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GROWTH IN MYA ARENARIA

by

A. Emerson Warren.

BIOLOGICAL BOARD OF CANADA

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The soft-shelled clam, Mya arenaria, ranks high in the shell-fish industry of our north Atlantic coast. It is quite fitting and necessary, therefore, that investigations into the nature of its growth, its habits of life, and its general distribution should be made from time to time. Much of the success attending the shell-fish industry is dependent upon the acquisition of such knowledge. In many instances clam beds have become almost depleted through too extensive, as well as intensive, digging. In others environmental influences have become altered to the extent that the clam survives only with difficulty, or dies out completely. It is of very practical interest, therefore, to gain more information concerning those factors which exert such limiting influences upon the distribution of the species. With more adequate understanding of some of these conditions much may be done in the future to foster the development of the clam in areas which are tending to become partially or entirely depleted.

The growth and distribution of the soft-shelled clam is dependent upon a great number of influences. Stafford (1901) states that although the littoral distribution varies with the conditions, generally speaking, it is most abundantly gathered along a belt 200 feet wide at half-tide mark. In recent years various workers have treated the distribution problem from many angles by the experimental method. Factors which directly concern the ecology of the clam such as the length of exposure between tides, the slope of the beds, the effects of shifting sand and deposits of fine silt, the sulphide content of the soil, the salinity of the water, and differences in temperatures have each received a measure of attention. Wilton and Wilton (1929) have studied the

the development of clam beds in relation to the beach level and have found that "Growth is impossible for any length of time unless the clam is submerged at least half the time.............. Exposure for more than half the time inhibits growth evidently due to the cutting short of the supply of food together with the rise in temperature for a longer period. Lower levels of the tide where silt collects in quantity appear to be entirely unsuitable for the clams, which grow but little or die rapidly depending upon the amount of silt." More recently Dr. C. L. Newcombe has found among other things that the rate of growth varies inversely with the beach level in which the clams are located. This confirms in a measure the findings of Wilton and Wilton.

Many other factors affect the growth of the clam. The food supply, varying as it does during the months and seasons, has a most important relation. Moreover, the rate at which food is brought to the beds, as determined by the amount of water flowing over them per unit of time, seems highly significant. This particular aspect of the problem called for investigations which do not appear to have been stressed hitherto, so it was with this objective in view that experiments were made by the writer at the Atlantic Biological Station during the past summer. The purpose of the investigation, in addition to procuring further data to supplement that of previous investigators, was to test the relations of the currents in this region to growth in clams planted at different levels on the intertidal zone.

The areas immediately adjacent to the laboratory proved to be very satisfactory grounds in which to make these comparisons. The water in Brandy Cove is relatively tranquil during the ebbing and flowing tides. The main currents are directed northward from the end of the station wharf to a point somewhat outside of the cove. Hence mild eddies are the chief movements of water except during stormy weather and during strong northwest winds. The south slope of Brandy Cove, just north of the station appears to be subjected to a minimum of disturbance in this respect. The stretch south of the station extending beyond Joe's Point is, on the contrary, subjected to much rapidly moving water during incoming and outgoing tides. Points quite high on the beach are affected by these water movements to a greater degree than points at lower levels in Brandy Cove. In view of these contrasting conditions, it seemed appropriate to compare the growth rates of clams planted at different intertidal levels. For further comparison the growth of clams was tested in currents which were practically continuous. This was accomplished by placing some of them under conditions of complete submergence.

For purposes of the experiment, eight wooden boxes (21" x 12" x 5") were made and fitted with wire covers. These were subdivided into three compartments each making a total of twenty-four compartments in all. This arrangement aided considerably in the study of growth in individual groups of approximately the same measurements. Numerous holes were made in each box to allow the water to pass readily in and out, and to permit drainage between tides. The boxes were filled with screened sand to a depth of three inches and then set out at different points along the shore.

The materials used consisted of 532 small clams, ranging from 9 mm. to 22 mm. in length. All were carefully measured with a vernier to the nearest tenth of a millimeter. Records were made of their three dimensions according to the customary methods for measuring molluscs. The clams were sorted into lots of about twenty-five individuals each, the linear size in each group not exceeding two millimeters' difference in length. These groups were distributed among the eight boxes in order that smaller and larger clams would be given equal opportunity for testing at each of the different points along the shore. Measurements were made at intervals of four weeks during the summer, and final measurements were obtained late in the season (November 24th). In each case the aggregates for each box were obtained, and averages calculated for the growth of the combined groups. These statistics are given in detail in Table I, and the increases in length for the period of the experiment are plotted in the graphs shown in Figure 1.

The boxes were set out between July 7th and July 10th at each of the following points:

Box I was suspended from the floating breakwater at a depth of 36 inches. In this position it was exposed to all changes in the movement of the water, and it was well protected against smothering by drifting seaweed and other debris.

Box II was placed on the south shore of Brandy Cove at a point which was on the level with 17.4 feet by the tide gauge on the wharf. In this position it was submerged but one-fourth of the time. The surrounding soil was of coarse gravel, which covered a layer of heavy gray mud of the consistency of brick clay. A depression was made in this substance, and the box was fitted into it and packed about with gravel. There was good drainage in this position.

Box III was placed on the north slope of the reef adjoining Green Island (south of the laboratory). Its position by the tide gauge was 15.1 feet, hence it was submerged daily about three-eighths of the time. Drainage here was quite complete owing to the sandy nature of the surrounding soil. A few feet below this point there was a clam bed of considerable size and extent.

Box IV was placed on the south slope of the same reef as that indicated above. It was at a height of 12.8 feet by the tide mark, which appeared to be the accurate mark for half tide level. There was an extensive clam bed in this region extending for some distance above and below this point. The soil is sandy with considerable black mud mixed with it. The box did not drain well, and an inch of water remained on top of the sand between tides.

Box V was placed on the south slope of Brandy Cove below Box II, at half-tide level (12.8 feet). In the gravelly area round about several clam holes were to be found. This part of the shore was about the same as that described for Box II. Drainage here was rather poor, and an inch of water remained in the box between tides.

Box VI was placed in the cove south of the laboratory, at a height of 8.2 feet by the wharf tide mark. It was, therefore, submerged three-fourths of the time. An extensive clam bed was located in this area, sheltered between the two ridges of rock. The soil consisted largely of black mud mixed with sand. The box did not drain well between tides, water remaining in it on each occasion.

Box VII was placed on the south shore of Brandy Cove at the mean low tide level. In this position it was exposed but little, probably about one-tenth of the time each month. There was much gravel and sand in this region, and a slight amount of mud, chiefly silt. There were clams in the beds round about, but these did not appear to be abundant.

Box VIII was set out on the north shore of Brandy Cove in the region where currents sweeping past the laboratory wharf appear to be directed. It was set at mean low tide level, and was in a bed of heavy black mud common to this area. This bed is sheltered by ridges of rock, and clams grow abundantly here.

The experiments were carried on for 139-140 days, beginning early in July and continuing until the 24th of November. In the case of Box VIII, however, a high mortality seemed to justify its removal at the end of 59 days. To continue under the conditions would not have yielded

TABLE I.

934 Data on the Growth of Mya arenaria

Date	Group	Number of Individuals	Average measurements in mm. Length	Width	Thickness	Increase in mm. Length	Width	Thickness
ly 10	I	75	15.21	10.06	5.77	----	----	----
g. 7	(28)	75	20.34	13.07	7.57	5.13	3.01	1.80
pt. 4	(56)	73	24.85	15.79	9.30	9.64	5.73	3.53
t. 4	(86)	72	27.56	17.70	10.06	12.35	7.64	4.29
ly 8	III	50	16.88	11.09	6.38	----	----	----
g. 8	(31)	50	19.34	12.68	7.30	2.46	1.59	0.92
pt. 3	(57)	49	21.09	13.59	7.93	4.21	2.50	1.55
v. 24	(139)	46	23.71	15.20	8.75	6.83	4.11	2.37
ly 8	IV	60	16.79	11.10	6.33	----	----	----
g. 5	(28)	52	18.64	12.39	7.12	1.85	1.29	0.79
pt. 1	(55)	49	20.75	13.62	7.99	3.96	2.52	1.66
v. 24	(139)	49	23.31	14.94	8.92	6.52	3.84	2.59
ly 8	VI	97	17.34	11.48	6.58	----	----	----
g. 7	(30)	96	19.55	12.81	7.47	2.21	1.33	0.89
pt. 3	(57)	94	21.96	14.19	8.38	4.62	2.71	1.80
ov. 24	(139)	93	24.99	16.08	9.39	7.65	4.60	2.81
ly 7	VIII	50	16.05	10.62	6.09	----	----	----
ug. 8	(32)	34 (16 died)	19.20	12.70	7.33	3.15	2.08	1.24
ept. 4	(59)	29 (5 died)	22.71	14.50	8.60	6.66	3.88	2.51
uly 8	II	75	15.90	10.42	6.01	----	----	----
ug. 8	(31)	63 (12 died)	17.41	11.63	6.63	1.51	1.21	0.62
ept. 2	(56)	62	18.49	12.18	7.04	2.59	1.76	1.03
ov. 24	(139)	61	19.17	12.77	7.30	3.27	2.35	1.29
uly 8	V	50	15.17	9.99	5.70	----	----	----
ug. 5	(28)	35 (15 died)	15.59	10.39	5.94	0.42	0.40	0.24
ept. 2	(56)	30 (4 died)	16.86	11.09	6.19	1.69	1.10	0.49
Nov. 24	(139)	31	18.54	12.10	7.04	3.37	2.11	1.34
July 7	VII	75	14.92	9.95	5.71	----	----	----
Aug. 4	(28)	70	17.21	11.38	6.59	2.29	1.43	0.88
Sept. 1	(56)	67	19.32	12.50	7.24	4.40	2.55	1.53
Nov. 24	(140)	63	22.62	14.53	8.41	7.70	4.58	2.70

(Figures in parentheses indicate the number of days since first measurements were made.)

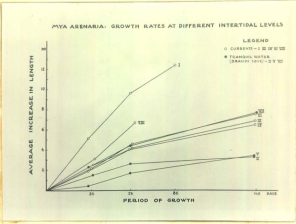
MYA ARENARIA: GROWTH RATES AT DIFFERENT INTERTIDAL LEVELS
LEGEND
CURRENTS – I III IV VI VIII
TRANQUIL WATER (BRANDY COVE) – II V VII
AVERAGE INCREASE IN LENGTH
mm
2
4
6
8
10
12
30
56
86
140
DAYS
PERIOD OF GROWTH
I
VIII
VII
VI
III
IV
V
II

Figure 1

average results comparable with those to be obtained in the other boxes. Owing to the breakwater being taken in on October 4th, the experiment with Box I automatically terminated at the end of 86 days. With these two exceptions the data herein given is for a period of almost five month's growth. In most boxes the mortality was low, the average for the season showing a survival of 83.5% of the whole. The chief mortality, other than that noted for Box VIII, was in Boxes II and V which were placed fairly high on the beach in Brandy Cove. In these two cases death occurred within the first month owing largely to smothering by shifting sand. This condition was corrected, and few clams died in the succeeding months. The data given in Table I, and in the accompanying graph (Figure 1) are largely self-explanatory. All boxes subjected to the influences of currents are placed in one grouping, and the others which were in the tranquil waters of Brandy Cove are in another grouping. It is quite evident that constant submergence, as in the case of Box I, has a decided advantage for growth in the clam, and particularly when the submergence is in a region of rapidly flowing water. Undoubtedly the suspension at a constant depth from the surface assured the clams of a fairly constant supply of the phytoplankton upon which it feeds. There seems to be every indication that growth would have proceeded along the same line, and at practically the same rate, had the experiment continued for the full period. The next most marked growth was observed in the case of Box VIII, which was placed in a region of open currents at low tide level in Brandy Cove. For the period under comparison growth in this lot was fully two-thirds as much as in the case of Box I. Had conditions proved favorable for the continuation of this part of the experiment, there would no doubt have been an increase in size quite in keeping with that observed, and the last limb of the graph would probably have been an extension of the other two in about the same direction.

There was reasonably good growth among the clams in Box VII situated at low tide level on the south shore of Brandy Cove. This was little better than that in Box VI situated higher up the shore in the cove south of the laboratory. In any case it was but two-thirds as much as that shown in Box VIII at the same tide level, but on the north shore of Brandy Cove (for the period under comparison).

The most striking contrast is seen in those boxes situated at and above the half-tide level in Brandy Cove and in the cove south of the laboratory. The increase in size of the latter clams was at least one and a half times the increase in the Brandy Cove specimens. Moreover, the growth of clams high up on the beach south of the station approximated very closely the growth of clams at or near the low tide level, as in Boxes VI and VII. The observations of Wilton and Wilton, as well as of Newcombe, are not substantiated by these findings, for they stated that growth in clams varied inversely as the beach level of the beds. Their statements hold good for local areas, such as different levels along the same beach, but when different beaches are compared their deductions do not necessarily hold true. The figures recorded in the data are significant in that they indicate that growth is not entirely determined by the level of a bed above the low water mark, though the relative periods of submergence and exposure are positive factors. It is more dependent upon the amount of food materials which is made available to the beds per unit of time than it is upon the length of the period of submergence. The solution of this apparently contradictory situation, therefore, apparently lies in the relation of water currents to the amount of food supplied to the different clam beds.

The submerged clams, in Box I, showed a growth at least twice as great as that of any clams on the beach at the low tide level. This indicates that exposure between tides is not an essential factor, since constant feeding makes for the greater growth. Neither is the clam dependent to any great extent at least upon the bottom detritus for food, as Newcombe has already pointed out. From the commercial point of view, however, submerged clams are not readily accessible, hence the data relating to those growing on the beach are of more practical significance. It is more probable that clams growing in regions where the tidal rise and fall is just a few feet can be considered of importance commercially. In the St. Andrews region, and at other points in the Bay of Fundy, any beds that exist below the low tide mark are quite inaccessible.

The distribution of clam beds in the region adjacent to the laboratory seems to coincide in an interesting way with the observations made with regard to their growth. Extensive beds are found at the half tide level, and even higher, in those areas which are nourished by a fairly rapid flow of water even for a few hours daily. At similar levels on other parts of the shore, where currents are not so evident, the distribution of clams is meagre, and in many instances none at all are to be found. The evidence gathered from the present experiments seems to support the view that currents play a very important rôle in the growth and distribution of Mya arenaria.

Although it may be stated that the influences of the surrounding soil media affect in a measure the growth of the clam, and prevent its becoming established in a particular area, there seems to be little evidence to support this contention. Clams set where burrowing is not too difficult, and are not inhibited to any appreciable extent by the peculiar chemical composition of the soil. This has been tested by Newcombe, who found that the sulphide content of the soil exerted little or no effect upon the clam's growth. The chief influences for growth are exerted through the water which the organism takes in through its incurrent siphon.

While linear measurements are convenient means for recording the sizes, as well as the growth of clams, they do not readily reveal the nature or the amount of increase in cubic content. From the viewpoint of the biologist the increase in the total mass is of the greater significance. If some definite relation can be established between a linear dimension, such as the length, and the volume or the weight, then that dimension can be interpreted in terms of the total size of the organism. Owing to the peculiar shape of the mud clam there is no easy way of computing its volume from a knowledge of its three dimensions. Any mathematical formula that may be applied can yield only approximate values at best. It is necessary, therefore, to make direct measurements of the volume and weight in individual clams, or in groups of clams of similar size, in order to procure data to which reference can be made. By plotting one or more linear dimensions against the measured volume, and the weight, curves can be obtained which show fairly constant relations between the linear dimensions and the cubic content. By referring to a curve of this order, when a linear dimension is known, one can determine with reasonable accuracy the mass of animal substance present, and from time to time record the increase in this mass.

The data recorded in Table II were procured (early in August) from careful measurements made upon 223 freshly gathered clams. These were arranged in groups ranging from 10 millimeters to 60 millimeters. Since the smaller clams were more important from the viewpoint of the experiment, those measuring between 10 millimeters and 31 millimeters were sorted into groups at one millimeter intervals. From 35 millimeters to 60 millimeters the groups were separated by intervals of five millimeters. The table indicates the number of individuals measured within each group. From the combined measurements of the several individuals in the group the averages were computed. Since volume was measured by the displacement of water, the figures recorded are reasonably accurate. With re-

TABLE II.

Mya arenaria --- Average Measurements for Specific Size Groups.

Number of Cases	Average Measurements, mm. Length	Width	Thickness	Measured Vol.- cc.	"Drained" Wt.- gr.	Shell Wt.- gr.	Soft Parts Wt.-- gr.
6	10.48	6.71	3.73	0.108	0.081	0.045	0.036
3	11.63	7.53	4.17	0.143	0.128	0.071	0.057
9	12.54	8.03	4.50	0.177	0.149	0.081	0.068
8	13.40	8.58	4.80	0.223	0.174	0.092	0.082
5	14.42	9.52	5.36	0.292	0.231	0.130	0.101
9	15.54	10.31	5.69	0.370	0.319	0.173	0.146
13	16.48	11.05	6.06	0.442	0.368	0.202	0.166
18	17.38	11.59	6.49	0.528	0.453	0.238	0.215
19	18.35	12.11	6.69	0.591	0.519	0.262	0.257
18	19.43	12.76	7.16	0.722	0.566	0.318	0.248
7	20.40	13.10	7.24	0.793	0.606	0.337	0.269
9	21.61	14.33	8.06	1.005	0.777	0.429	0.348
6	22.38	14.70	8.39	1.160	0.881	0.489	0.392
6	23.40	15.37	8.76	1.350	1.011	0.552	0.459
7	24.48	15.76	9.05	1.510	1.260	0.672	0.588
7	25.39	16.63	9.67	1.800	1.483	0.823	0.660
7	26.66	17.73	10.46	2.064	1.644	0.936	0.708
7	27.63	18.17	10.81	2.363	2.045	1.057	0.988
6	28.52	18.62	10.88	2.409	1.993	1.113	0.880
7	29.53	19.34	11.34	2.779	2.418	1.342	1.076
8	30.47	20.27	12.07	3.181	2.556	1.436	1.120
7	31.44	20.56	12.50	3.386	2.660	1.522	1.138
6	35.33	22.55	13.66	4.509	3.610	2.045	1.565
5	40.42	25.12	14.98	6.540	5.102	2.801	2.301
5	45.34	28.04	17.40	8.700	7.483	4.161	3.322
5	50.06	30.84	19.40	12.500	11.240	6.666	4.574
5	55.04	33.68	21.34	16.500	13.994	9.079	4.915
5	60.52	37.02	23.08	22.200	18.553	11.998	6.555

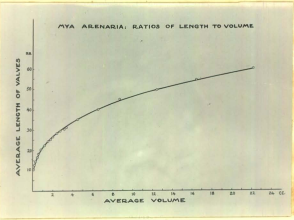

Figure 2

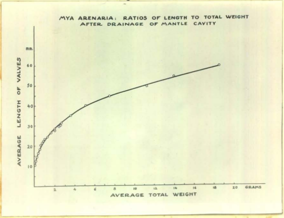

Figure 3

gard to the weight (after drainage of the mantle cavity), there is considerable discrepancy, especially in the older individuals. It is practically impossible to drain the water completely, since many small sinuses in the foot and visceral mass retain some water even after the mantle cavity appears empty. The weight of adult clams depends in large measure upon the amount of food materials present in the digestive tract, as well as upon the presence or absence of mature sexual products at the time of measurement. If a large number of adult individuals of similar length is weighed, the average weight for the group should be sufficient for general practical purposes.

Taking into consideration the various possibilities of error, fairly satisfactory measurements have been made none the less for the entire series from 10 millimeters to 60 millimeters, These indicate in a general way the nature of the growth curve. The ratios of the average lengths to average volumes (see Figure 2) and of average lengths to average weights, after drainage of the mantle cavity, (see Figure 3) have been plotted. By comparing the known lengths of clams in the different groups given in Table I, we can through reference to each of these curves determine the increases in volume and in body weight for the various environments in which the experimental clams were growing. Thus we see that in the submerged Box I the volume and also the body weight increased 4 times during the first 56 days, and 6.4 times during the 86 days of the experiment. In the case of Box VI, located at a point where it was submerged three-fourths of the time, the volume increased 2 times, and the weight 1.8 times during the first 57 days; and the volume increased 3.1 times and the weight 3 times during the entire 139 days.

If we compare the growths at half tide level, we find that Box IV, near Green Island, contained clams whose volume increased 1.9 times, and weight 1.7 times during the first 55 days; and whose volume increased

2.8 times, and weight 2.5 times during the 139 days. (In the case of Box III, slightly higher up the beach, the increases in volume and in weight were approximately the same as in Box IV.) In Box V, situated at the half tide mark in Brandy Cove, the clams increased in volume 1.5 times, and in weight 1.5 times during the first 56 days; and they increased in volume only 1.8 times, and in weight only 1.9 times during the 139-day period, or practically the same as the increases noted in Box IV, at a similar level on another beach, for the 55-day period. In Box II, high on the beach in Brandy Cove, the increases were still less than those in Box V. From these observations we can arrange the clams in a descending series according to the growth which took place in each box during the period of the experiment. The order is as follows: Boxes I, VIII, VII, VI, III and IV (about equal), V, and II. The general conclusions to the experiment may now be given in the form of a summary.

SUMMARY.

As previous investigators have shown, growth in the soft-shelled clam is, in large measure, proportional to the relative amounts of submergence and of exposure of the beds between tides. In experiments performed at St. Andrews during the past summer it was observed that the level of the beds above low water mark did not necessarily determine the rate or the amount of growth in individuals of this species. Several hundred small clams were set out at different points in the intertidal zone, and also under conditions of complete submergence. Five groups were subjected to the influences of currents; the other three were in relatively tranquil water. In the group constantly submerged growth was greatest. In the other groups it decreased with increased intertidal exposure. The rate of growth, however, varied with the amount of water passing over each bed per unit of time. Clams under rapid currents

attain greater growth than those in quiet water. Even clams at high intertidal levels in the former instance grow almost as much as those at low water level in the latter. It is concluded, therefore, that currents, with their effects upon the distribution of the food supply, are of greater significance to growth in Mya arenaria than differences in intertidal levels. It is interesting to note also that the locations of many beds in the vicinity of the station coincide with the findings of the present experiment with respect to the most suitable places for growth.

Experiments in Transplantation.

During the latter part of July and the early part of August, some experiments were made to determine the rapidity with which clams become re-established after transference to new beds. Eight groups of fifty clams each were tested in this manner. The sizes varied considerably but were uniform for each group. In some the length did not exceed one inch, in others it ranged from one and a half to two inches, and in others from two inches upwards. These were placed in beds near low tide level. The substrate in certain instances consisted largely of fine gravel, in others it was mud, and in others sand. In some cases the beds were carefully raked to facilitate the act of burrowing. No particular attention was given to the orientation of the clams when planted, except in one bed in which they were placed with the foot end downwards.

Numerous distracting influences interfered with the experiments to render them rather unsuccessful. Stormy weather, strong wave action, unanticipated tidal conditions, attacks from enemy forms, and other factors prevented the clams from becoming settled, and also handicapped the procuring of data. On several occasions observations were not feasible in consequence of the inclement weather. The data are fragmentary, and in many cases so confusing that interpretation at this point seems quite inadvisable. Repetition of the experiment over a longer period with a large number of cases is necessary before adequate conclusions can be drawn.

The following cases are cited:

Bed I. - South of the laboratory. Sandy shore with some black mud. Near low tide level. Numerous clams in the area. Bed raked with a clam fork. Semicircle of stones arranged for protection against the action of waves. (26 large clams, 2-2½ inches long; 25 small clams, 1-1½ inches long.)

Transplantation - July 23rd, 2:30 P.M.

	Exposed Large	Exposed Small	Partly exposed Large	Partly exposed Small	Destroyed Large	Destroyed Small
July 24th P.M.	16	13	3	1	3	4
" 25th P.M.	5	13	1	1	6	2
" 26th P.M.	5	1	2	0	1	2
" 28th P.M.	3	2	2	1	1	2
" 30th P.M.	0	0	0	0	0	0

Approx. percentage imbedded -- Large 56% (by fourth day)
Small 60% (mostly by the second day)

Bed II. - Brandy Cove. Soft muddy area, exposed about six hours daily. Many clams in the area. No raking. No stone protection given. (25 clams $1\frac{3}{4}$-2 inches long; 25 clams about $1\frac{1}{2}$ inches long).

Transplantation - July 23rd, 4:00 P.M.

	Exposed Large	Exposed Small	Partly exposed Large	Partly exposed Small	Destroyed Large	Destroyed Small
July 24th P.M.	23	14	0	1	0	0
" 25th P.M.	19	11	3	3	1	0
" 26th P.M.	18	11	4	3	0	0
" 28th P.M.	24	6	3	0	0	0
" 30th P.M.	19	6	2	2	0	0
Aug. 2nd P.M.	22	4	3	1	0	0
" 4th P.M.	19	4	2	0	1	0
" 7th P.M.	19	4	2	0	0	0

(no further observations)

Approx. percentage imbedded -- Large 20% (by fifteenth day)
Small 82% (mostly by the second day)

Bed III - Brandy Cove. Sand and mud. Low tide region. Soil raked. No stone protection afforded. (25 large clams, 2-$2\frac{1}{4}$ inches long; 25 small clams, about $1\frac{3}{4}$ inches long.)

Transplantation - July 24th, 3:30 P.M.

	Exposed Large	Exposed Small	Partly exposed Large	Partly exposed Small	Destroyed Large	Destroyed Small
July 25th P.M.	14	8	8	1	3	6
" 26th P.M.	8	6	2	0	1	6
" 28th P.M.	9	2	1	0	4	5
" 30th P.M.	4	2	1	1	3	0
Aug. 2nd P.M.	3	0	2	0	2	0
" 4th P.M.	3	0	2	0	0	1
" 5th P.M.	(no records - bed submerged for next three days - stormy weather)					
" 7th P.M.	3	0	0	0	2	0
" 9th P.M.	3	0	0	0	3	0

(In this case the data is very confusing and hard to interpret. It is difficult to explain the variations in the figures shown in the "Destroyed" columns. It seems as though a large number of clams were destroyed by starfish or other enemies during periods of submergence, even after they appeared to be covered by soil. This bed does not yield satisfactory information, except that the smaller clams became imbedded, or disappeared, first.)

Bed IV.- Adjacent to Bed III. Brandy Cove. Gravel covered with mud. Bed raked. No stone protection. (50 clams, 1 inch long.)

Transplantation - Aug. 2nd, 11:00 A.M.

	Exposed	Partly exposed	Destroyed
Aug. 4th, P.M.	33	3	0
" 5th, P.M.	(all submerged - no observations made)		
" 7th, P.M.	2	0	2
" 9th, P.M.	2	0	1
	(no further observations made)		

Approx. percentage of imbedded individuals: 90% (mostly by the fourth day)

Bed VIII - Brandy Cove. Near low tide level. Bed raked. Gravel area. Clams planted with foot end down. (50 clams, $1\frac{1}{2}$-$1\frac{3}{4}$ inches long.)

Transplantation - Aug. 4th, 1:00 P.M.

	Exposed	Partly exposed	Destroyed
Aug. 5th, P.M.	(bed submerged - 3 clams lying flat.)		
" 7th, P.M.	6 flat	2 flat 9 upright	1 upright
" 9th, P.M.	6 flat	6 upright	1
	(no further observations made)		

Approx. percentage imbedded: 72% (mostly by the second day)

If the data recorded herein has specific value, we may conclude that clams transplanted to new beds either become imbedded within the first three days after transplantation, or do not become covered at all. In the latter situation they often become the prey of their natural enemies, or are destroyed by other hostile forces of their environment. It is not unusual, however, to find clams lying uncovered on the beach, and many survive for long periods in this manner. Large clams experience more difficulty in becoming reimbedded than do small clams. The latter are less bulky and less unwieldy in proportion to the efficiency of their burrowing organ, hence they can become reoriented with greater ease. The foot of Mya is rather a feeble organ, and does not assist much in the burrowing activities of clams which have been removed from the soil, especially when the clams are large.

The clams in Bed VIII, which were placed with the foot end down, showed a greater degree of success in becoming reimbedded than did many of the others.. As long as the upright orientation was maintained the burrowing activities seemed to be facilitated. Those clams which fell out flat were still uncovered at the end of five days.

A number of factors influence the reimbedding activities of the clam,- the nature of the soil substrate, the length of the period of submergence during tides, and whether the surface of the soil has been raked or harrowed to facilitate burrowing. If sterile areas are to be stocked or re-stocked on a large scale, it would seem necessary that a good quantity of the native soil be transported along with the clams. The less the disturbance experienced by clams in transit, the greater will be their chances of becoming reestablished in a new area. Precautions of this nature are necessary in order to make the transplantation of clams a successful economic venture.

Growth in Macoma baltica.

Simultaneously with the studies made on Mya arenaria, similar studies were made in the same boxes with Macoma baltica. In each container a group of 25 individuals of the latter species was placed. While Macoma grows very slowly, rarely attaining a length in excess of 22 mm., it was thought that some observations might be made on this form which would serve as an interesting comparison with the observations made on Mya arenaria.

It is unnecessary to repeat here the details of the experiment, for these have all been given in preceding pages. The results are of more interest, and these are recorded in Table III. The relative increases in length for the groups of the various boxes, except Box VIII which was eliminated from the experiment, are plotted in the accompanying graph. Analysing the data we find that currents play very little role in the growth of this species, for the growth at similar levels is approximately the same for any part of the beach. The growth is greatest at the low water mark, and decreases as one ascends the beach. At a point where the intertidal exposure exceeds fifteen hours per day, growth is very slow, being scarcely perceptible over long periods. At half-tide level the growth seems to be average. Constant submergence does not appear to hasten growth, since the growth observed was very little more than that observed at half-tide mark.

The distribution of this species is rather peculiar in that it is found, often with Mya arenaria, in sheltered sandy regions at the half-tide mark, or thereabout. The factors which limit this distribution, are not primarily those concerned with the food supply, else it would be found at many levels on the beach. The organism apparently is incapable of withstanding the more violent forces that influence the regions about and thrives best only in areas where it is adequately sheltered.

TABLE III.

Data on the Growth of Macoma baltica

ate	Group	Number of Individuals	Average measurements in mm. Length	Width	Thickness	Increase in mm. Length	Width	Thickness
ly 10	I	25	9.14	7.73	3.64	----	----	----
g. 7	(28)	25	9.73	8.23	3.86	0.59	0.50	0.22
pt. 4	(56)	25	10.32	8.73	4.17	1.18	1.00	0.53
t. 4	(86)	12 (13 lost)	10.63	9.02	4.38	1.49	1.29	0.74
ly 8	III	25	10.80	9.05	4.35	----	----	----
g. 8	(31)	25	10.80	9.08	4.36	0.00	0.02	0.01
pt. 3	(57)	25	10.88	9.14	4.42	0.08	0.09	0.07
v. 24	(139)	25	11.20	9.46	4.60	0.40	0.41	0.25
ly 8	IV	25	10.92	9.18	4.36	----	----	----
g. 5	(28)	22 (3 died)	11.20	9.45	4.51	0.28	0.27	0.15
pt. 1	(55)	22	11.87	9.89	4.82	0.95	0.71	0.46
v. 24	(139)	22	13.08	10.95	5.42	2.16	1.77	1.06
ly 8	VI	25	10.40	8.74	4.25	----	----	----
g. 8	(31)	25	11.15	9.46	4.62	0.75	0.72	0.37
pt. 3	(57)	24 (1 died)	12.12	10.17	5.05	1.72	1.43	0.80
ov. 24	(139)	23 (1 died)	12.68	10.71	5.35	2.28	1.97	1.10
uly 7	VIII	25	10.78	9.05	4.24	----	----	----
ug. 8	(32)	21 (4 died)	10.78	9.09	4.26	0.00	0.04	0.02
ept. 4	(59)	18 (3 died)	10.88	9.19	4.33	0.10	0.14	0.09
uly 8	II	25	11.33	9.61	4.58	----	----	----
ug. 8	(31)	22 (3 died)	11.35	9.61	4.58	0.02	0.00	0.00
ept. 2	(56)	22	11.42	9.62	4.58	0.09	0.01	0.00
ov. 24	(139)	12 (10 died)	11.68	9.84	4.68	0.35	0.23	0.10
July 8	V	25	10.48	8.76	4.14	----	----	----
Aug. 5	(28)	25	11.08	9.28	4.39	0.60	0.52	0.25
Sept. 2	(56)	25	12.13	10.02	4.82	1.65	1.26	0.68
Nov. 24	(139)	24 (1 died)	12.40	10.37	5.04	1.92	1.61	0.90
July 7	VII	25	9.03	7.56	3.56	----	----	----
Aug. 4	(28)	21 (2 died)	9.85	8.25	3.95	0.82	0.69	0.39
Sept. 1	(56)	23	11.25	9.41	4.62	2.22	1.85	1.06
Nov. 24	(140)	20 (3 died)	12.53	10.57	5.28	3.50	3.01	1.72

(The figures in parentheses indicate the number of days which have elapsed since the first measurements were made.)

Macoma baltica: Growth Rates at Different Intertidal Levels