Figure 5). Actually, more clams were removed from the bullrake area than from the dredge area since the rake regularly catches clams as small as 45 mm., whereas the minimum size caught efficiently by the dredge is about 60 mm. as shown in figures 9, 10, 11, and 12. The few clams below 60 mm. taken by the dredge were usually caught in the mud, shells and debris and in commercial practice would have been washed through the bag before it was brought aboard.

Underwater Photography

Woods Hole Oceanographic Institution took underwater photographs of the bottom after digging had been completed in 1949. Seven pictures were taken in each quarter of the two test areas and fourteen in the control. The photographs included a total of 2,520 square feet of the bottom, or 2-1/2 percent of the total area of the plot. Unfortunately, due to technical difficulties, many of the pictures were unsatisfactory. Enough were usable, however, to demonstrate that this method could be a practical tool for assessing bottom surface conditions if operational difficulties were overcome.

Bottom Samples

We obtained bottom samples with a 2-1/2-cubic foot clamshell bucket after fishing had been completed (Figure 6). This bucket sampled an area of five square feet to a great enough depth to remove all of the clams. After lifting the bucket aboard with the winch, the sample was dumped into

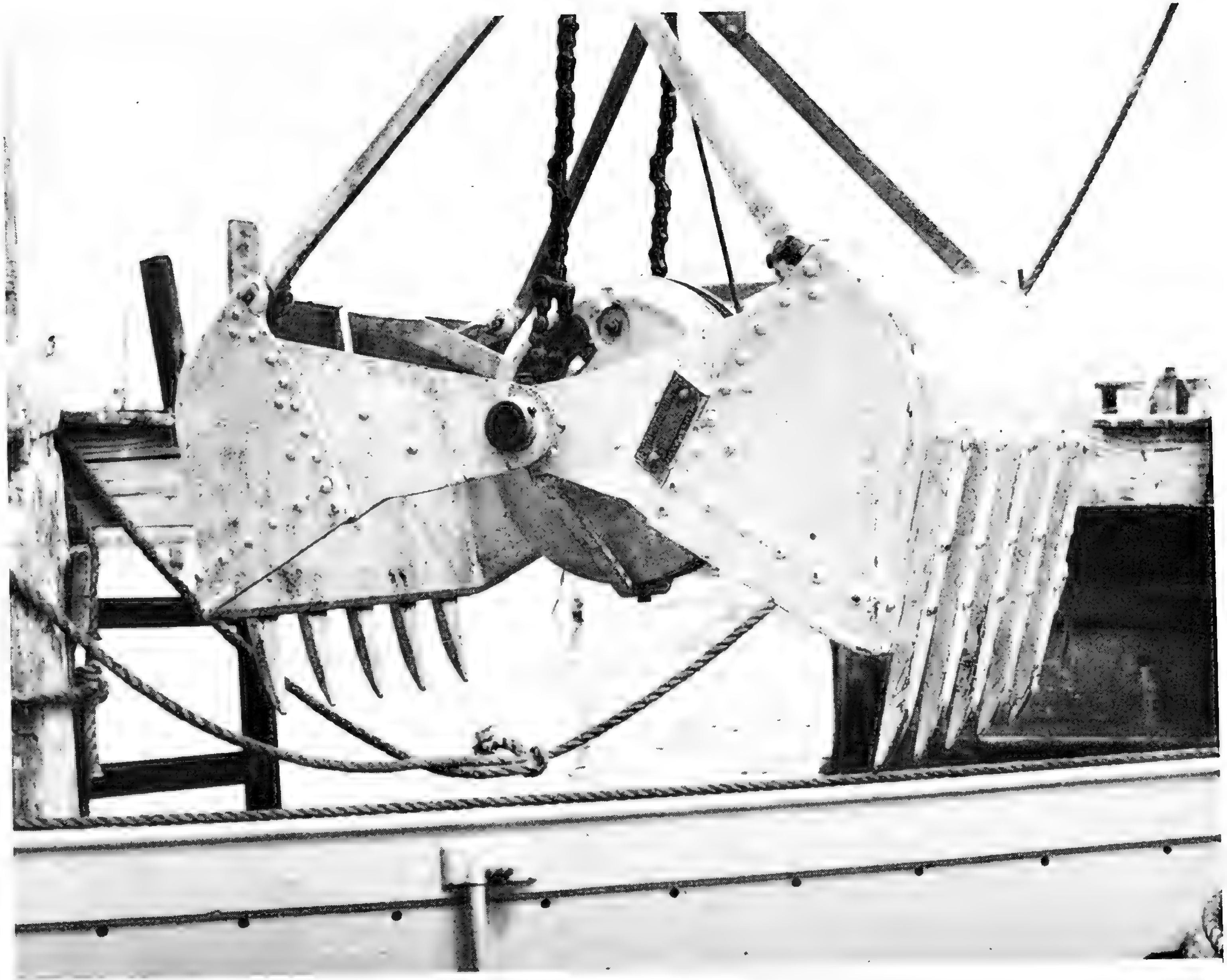

Fig. 6.--Clamshell bucket samples five square feet of bottom.

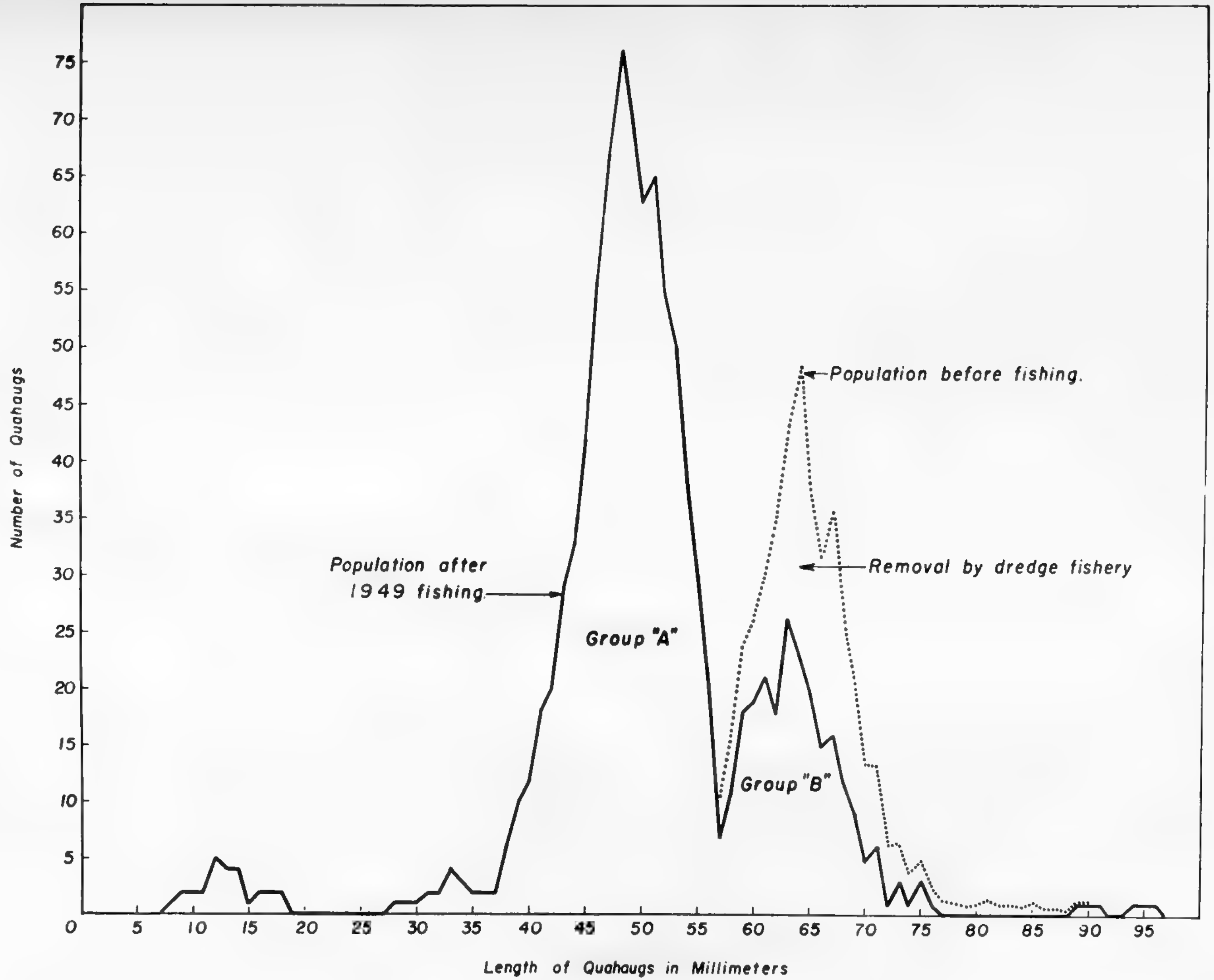

Fig. 9.--Size distribution of quahaugs from dredged area after 1949 fishing. Difference between dotted and solid lines shows removal by dredge fishery. Based on 28 clamshell bucket samples increased to 100 for comparison with Figure 10. Data smoothed by moving average of 3's.

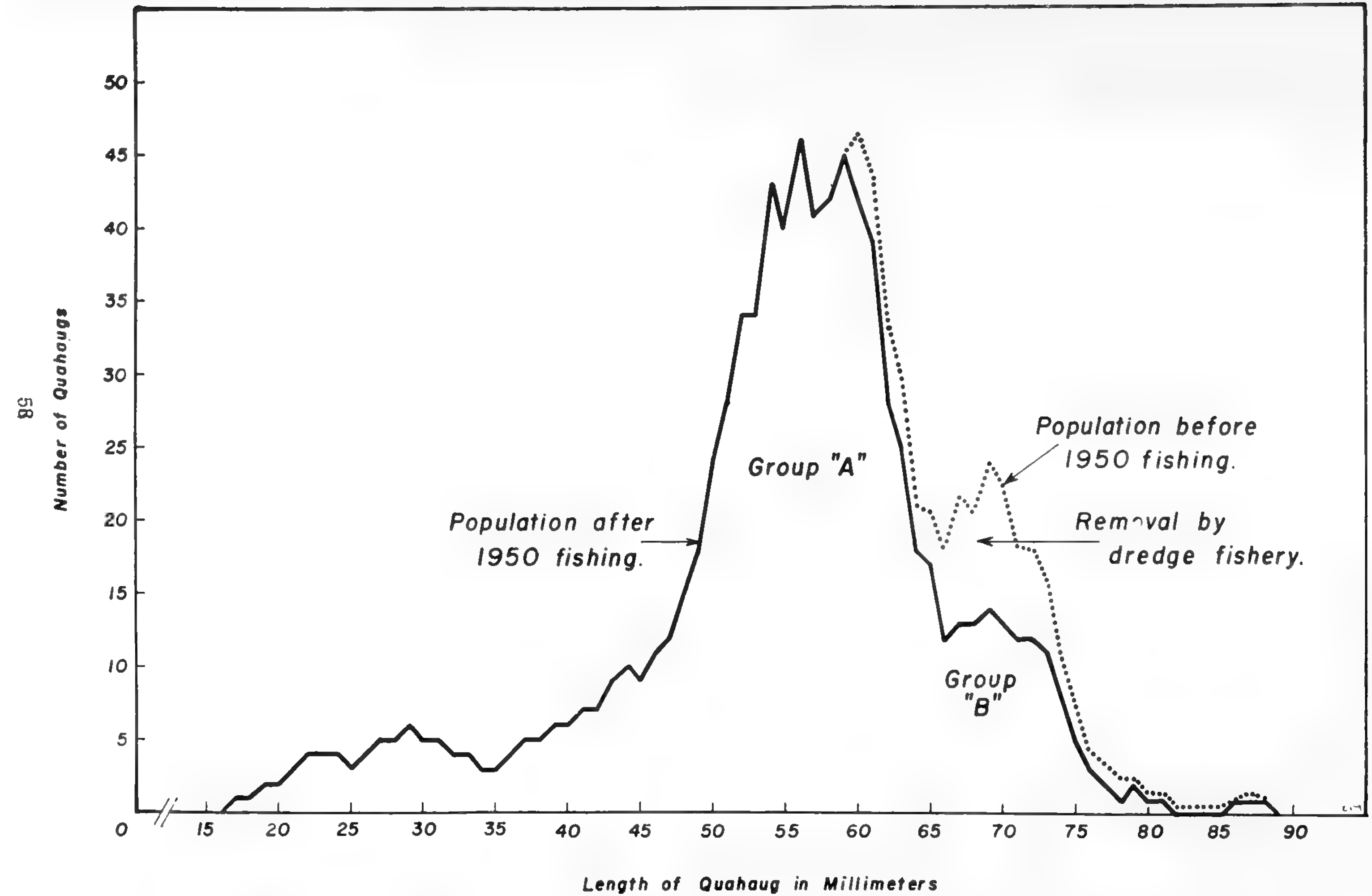

Fig. 10.--Size distribution of quahaugs from dredged area after 1950 fishing. Difference between dotted and solid lines shows removal by dredge fishery. Based on 100 clamshell bucket samples. Data smoothed by moving average of 3's.

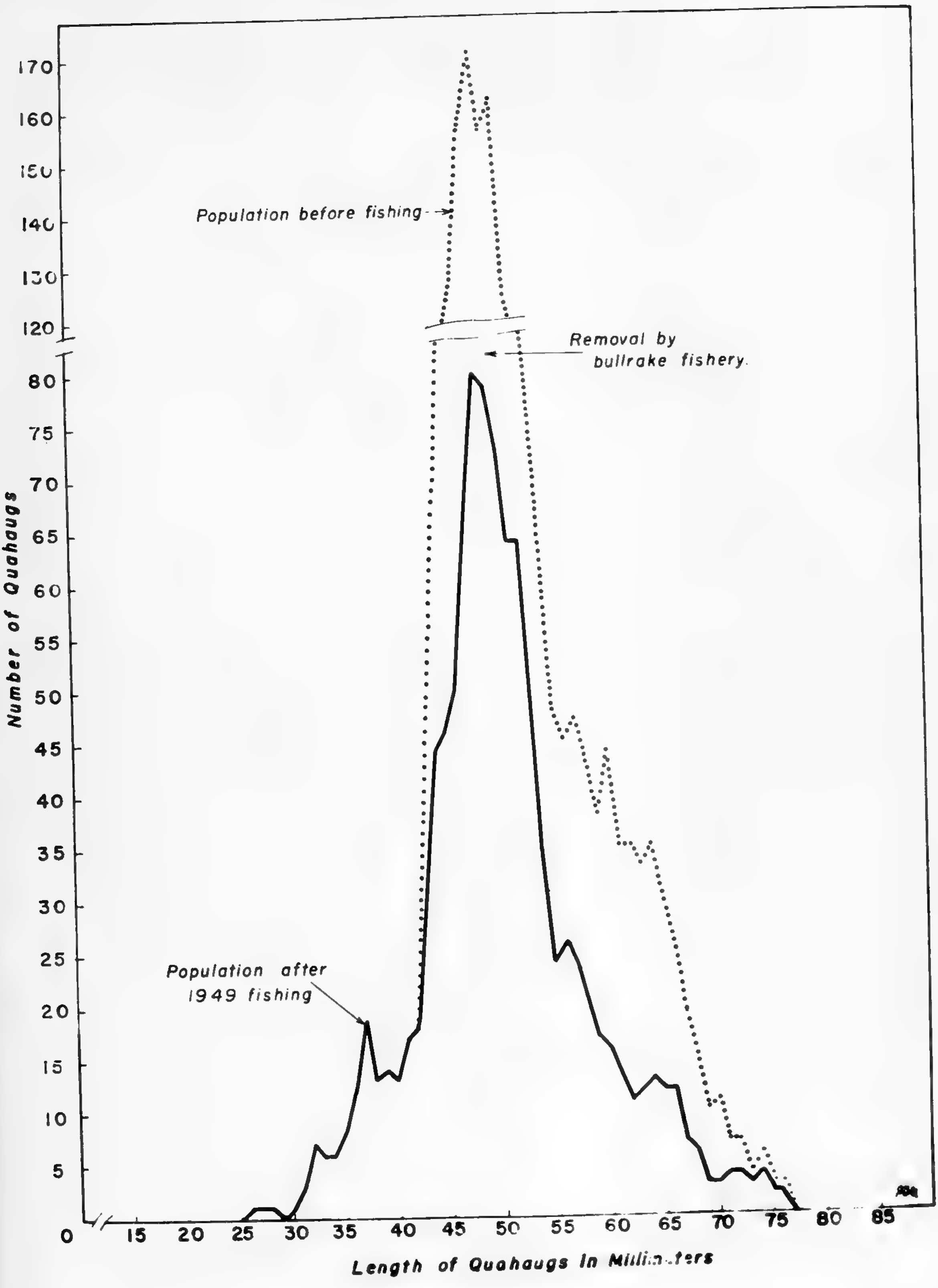

Fig. 11.-- Size distribution of quahaugs from bullraked area after 1949 fishing. Difference between dotted and solid lines shows removal by bullrake fishery. Based on 28 clamshell bucket samples increased to 100 for comparison with Figure 12. Data smoothed by moving average of 3's.

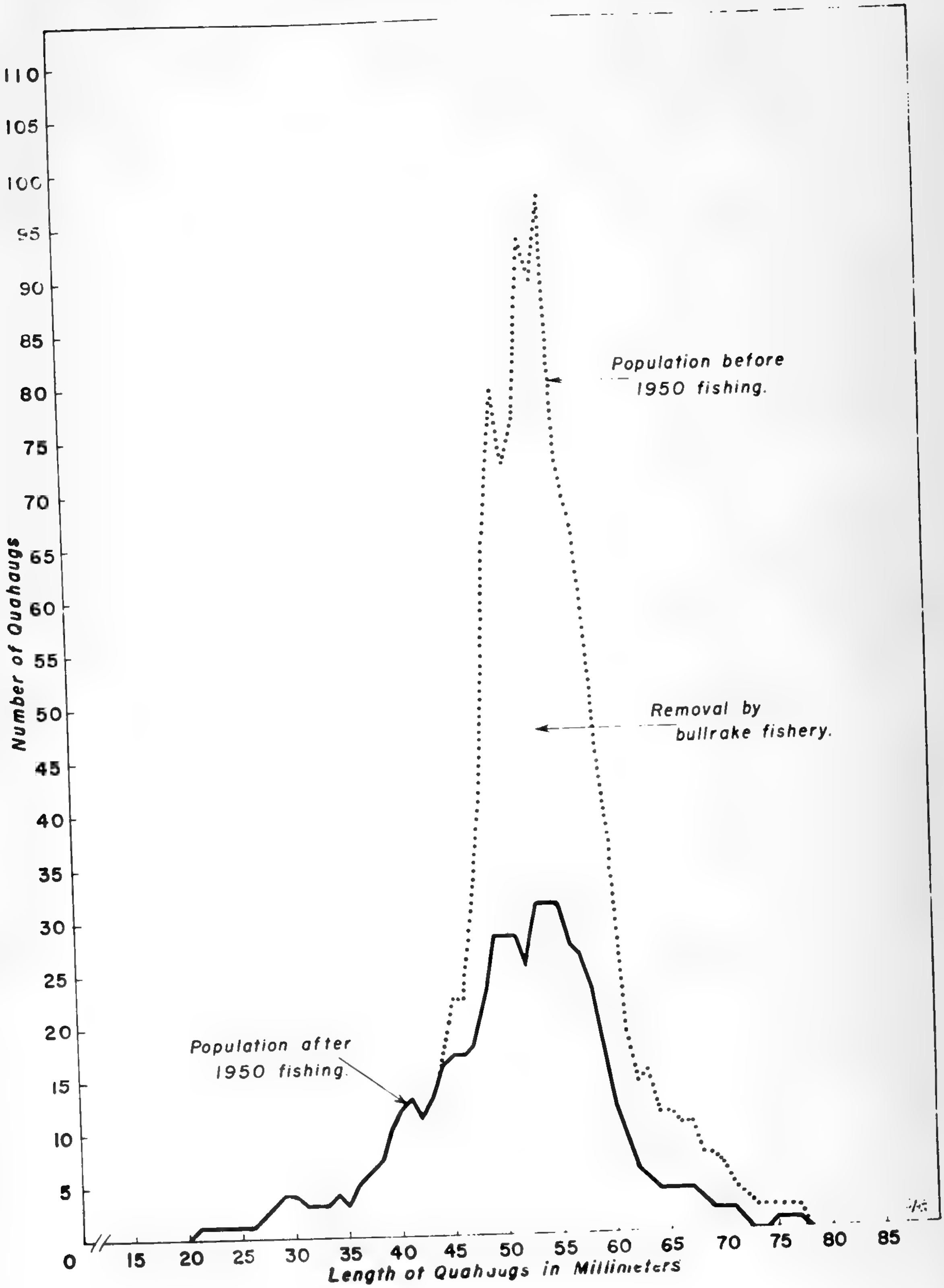

Fig. 12.--Size distribution of quahaugs from bullraked area after 1950 fishing. Difference between dotted and solid lines shows removal by bullrake fishery. Based on 100 clamshell bucket samples. Data smoothed by moving average of 3's.

a box with screen bottom, and the mud washed through with a fire pump. The quahaugs were counted and measured and returned to the water outside of the test plot.

Sampling included 28 grabs in each of the three areas in 1949 and 100 in each in 1950.

Breakage of commercial sized quahaugs

Breakage records for dredging are for clams above 60 mm. in length, whereas bullraking records include clams as small as 56 mm.

TABLE I - Breakage of Commercial Sized Quahaugs by Bullraking and by Dredging in Test Plot.

	1949	1950
Bullraking	0.1%*	0.3%**
Dredging	1.2%	0.7%

* Most of breakage caused by handling
** 0.02% gear breakage; balance from handling

The gear caused most of the breakage in the dredging operation, whereas in raking the breakage was mostly from handling the catch. The difference in size composition of the catches probably resulted in greater breakage in handling for the hand digging operation since the smaller quahaugs are more fragile.

Narragansett Marine Laboratory conducted a population survey of quahaugs in Narragansett Bay during the summers of 1949 and 1950 using an 8-tooth commercial dredge. Records of this survey show average breakage of 1.0% of the quahaugs in bottoms without rocks and 2.9% in bottoms with rocks. The bottom in our test plot is uniformly sandy mud without rocks, and the breakage there agrees closely with that reported by the Narragansett Marine Laboratory for similar bottoms. The maximum breakage reported in the survey of the Bay was 21.1% at one station where the bottom was mud with rocks and shells, although at tow other stations having bottoms in the same category no breakage was observed.

Breakage of undersized clams

We examined borken shells in bottom samples to determine the breakage of clams below the legal size of 47-48 mm. length. We found no evidence that this breakage was important in either test area, nor was there evidence of extensive breakage of clams below 60 mm. which had been left in the dredge area.

Smothering

Fishermen thought that one or both types of fishing might stir up the bottom to such an extent that some clams would be buried beyond the depth at which they could survive. Observations of recently dead clams mde during the bottom sampling showed no evidence of significant mortality which might have been due to smothering.

Effect of fishing upon setting and set survival

Each experimental plot was divided into quarters which were fished successively during the summer to detect the effect of fishing at different times in relation to setting. Unfortunately, practically no setting of clams occurred in the test plot during 1949 or 1950 and therefore no results were obtained. Bottom sampling in 1949 obtained a total of 7 spat in the control area, 5 in the bullrake area, and 6 in the dredge area. No spat were found in 1950.

Effect of fishing upon the physical characteristics of the bottom

We examined bottom samples each year for evidence of silting, scouring, and mixing. Surface conditions were practically identical in the test areas and in the control one to three months after fishing. This was substantiated by the underwater photographs. The top one to two inches of soil is uniformly yellow mud or silt throughout the test plot. Below this is a 5-6 inch layer of black sandy mud in which the quahaugs live, and below that clay which supports no life. The general appearance of these layers was the same in all three areas in 1949 but in the two test areas the clay and sandy-mud layers were mixed more than in the control. No difference in extent of mixing was observed in clamshell bucket samples from the dredged and raked areas. In 1950 the control area showed more mixing of the clay and sandy-mud layers than it had in 1949, although mixing in the fished areas was still more pronounced than in the control. The bullraked area seemed to be softer than the control, whereas the bottom in the dredged area varied in compactness from firm as the control, to soft as the bullraked area. The firm spots were probably places which had been missed by the dredge. The odor of decomposition was greater in the control than in either test area, probably because less mixing occurred there than in the fished areas.

Effect on other bottom forms

Bottom samples in the control area contained the following species in addition to the quahaug, *Venus mercenaria*:

Common name	Species	Remarks
Amphipod	*Ampelisca macrocephala*	Abundant in places. lives in mud tubes.
Tube worm	*Cistenides gouldi* (Verrill)	This Polychaete was very abundant.

Common name	Species	Remarks
Worm	Clymenella torquata (Leidy)	This Polychaete was very abundant in surface layer.
Clam worm	Nereis virens (Sars)	Infrequent.
Worm	Amphitrite sp.	Infrequent.
Softshell clam	Mya arenaria (Linne)	About two dozen up to 2" in length found in clamshell bucket samples. Some recently dead.
Little surf clam	Mulinia lateralis (Say)	Many shells, but few live specimens.
Starfish	Asterias forbesi (Desor)	Some shown in underwater photographs.
Borer or drill	Eupleura caudata (Say)	Common.
Scallop	Pecten irradians (Lamarck)	Some shown in underwater photographs.
Clam	Nucula proxima	Abundant.
Delicate tellin	Tellina tenera (Say)	Common.
Boring clam	Petricola pholadiformis (Lamarck)	Infrequent.
File Yoldia	Yoldia limatula (Say)	Common.

Bottom samples and underwater photographs in the bullraked area indicated fewer living forms than the control. Decrease in the number of tube worms Cistenides was especially noted.

Bottom samples and underwater photographs in the dredged area showed a decrease in living forms similar to that observed in the bullraked area. On the basis of these observations no difference was noted in the effect of the two fishing methods on bottom forms associated with the quahaugs.

Size composition of clams left in plot

Figures 9 and 10 show the size composition of the clam population left in the dredged area after fishing. The dotted line in Figure 9 shows the original pouplation in the dredged area as determined by adding those removed by 1949 fishing to the population shown by bottom samples after the dredging had been completed. Figures 11 and 12 show similar information for the bull-raked area. The dotted line representing those clams removed by bullraking begins slightly below 45 mm. instead of just under 60 mm. as in the dredge area. This reflects the difference in the size composition of the catch by the two methods.

It would be desirable to know whether it is better to remove only large clams as dredging does, or to remove both large and small clams as raking does. The present experiment, however, does not provide an answer to this question, nor was this an original objective. We know that a spawning stock must be left, but the magnitude of this stock and its size composition has not yet been established. Further information is needed on the annual mortality from causes other than man before we can decide if growth from "little neck" to "medium" size will increase the yield sufficiently to offset mortality. These factors are under investigation in Greenwich Bay where quahaugs are fished by hand methods. A similar study in the Sakonnet River could answer these questions for a dredged area.

Economic considerations such as the price differential between little necks and mediums would affect a decision on the best method of harvesting quahaugs, but these factors are beyond the scope of the present investigations.

Disappearance of Group "B" in control and in bullraked areas

Figures 7 and 8 show the size composition of the population in autumn 1949 and 1950 in the control area. A great change has occurred in this area even though we removed no clams. The group of clams from 30 to 56 mm. in Figure 7, which we will designate as Group "A", decreased 19.0% by 1950 as determined from clamshell bucket samples. The larger group from 57 to 75 mm. in 1949, which will be known as Group "B", decreased 70.5% by 1950. The combined groups had a loss of 35.7%.

The original presence of Group "B" is substantiated by sampling of the test plot in May 1949 with a dredge equipped with a liner in the bag to retain small clams. At that time this group ranged from 52 to 70 mm. and comprised 35.3% of the total as shown in Figure 5. In the November 1, 1949 survey (Figure 7), Group "B" had grown to 57-75 mm. and included 30.3% of the total. By November 8, 1950 (Figure 8) it had grown to 64-79 mm. but contributed only 13.4% of the population. Duplicate sampling in 1950 substantiated the disappearance of Group "B".

Statistical analyses of the differences in mean number of clams per sample in 1949 and 1950 showed the probability of this difference occurring by chance is only one time in 100. This means there was a real difference in the population of the control area in the two years and that this difference was not due to sampling error.

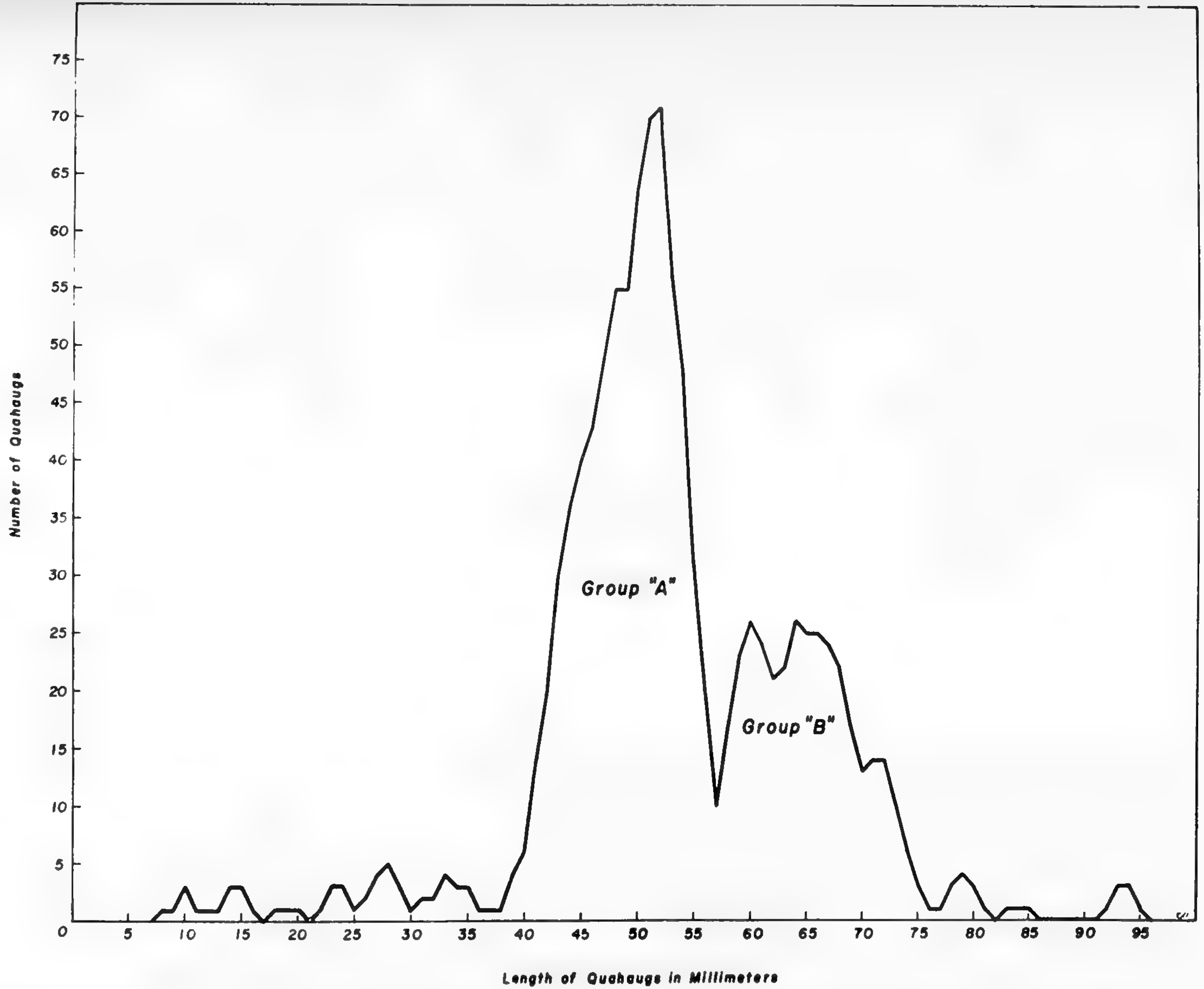

Fig. 7.--Size distribution of quahaugs from control area Autumn 1949. Based on 28 clamshell bucket samples increased to 100 for comparison with Figure 8. Data smoothed by moving average of 3's.

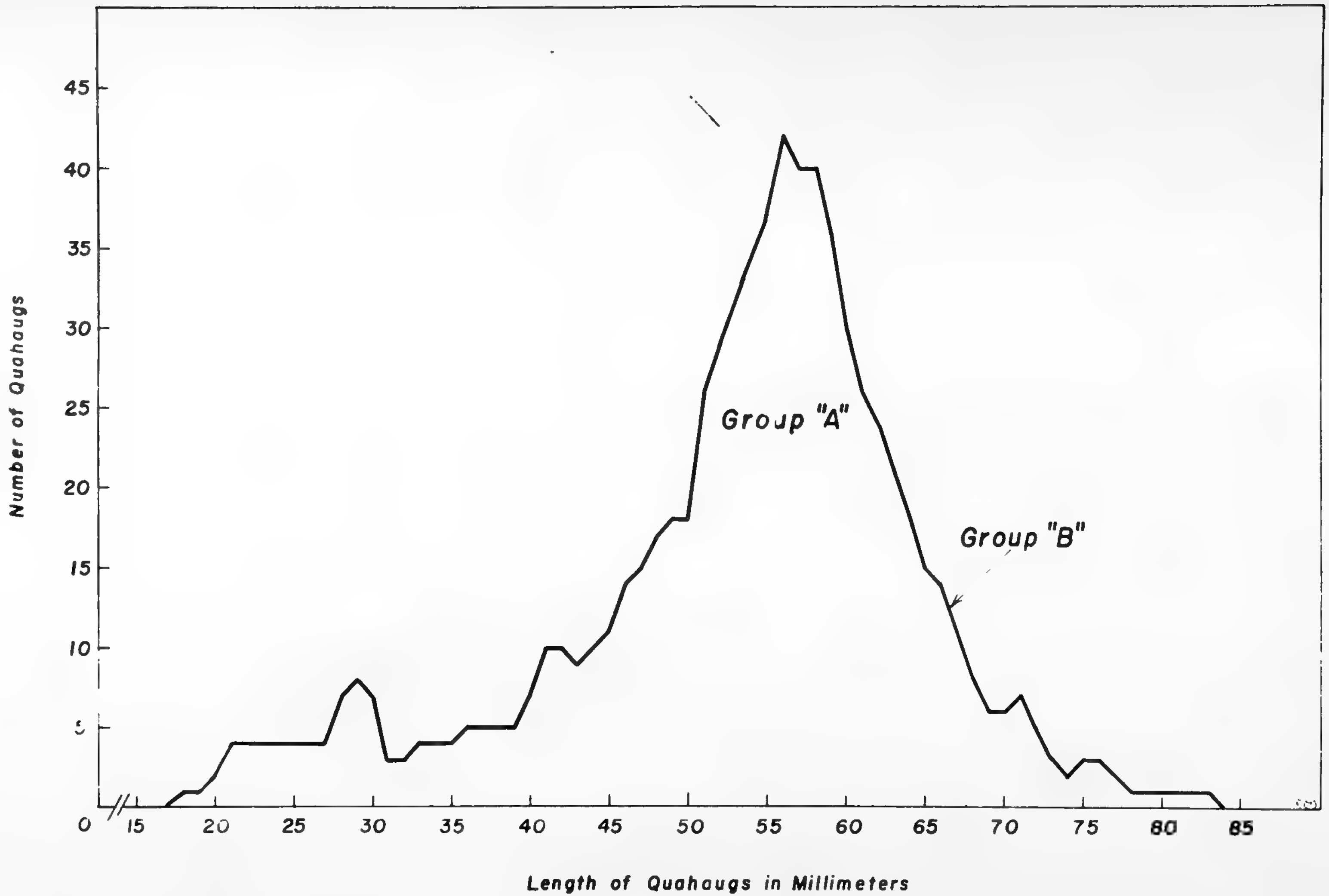

Fig. 8.--Size distribution of quahaugs from control area Autumn 1950. Based on 100 clamshell bucket samples. Data smoothed by moving average of 3's.

During this same period Group "B" had largely disappeared from the bullraked area also.

Catch measurements of quahaugs bullraked from each of the four quarters in 1949 showed the presence of this larger group of quahaugs. Bullraking was completed September 30, 1949.

The clamshell bucket census of the bullraked plot was taken December 15, 1949. Group "B" was not indicated by this sampling (See solid line Figure 11).

Catch measurements of quahaugs bullraked from each of the four quarters during 1950 also indicated the absence of Group "B" which substantiated the results of the 1949 clamshell bucket census.

The 1950 clamshell bucket census taken September 6-13 also showed no peak for Group "B" (Figure 12).

One explanation for the disappearance of Group "B" in both bullraked and control areas is illegal fishing. Catch measurements from quarter 4-B had shown that group was present as late as September 30 in the bullraked area. Clamshell bucket sampling in the control area showed Group B was present on November 1, 1949. Clamshell bucket samples December 15 in bullraked area showed group B was absent. If illegal fishing occurred it must have been between November 1 and December 15, 1949.

Reports by shore residents confirm the theory that illegal fishing occurred in the Highbanks area during autumn 1949.

The dotted line in Figure 11 would then indicate a lower original population than actually existed. This line would be low by the amount of clams illegally fished from the sampled area.

CONCLUSIONS

1. The objective of the present experiment was to determine the relative biological effects of power dredging as compared with hand digging on a population of quahaugs. The use of the term "biological effects" should be emphasized since we made no attempt to investigate the economic, sociological, or legal phases of this problem. Therefore, the information presented in this report must not be considered as the final answer to the power vs. hand digger controversy, but rather as information on the biological phase alone.

    Because of the time, effort and expense involved, it was possible to conduct this experiment in only one location. Care must be taken, therefore, in applying the results to all areas. Likewise, the fishing methods used followed a set pattern necessitated by the size of the test area. Deviation from these fishing methods might also modify the results.

2. Fishing operations during the summers of 1949 and 1950 demonstrated the differences in size composition of the catch. Dredges removed only quahaugs above 60 mm. in length, whereas bullrakes regularly caught those above 45 mm. The effect of this difference on the quahaug population over a long period of time is not known.

   Productivity studies which are now underway in Greenwich Bay may also provide information on the long range effect of removing both small and large sized quahaugs by hand-digging.

3. Underwater photographs failed to show any difference in the surface condition of the two fished sections of the plot. Both parts appeared similar to the control area. The unsatisfactory nature of many of the pictures prevents their use as a positive criterion for comparing the two fishing methods.

4. Bottom samples confirmed the indications of the underwater photographs that surface appearance of the three areas was similar. Mixing of the sandy-mud layer and the underlying clay was more pronounced in both fished areas than in the control. Fished areas were also softer and had less odor of decomposition than the control. No difference in the above physical characteristics was observed between dredged and bullraked sections.

5. Breakage of commercial sized quahaugs was recorded during the experimental fishing. Bullraking operations broke about 0.1% of the clams above 45 mm. but most of this breakage was from handling. Dredging broke about 1.0% of the clams above 60 mm. in length. Even though dredging breakage was 10 times that of raking, it is still extremely low in this sandy-mud bottom, and is not considered to be important. The observations of Narragansett Marine Laboratory agree with our records for this type of bottom, but list dredge breakage of 2.9% in rocky bottoms. In one instance 21.1% breakage was observed in a rocky-shelly bottom.

6. Breakage of undersized clams by raking and dredging is shown to be negligible in the sandy-mud of the test plot, but this might not be true in rocky or shelly ground.

7. Observations of recently dead quahaugs made during bottom sampling showed no evidence of significant mortality which might be due to smothering in either fished area.

8. No setting occurred on the test plot during the summers of 1949 and 1950. Therefore, no observations could be made on the effect of fishing upon setting and set survival.

9. Bottom samples and underwater photographs indicated fewer living bottom forms in the test areas than in the control. Decrease in number of tube worms Cistenides was especially noted. No difference was shown in the effect of dredging and raking on bottom forms associated with the quahaugs.

10. The disappearance of 35.7% of clams in the control area from 1949 to 1950 is real as demonstrated by statistical analyses and is not due to sampling errors. A similar disappearance of the larger group of clams occurred in the bullraked section between September 30 and December 15, 1949. Natural mortality could not have caused this loss or shells would have been found in bottom samples. It is therefore concluded that these clams were removed by illegal fishing.

OYSTER CONDITION AFFECTED BY ATTACHED MUSSELS

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Oyster production has declined materially since the turn of the century. On the basis of government statistics, the only figures of national scope available, the present yield is about one-third of what it was in the first decade of the 20th century. (Table I).

Production in the years prior to 1900 undoubtedly demonstrated exploitation of a vast accumulation of a natural resource. Efforts to maintain the high yield pushed the capacity of the natural population beyond its ability to reproduce the stock, hence the decline. Losses, cumulative in the natural population, are more acute as the stock becomes smaller. We must attempt to control the sources of these losses, due in part to predatory and competitory animals, mortalities from changing conditions such as flooding, silting and contamination, and man-caused destruction of bottoms. To some extent we have accomplished a measure of relief in isolated instances. Efforts of the combined research team of Federal, State and private interests have not been sufficient, however, to plug all the holes draining this resource, partly because fingers are too few and we have been unable to investigate all the leaks sufficiently.

At the Chesapeake Shellfish Investigations Station we have observed the condition of oysters and the causes of its variation. In Maryland and in many other areas oysters must compete with mussels (Brachiodontus recurvus in Maryland) for food and space. The question in our minds was to what extent this competition affected the condition and therefore the yield of oysters. Oysters with large clumps of mussels attached were poorer than those free of mussels taken from the same location. Fat oysters produce more pounds of meat than lean ones. The measurement of the difference is the theme of this report. Our observations were conducted in two parts.

(1) Oysters were collected at two week intervals over a period of six months from mussel infested oyster bars and divided into two groups, according to the amount of mussels attached. Those heavily covered were used as one group, and those free of mussels as the other. Comparison of these groups proceeded as follows: physical characteristics of size, shape and cavity volume; meat condition determined by percent solids, percent glycogen on a dry basis; and the condition factor, a ratio between amount of meat and cavity volume.

(2) When the preceding observations established the existence of a difference, an experiment was designed to test the permanence of the difference when the attached mussels were removed. The same methods of analysis were used as in (1).

Table I.

Oyster Production in the United States 1/

1888	---	149	million	pounds	of	meats
1892	---	183	"	"	"	"
1908	---	234	"	"	"	"
1929	---	152	"	"	"	"
1937	---	95	"	"	"	"
1939	---	93	"	"	"	"
1940	---	89	"	"	"	"
1942	---	75	"	"	"	"
1944	---	75	"	"	"	"
1945	---	76	"	"	"	"
1946	---	80	"	"	"	"
1947	---	79	"	"	"	"
1948	---	78	"	"	"	"

1/ Fishery Statistics of the U. S. and Alaska, U. S. Fish and Wildlife Service, Washington, D. C.

The results of these observations demonstrated the extent of the differences. Physically, oysters with mussels attached were generally larger, more elongate and contained larger shell cavities. The difference in size was not great, about 1.5 centimeters; the difference in cavity volume, also small, was about 12.5 cubic centimeters. The ratio of length to width pointed out a more significant difference and indicated the elongation characteristic of mussel-covered oysters. These oysters had a ratio of width over length of 0.67 while mussel-free oysters had a ratio of 0.75. Elongation was usually caused by a deformity at the bill or posterior end of the oyster away from the main cluster of mussels. Irregularity in shape in itself made this oyster less desirable commercially because of added difficulty in shucking. Other detrimental effects of mussels attached to oysters will be discussed later in this paper.

Analysis of the meats of these two groups of oysters gave more tangible evidence of the effect of mussels on oysters. Considering first the total solids produced, a difference, constant over the six months, amounted to 12.8 percent. From this we conclude that more meat is produced from mussel-free oysters. As a measure of quality we examined the total glycogen content of these oyster. Glycogen determines the "fatness" of oysters, and in these two groups the difference was 11.1 percent favoring the mussel-free oysters. From this we say that mussel-covered oysters have a lower nutritive value. A third index of meat value, the "condition factor", is of direct interest to producers because it shows the variation in yield of meats per unit of shell stock. Mussel-free oysters on this basis were 27.5 percent better than those with mussels attached. (Table II).

To indicate the effect of mussel masses on the condition of oyster meats may, at first glance, appear to be more academic than practical. We went a step further and examined oysters from which mussels were removed to see how permanent the differences were. Oysters with attached mussels were collected, the mussels removed and a series of observations made to see if the oysters thus freed of mussels could recover the advantage they lost over those originally free of mussels. The cleaned oysters were put overboard in trays with controls of mussel-free animals. The two groups were periodically checked in the same manner as those in the field study discussed earlier in this report. The results of this experiment are as follows:

(1) No material change occurred in the shape, size or cavity volume of the oysters during the six week period.

(2) In the condition of the meats, however, progressive changes were noted. Oysters with attached mussels at the beginning of the period had a percent solids of 13.38 and those free of mussels 14.58. At the end of two weeks there was no improvement following the removal of mussels. But at the end of four weeks the two groups of oysters showed about the same percent solids or 16.77 for oysters with mussels removed and 16.63 for oysters free of mussels. After six weeks, at the end of the experiment,

Table II.

Field Study Condition of Oysters

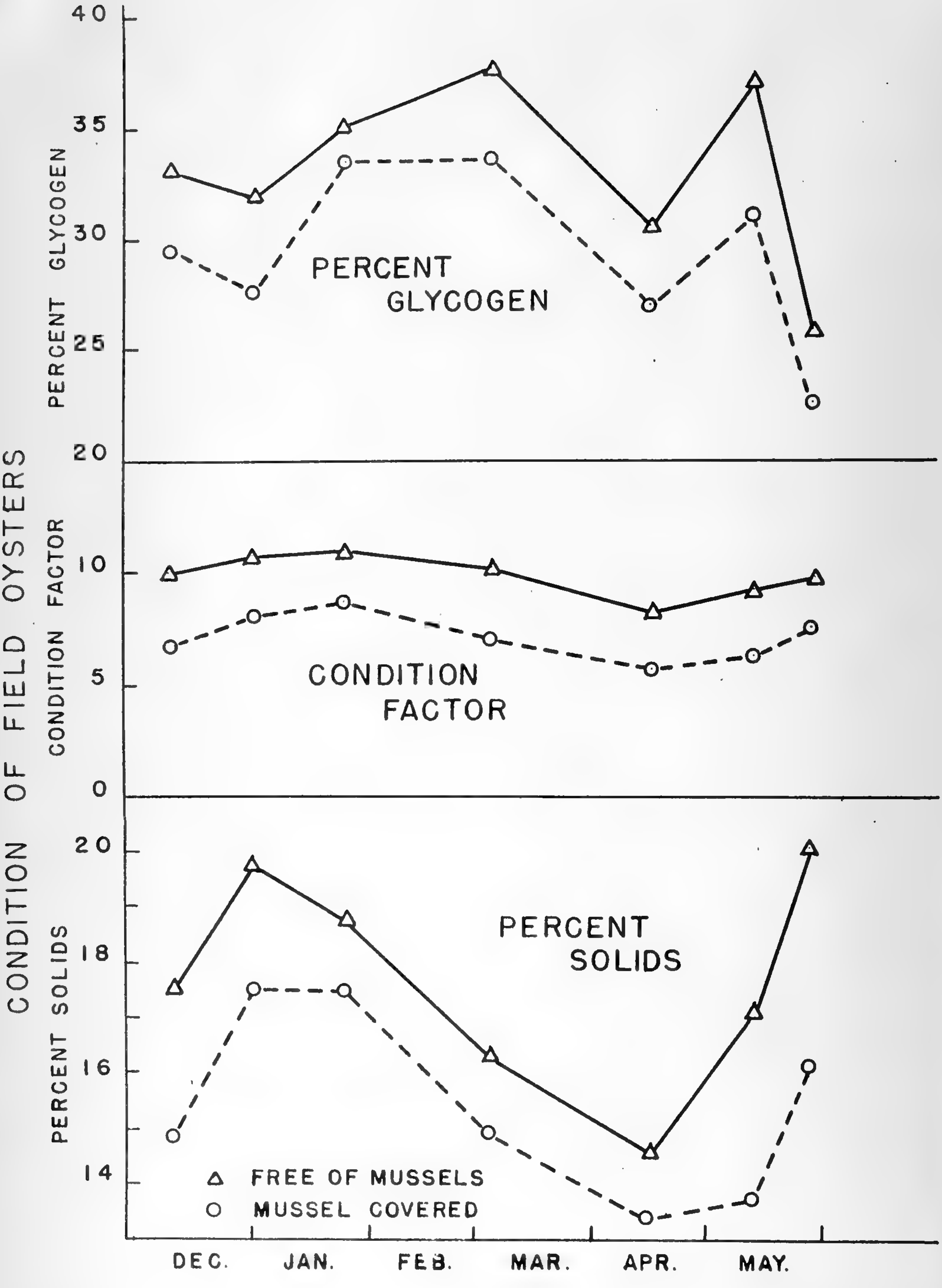
Date	Shell Cavity in cc.		Percent Solids		Percent Glycogen		Condition Factor	
	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels
12/11/50	40.6	32.4	14.81	17.53	29.67	33.32	6.79	10.03
1/2/51	47.8	34.8	17.44	19.66	27.90	32.03	8.03	10.81
1/29/51	49.0	35.6	17.41	18.74	33.67	35.37	8.83	11.10
3/5/51	48.2	38.0	14.82	16.24	33.77	37.78	7.17	10.35
4/16/51	47.8	35.4	13.38	14.58	27.10	30.75	5.85	8.43
5/14/51	50.5	32.8	13.70	17.06	31.20	37.22	6.43	9.45
5/28/51	49.8	41.4	16.14	20.04	22.67	25.21	7.61	9.85
Average	48.2	35.8	15.43	17.69	29.43	33.10	7.24	10.01

Average Difference Shell Cavity = 12.4

Average Difference Percent Solids = 2.26

Average Difference Percent Glycogen = 3.67

Average Difference Condition Factor = 2.76


CONDITION OF FIELD OYSTERS
PERCENT GLYCOGEN
PERCENT GLYCOGEN
40
35
30
25
20
CONDITION FACTOR
CONDITION FACTOR
10
5
0
PERCENT SOLIDS
PERCENT SOLIDS
20
18
16
14
FREE OF MUSSELS
MUSSEL COVERED
DEC.
JAN.
FEB.
MAR.
APR.
MAY.

oysters with mussels removed showed a percent solids of 17.80 and the control 17.71. Oysters in the field during this same period showed a percent solids at the start of 13.38, after four weeks 13.70, and at the close of the experimental period of six weeks 16.14. These figures are compared at the same time with mussel-free oysters in the field and gave 14.58, 17.06 and 20.04 respectively, indicating no relative difference occurred in the field.

With the experimental groups the percent glycogen also showed a trend similar to percent solids. At the beginning of the period the percent glycogen of oysters with mussels removed was 27.10 and of oysters originally free of mussels 30.75. Two weeks later the percent glycogen was 35.94 and 41.25 respectively. At four weeks the percent glycogen was 33.76 and 35.25, and at six weeks when the experiment was concluded the percent glycogen was 25.41 and 25.61. Oysters in the field collected and analyzed at the same intervals maintained the same difference in percent glycogen from the start to the end of the experimental period.

The improvement in the condition of the meats was again demonstrated by the condition factor index. The difference existing at the start of the experimental period was 2.58; in two weeks no improvement occurred, the difference in C. F. being 3.91; at four weeks the difference was reduced to 1.36; and at the end of the sixth week it was further reduced to 1.09. In the field, condition factors for the above intervals of examination maintained the same difference from start to finish of about 2.76 - plus or minus - 0.5 (Table III).

SUMMARY

These two series of observations, one on the oysters in the field exposed to a natural condition where they compete with mussels and the other on a group of oysters where this competition has been removed have been analyzed to show the effect of the competition on the oysters. The results are summarized as follows:

1. Oysters covered with mussels have poorer meats than those free of mussels.

2. When mussels are removed from these oysters they recover in four weeks to the same condition of percent solids and percent glycogen as the oysters originally free of mussels.

3. Mussel-covered oysters in the field have 27.5 percent less meat per animal than those free of mussels on the basis of condition factor.

4. In the experiment this difference dropped to 10 percent in six weeks with the trend still approaching equality.

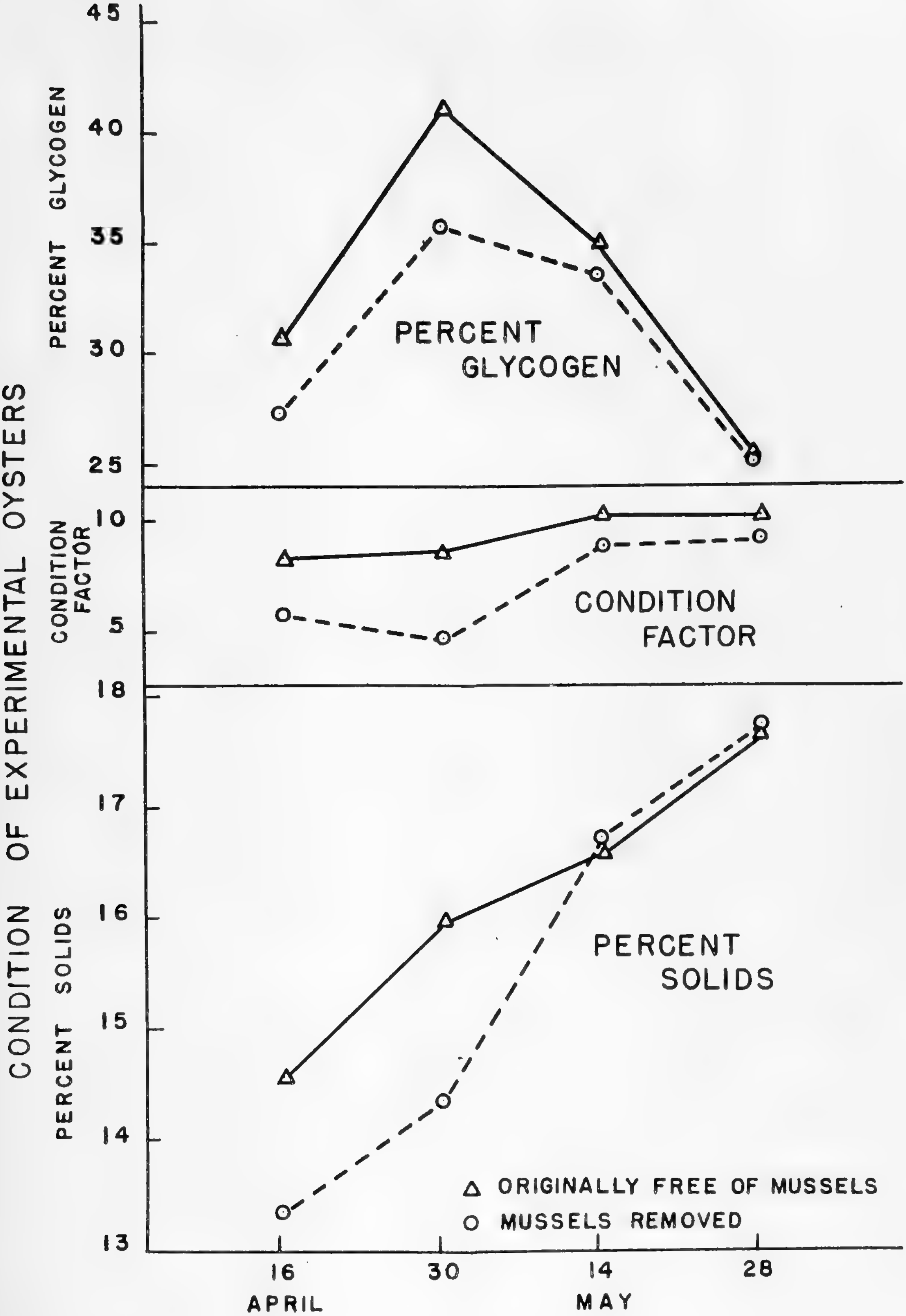
Table III

Condition Experiment with Oysters Cleaned of Mussels

Date	Shell Cavity in cc.		Percent Solids		Percent Glycogen		Condition Factor	
	Oysters with Mussels removed	Oysters originally free of Mussels	Oysters with Mussels removed	Oysters originally free of Mussels	Oysters with Mussels removed	Oysters originally free of Mussels	Oysters with Mussels removed	Oysters originally free of Mussels
4/16/51	47.8	35.4	13.38	14.58	27.10	30.75	5.85	8.43
4/30/51	53.0	39.3	14.36	16.00	35.94	41.25	4.65	8.56
5/14/51	47.0	39.5	16.77	16.63	33.76	35.25	8.91	10.27
5/28/51	46.8	41.0	17.80	17.71	25.41	25.61	9.25	10.34

Field Study Condition of Oysters

Date	Shell Cavity in cc.		Percent Solids		Percent Glycogen		Condition Factor	
	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels
4/16/51	47.8	35.4	13.38	14.58	27.10	30.75	5.85	8.43
5/14/51	50.5	32.8	13.70	17.06	31.20	37.22	6.43	9.45
5/28/51	49.8	41.4	16.14	20.04	22.67	25.21	7.61	9.85


CONDITION OF EXPERIMENTAL OYSTERS
PERCENT GLYCOGEN
45
40
35
30
25
PERCENT GLYCOGEN
CONDITION FACTOR
10
5
CONDITION FACTOR
PERCENT SOLIDS
18
17
16
15
14
13
PERCENT SOLIDS
△ ORIGINALLY FREE OF MUSSELS
○ MUSSELS REMOVED
16
30
14
28
APRIL
MAY

5. Mussel-covered oysters tend to be irregular in shape and therefore more difficult to shuck.

All investigators should have the prerogative of speculation based on the results of experiments and observations. We feel that the yield in pounds or pints of oyster meats may be increased in a region like Maryland, where many acres of oyster bottom are heavily infested with mussels. This increase is possible without increasing the number of oysters present if the mussels are destroyed in time on the beds. We demonstrated this in our experiments.

Methods and equipment for accomplishing the destruction of mussels are in our plans and on our drawing boards at the present time, and the attempt to demonstrate the economic feasibility in the field is on our program of research for the near future.

SOME FACTORS INFLUENCING STEAM YIELDS IN OYSTERS

Francis X. Lueth
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Not all oysters taken from the waters of our coasts are eaten raw at some osyter bar or served in some exclusive restaurant "a la Rockerfeller". There are many oysters that are steamed and canned for use - usually at some inland point where few persons have ever tasted the delightful flavor of a really fresh oyster.

Some recent figures of the U. S. Fish and Wildlife Service reveal that over 3,000,000 pounds of steamed oyster-meats were canned on the Gulf Coast during the 1950-51 canning season. Alabama factories took more than twice as many barrels of oysters than the forty-odd raw shucking houses during the past season.

Any factory or factories that handle as high a percentage of a harvest of a natural resource as do the oyster factories of Alabama certainly have a great influence on that harvest. Too, the harvest, in this case the oyster, affects greatly the profits of the factories and thus the economics of the localities in which the factories are located. A study this past winter and early spring was devoted to the kind, size and value of steam oysters in Alabama.

The three factories that operated in our state this past season assisted in the study by giving oysters and confidential reports on daily or load yields. Assistance from McPhillips Packing Cooperation, Graham's Seafood, and Mexican-Gulf Seafoods are gratefully acknowledged by this biologist.

It was evident from observations made in 1950 that the steam yield varied in the number of cans of meat per barrel of oysters. It was hoped that the study now being reported might throw some light on the causes of variance.

In all, thirty samples (usually of one-tenth barrel) were taken from the factories and tested. These samples were weighed, all or most of the oysters measured, and either shucked raw or steamed in a pressure cooker where the pressure was raised to fifteen pounds and then left for five or more minutes. (The factories usually steam their oysters at fifteen pounds for five minutes.) Notes were made as to the amount of loose shell in each sample and some samples were culled until the oysters were singles and then the amount of culled waste was weighed. Computations were later made using a barrel weight of 225 pounds. When it was necessary to convert raw weights to steam weights the conversion factor .56 was used. Dry solids were obtained by drying either the raw meat or the steamed meat in a constant temperature oven for three days at a temperature of 80° C.

Dry solids were based on only five or ten oysters from the original sample. Laboratory yields were checked against the factory yield for the same day, and if possible for the same load from which the sample came.

Laboratory samples yielded from 5.7 pounds to 10.4 pounds of steamed meats per barrel of shell stock. The later yield was that of a selected sample of single medium sized oysters. The average yield of non-selected samples was 7.6 pounds of steamed meats per barrel of shell stock.

The factory yields on loads or even days are considered as confidential information. However, these yields varied from just below 5.7 pounds to a little better than 8.2 pounds of steamed meats per barrel of shell stock. The yields of only a few loads ever exceeded, or ever approached, eight pounds. Factory yields, as an average, were from 8% to 15% less than laboratory yields.

There were considerable differences in the weights of the barrels of shell stock that were purchased by the factories. Purchased at identical prices were oysters that weighed as little as 186 pounds to as much as 248 pounds per barrel. The factory buying the larger barrel got 32% more for its money than when it purchased the smaller barrel. This however, is not so important as it might at first appear. Buying in large quantities the factories averaged out the daily differences. The average barrel of shell stock, this past season weighed 228 pounds. Over 50% of the purchases were of shell stock that weighed within ten pounds of this figure. There was a definite tendency this past season for the weight of the average barrel of shell stock to increase slightly as the season progressed.

The following is based on observation only; but it is believed to be of some significance. The lighter barrel of shell stock contained oysters that were "bunchy" with from five to many oysters in a cluster. The heavier samples contained a high percentage of singles. The percentage of single oysters increased as the season progressed.

Laboratory yields, when corrected to a 225 pound barrel of shell stock, still varied from 6.4 to 9.4 pounds of steamed meats per barrel of shell stock. The average was again 7.6 pounds per barrel.

Records were kept on twenty of the samples on how much of the original weight was loose shell (or boxes) and of no value to the factory. Surprisingly to the biologist, this varied from only 5% to 9% of the weight of the shell stock. The amount of waste in loose shell was relatively constant throughout the season and apparently was a minor factor in differences in yields.

Only five samples were inspected for "attached waste" a name given to the dead shells, mussels, and other waste directly attached to the oyster. To obtain this, all oysters were culled to singles and the waste weighed.

The varience was from 6% to 17% of the original weight. This could, and probably did, affect factory yields. There were indications that the "bunchy" oysters ahd the greatest amount of attached waste.

As previously mentioned, laboratory yields were consistently better than those of the factory. In the laboratory, at first all oysters were shucked out. Later only those over forty millimeters from hinge across the greatest distance of shell were shucked out. On two samples the smaller oysters were shucked separately and the increase in weight was only 2%.

In order to determine, if possible, where the differences in the laboratory and factory yields might be, the shell piles of the factories were examined on six different occasions. From 10% to 20% of the oysters were being discarded with the meats still attached to the shell. These oysters, however, were of such size that only 4% to 12% of the weight of the oyster meats were being discarded. It was quite evident that whenever the oysters were of a regular size there was less waste than when the oysters were of many sizes. This held true even if the oysters were quite small. Where the oysters were in bunches, the number of discarded meats was also higher. Shuckers used a few oysters from the 41-50 millimeter size group, over 75% of the oysters from the 51-60 millimeter size group and only a few oysters that measured over 61 millimeters were discarded.

One factory operator informed the biologist, and it was checked on one occasion, that there was a difference in the amount of wasted meats according to the time of day the oysters were shucked. On the day in question about 4% of the weight of meats was being discarded in the early morning hours, but just before closing time 10% of the weight of meats was discarded.

The factory yields on separate loads brought in the same day varied from less than one-half pound to over one pound of meats per barrel of steam stock. These variances are the ones that can be explained by the preceding information. These differences are the ones that can be partially overcome and the lower yields increased by closer supervision of the buying and shucking of the shell stock.

The differences in pounds of steam meats per barrel of shell stock that occur over a period of time, particularly when there is a definite tendency for an increase in yield as the season progresses are not so easily explained. The average barrel weight increased slightly and there was apparently less attached waste as the number of single oysters increased; but the average yield in March was still somewhat better than the yield in January if these were the only factors involved.

It is this difference that was next tested - and tested rather unsuccessfully.

Although the factories steam their oysters at nearly the same interval throughout the season, it was decided to first see what effect steaming had on yield. Three samples were tested by placing ten pounds of shell stock into pressure cookers and cooking for five, ten and fifteen minutes each at fifteen pounds pressure. There was little or no difference in the hield providing the full eye was shucked from each oyster. This was definitely harder to do if the oyster had been overcooked - as it had been when steamed the longer period.

Measurement of a high percentage of the oysters in the samples revealed that a large number of small oysters were being purchased and shucked out. In fact, when measured from the hinge across the greatest distance of the shell, over 75% of the oysters purchased were less than three inches long. The average length varied only a small amount during the season with more uniform sizes being taken in March and April (due apparently to a depletion of the larger oysters) than in late January and February.

In order to determine the differences in yield due to the size of the oyster, a number of oysters were collected, culled into singles, placed in a tank at the laboratory from five to ten days, and then, after conditioning, they were measured and placed into ten millimeter size groups. They were then measured in a 1/40 barrel container, weighed to the nearest .1 pound and then opened as raw stock. The shucked oysters were then drained and weighed. Five oysters from each group were then dried at 80° C. for three days. The following tabulations are based on the bulk and not upon the weight of the shell stock. Total sample equaled only one-fourth barrel.

TABLE 1

OYSTER SIZE - YIELD EXPERIMENT

Size of Oysters MM	Weight of Barrel Pounds	Number of Oysters in Barrel	Weight of Shucked Oyster Pounds	Weight of Dry Solid Pounds
40-49	264	3600	19.3	3.1
50-59	264	2560	21.0	3.2
60-69	256	1600	20.8	3.0
70-79	244	1320	22.1	3.4
80-89	240	1240	21.8	3.8
90-99	228	840	22.1	3.7
100-109	252	840	24.3	3.7

From this, even though the sample was small, it appears that there is a little difference in yield, within the limits examined, that is caused by size. This perhaps needs further study for despite the heavier weight of the shell stock of the smaller oysters, the yield (in dry solids at least) was no greater than from larger oysters. It is possible that whatever gain in yield made by the smaller oysters due to an increase in the weight of the shell stock is lost because of the better quality of the larger oyster.

It is the problem of "quality" that still remains a mystery. Trying to find a constant on which to determine this quality for steam stock is still a major problem.

Volume or weight of raw shucked oysters did not vary in proportion to the weight of steamed meats. Early in the season the weight of the steamed meats averaged .56 the weight of the raw meats. This was used for a conversion factor; but late in the season was found to be erroneous when the average of the steamed meats weighed .64 times the weight of the raw meats.

The ratio of the weight of the dry solids to the weight of drained raw meats varied considerably. The weight of the dry solids was from 11.9% to 18.8% (average 15.0%) of the weight of the drained raw meats.

Even the ratio of the weight of the dry solids to the weight of steamed meats varied from 22.0% to 28.4% with an average of 25.2%. Factory men explained the latter by stating that during a portion of the year (which corresponded to the time when the percentage of dry solids is high) that they do not put the full measure of steamed meats into the can. The oysters, during this part of the season, absorb water after being placed in the can and being further processed. When opened these cans contain oysters whose drained meats weigh the number of ounces marked on the can. Late in the season the factories must put in the full measure so that they will "cut" the required weight the following morning. It is entirely possible, and even probable, that the factories are packing a product where the dry solids remain constant, and that the laboratory yields varied because the processing was not continued.

There appeared to be a direct correlation between the salinity of the raw oyster liquor and the percentage of dry solids in the steamed meats. The lower the salinity, the higher the percentage of dry solids.

The roles of glycogen content, ratio of cavity volume to dry solids, and the amount of sex products in the oyster were not studied. Certainly in these factors are some fertile fields for study.

Conclusions:

It was possible to evaluate the roles of the size of the barrel, percentage of waste in a barrel, and percentage of wasted meats in shucking as factors that influence the yield in steam oysters.

Time of steaming plays a minor role in the yield of steamed oysters, except that overcooking may increase waste.

Size of the shell stock apparently plays a minor role in yield of steam stock. Whatever gains there might be because of increased shell stock weight per barrel in small oysters is apparently overcome by an increased quality of the larger oysters.

The role of quality as it affects steam yields could not be evaluated because no constant was found.

STUDIES OF THE NORTH CAROLINA CLAM INDUSTRY

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Clams have been harvested in commercial quantities from North Carolina since about 1880. A review of the available catch statistics for North Carolina shows an unusually high production of 1,175,000 pounds of clams as early as 1902. This production is attributed to the activities of a clam plant established at Ocracoke, on the outer banks, in 1898 by Mr. J. H. Doxsee who came to North Carolina from Islip, Long Island, New York. Several older residents of Ocracoke Island who worked in the plant report that the clams were packed as clam chowder, whole clams and clam juice. The shipments were labeled as "quahaugs" with the origin as Islip, Long Island, New York. Later, the plant was moved to the mainland at SeaLevel, North Carolina and finally was moved to the west coast of Florida in the vicinity of Marco, Florida. Statistics are not available during the period that the Doxsee plant was in operation in North Carolina, except for the year 1902, but this is reputed to be the period of greatest clam production in North Carolina.

There is little information pertaining to clams in North Carolina. In 1949, the Institute of Fisheries Research began studies on the biology of clams, the operations of the industry, population studies and collections of catch statistics. This information is to be used in developing a sound program of management. This discussion is limited primarily to the activities of the industry.

Production of clams has fluctuated considerably through the years as indicated by the statistics in Table I. From the available information, the fluctuations in production reflect the lack of development of a steady market rather than a decrease in supply of clams.

The clam industry at present is concentrated in Core Sound between Harkers Island and the vicinity of Drum Inlet. Commercial quantities of clams are gathered from Bogue Sound, Ocracoke Inlet, Brunswick County and from the sounds of Pender and Onslow counties. The clams are found in the sounds with the greatest concentrations found along the outer banks and in the areas coming under the influence of the numerous inlets. The bulk of the clam population is composed of the species *Venus mercenaria* and the variety *Venus mercenaria notata*. Some *Venus campechiensis* are found in the catches from the immediate areas of Drum and Barden inlets of Core Sound.

Clams are gathered by hand with rakes in the shallow waters and, to a limited extent, with tongs in the deeper waters up to fifteen feet. Since December 1949, the bulk of the commercial clams has been dredged in Core Sound, utilizing a method developed by some local clammers.

TABLE I

HARD CLAM PRODUCTION, NORTH CAROLINA, 1880 to 1950

Year	Pounds*	Value
1880	310,000	$ ---
1887	78,000	3,233
1888	148,000	6,150
1889	155,000	8,265
1890	226,000	12,090
1897	938,000	53,703
1902	1,175,000	86,662
1908	726,000	82,000
1918	197,000	46,598
1923	263,000	64,064
1927	315,000	70,940
1928	324,000	61,168
1929	380,000	59,834
1930	317,000	40,680
1931	332,000	30,775
1932	261,000	17,278
1934	338,000	33,647
1936	839,000	75,326
1937	430,000	34,343
1938	358,000	27,756
1939	628,000	50,360
1940	530,000	45,067
1941	1,011,613#	---
1942	897,612#	---
1943	519,381#	---
1944	320,757#	---
1945	502,000	151,447
1946	208,730#	---
1947	297,203#	---
1948	203,283#	---
1949	163,802#	---
1950	483,863#	---

*Production figures of edible portions from Federal statistics except as noted.

#Production figures based on tax receipts to N. C. Division of Commercial Fisheries, bushels converted to U. S. Standard Bushels and converted to pounds by factor of 7.65 pounds per bushel.

The dredging method employes a principle of loosening and washing the sand from around the clams with the propellor wash of the boat. Extensive sand shoals are found in this sound. Small boats are anchored by the bow with a length of cable to an iron stake driven into the bottom. A swivel is used at the end of the line secured to the iron stake to avoid fouling the line. As the boat circles about the stake, the engine is turned up to the maximum revolutions to create a strong current of water with the propellor. A set of shrimp trawl doors, tied together with a short length of chain, are towed from the stern to slow the boat to a proper dredging speed. The stern of the boat is weighted with sand bags or water barrels to direct the propellor wash toward the bottom. An ordinary oyster dredge with a four or five foot tooth bar is used to gather the clams. As the clams are removed, the radius of the circle is increased by lengthening the cable from the bow to the stake. Dredging by this method is limited to shallow depths up to five or six feet, depending upon the draft of the boat.

The action of the propellor cuts a furrow in the bottom from eighteen to wenty-four inches wide and from eight to ten inches deep. Dredge hauls of fifteen or twenty-minute intervals yield about a hundred pounds of clams, or approximately one bushel, from areas where clams are concentrated. Daily catches by small boats vary from 1,500 to more than 10,000 pounds, with an average catch of about 3,500 or 4,000 pounds. Raking by hand yields from 300 to 1,000 pounds per day per individual. However, the dredging method involves an initial capital outlay for a boat and equipment which is subjected to rigorous treatment. Between forty and fifty gallons of gasoline are consumed during a day of dredging. The number of clammers using the dredging method has increased from about thirty-five during the 1949-50 season to approximately 85 during the 1950-51 season. Although clamming is permitted through the year, the clammers generally prefer to engage in shrimping, long-haul seining and oyster dredging and resort to clamming when the other fishing activities are at a minimum. Thus, clamming activities are a peak from December to May. Hand raking for clams occurs throughout the year, but the greatest number of rakers work during the months when water temperatures permit wading.

Weather conditions limit the number of days that dredgers work. During January, February and March, 1951 the dredgers averaged ten working days per month. In December, 1950 and April, 1951 the average number of working days was fifteen days per month.

The composition of the catches by the dredgers showed that the bulk of the clams were of chowder size. The percentage of different size groups varies with the locality, but on the average a daily catch of 4,000 pounds contained five percent cherry-stone and little-neck clams. Examinations of catches aboard the dredge boats showed that breakage varied from two to six percent. A greater percent of breakage was found in some isolated cases when dredgers attempted to conserve on gasoline consumption by decreasing the speed of the engine. The result was that the bottom was not loosened sufficiently and the clams not exposed to facilitate gathering with the short teeth of the oyster dredge.

The price received by the clammers for their catch has increased over the past two years. In June, 1949 the clammers received one cent per pound. By January, 1950 the price had increased to one and one-half cents per pound and by January, 1951 the price was two cents per pound. The catch is sold as caught with no attempt made by the clammers to grade their clams. The dealers usually sort the clams into two or three sizes; chowders, cherry-stones and/or little-necks.

Since about 1940, the bulk of the clams from Core Sound has been shipped as frozen, fresh-shucked clams destined for the manufacture of clam chowder. A substantial quantity of small clams, cherry-stones and little-neck grades, are shipped to mid-western markets in the shell. During the past two years an increased quantity of mixed sizes of clams has been shipped in the shell to dealers in Virginia, Maryland and further north.

There have been no attempts made to cultivate clams in North Carolina. A few dealers have leased small areas where clams are stored until a favorable market develops. This is generally limited to holding the smaller sizes of clams.

The potentialities for the development of a substantial clam industry appear to be promising in North Carolina. Perhaps the most pressing need is the development of harvesting methods to insure a steady supply of clams.

A SOFT CLAM POPULATION CENSUS IN SAGADAHOC BAY, MAINE
1949-'50-'51

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INTRODUCTION

The Clam Investigations started population studies of the soft clam, Mya arenaria, in 1949. The objective of these studies is to determine the productivity of a flat in terms of the number of bushels of clams which can be removed each year without endangering the supply.

Preliminary estimates of total population, growth rate and ultimate size, which must be made to establish productivity, are discussed in this paper.

Sagadahoc Bay is located on the southern tip of Georgetown Island, Maine facing the open ocean. This bay was chosen because the center has a sand soil and the edge a muddy soil with a small amount of sand mixed with mud, the two types of flats common along the coast of Maine. At low tide Sagadahoc Bay has exposed flats three-quarters of a mile long and one-half mile wide which are dug commercially for soft clams.

Methods (Census)

To determine the population of clams in the bay, we dug two-foot-square sample plots which were distributed over the entire area. For each year's census we dug the first sample at a random spot in the bay and established a grid of lines from the location of the first sample. With the aid of a hand compass, we ran the grid lines approximately north to south and east to west, and located sample plots at the inter-sections of the grid lines over the entire area. Distances in the grid system were paced.

In 1949 the sample plots were dug and the clams picked out and counted. However, we suspected that many of the 0-25 mm. clams were overlooked in some of the plots. In 1950 the sampling method was expanded by the washing out of a 6" x 6" x 2" sub-sample with a fine mesh screen. This gave us a more accurate count of the actual number of clams in the sample. This method

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Note:-- Field work for this papers was done by John B. Glude, Richard E. Tiller, Walter R. Welch, Gareth W. Coffin and the writer.

The outline of Sagadahoc Bay in Figures 1-4 is based on a survey by Dr. W. H. Bradley, Chief Geologist of the U. S. Department of the Interior Geological Survey.

is now being carried out.

In the laboratory, we measured and recorded lengths of all clams found in the sample plots. Estimates of total populations were calculated from the mean number of clams per square foot and the size of the area surveyed. Volumes in bushels were estimated for the 26-50mm. size group and the over-50 mm. size group.[1/]

At the beginning of the study the entire bay was sampled to determine the productive areas. Small unproductive sections are outside the workable areas but are sampled for the annual census. To make workable sections of the productive flats, we divided the bay into three areas based on soil types (see Figure 1). Area A and Area B, widely separated, have mud soils; Area C, in the center of the bay, a sand soil. A survey of the three areas shows the size of each: Area A has 2,459,000 square feet; Area B, 825,000, and Area C, 4,484,000.

Results (Census)

The 1949 census was started in January and completed in March. We established north to south grid lines 150 feet apart, and east to west grid lines 300 feet apart. Plots are located at the intersections of the grid lines (see Figure 2).

Area A had a total of 94 square feet sampled and a mean number of 12.7 clams per square foot; Area B, 34 square feet sampled and 11.7 clams per square foot; Area C, 150 square feet sampled and 1.1 clams per square foot. Population estimates for the three areas were 31,336,000, 10,220,000 and 4,962,000 clams respectively, or a total of 46,518,000 clams in 1949. Estimated number of bushels in the over-50mm. size group were: 2,599 bushels in Area A, 858 in Area B, and 6,020 in Area C, or a total of 9,477 bushels of clams over-50mm. (see Table I and Figure 7).

The 1950 census was started in April and completed in May. Grid lines in this census varied from area to area because analysis of the first census indicated that more samples than necessary had been taken in Area A and Area B, and too few had been taken in Area C. We located plots at the inter-sections of the grid lines (see Figure 3). Area A had a total of 48 square feet sampled and a mean number of 13.5 clams per square foot; Area B, 46 square feet sampled and 17.9 clams per square foot; Area C, 46 square feet sampled and 1.0 clams per square foot. Population estimates for the three areas were 33,194,000, 15,677,000 and 4,483,000 clams respectively, or a total of 53,354,000 clams in 1950. Estimated number of bushels in the over-50mm. size group were: 2,803 bushels in Area A, 1,111 in Area B and 4,006 in Area C, or a total of 7,920 bushels of clams over-50 mm. (See Table II and Figure 7).

1/ For the table of clam volume, see Belding (1930).

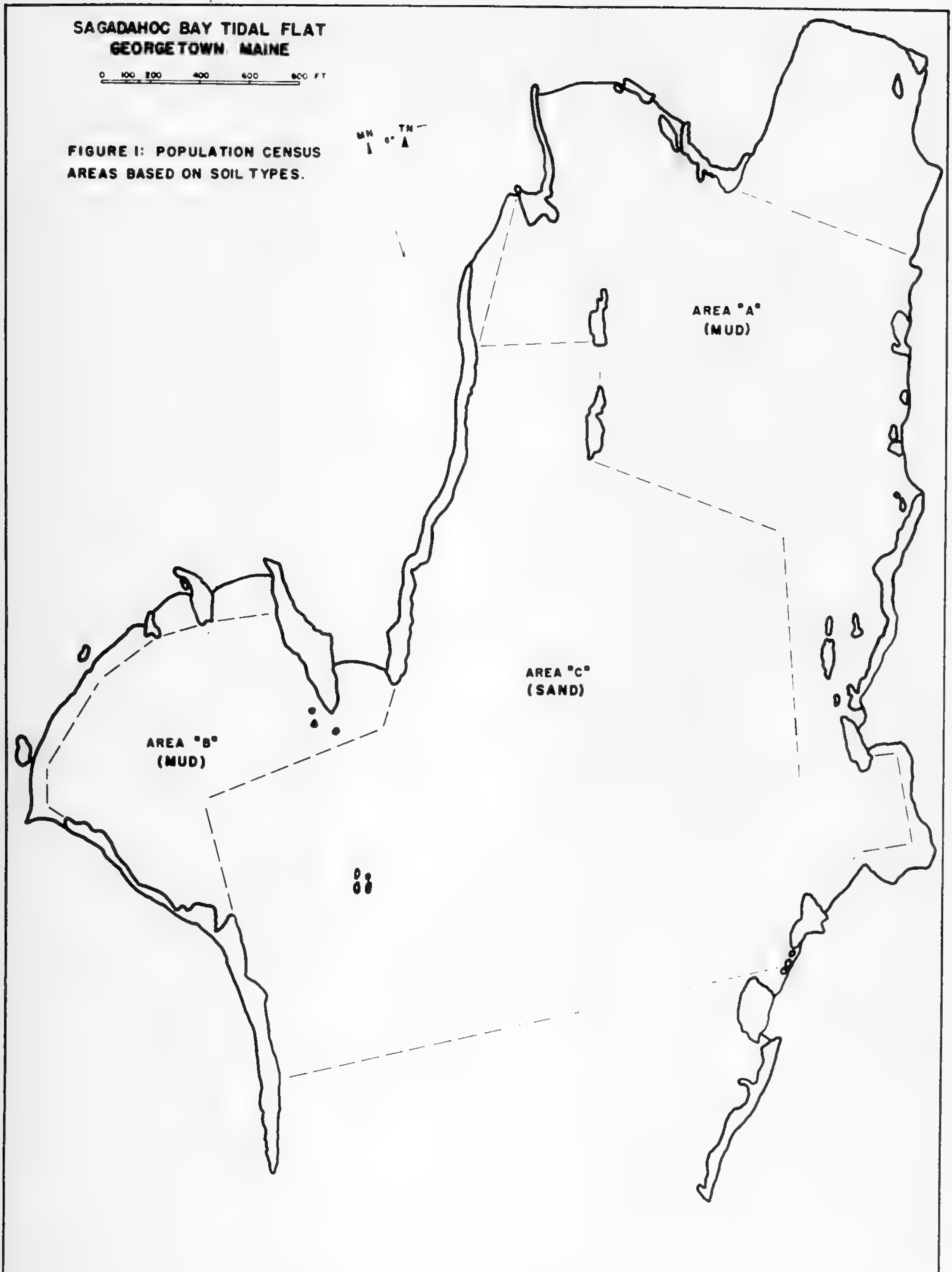


FIGURE I: POPULATION CENSUS AREAS BASED ON SOIL TYPES.

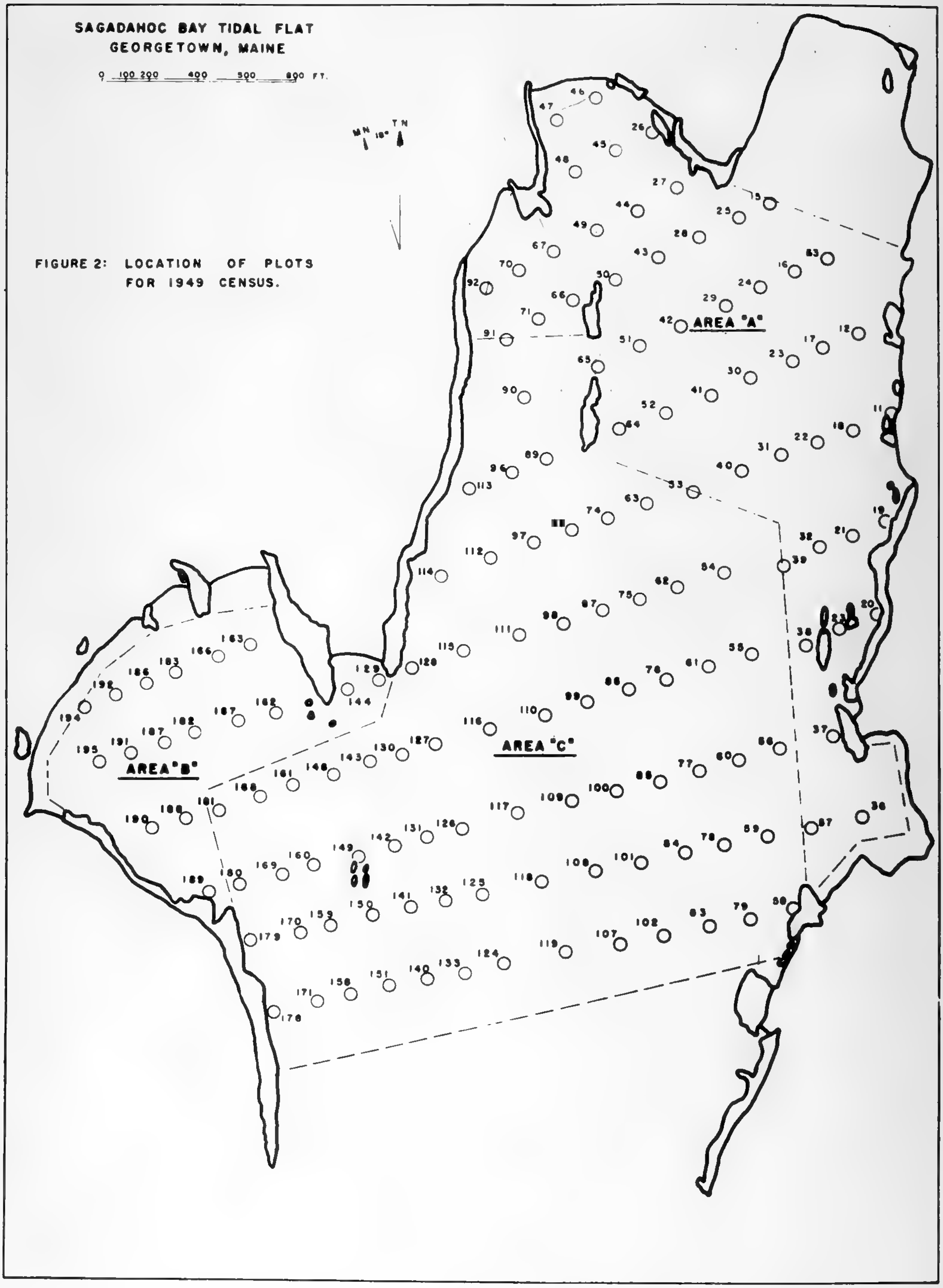


FIGURE 2: LOCATION OF PLOTS FOR 1949 CENSUS.

TABLE I - POPULATION ESTIMATE OF SOFT CLAMS

Sagadahoc Bay

1949

Area	Soil Type	Square Feet Sampled	Total Area Surveyed in 1000 Sq. Ft.	Size Group No. Clams in Samples 0-25 mm.	26-50 mm.	Over-50 mm.
A	Mud	94	2,459	84	959	155
B	Mud	34	875	4	341	52
C	Sand	150	4,484	5	49	112
	Totals	278	7,818	93	1,349	319

Area	Mean No. Clams Per Sq. Ft.	Size Groups Total No. Clams (thousands) 0-25 mm.	26-50 mm.	Over-50 mm.	Total (thousands)	No. Bu. 26-50 mm. Size Group	No. Bu. Over-50 mm. Size Group
A	12.7	2,197	25,085	4,054	31,336	4,389	2,599
B	11.7	103	8,778	1,339	10,220	2,282	858
C	1.1	149	1,465	3,348	4,962	426	6,020
	Totals	2,449	35,328	8,741	46,518	7,097	9,477

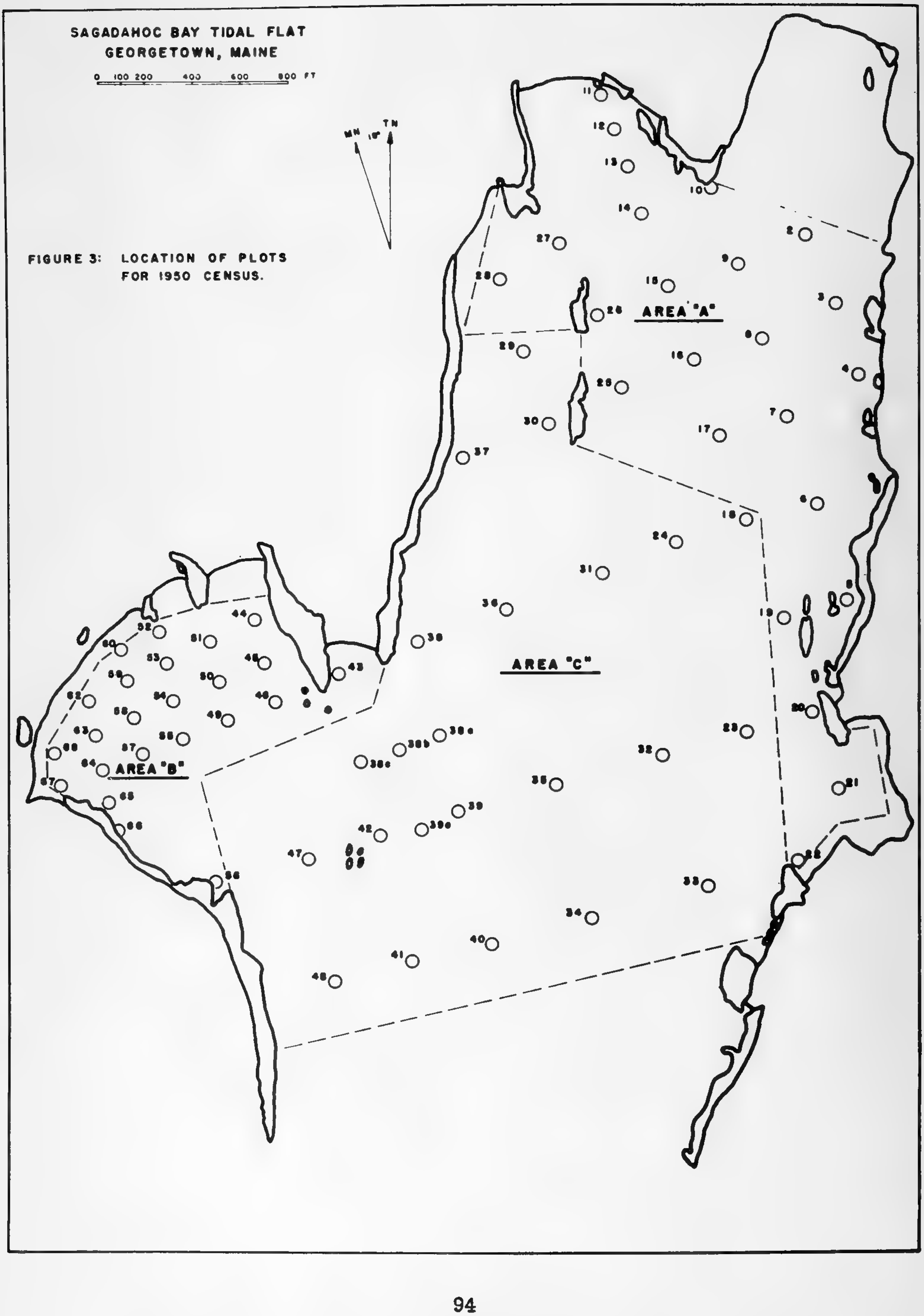


FIGURE 3: LOCATION OF PLOTS FOR 1950 CENSUS.

TABLE II - POPULATION ESTIMATE OF SOFT CLAMS

Sagadahoc Bay

1950

Area	Soil Type	Square Feet Sampled	Total Area Surveyed in 1000 Sq. Ft.	Size Groups No. Clams in Samples 0-25 mm.	26-50 mm.	Over-50 mm.
A	Mud	48	2,459	182	378	88
B	Mud	46	875	336	395	93
C	Sand	38	4,484	1	11	34
	Totals	132	7,818	519	784	215

Area	Mean No. Clams Per Sq. Ft.	Size Groups Total No. Clams (thousands) 0-25 mm.	26-50 mm.	Over 50 mm.	Total (thousands)	No. Bu. 26-50 mm. Size Group	No. Bu. Over 50 mm. Size Group
A	13.5	9.323	19.363	4,508	33,194	4,919	2,803
B	17.9	6,393	7,515	1,769	15,677	2,046	1,111
C	1.0	97	1,072	3,314	4,483	326	4,006
	Totals	15,813	27,950	9,591	53,354	7,291	7,920

The 1951 census was started in April and finished in May. Grid lines established for the 1951 census are similar in spacing to the grid lines used in the 1950 census. We located plots at the intersections of the grid lines (see Figure 4). Area A had a total of 48 square feet sampled and a mean number of 11.8 clams per square foot; Area B, 40 square feet sampled and 14.8 clams per square foot; Area C, 44 square feet sampled and 1.8 clams per square foot. Population estimates for the three areas were: 29,044,000, 12,953,000 and 7,847,000 respectively, or 49,844,000 clams in 1951. Estimated number of bushels in the over-50 mm. size group were: 2,514 in Area A, 911 in Area B, and 4,947 in Area C, or a total of 8,372 bushels of commercial size clams (see Table III and Figure 7).

Population estimate for the 0-25mm. size group in 1949 is low because no sub-samples were screened in that year. The low population of the 0-25 mm. size group in Area C for all years is believed to be caused by tidal currents which prevent many seed clams for establishing themselves. There is a large number of clams in the 26-50mm. size group, and a relatively small number of clams in the over-50 mm. size group in Area A and Area B. The possible cause for this is slow growth and small ultimate size. Fluctuations in volume of clams from year to year are probably partially caused by commercial digging.

Methods (Growth)

Shells of clams found in sample plots located in Areas A, B and C were "read" for growth. Growth "readings" are based on shell rings made by interruptions of growth during the winter. We combined growth readings for 1949, 1950, and 1951 to have a more adequate number of readings for each age (see Table IV).

Results (Growth)

The growth curves plotted from the shell readings indicate slow growth in Area A and Area B, and fast growth in Area C (See Figure 5).

Methods (Ultimate Length)

Ultimate length of soft clams in Sagadahoc Bay was determined by a new method described by L. A. Walford in his paper of 1946, "A New Graphic Method of Describing the Growth of Animals". The body length of the animal is represented along both the x axis and the y axis on graph paper. Length at age n on the x axis is plotted against length at age n + 1 on the y axis. For several animals, the points plotted for lengths at several ages will fall in a straight line. This line may be regarded as a sort of transformation of the usual growth curve. By extending this line, ultimate length of the animal can be located at the point where the length at age n equals the length at age n + 1.

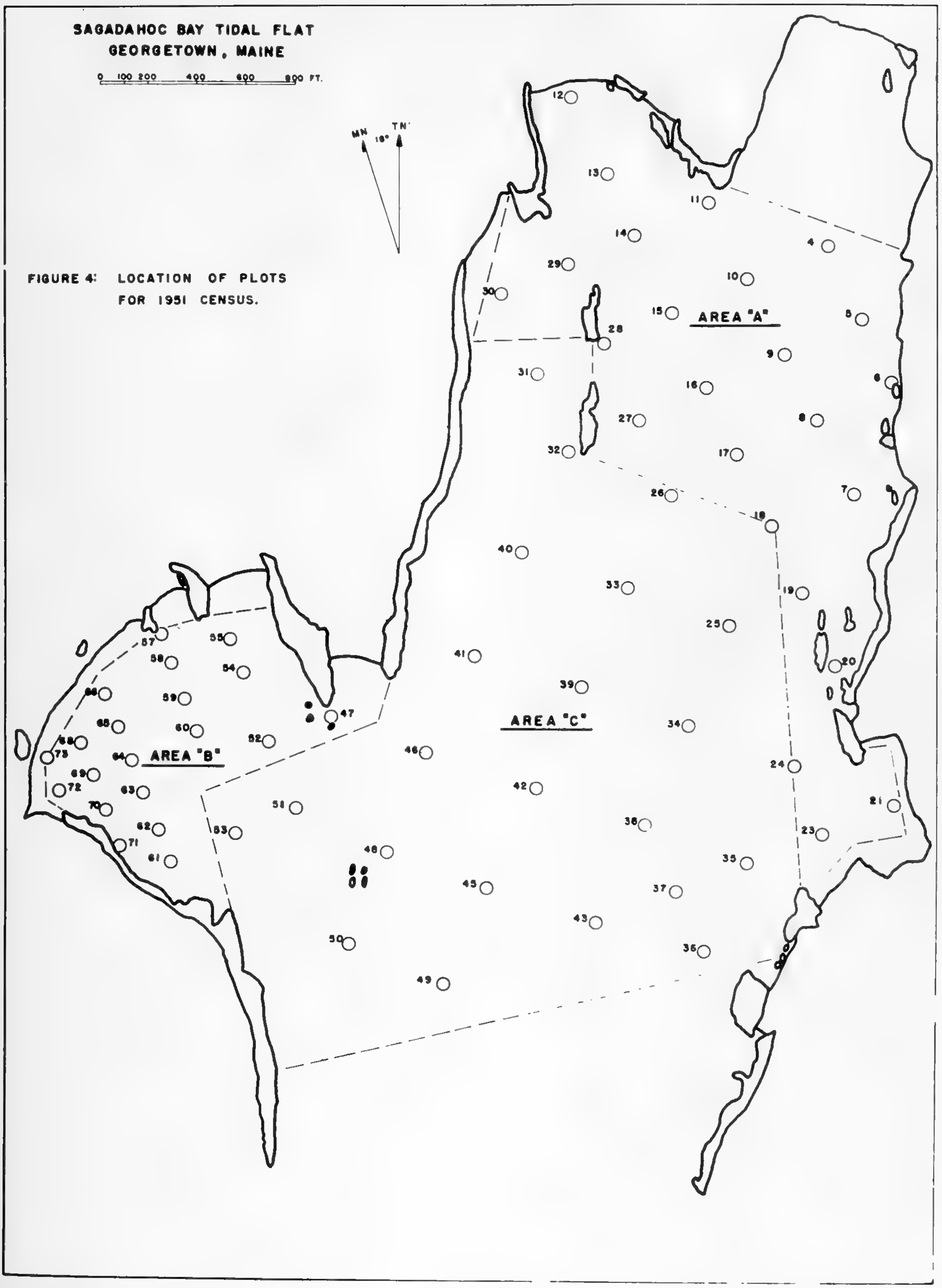


FIGURE 4: LOCATION OF PLOTS FOR 1951 CENSUS.

TABLE III - POPULATION ESTIMATE OF SOFT CLAMS

Sagadahoc Bay

1951

Area	Soil Type	Square Feet Sampled	Total Area Surveyed in 1000 Sq. Ft.	Size Groups No. Clams in Samples 0-25 mm.	26-50 mm.	Over-50 mm.
A	Mud	48	2,459	146	335	86
B	Mud	40	875	273	249	70
C	Sand	44	4,484	25	20	32
	Totals	132	7,818	444	604	188

Area	Mean No. Clams Per Sq. Ft.	Size Groups Total No. Clams (thousands) 0-25 mm.	26-50 mm.	Over 50 mm.	Total (thousands)	No. Bu. 26-50 mm. Size Group	No. Bu. Over 50 mm. Size Group
A	11.8	7,479	17,160	4,405	29,044	4,222	2,514
B	14.8	5,973	5,448	1,532	12,953	1,396	911
C	1.8	2,548	2,038	3,261	7,847	463	4,947
	Totals	16,000	24,646	9,198	49,844	6,081	8,372

TABLE IV - GROWTH READINGS 1/

Sagadahoc Bay

Age	AREA A		AREA B		AREA C	
	No. Samples	Average Length	No. Samples	Average Length	No. Samples	Average Length
1	1,690	11.2	813	11.0	234	10.3
2	1,689	24.9	759	24.8	227	28.0
3	1,332	34.9	611	35.2	200	43.1
4	778	42.5	394	43.3	144	56.5
5	246	47.8	107	48.9	81	68.5
6	35	51.3	12	52.4		

1/ Combined for 1949, 1950 and 1951.

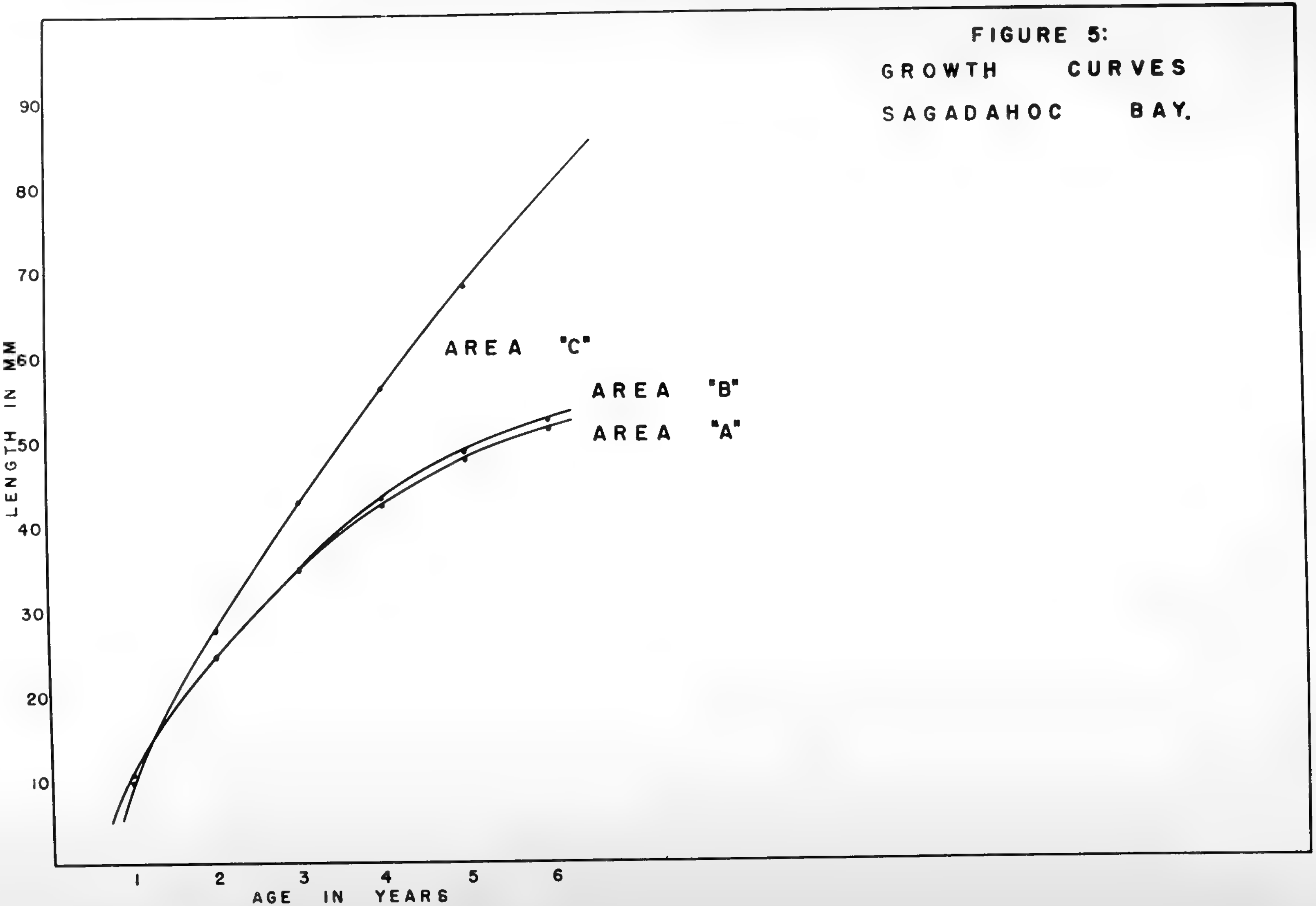


FIGURE 5:
GROWTH CURVES
SAGADAHOC BAY.

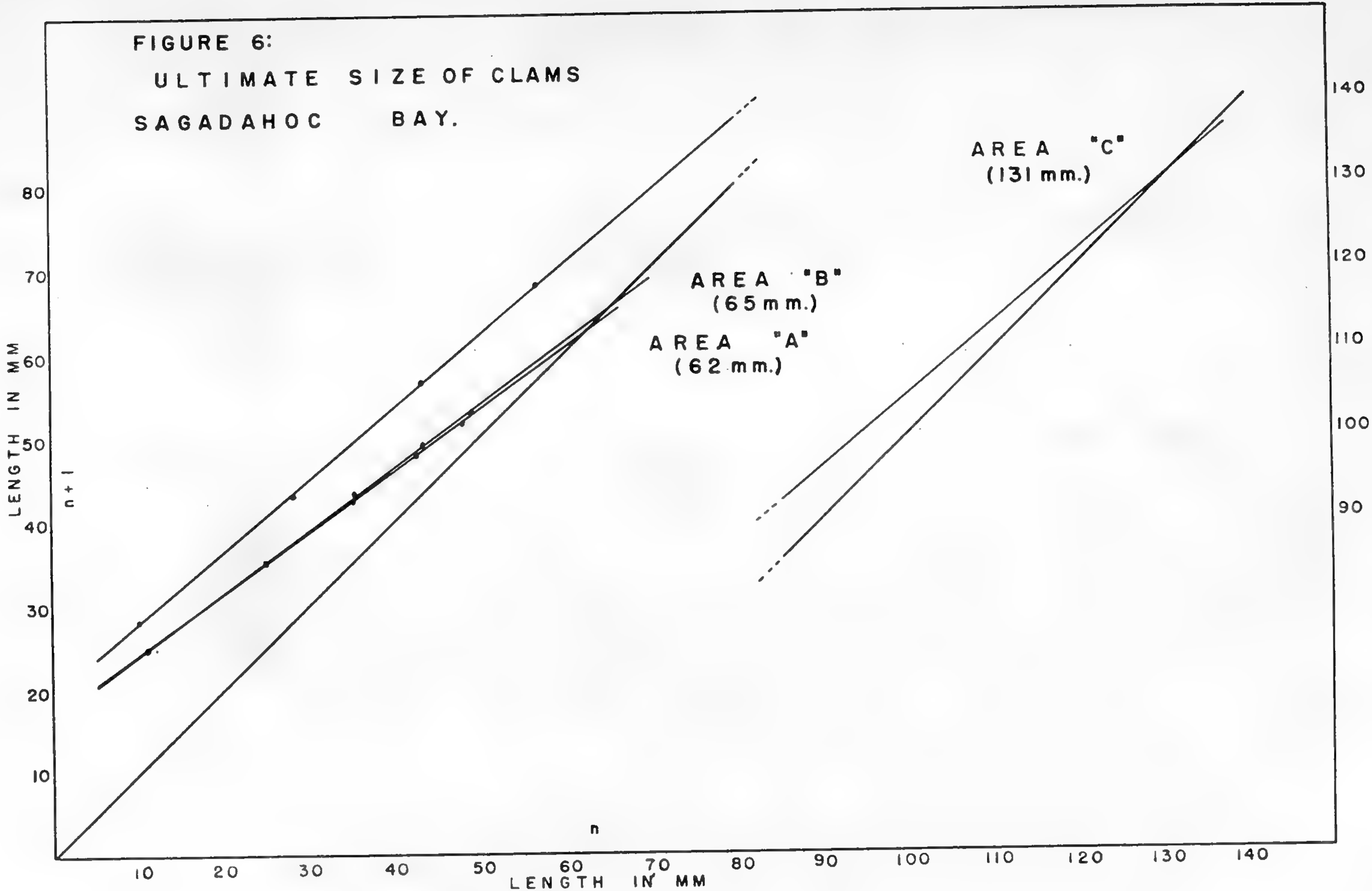
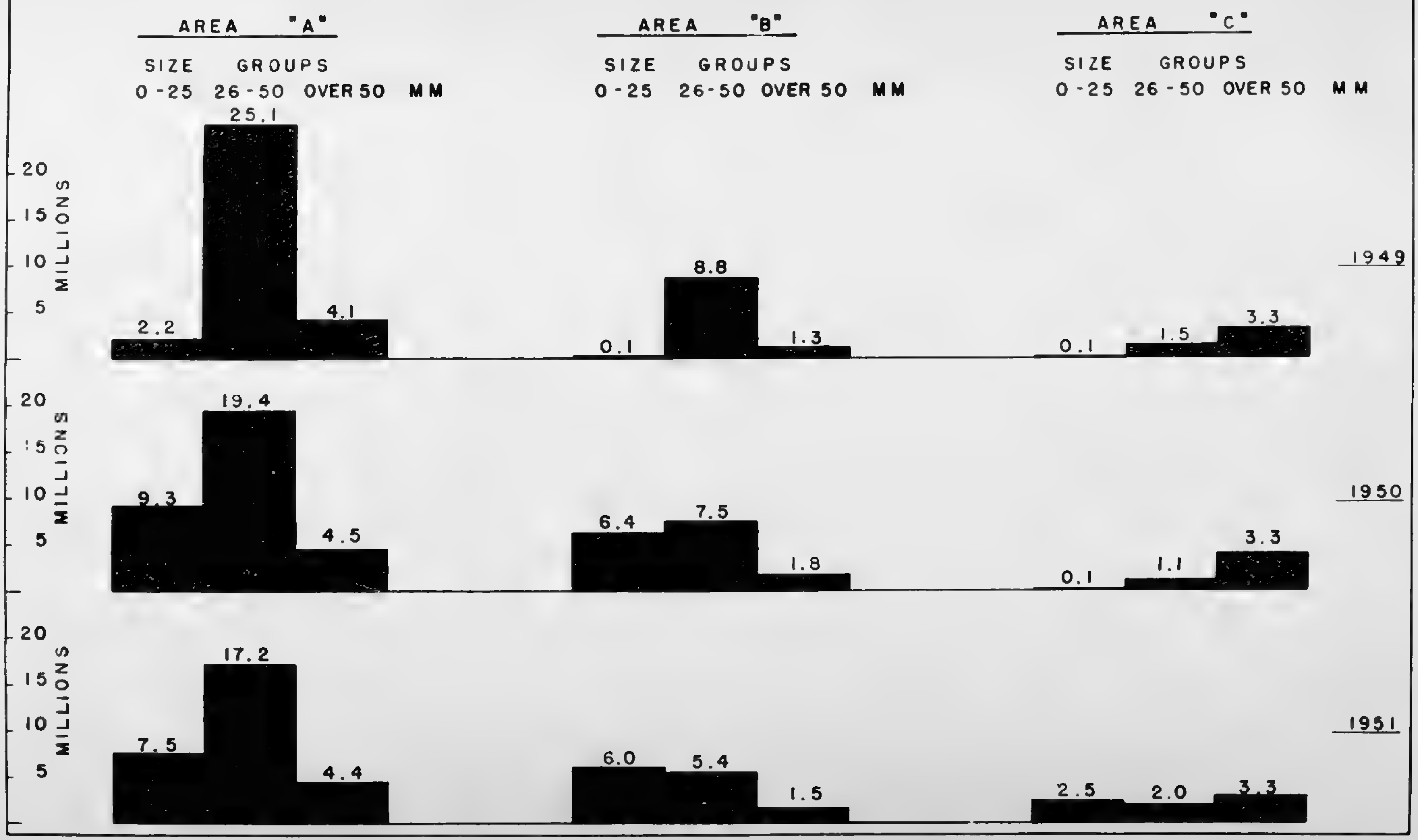


FIGURE 6:
ULTIMATE SIZE OF CLAMS
SAGADAHOC BAY.

FIGURE 7: POPULATION ESTIMATES

SAGADAHOC BAY



Among the examples given by Walford are the fresh water mussel and the Pacific razor clam. As ultimate length is a factor in establishing productivity, we are using this method for indicating the ultimate length for the soft clam.

Results (Ultimate Length)

The ultimate lengths of clams in Sagadahoc Bay (see Figure 6) located by the new graphic method are 62 mm. in Area A, 65 mm. in Area B, and 131 mm. in Area C. These lengths are in close agreement with the lengths of the largest clams found in the census plots.

The point plotted for the length at age 5 (n), against the length at age 6 (n +1), is omitted because of an inadequate number of samples in the 6-year clams.

Discussion

The center of Sagadahoc Bay has a good stock of large clams and a low stock of small clams.

The mud areas on the edge of the bay have a large stock of small clams and a small stock of large clams.

Fast growth occures in the center of the bay; slow growth occurs along the edge.

The ultimate lengths of clams as plotted by areas indicates that clams in Area C have two times the possible ultimate size of clams in Area A and Area B.

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1. Belding, D. L. 1930. The soft-shelled clam fishery of Massachusetts. Mass. Dept. Consv. Mar. Fish., Series No. 1

2. Walford, L. A. 1946. A new graphic method of describing the growth of animals. Biol. Bull. 90(2): (April 1946), pp. 141-147.