FEEDING AND GROWTH OF JUVENILE SOFT-SHELL CLAMS, *MYA ARENARIA*

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ABSTRACT

Laboratory experiments and observations on the growth of juvenile clams, *Mya arenaria*, of known age were conducted to aid in developing artificial rearing procedures. Laboratory clams held in running natural sea water without supplemental food, or in standing water with supplemental food, grew as well or better than those in nearby clam flats. The only suitable foods for artificial feeding were species of unicellular algae. Population density affected growth chiefly through competition for food. Growth increased with temperature when food was adequate, although the winter decline in growth rate apparently was related to decreased food supply as well as to low temperature.

When clams were fed artificially, the concentration of food in the water was critical: concentrations of over 30,000 cells per ml. water led to inefficient utilization by the clams. Need for additional information on water pumping rates, duration of feeding activity, efficiency of food utilization, and the abundance and kinds of clam food in natural sea water is discussed.

Estimating the age of an organism is essential in studying its growth rate and calculating the potential yield of a population. The age of the soft-shell clam, *Mya arenaria*, is generally estimated by counting winter checks or annuli on the shells; however, this method may result in error because the first and possibly the second annulus is apt to be obscured or worn away. Judgement of the first year's growth often is based on experience gained from field observation of juvenile clams at different times of the year. These observations are apt to be misleading, for one seldom knows exactly when the small clams were spawned or whether they represent one or several spawnings, perhaps months apart. Small clams observed in midsummer could be either slow-growing individuals spawned the previous year or fast-growing individuals spawned in the current year. Furthermore, sampling procedures ordinarily used in field studies may introduce a bias leading to inaccurate estimates of size distribution. Unless the clam-bearing sediments are subjected to long and painstaking separation in the laboratory, the smallest individuals generally are missed. The customary practice of sieving the sediments in the field becomes impracticable with mesh small enough to retain the early postlarval juveniles.

Observations on the growth of clams of known age should provide a more accurate means of interpreting field data. In addition, a knowledge of early clam growth is valuable in planning artificial culture techniques. The artificial culture of shellfish, particularly the hatching and rearing of juveniles as "seed," has achieved worldwide interest in recent years. Although much of the current interest concerns species other than *Mya*, the artificial propagation of this clam frequently has been proposed as a management tool. Because economical artificial rearing demands rapid growth rates, the conditions favoring such growth and the factors limiting it should be understood.

The experiments described in the following pages were undertaken to determine whether juvenile

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clams could be reared under artificial conditions. Although primarily intended as guidelines for the development of rearing techniques, the results provided basic biological information about the early growth of clams. The purpose of this paper is to present (1) a standard of growth for clams of known age under laboratory conditions; (2) an evaluation of this standard (the degree to which it is representative of natural growth in various clam producing areas); and (3) information about environmental influence on growth.

METHODS

The growth experiments described in this paper utilized clams of known age, having been spawned and reared in the laboratory. Clams used in any one experiment were from the same brood (i.e., all spawned at the same time, but not necessarily from the same parents). Some of the clams were held in natural running sea water, while others were subjected to experimental treatments in both running and standing sea water. When standing sea water was used, periodic changes of the water and artificial feeding were necessary. These conditions provided better control of some environmental factors, such as food supply, than did the use of running water.

Except where temperature was itself the variable under investigation, all experiments were conducted at prevailing seasonal temperatures; that of the sea water in the supply lines (fig. 1, A) or of the ambient air in the laboratory. Laboratory air temperatures, which determined the temperature of most standing water experiments, ranged from 18° to 22° C. in summer and from 14° to 17° C. in winter. Water temperatures were varied by immersing standing-water containers in a water bath. Running water was heated or cooled by passing the incoming water through a heat exchanger. In early experiments, these heat exchangers were polyethylene cylinders equipped with electric immersion heaters or a refrigerator coil controlled by thermostats. For Experiment 7, a specially engineered control system provided desired flow rates and temperatures.

Growth, the criterion used to evaluate the effects of experimental treatment, was determined by measuring the shell length before and after treatment. Clams over 2 mm. long were measured with vernier calipers, those less than 2 mm., with an ocular micrometer. In Experiment 2, the number of clams was large and the individuals were small and difficult to measure; therefore, some of the initial and terminal mean sizes were estimated from samples rather than from measurements of all individuals. These estimates and the mean growth derived from them were subject to sampling error. However, the estimated mean sizes plus or minus two standard errors were found reliable at a confidence level of 95 percent or better. For growth means (the difference between initial and terminal mean sizes) with this degree of reliability the following confidence limits were assigned: the lower limit was the difference between the terminal mean size less two standard errors and the initial mean size plus two standard errors; the upper limit was the difference between the terminal mean size plus two standard errors and the initial mean size less two standard errors. When only the initial mean size was estimated from a sample and the terminal mean size was determined by measuring every individual, the 95 percent confidence interval was reduced by about one-half. When all the clams were measured, before and after the treatment period, sampling error was not involved.

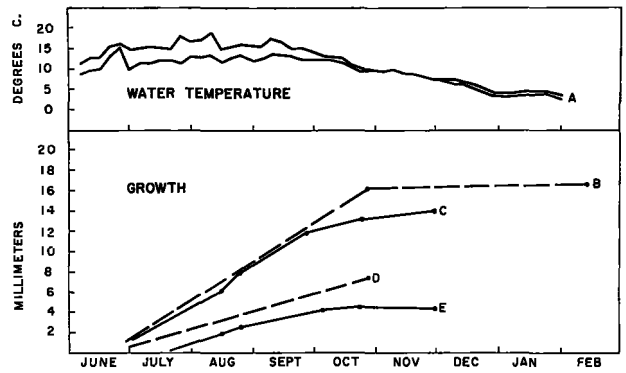

FIGURE 1.—Growth of laboratory reared clams in running sea water. Dash lines indicate lack of intervening measurements.

A. Five-day averages of maximum and minimum supply line water temperatures.
B. Growth of May 28 brood at a population density of less than one clam per 5 cm.^{2}.
C. Same as (B), except disturbed periodically for measurement.
D. Growth of May 28 brood at a population density of more than one clam per cm.^{2}.
E. Growth of June 20 brood at a population density of more than one clam per cm.^{2}.

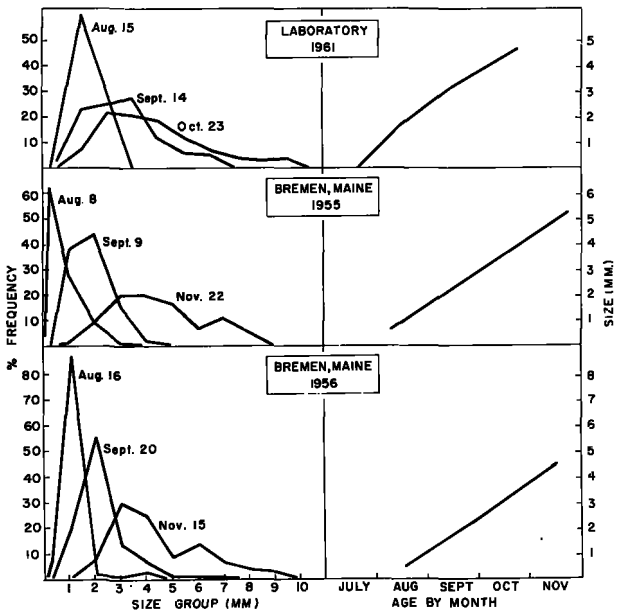

FIGURE 2.—Size-frequency distributions and mean lengths of laboratory and natural clam populations at monthly intervals.

Except when held in running water, clams were fed suspensions of unicellular algae of known volume and measured for cell concentration with a haemocytometer. When dry-weight values of the food supply were desired, 10 volumetric samples of the food suspension were filtered, washed, dried, and weighed, and the mean weight converted to dry weight per million cells.

RESULTS

Concurrently with the experiments described below, the broods providing the experimental clams were held in containers of running sea water and were not disturbed except for occasional measurings. The population density under these conditions was relatively high—in excess of one clam per cm.^{2}; therefore, a portion of one brood was removed and held at a much lower density (about one clam per 5 cm.^{2}) for comparative observation. The growth of these clams, reflecting the most elementary sort of laboratory culture, served as a guide for evaluating growth under more artificial conditions. Dense populations grew more slowly than populations from the same brood held at reduced density. Growth was slightly better when the clams were not disturbed than when they were removed periodically for measurements. The optimum growth rate achieved averaged about 3.8 mm. per month. The growth rate in the high density populations averaged about 1.8 mm. per month. Growth in all groups became slower during the fall, and virtually ceased in the winter. The comparative growth rates are shown in figure 1. The size-frequency distributions of a dense population (that shown in figure 1, E) at each measurement period are shown in figure 2, top left.

EXPERIMENT 1

Effect on Growth of Competition Between Fast and Slow Growing Individuals

The size frequency distribution of young clams of the same age changes as the clams grow, reflecting an increase in range and skewness. The large individuals grow faster than the smaller ones. Not only does the growth increment per unit time increase with size, but this increment as a fraction of the total length also increases. The non-linearity of the early growth rate skews the distribution curve to the right. Although this is a recognized attribute of early growth in many organisms, it seemed possible that the phenomenon also was influenced by interaction among the clams. Thus, if the food gathering ability of the individuals increased with size, fast growing clams might grow even faster at the expense of the others. To test this experimentally, two sizes of clams were distributed in 200-ml. glass finger bowls of filtered sea water:

(1) Bowls 1 and 2 with 50 "small" (about 1.2 mm.) clams each.

(2) Bowls 3 and 4 with 5 "large" (about 2.6 mm.) clams each.

(3) Bowls 5 and 6 with 4 "large" and 10 "small" clams each.

The individual and mean sizes of the "large" and "small" clams in each bowl were recorded. The relative numbers of "large" and "small" clams assigned to each bowl were determined on the basis of the cube of their length: one "large" clam was assumed equivalent to 10 small ones. Thus, the total food requirement for each bowl was considered equal. The mean daily ration was 35.9×10^6 algal cells (*Dicrateria* sp. and *Monochrysis lutheri*) per bowl. After 27 days, the clams were measured and the mean growth of both "large" and "small" clams determined (table 1).

The similarity in growth between "small" clams with and without competition from the larger, and also between the "large" clams with and without the competition of the smaller, indicates that interaction between clams of different sizes does not have a more appreciable effect on the growth rate than competition between clams of similar sizes.

TABLE 1.—*Growth of juvenile clams in populations of uniform and of mixed sizes*

Experimental group	Initial size	Terminal size	Growth
	Millimeters	*Millimeters*	*Millimeters*
"Large" clams only	2.5	6.7	4.2
"Large" clams only	2.6	6.7	4.1
"Small" clams only	1.1	3.1	2.0
"Small" clams only	1.2	3.0	1.8
"Large" clams in mixed populations	2.7	6.7	4.0
"Large" clams in mixed populations	2.8	6.4	3.6
"Small" clams in mixed populations	1.2	3.3	2.1
"Small" clams in mixed populations	1.2	3.1	1.9

EXPERIMENT 2

Effect of Population Density on Growth

Although the effects of reducing population density are apparent (fig. 1), a more precise test was desirable, particularly to ascertain whether the effects were associated with density in some way other than in competition for food. The mean size of the clams in the December 1 brood was estimated from a sample of 127 individuals on February 9. From this brood, 1,480 individuals were distributed among 16 glass bowls, each containing 200 ml. of filtered sea water, so that one series of four bowls contained 200 clams each; a second series, 100 clams each; a third series, 50 clams each; and a fourth series, 20 clams each. To facilitate feeding and handling, the physical positions of the bowls were not randomized, but arranged in a square of four rows of 4 bowls at each population density. The clams composing the population of each bowl were selected at random. The initial mean size of the clams in all but the last 4 bowls was assumed to be that of the brood mean plus or minus two standard errors. The initial mean size of the clams in the last 4 bowls was determined by measuring all individuals. Food (*Dicrateria* sp.) was supplied twice daily in measured quantities, so that one bowl in each series received twice that of the second bowl, 4 times that of the third bowl and 8 times that of the fourth. Thus a range of feeding rates (food available per clam) was obtained. This range included several duplications of feeding rates resulting from different combinations of food supply and numbers of individuals to share it. Twenty-four days later, the clams were again measured. From the four high-density bowls, randomly selected samples of 100 individuals were measured; from the other bowls, all of the clams were measured (table 2 and fig. 3).

TABLE 2.—*Effects of competition on the growth and size distribution of juvenile clams*

Bowl number	Clams used	Food		Mean size		Growth	
		Cells supplied	Cells per clam	Initial	Terminal	Absolute	Relative
	Number	*Millions*	*Millions*	*Millimeters*	*Millimeters*	*Millimeters*	*Millimeters*
1	200	992	4.96	1.62	2.08	0.46	0.09
2	200	496	2.48	1.62	2.09	.47	.19
3	200	248	1.24	1.62	1.93	.31	.25
4	200	124	.62	1.62	1.99	.37	.59
5	100	992	9.92	1.62	2.26	.64	.06
6	100	496	4.96	1.62	2.02	.40	.08
7	100	248	2.48	1.62	1.92	.30	.12
8	100	124	1.24	1.62	1.87	.25	.20
9	50	992	19.84	1.62	2.48	.86	.04
10	50	496	9.92	1.62	2.35	.73	.07
11	50	248	4.96	1.62	2.08	.46	.09
12	50	124	2.48	1.62	1.90	.28	.11
13	20	992	49.6	1.52	2.60	1.08	.02
14	20	496	24.8	1.65	2.41	.76	.03
15	20	248	12.4	1.41	2.16	.75	.06
16	20	124	6.2	1.47	1.66	.19	.03

As expected, growth was inversely proportional to population density and directly proportional to the amount of food supplied, although this relationship did not appear significant at the highest population density. These results could be related to competition for food alone, or to competition for food plus other density dependent effects. In almost every instance, however, where the amount of food per clam was similar and the population density was different, growth showed no consistent or significant relationship to the density. This can be seen by tracing the positions of corresponding geometrical symbols across figure 3. Here only the three highest population densities are considered, since among these are several cases of duplication or triplication of feeding rates. Feeding rates of 1.24×10^6 cells per clam occurred in bowls 3 and 8; rates of 2.48×10^6 cells per clam occurred in bowls 2, 7, and 12; rates of 4.96×10^6 cells per clam in bowls 1, 6, and 11; and rates of 9.92×10^6 cells per clam in bowls 5 and 10. These feeding rates are indicated in the graph by crosses, squares, circles and triangles, respectively. In no case is there a consistent or significant slope to the lines determined by corresponding symbols.

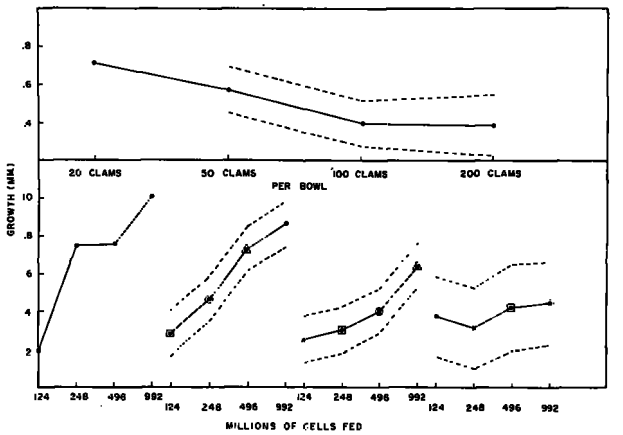

FIGURE 3.—Top: relation between population density and growth. Each point represents the mean growth in all bowls at each population density. Bottom: relation between available food and growth at the four population densities designated above. Corresponding geometrical symbols represent equivalent feeding rates (number of cells available per clam). Dash lines indicate 95 percent confidence limits.

One instructive feature of the data obtained from this experiment is the mean growth plotted against feeding rate (fig. 4). The growth, which increases with feeding rate, does not increase linearly. The growth per unit of food (table 3, last column) is lower at a high feeding rate than at a low feeding rate. This phenomenon suggests inefficient utilization of food at high concentrations. The method of feeding may be partly responsible for this effect. Food was introduced twice daily and, immediately following its introduction, the concentration of cells was highest in the maximally fed bowls. Here the concentration averaged about 145×10^3 cells per ml., substantially higher than clams normally encounter in nature. Had the same amount of food been introduced in smaller quantities at more frequent intervals, the feeding efficiency of the maximally fed clams might have been improved. Some effects of cell concentration on feeding efficiency are described below.

EXPERIMENT 3

Effect of Food Concentration on Feeding Efficiency

Under certain conditions, clams reject masses of particles filtered from the water instead of ingesting them. The presence of these masses (pseudofeces) among the true fecal material in the containers indicates inefficient food utilization.

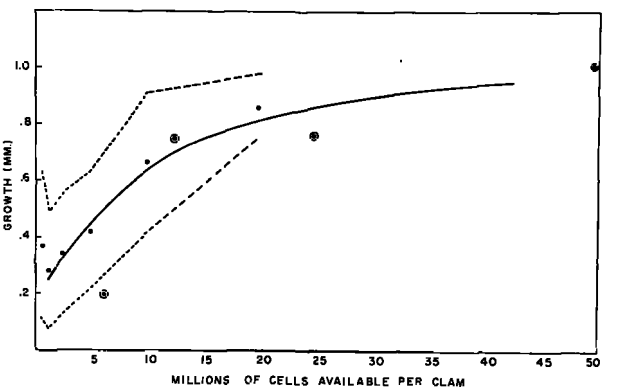

FIGURE 4.—Relationship between growth and feeding rate. Solid points represent estimates based on sampling, for which the 95 percent confidence limits are designated by dash lines. Circled points represent means obtained from measuring entire groups of clams. The curve (solid line) has been fitted by eye.

To determine the effect of food concentration on the amount of pseudofeces produced, food was supplied in different initial concentrations. Four pairs of bowls, each containing five clams (averaging 8.0 mm.) and 200 ml. of filtered sea water were provided with *Dicrateria* cells according to the following schedule:

(1) First pair fed 90×10^6 cells once in 8 hours.

(2) Second pair fed 45×10^6 cells twice in 8 hours.

(3) Third pair fed 18×10^6 cells five times in 8 hours.

(4) Fourth pair fed 9×10^6 cells 10 times in 8 hours.

All groups, therefore, received the same amount of food, but the initial concentrations of cells in the water were different: 450×10^3, 225×10^3, 100×10^3, and 50×10^3 cells per ml., respectively. After 8 hours the material accumulated in the bowls was examined under the microscope. Much of the food had been rejected as pseudofeces except in those bowls where the concentration immediately after feeding was less than 100×10^3 cells per ml.

EXPERIMENT 4

Effect of Food Concentration on Digestive Efficiency

Food particles ingested and passed through the gut sometimes were not digested, and the presence of intact algal cells in the feces also indicated inefficient food utilization. The effect of cell concentration on this type of inefficiency was

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investigated in an experiment similar to the preceding one. Four pairs of bowls, each containing five clams (averaging 16.5 mm. in size) and 1,000 ml. of filtered sea water were provided with *Dicrateria* cells on the following schedule:

(1) First pair fed 136×10^6 cells once in 8 hours.

(2) Second pair fed 68×10^6 cells twice in 8 hours.

(3) Third pair fed 27.2×10^6 cells five times in 8 hours.

(4) Fourth pair fed 13.6×10^6 cells·10 times in 8 hours.

The initial concentrations therefore were 136×10^3, 68×10^3, 27.2×10^3, and 13.6×10^3 cells per ml., respectively. Examined after 8 hours, the feces in the first and second pairs of bowls contained substantial quantities of undigested cells. In the third pair, fewer undigested cells were present, but only in the fourth pair was the amount negligible. Therefore, at concentrations greater than about 30×10^3 cells per ml., inefficiency of food utilization occurs due to incomplete digestion. Although concentrations of this magnitude are not frequent in the natural environment, they might occur in laboratory clam culture through misguided attempts to force growth. Not only do moderately high concentrations result in poor efficiency, but very high concentrations may inhibit feeding almost entirely (Blake, 1961).

EXPERIMENT 5

Relationship Between Quantity of Food Eaten and Growth

Several attempts were made to relate growth to the quantity (weight) of food eaten. Experimental and control groups of clams were measured and placed in separate bowls, each containing 200 ml. of filtered sea water. The experimental groups were provided with measured quantities of *Dicrateria* cells twice daily, while control groups were fed nothing. After a few weeks the mean growth was determined (table 3). This value was corrected for growth not due to the food supplied, by subtracting the mean growth of the controls. The corrected mean growth was then converted to a monthly basis. The numbers and sizes of the clams, the amount of food provided, and the duration of each experiment are recorded in table 3. In the third group, the 25 experimental clams were divided equally among 5 bowls, rather than held all in one bowl as with the other groups.

The growth rates for 5 mm. clams were 2.7 and 3.0 mm. per month, respectively—rates similar to those observed in running water at low population density. Although the quantities of food supplied were accurately measured, it was not possible to determine how much of this was actually eaten and digested. Since the cell concentration immediately after feeding in these experiments was high (0.2×10^6–0.3×10^6 cells per ml.) some inefficiency in utilization probably occurred and the actual consumption of food probably was less than indicated.

In this experiment, as with most of the others, *Dicrateria* sp. was used as food. Experiments to evaluate other algal species showed that a diatom, *Cyclotella nana*, was slightly better, and a flagellate, *Monochrysis lutheri*, was slightly poorer. Still poorer, but not unsatisfactory, foods were *Phaeodactylum tricornutum* and *Olithodiscus* sp. *Chlorella* sp. and *Tetraselmis* sp. promoted very little growth. No growth was obtained by feeding nonliving food materials such as pulverized seaweeds (*Fucus* and *Ulva*), flour, tomato juice, and dehydrated dogfood or mouse food.

TABLE 3.—*Growth data for artificially fed clams in experiment 5*

	First group		Second group		Third group	
	Experimental	Control	Experimental	Control	Experimental	Control
Number of clams	20	20	10	10	25	5
Mean initial length (mm.)	2.36	2.32	5.02	5.02	5.40	5.40
Mean terminal length (mm.)	3.90	2.37	6.96	5.11	7.60	5.80
Observed increase (mm.)	1.54	.05	1.94	.09	2.20	.40
Corrected increase (mm.)	1.49	----	1.85	----	1.80	----
Millions of cells supplied/day/clam	2.49	----	9.77	----	8.01	----
Dry weight of cells supplied (mg./day/clam)	.03	----	.11	----	.21	----
Duration of experiment (days)	28	----	20	----	18	----
Growth in mm./month (30 days)	1.5	----	2.7	----	3.0	----

EXPERIMENT 6

Effect of Temperature on Growth

Observations on juvenile clams in running natural sea water, and otherwise unfed, showed that the growth rate declined in autumn and virtually ceased in winter. Several experiments were conducted to learn the effects of temperature on growth. The first of these were in December and January. Two groups of 60 small clams each were held in running sea water (about 20 l. per

hour), one group at the seasonal temperature of 6° C., and the other at an average temperature of about 19° C. Preliminary trials indicated that as long as the flow rate exceeded the combined pumping rates of the clams, variations in flow rate had no appreciable effect on growth. A third group of 65 individuals was held in standing water, which was cooled in a sea-water bath to an average temperature of 8° C. These clams were fed a daily ration of *Monochrysis lutheri*. After 1 month the fed clams showed a mean growth of 0.7 mm. Those in running water showed negligible growth at either temperature level (table 4).

TABLE 4.—*Effect of temperature on the growth of juvenile clams*

Season	Mean water temperature	Clams used	Mean size		Duration of experiment	Growth per month
			Initial	Terminal		
	° C.	*Number*	*Millimeters*	*Millimeters*	*Days*	*Millimeters*
Summer: In running natural sea water.	6	16	11.28	11.56	22	0.38
	12.5	16	11.31	12.35	22	1.42
	20	16	11.33	12.79	22	1.99
Winter: In running natural sea water.	6	60	9.9	9.9	31	--------
	19	60	9.6	9.7	31	.1
In standing water, artificially fed.	8	65	10.7	11.4	32	.7

EXPERIMENT 7

Experiment Conducted the Following September

Three groups of 16 clams were held in running sea water at mean temperatures of 6°, 12°, and 20° C., the flow rates of the water being equal. After 3 weeks, increases in mean size at the temperatures cited were 0.28, 1.04, and 1.46 mm., respectively (table 4).

In summer, growth occurred at all temperatures but was better in warmer water. In winter, little or no growth occurred in either warm or cold natural water, but did occur in cold water when supplementary food was provided. Therefore, reduction of temperature does reduce growth, but with adequate food, some growth can occur in cold water. Furthermore, as little growth was achieved during winter in either warm or cold natural water, the winter decline in growth is probably due to a paucity of food in the water.

DISCUSSION AND CONCLUSIONS

To compare natural and laboratory growth of clams, data obtained in the field are necessary, but for reasons stated earlier, these data are difficult to obtain. Fortunately, some dependable data were available, taken from samples collected and processed in such a way that unbiased representation of all size groups was assured. These samples were collected during years when the setting period was comparatively short. Bias due to continued recruitment of small, postlarval sizes therefore was minimal. The samples were obtained in the late summer and autumn of 1955 and 1956 from a small cove near Bremen, Maine, a location typical of the Maine coast. In both years, the growth rate and size distribution were similar and not greatly different from those observed subsequently in the laboratory (fig. 2).

A comparison of the three sets of size and growth data reveals that, during the first months, the Bremen clams have slower growth and a narrower range of sizes than the laboratory clams. This may be due to some continued recruitment from the plankton prior to sampling. If so, the first month's growth would be faster than indicated by the data, and the almost linear growth curves for the field samples would be more convex, resembling the laboratory growth more closely.

Growth in other regions could be expected to differ—to be more rapid, for example, in the southern part of the range. Data from Mead and Barnes (1905) seem to demonstrate more rapid growth in southern areas, although their samples probably were biased by the errors previously mentioned, particularly since their sampling was done with "a rather coarse sieve." According to their report, the mean size of clams sampled in upper Narragansett Bay, R.I., increased from 6.1 mm. on July 4 to 23.7 mm. on September 30, an apparent mean growth of about 6 mm. per month. More recent data for southern New England is given by Matthiessen (1960), who measured the growth of marked clams held in trays in a Martha's Vineyard, Mass., salt pond. The smallest of these clams, 15–20 mm. in size, although not specifically aged, were probably the current year's juveniles and were growing at a rate of about 5 mm. per month in September.

The laboratory growth of clams at Boothbay Harbor was markedly better than natural growth when the laboratory clams were held at low population densities. A comparison between the growth of artificially fed clams and either natural growth or laboratory growth in running water is rather difficult, however. The environments, particularly the food supply, are not readily com-

parable. Adequate data, from the literature or from these experiments, are not available to place values on several important parameters necessary for this comparison. The amounts and kinds of food present in sea water, the pumping rates of the clams, the time actually spent in feeding, and the efficiency of food utilization are too imperfectly known. Nevertheless, growth as good or better than that obtaining in Maine coastal water was achieved by artificial feeding at a rate of 0.2 mg. of food daily per 5 mm. clam, and probably could have been achieved with even less food.

The greatest divergence of artificial feeding from natural conditions seemed to be in the rate and method of supplying food rather than the actual quantity or kind supplied. In nature, clams obtain adequate food by filtering large volumes of water containing sparsely dispersed particles. Artificial feeding permits the increase of food concentration, so that the clams may remove much greater quantities at the same filtering rate; however, the intermittent feeding used in the preceding experiments eliminates much of this advantage. In the first place, high initial concentrations are rapidly and wastefully reduced; secondly, residual concentrations between feedings may become too low for adequate nourishment, and energy used in continued water filtering is wasted. More natural conditions and better growth would probably be achieved by frequent or continuous feeding to maintain a more constant food concentration, not exceeding about 30,000 cells per ml.

The detrimental effects of crowding are apparent from the experimental results and are probably related largely to competition for food. Optimum population densities, therefore, would depend on the amount of food available, the water circulation, and the sizes of the clams.

Temperature also has an effect on growth, probably through its effect on water filtering rate. Although growth slows down appreciably in winter, this effect is caused by a decrease in food material in the sea water as well as by a reduction in the water filtration rate. The reduction in growth rate with temperature is not linear. The experimental data show that between 12.5° and 20° C., the rate per month decreases an average of 0.08 mm. per degree of temperature drop. Between 6° and 12.5°, the rate decreases an average of 0.16 mm. per degree, about twice as much. This decrease extrapolated would indicate cessation of growth at 3.7° C. According to Belding (1930), clams cease feeding entirely at 2.8° C.

These growth rates are based on the availability of food in summer. During the winter, growth ceases at higher temperatures, presumably due to a decrease in the phytoplankton content of the water. When this paucity of natural food was compensated by artificial feeding, the observed growth at a mean temperature of 8° C. was 0.7 mm. per month, almost the same as the expected summer growth calculated at 0.16 mm. per degree above 3.7°.

In conclusion, the results of the laboratory observations supported by the best available field data show that the first summer's growth of young clams in a densely seeded Maine clam flat (and probably in other northern New England areas as well) averages about 5 mm. and seldom exceeds 10 mm. Where the clams are more thinly dispersed or where hydrographic conditions are highly favorable, these values may be greater. In southern New England, warmer summer water temperatures (20°–27° C.) may permit faster growth and a longer growing season.

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