some oyster biologists who were familiar only with growth rates of oysters in the colder North Atlantic waters. Although we in South Carolina have no long series of oyster growth measurements exactly comparable to those given by Ingle, we have some measurements (admittedly our best) which virtually confirm Ingle's records. Averaging our best measurements a growth rate of 0.56 millimeter in a day has been found. An average of Ingle's figures gives a mathematical growth of 0.688 millimeter in a day. Assuming (erroneously to be sure) the growth rate is continuous and constant during the day, from the above figures, the conclusions reached are that Bears Bluff Laboratories' oysters grow at the rate of 0.023 millimeter per hour and that Ingle's oysters grew at a rate of 0.028 millimeter per hour. This seems to be mathematically accurate even though it is extremely doubtful that it occurs thus in nature. Now suppose that a series of oysters are taken for measurements beginning in the morning at 8 o'clock. Sampling continues periodically through the day until the last oyster taken for measurement is secured at 1 o'clock. These oysters are held out of water until they can be measured. For absolute accuracy it would be necessary to record the time at which the various specimens are taken. Since, mathematically and theoretically they are growing at the rate of almost a 0.03 millimeter per hour, the oysters taken at 1 o'clock would have had an opportunity of growing more than a tenth of a millimeter in the interval of time between the taking of the first oyster at 8 o'clock and the last oyster at 1 o'clock. Thus a time-growth element should be taken into consideration if measurements are given to an accuracy of a tenth of a millimeter.

Growth Rates and Movements of Hard Clams, *Venus mercenaria*

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AMONG THE NUMEROUS OBSERVATIONS that have been made of the growth rates of various species of pelecypods there are but few references to growth studies of hard clams, *Venus mercenaria*. These references are limited to studies in the northern range of *Venus*, from New Jersey northward. Kellog (1903) made some preliminary studies at Cold Spring, New York with small clams 2.8 to 4.4 centimeters in length. Unfortunately his experiments were continued for only six months from June to December, but the results clearly demonstrated the rapidity of growth in *Venus* with an increase, in some cases, of 225 percent in volume. The extensive plantings made by Belding (1912) in Massachusetts were followed for four years. The growing season in Massachusetts was found to extend from May to November when water temperatures were above 45°F. Various ecological factors such as current tides, depth of water, salinity, type of soil and temperature were found to influence the growth rate. Under favorable conditions Belding recorded clams growing two inches in length in two and one-half years from time of setting, to two and one-half inches in three and one-half years. He estimated that sixteen years would be required to produce a clam four inches in length. Haskin (1949) concluded after one growing season that the results in Delaware Bay, New Jersey checked almost exactly with those of Belding at Wellfleet, Massachusetts, The present study was undertaken to determine the growth rates of this species in North Carolina and to secure information on procedures for future experiments.

Two areas were selected for the plantings in North Carolina, the beach at the Institute of Fisheries Research along the north shore of Bogue Sound, and a small cove one mile across the sound on the opposite shore. Both areas are approximately five miles west of Beaufort Inlet.

The north shore of Bogue Sound in this locality consists of a sand bottom and is exposed to the prevailing southwest winds. In contrast, the irregular south shoreline with the bottom varying from soft mud to hard sand is broken by many marsh islands and meandering tidal streams. A soft mud bottom was selected for the south shore plantings where an abundant supply of clams was found.

Acknowledgement is made to Mr. William A. Ellison, director of the Institute of Fisheries Research for his interest and suggestions, and to Mr. D. Teichroew of the University of North Carolina Institute of Statistics for helpful advice in planning the experiments. For technical assistance in measuring and compiling data, the writer is indebted to Mr. Leigh Winslow, a former member of the Institute staff and to Dr. William E. Fahy who performed the statistical t-tests and analysis of variance.

Methods

In December, 1949, a total of 359 clams were collected for the experiments, 63 from the north shore and 296 from the south shore. The number of clams obtained from the north shore was limited because of the sparse population. Each clam was notched with a file and a number cut in the shell with a dental drill. Duplicate plantings of clams, selected at random, were made at a concentration of three clams per square foot in a square yard using only the clams native to the immediate area. The plantings were made in the intertidal zones where the bottom is exposed during extreme low tides. The clams varied in length from 2.7 to 10.1 centimeters with smaller size groups absent since the animals were gathered with a rake. An additional series of clams from the south shore were transplanted from their natural environment of soft mud to a tidal pond of hard sand bottom about three hundred yards from the original location.

Monthly measurements, except for November, were made of the individuals of one plot in each area, with the duplicate plots left as controls to be measured at six month intervals. Three measurements of each clam were made with vernier calipers to obtain the length, the anteroposterior axis from the region of the siphons to the opposite end; the width, at right angles to the length, from the umbo to the greatest curvature of the shell on the ventral edge; and the thickness, on a perpendicular axis to length and width or the distance through the valves from the outer shell surfaces. The previous studies of Kellogg (1903), Belding (1912), and Haskin (1949) have shown that an increase in length does not actually express the gain in bulk. However, Haskin has shown that when width, thickness or cube root of the weight is plotted against length a straight line results. This indicates that little or no change in proportions takes place as the animal grows. If one average dimension for a group of clams is known the other dimensions can be obtained from a prepared graph. In the results presented in this study only the lengths are considered.

Weekly records were kept of water temperatures and salinities with occasional plankton tows made through the year 1950. Rainfall and air temperature data were obtained from the U. S. Weather Bureau station in Morehead City, located two miles east from the planted areas.

Each clam was numbered and a record was kept of the exact position in which the clam was placed in respect to its neighbors in the plot and of the distance moved during each month. Following each monthly examination the clams were returned to their original position and buried in the soil.

Growth Results

The results obtained in 1950 showed wide variations in growth rates between groups of individuals from the two localities. The percent increase in mean length of all individuals within each plot is represented by the graphs in Figure 1. There was little or no increase in length among the clams from the south shore (Fig. 1, EP, MW, ME) in comparison to the growth shown by the clams

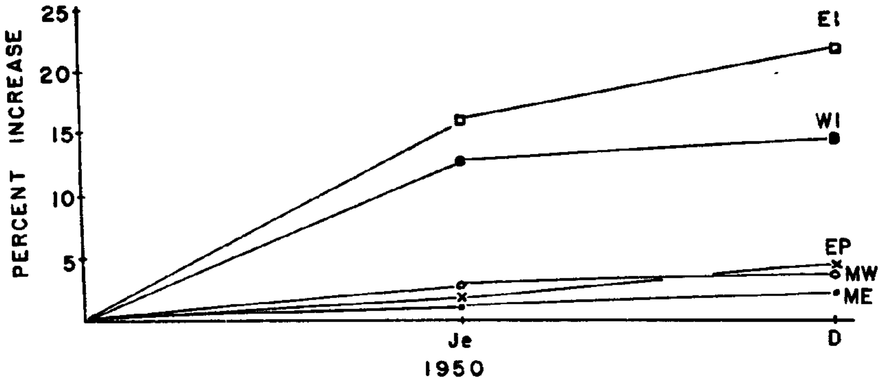

FIGURE 1. Graphs showing percent increase in mean length of shell at six month intervals for five plantings of clams from two locations in Bogue Sound, North Carolina.

from the Institute Beach (EI, WI). From 87 to 100 percent of the clams from the south shore showed no increase in length or an increase of five millimeters or less (see Table 1). In many cases the only visible growth was in filling of the notch filed at the time of planting. Transplantation of a group of these clams from the soft mud bottom to a tidal pond (Fig. 1, EP) did not stimulate shell growth.

At the Institute beach plantings, the greatest growth was found to occur during the first six months of the year. Eighty-two to eighty-five percent of the increase in length for the year was from January through June in the east and west plots, respectively. The mean increase in length for the various ten millimeter size groups at the Institute beach (EI, WI) are plotted in Figure 2, which includes the clams that did not grow. The measurements of length increments through the year in all the plots show a trend of decrease in growth rate with increase in size.

Although growth occurred in all months of the year, monthly variations were found in total gain in length. In Figure 3, the total increment in length for each month of the year is correlated with salinity, water temperature, and air temperature for one group at the Institute beach (EI). The data show that the growth rate was greatest in April and May, and decreased during the summer months through September when but two individuals showed any signs of growth. With cooling of the waters in October, when the temperatures were of the same level as in May, there was an increase in growth which decreased in November and December with a decline of temperature. The values represented for November and December are the average of the combined increment for the two months. The heavy rains during July, when 10.9 inches of rain lowered

TABLE 1

PERCENT OF CLAMS FROM EACH PLOT SHOWING INCREASE IN LENGTH AFTER TWELVE MONTHS. PERCENT MORTALITY IN EACH PLOT RECORDED IN RIGHT HAND COLUMN.

Location	*Increase in Length (MM.)*						% *Mortality*
	0	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	
Inst. Beach							
(EI)	4.1%	16.7%	16.7%	37.5%	25.0%		11
(WI)	7.4	29.6	22.2	22.2	11.1	7.4	25
South Shore							
(MW)	52.2	34.8	8.7	4.3	0	0	25
(ME)	29.2	70.8	0	0	0	0	11
Tidal Pond							
(EP)	43.2	51.0	4.2	0.5	0.5	0.5	21

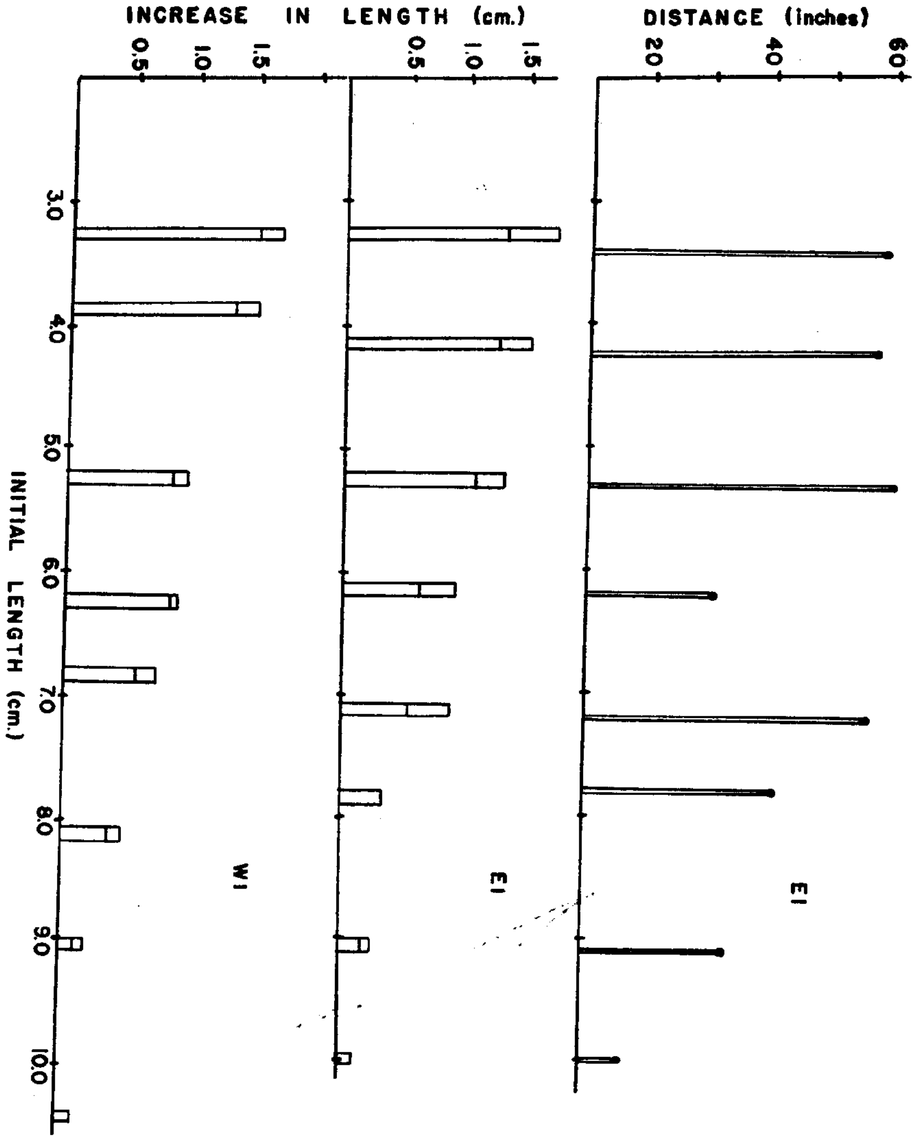

FIGURE 2. Mean increase in length of shell for different size groups from duplicate plantings at the Institute beach compared with the mean distance traveled by each size group in 1950. The distance from the abscissa to the horizontal line in each bar represents the increase in length for the first six months of 1950.

the salinity to 18 parts per thousand (see Figure 3), probably influenced the growth rate temporarily.

The greatest mortality of clams was at the Institute beach where such predators as seagulls and conchs are numerous, (see Table 1). Conchs (*Busycon caricum*) accounted for 69 percent of the total mortality and seagulls killed the remainder. Most of the shells of clams killed by seagulls were recovered

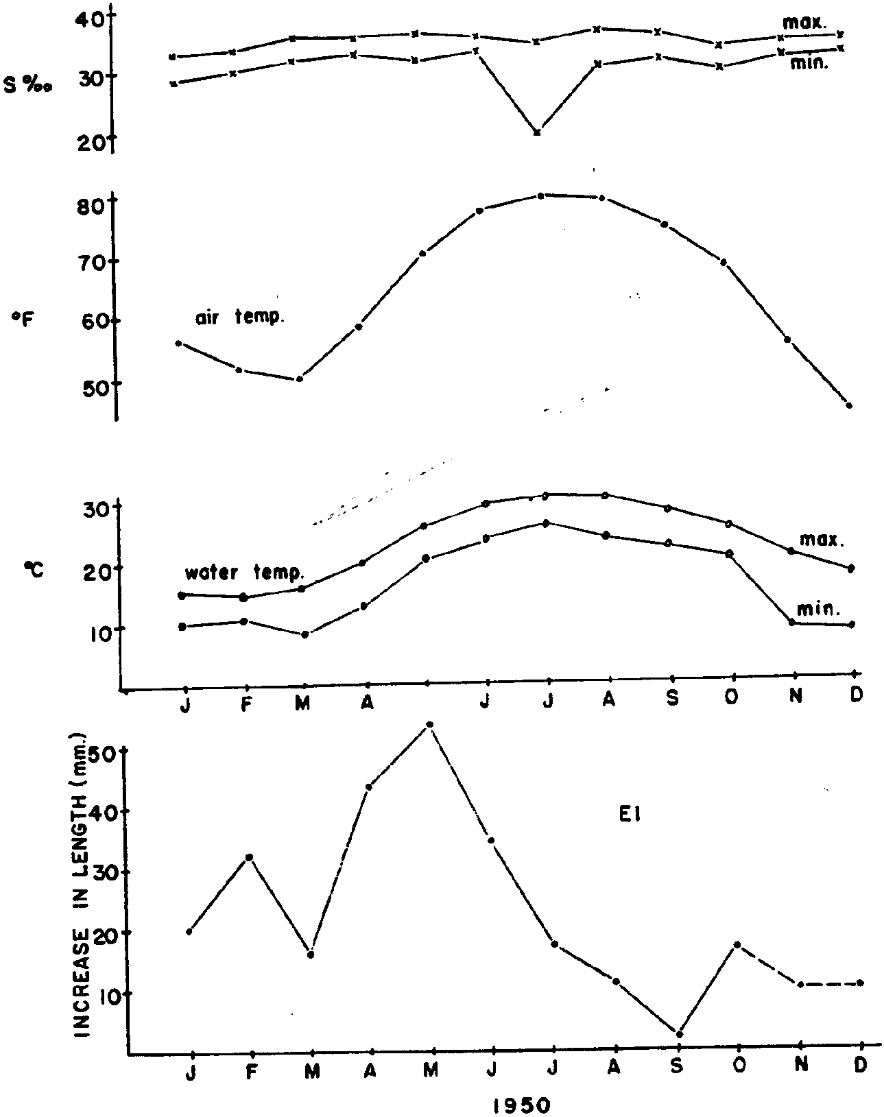

FIGURE 3. Total increment in length for each month at the east plot of the Institute beach planting correlated with the mean air temperatures, maximum and minimum water temperatures and salinities recorded in Bogue Sound, North Carolina at the Institute of Fisheries Research.

from the nearby pier where the clams had been dropped to open them. The high mortality recorded for the clams from the south shore (MW) resulted after transplanting the plot to the Institute beach. All of these clams from the mud bottom plot (MW) were recovered after the first six months but on transplanting them to the Institute beach in July, 1950, a 25 percent mortality occurred in the next six months due to predation.

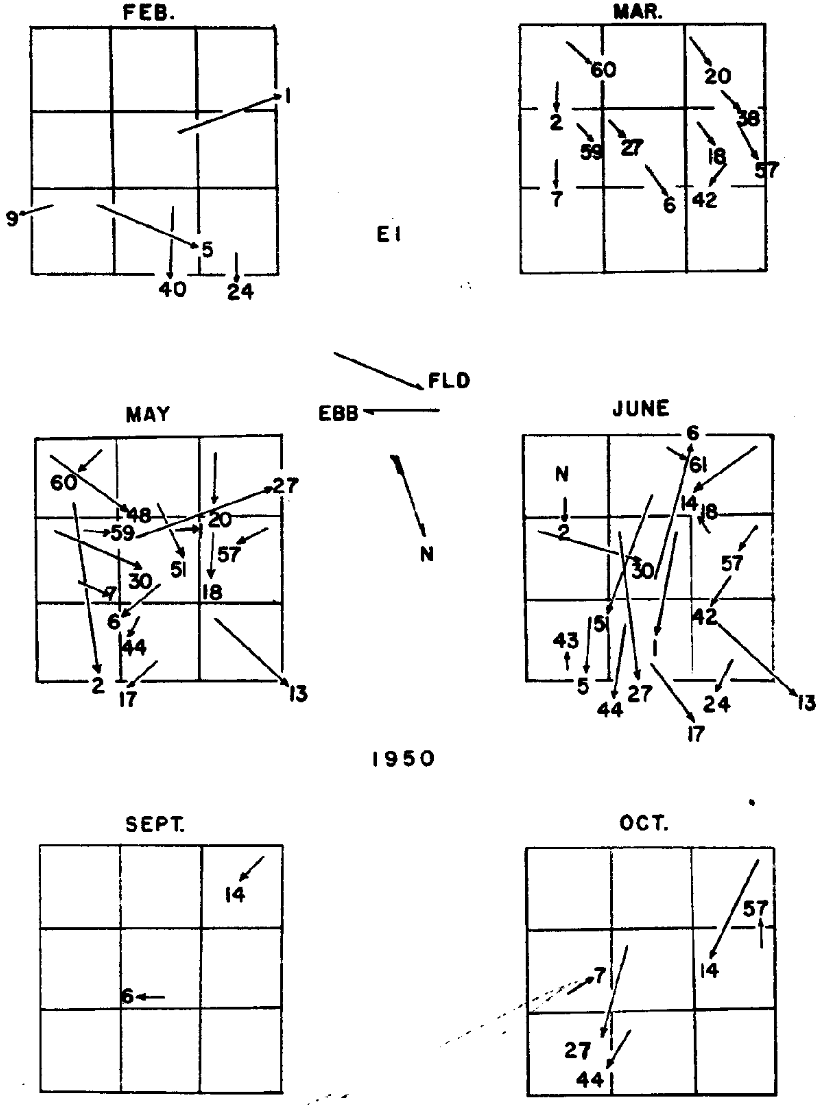

FIGURE 4. Direction and distance of migrations of individual clams in the east plot at the Institute beach during six months of 1950. The length of the arrows represent the distance between the locations in which the clams were found at the end of each month as compared with the original position. Individuals not recorded were found in the positions in which they were placed. Each block within the area represents a square foot.

Movements

Migrations of some clams were noted each month in all plots examined. Since the observations were limited to monthly intervals these results indicate the position of the clam when it was found in comparison to the position in which it had been placed. At the Institute beach (EI), the movements of the clams plotted in Figure 4 for six months were in various directions but predominantly

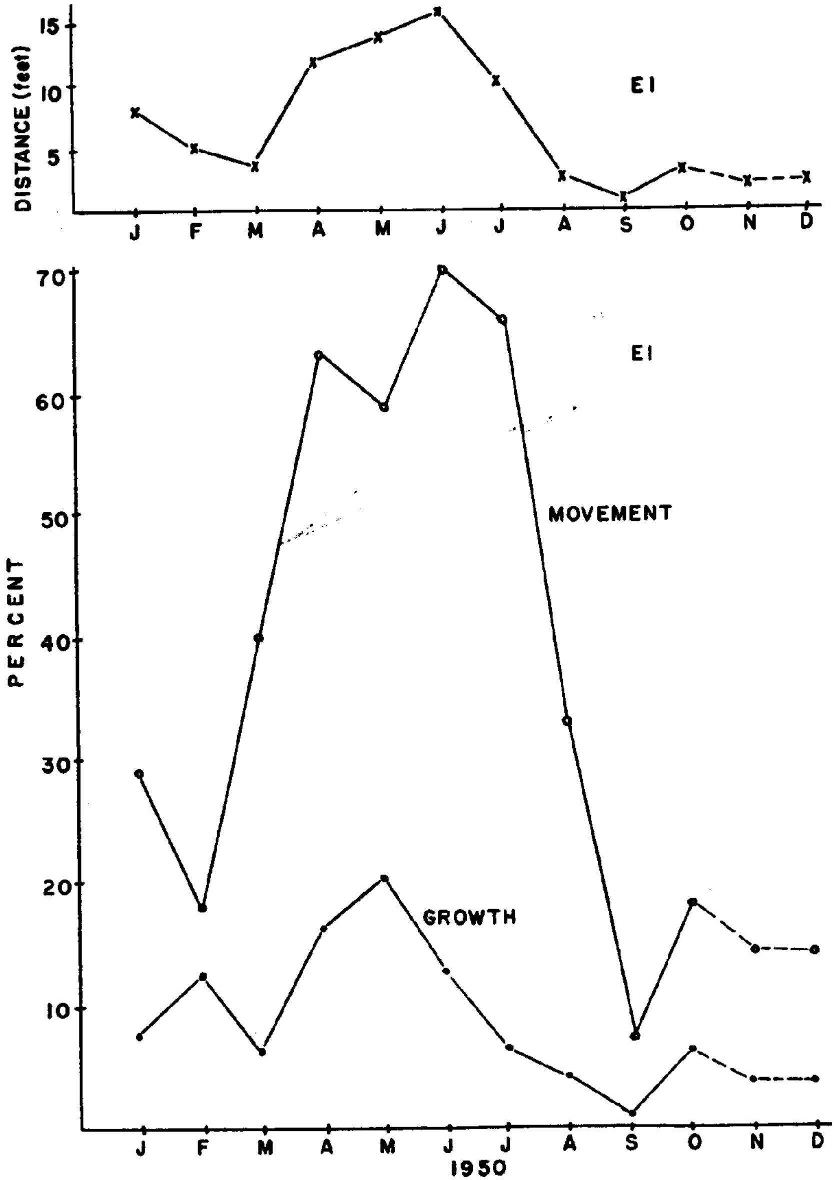

FIGURE 5. Percent of increase in length during 1950 correlated with percent of clams showing migrations and the aggregate distance traveled each month by the clams from the east plot at the Institute beach. The graphs show that during some months, as in March and July, more clams may have moved than in other months but the total distance traveled was not as great. In general the correlation between percent of increase in length and total distance of migration is in close agreement.

toward the shoreline. During the year 49 percent of the clams migrated northward toward the shoreline, 16 percent in the direction of the flood tide, 13 percent away from the shore and 12 percent in the direction of the ebb tide.

In the tidal pond which is protected from rigorous wave action, 36 percent of the migrations through the year were in the direction of the ebb tide, 22 percent with the direction of the flood tide and the remainder were dispersed in various other directions.

The number of individuals moving and the distance traveled each month is compared with the growth rate in Figure 5. The data show that the total distance migrated and the percent of growth was highest in April, May and June. In general the correlation between percent of growth and distance traveled is in close agreement.

Variations were noted in the distances traveled by individuals in the different size groups. A few individuals in the ten centimeter group did not move at all during the year. Among the clams showing signs of movement and the greatest distance traveled during the year was 83 inches for a clam of an initial length of 5.3 centimeters and the least was three inches for a clam of an initial length of 6.2 centimeters. The mean distance migrated in the year is plotted in Figure 2 for the ten millimeter size groups at the Institute beach (EI). Except for the six centimeter size group the data show a general trend of a decrease in distance of migration with increase in size.

Discussion

The abnormal growth rates observed for the clams from the mud bottom along the south shore would indicate that these clams are stunted and possibly dwarfed by the adverse conditions under which they are growing. These clams possess shells that are thickened at the edges, deeply eroded and chalky in nature. These shell characters suggest the presence, in the soil, of an acid condition which may be augmented by the drainage from the surrounding marshland and repeated exposure of the bottom to the air on most low tide periods. Belding (1912) noted the presence of both blunt clams which typically have thickened edges and dwarf clams which exhibit slow growth. The negative results obtained on transplanting a group of clams from the mud bottom to the tidal pond present further evidence that the clams are dwarfed or stunted. Conditions in the tidal pond were found favorable to shell growth when two plots of clams from another area planted at the same time showed an average increase of 1.5 centimeters in length for the twelve month period. It was of interest to note that oysters growing in the mud bottom, frequently with only the edges of the posterior margins of the valves exposed, showed signs of rapid shell growth as indicated by the razor-sharp edges.

T-tests performed between the mean lengths of the clams from the Institute beach and the mud bottom revealed that no significant difference in mean length existed at the start of the experiment. The clams planted in the plots varied in length as would be expected in a random sample of a homogeneous population.

An analysis of variance, shown in Table 2, was applied to the clam lengths of the four plots (EI, WI, MW, ME), from the two different bottoms, at the end of the first six months. To determine whether the variation within each plot, the mean squares ratio of between plots to within plots was calculated. This yielded an F - value of 1.51. Such an F - value has a probability of occurring by chance more than 5 percent of the time in a random sample from a homogeneous population and is therefore considered not significant. When the mean squares ratio of between bottoms to within plots is calculated an F - value of 6.79 is obtained. Such an F - value could be expected to occur by chance in a random sample from a homogeneous population less than five percent of the time and approaches the one percent level of probability, which in this case

TABLE 2

ANALYSIS OF VARIANCE OF THE INCREASE IN VALVE LENGTH OF 97 CLAMS (*Venus mercenaria*) FROM DECEMBER 1949 TO JUNE 1950 IN FOUR PLOTS ON TWO BOTTOM TYPES IN BOGUE SOUND, N. CAROLINA.

Source of Variation	*Degrees of Freedom*	*Sum of Squares*	*Mean Square*	*F*	*P*
Between bottoms	1	13.799	13.799	6.79	<.05
Between plots	2	6.131	3.066	1.51	>.05
Within plots	93	189.110	2.033		
Total	96	209.040			

requires an F - value of 6.90, thus the F - value of 6.79 is highly significant. The difference between the mean lengths of the clams growing at the Institute beach and those in the mud bottom is highly significant.

The results obtained from the plantings at the Institute beach are considered as indicative of a favorable locality for growth of clams. Shell growth occurred in all months of the year with the greatest increase in May and the least in September as seen in the graphs of total increment in length and percent of growth in Figures 3 and 5. These results differ from those of Belding (1912) who found that 51.7 percent of the total growth for the year took place in August and September with no shell growth during the winter months of December through April. The difference in water temperature between the two widely separated areas on the coast is probably the greatest factor in determining the relative value of the various months in which growth occurs. Belding does not record any water temperatures except that water temperatures in July 1909 reached 77° F. (25.0°C) in Wellfleet harbor, Massachusetts. Summer, Osborn and Cole (1913) record the mean water temperature at Woods Hole, Massachusetts for the five year period from 1902 to 1906 as 68.8°F. (20.4°C) for July and 69°F. (20.5°C.) for August. At the Institute beach in Bogue Sound, North Carolina the water temperatures were above 22°C. from June through September and exceeded 30°C. in July and August, 1950. These high temperatures are less favorable for general metabolism and might furnish a clue to an explanation of the decreased growth rate during the summer months.

Although the influence of spawning upon the rate of growth was not determined, spawning did occur during the months when the growth rate was decreasing. Well developed gonads with mature eggs and active sperm were found during May. The first clam set was found in the latter part of June and sporadic sets continued through the summer months into November. Belding (1912) found in Massachusetts that spawning occurred in July and August when clams were growing rapidly.

The major portion of the anatomy of the hard clam consists of a well developed foot activly used by the animal to burrow in the bottom and frequently in crawling. In shallow water, clams can often be seen crawling through the bottom leaving a characteristic trail. Kellogg (1903) concluded from his studies that clams do not have any wandering tendencies. Belding (1912) placed 24 clams about a stake and observed the distance of migration at intervals of 3, 14 and 38 days. At the end of 38 days, four clams were missing and fourteen had moved an average of 2.15 inches with a maximum of 6 inches. One blunt clam was reported moving 7 inches in 24 hours. Belding noted all the movements in one experimental bed were in the direction of the retreating (ebb) tide with no difference in the distance migrated between the 28 millimeter and 41 millimeter clams. Belding concludes that the hard clam leads practically a sedentary life.

The present studies have shown that clams do crawl and that the distance traveled is in general correlated to growth rate and size of the clams. In general, the smaller clams were more active in their movements. This was true for the plantings at the Institute beach and in the tidal pond. In the soft mud bottom area the movements were limited to a few individuals usually not more than three clams and in some months only one clam had moved from the original position.

Since the experimental clams had been disturbed in planting it was suspected this may have influenced their movements although several times native clams were found which had migrated into the experimental plots. Thirty clams, 17 along the Institute beach and 13 in the mud bottom, were located in shallow water by their extended siphons while feeding and a numbered wire placed beside each clam. At the Institute beach one clam traveled a distance of 26 inches in 34 hours and four other clams moved from 6 to 8 inches in three months, March through May. None of the clams in the soft mud bottom showed any change in position. All these clams located in their natural position were found to be large clams from nine to eleven centimeters in length, when they were measured after the three months of observations. Since the studies in the experimental plots have shown that the tendency among large clams is to exhibit but little migration, these results with the undisturbed clams are in accord with the observations in the planted areas.

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Sexual Dimorphism in Weight and Length Relationships of the Bermuda Spiny Lobster

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DURING THE MONTHS of January and February 1950, the writer and associates* at the Bermuda Biological Station measured and weighed more than 1,000 spiny lobsters (*Panulirus argus*) retained in pounds in Bermuda. These specimens essentially represent a random sampling of the commercial catch of the

*The author gratefully acknowledges the assistance of Dr. Louis Hutchins, Mr. Tommy Gleason, Mr. Brunell Spurling and the facilities of the Hofstra College Biology Department in these investigations.