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Observations on the Biology of *Meretrix casta* (Chemnitz)*

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CONTENTS

Introduction

Meretrix casta (Chemnitz) (Eulamellibranchiata : Family Veneridae) occurs in extensive and dense beds all over the east coast of India wherever estuarine conditions prevail. The clam is also known from quite a few places on the west coast. In countries where the industry based on edible bivalves is advanced as in the United States, Great Britain and Japan, a great deal of work has been done on the biology and growth of the more common species. In spite of enormous numbers of these clams being available in India, which provide food for a large section of the poor people of the coastal tracts, even under the existing conditions of indiscriminate fishing, little attention has so far been paid to systematic studies on clam fisheries.

Hornell (1916) who made a detailed study of the utilization of shells for making lime, was the first to focus attention on the significance of the clam resources, of the Madras Presidency. He recorded that extensive deposits of subfossil shells are utilized in the lime industry, the most common and valued of which are those of *Meretrix*. Shells obtained from live animals are equally useful but the numbers are insignificant. In the following year (Hornell 1917a) he recorded that this clam (*M. casta*) "is probably the most important food mollusc of the Presidency". Rai (1932) showed that *Meretrix meretrix* was the one species of prime fishery importance among bivalves of the Bombay coast. He valued the clam industry at approximately Rs. 1,02,000 per annum. In a review of the Indian shell fisheries, Rao (1941) mentioned that

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"clams, cockles and mussels are perhaps a more important element in the shell-fish populations of our coasts than the oysters" and that "the backwater clams form the basis of a more important fishing industry than the sea clams". Pearson's (1923) studies on *Placuna placenta* from Ceylon, a brief note on growth of *Paphia* by Winckworth (1931), a study of ten years' data on the age and rate of growth of the Ceylon Pearl Oyster by Malpas (1933), observations by Paul (1942) on *Mytilus* and *Ostrea* from the Madras harbour and the recent studies on the growth and sexual maturity of *Katelysia opima* in the Adyar estuary by Rao (1951a) are the only works on growth of Indian bivalves. The present study was therefore undertaken with the object of understanding the growth of *M. casta* and the aspects of its biology which are of significance in clam fishery, since such data are essential to plan a rational exploitation of these clam resources.

The Environment and Methods

The observations on growth were confined to the Adyar backwater and river mouth (referred to hereafter as the Adyar watermass) which form a continuous stretch of water on the outskirts of the city of Madras (fig. 1). Extensive and dense beds of these clams occur at various places in this area throughout the year. Except during the short rainy season (September, October and November) the water is not very deep in the major part of this area. A detailed description of the area and the environmental features of biological significance are given by Panikkar

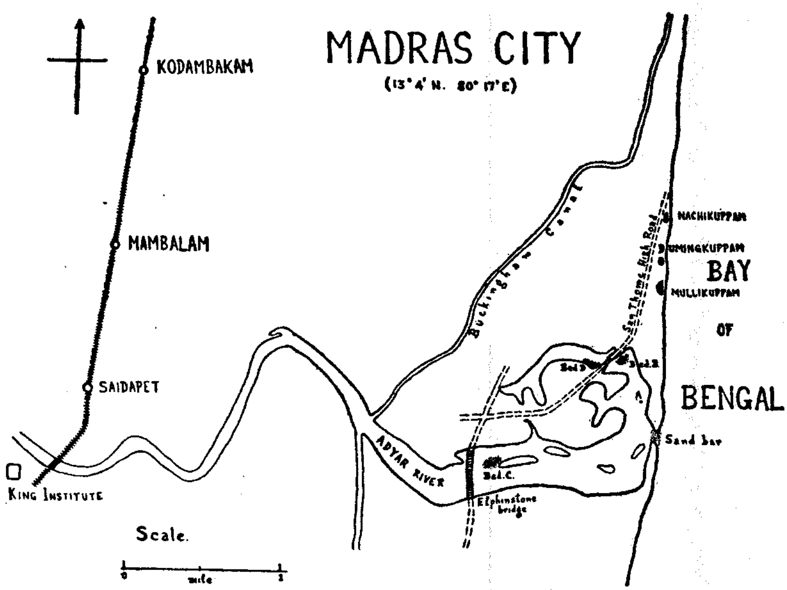

Fig. 1—Map of Adyar backwaters and River mouth.

and Aiyar (1937). It is necessary to mention here that there has been a great difference in environmental conditions between 1933-1936 and the period during which this work was carried out. In Madras ever since 1946 the North-East monsoon has failed more or less and the rainfall has been far below normal. Consequently the sand bar at the river mouth continued to open late and close early and the period during which it remained open (end of October to middle of February in 1948-1949) was short in all these years. The erratic distribution of the monthly rainfall and the low annual total (table 1) has resulted in wide fluctuations of salinity in the backwater and a high level of it in the river. The highest salinity recorded by Panikkar and Aiyar (1937) in 1933 was 30.44 $^{o}/_{oo}$ in February and the lowest 16.91 $^{o}/_{oo}$ in June when the bar was closing up. But during the period of observations, in the backwater the salinity was 15.65 $^{o}/_{oo}$ by the middle of November 1948 when the bar was open and reached its maximum of 35.92 $^{o}/_{oo}$ in April 1949. In the river on the other hand the salinity went up to 38.47 $^{o}/_{oo}$ in July and was 22.6 $^{o}/_{oo}$ in December. The salinity of the river water was higher than the backwater, probably because the rain water brought down by the river on meeting the plug of sea water coming up through the open bar was deflected into the backwater causing dilution there. This is probably the reason why the curve showing salinity of the river water dips (fig. 6) below that in the backwater by the middle of August when rain begins (table 1) and stays below throughout September and October. But the salinity in the backwater drops sharply below that of the river by the beginning of November as the bar opens by the end of October. The salinity values given in this paper have been calculated using Knudsen's formula ($S\ ^{o}/_{oo} = 0.03 + 1.805\ Cl\ ^{o}/_{oo}$, corrected for density) from the total chlorides estimated by titration with silver nitrate.

All linear dimensions of the clam (length, breadth and depth) were measured with a vernier calipers correct to 0.1 mm. (fig. 2).

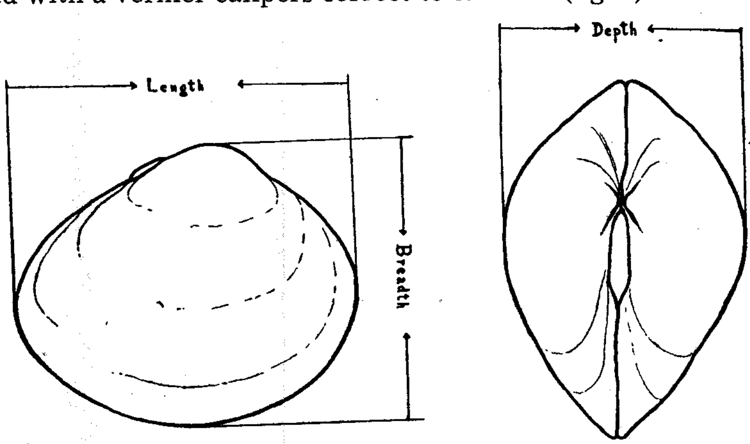

Fig. 2—Diagram of the shell of *M. casta* indicating the linear dimensions.

Length—The distance between the anterior and posterior extremities of the shell in a direction parallel to the ventral margin. In shells where the ventral margin is very much rounded the tangent through its midpoint is taken as the guide.

Breadth—The distance between the umbo and the ventral margin in a direction perpendicular to the antero-posterior axis.

Depth—The greatest distance between the outer surfaces of the two valves when they are kept closed together, measured in a direction perpendicular to both the previous axes of measurement.

Three different methods were employed in the study of growth, namely, (1) Leaving marked clams in the natural habitat and observing their rate of growth : (2) Periodical random sampling of populations from two selected beds at Adyar: (3) Rearing clams in the laboratory and measuring them periodically.

Growth in Size

(a) *Growth as shown by marked clams left in the natural habitat.* A suitable locality, where clam beds have occurred in the past and which was relatively safe from fishing, was chosen. This spot in the backwater (indicated A in fig. 1) was marked in the water by a large stone half buried, which was fixed by other permanent landmarks. Clams of different sizes were collected, their length and breadth measured, they were numbered and returned to the spot. The numbering was done with Indian ink after drying the periostracum, which was then covered over with a layer of Canada balsam, the clams being returned to the water only after the layer of balsam was well dried. A search was made periodically to retrieve the clams and on each such occasion the clams obtained were measured and restored to the spot. Periodically a new set of clams was

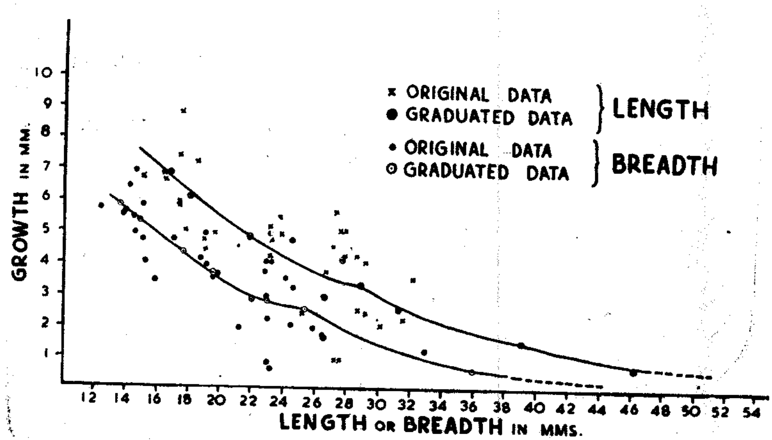

Fig. 3—Showing rate of growth in length and breadth of *M. casta*.

introduced in the area. Difficulties were encountered from clam collectors as well as others who noticed the operations and out of curiosity picked up and scattered the clams. However, the data obtained form a useful indication of the rate of growth in *M. casta*. Table 2 gives the actual measurements.

The data obtained by this method have been plotted in figure 3 and after graduation by the graphic method* (the groupings adopted being represented by horizontal lines in table 3), curves have been obtained which satisfy the tests for smoothness and adherence to data. They represent the growth in length and breadth in *M. casta*. Beginning with a length of 15 mm. (which it reaches in two months, if we assume a rate of growth during this period not less than the rate of the third month) it grows by monthly increments of 7.5, 4.6, 3.5, 2.8, 2.2, 1.9, 1.6, 1.5, 1.3 and 1.1 mm. to a size of 43.0 mm. in twelve months. Similarly beginning with a breadth of 12 mm. (which it reaches in a little less than two months on the above basis) it grows by monthly increments of 6.5, 4.0, 2.8, 2.5, 2.0, 1.5, 1.2, 1.0, 0.9 and 0.8 mm. to a breadth of 35.2 mm. in twelve months. Thereafter the growth is much slower. The clam reaches a length of 48.7 mm. and a breadth of 38.7 mm. in about 18 months, provided growth takes place in all the months of the year. But growth is retarded at least twice a year, as shown below. Allowance has to be made for these periods of 'no growth' when the above rate of growth is used to estimate the age of the clam. This is confirmed by the study of population samples. Thus the batch of clams spawned at the end of August 1948 in the backwater bed, have had only five months' growth by April 1949, which means they would be 30.6 mm. long. Analysis of the population sample for April shows the mode to be at 30 mm. (fig. 6).

Hamai (1935) has shown that *Meretrix meretrix* in Japanese waters grows to about 20 mm. in length and 18 mm. in breadth in 9 months, about 32 mm. length and 27 mm. breadth in 21 months, and to about 44 mm. length and 36 mm. breadth in 33 months, the growth being cyclical and confined to a period from May to September, when the salinity drops and the temperature rises. Coe (1947) records that the Pismo clam (*Tivela stultorum*) grew by 21 mm. in average length in the first three years. *M. casta* shows a much higher rate of growth.

In tropical waters Pearson (1923) has shown that *Placuna placenta* grows to 83 mm. in length (short diameter) in the first year at lake Tamblegam on the east coast of Ceylon. Winckworth (1931) in his note on *Paphia undulata* from the Madras harbour, suggests that it grows to 18 mm. in length in 6 months, to 20 mm. in a year and takes a year and a half to reach 34 mm. Rai (1932) is of the opinion that *Meretrix meretrix*

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* Tetley, H. Actuarial Statistics. Vol. I. Statistics and Graduation. 1950 Cambridge University Press.

grows to the adult stage (average size 60 to 70 mm.) in about two years on the Bombay coast, but this seems to be based largely on inference since he has given no observations in support of this conclusion. According to Malpas (1933) *Margaritifera vulgaris* grows to a length (long axis) of 40 mm. in the first year and to about 70 mm. in five years in the gulf of Manaar. In the Madras harbour, Paul (1942) observed that *Mytilus viridis* grows to about 56 mm. in 6 months and to about 95 mm. in one year, while *Ostrea madrasensis* grows to about 39 mm. in 3 months. *P. placenta* has much thinner shells than *M. casta,* which probably explains the higher rate of growth of the former. Growth in *Mytilus* is mostly addition at one point opposite the umbo and hence the much higher rate in the mussel. Rao (1951a) has estimated that in the Adyar estuary, *Katelysia opima* attains an average length of 22.5, 31.5 and 40.5 mm. in the first, second and third years of life. It is significant that growth observed in *M. casta* in the backwater is much faster than that of the venerid clams *P. undulata* (Winckworth 1931) and *K. opima* (Rao 1951a).

There is a significant portion of each curve in figure 3 which has survived the process of graduation and stands out prominently. The length curve is smooth till about 27 mm. when it falls abruptly till about 31.0 mm. Corresponding to this there is a sudden fall in the breadth curve from 22.5 to 27 mm. The data on the growth of these clams (27 to 31 mm. long) were collected during February (table 2). Since, as explained below, February-March is a period of 'no growth' in the backwaters and spawning has been observed to occur during this time, this rapid fall in the rate of growth is most probably due to the reproductive activity of the clams. This is not the first period of reproductive activity, since at a length of about 21.5 mm. there is a suggestion in the curve of a similar phenomenon, but the one at 29 mm. being of a much more intense nature appears as a conspicuous break in the curve even after graduation.

(b) *Growth as shown by random sampling of populations.* Two clam beds were located, one in the backwater (bed B in fig. 1) and the other in the river (bed C in fig. 1) at Adyar. Clams in a known area of the bed were collected in the following manner. A square wooden frame whose inner dimensions were exactly twelve inches to a side was forced into the clayey soil. The entire soil from inside the frame to a depth of about six inches was taken and sifted for clams. All the live clams were taken to the laboratory along with a sample of water over the bed for determination of the size of the clams and the chlorinity of water. Bed B was in the backwater, where there was a clayey soil mixed with fine grains of sand, with about one foot of water over it and no vegetation. Bed C was situated in the river, where the soil was made up of large coarse sand particles, with about two feet or more of water over it and plenty of vegetation as a dense algal mass. The clams in bed B being in a stage of rapid growth, samples were taken from one square foot of this bed every fortnight till the density of the bed went low in December 1948, after which samples were collected from 9 square feet once in four weeks. Samples from bed C were collected from 9 square feet every fortnight for 3 months, after which collection was done once in four weeks, owing to the fall in density of the bed.

The main difficulty that confronted this method was the interference by the clam collectors, who spotted the beds in about a month after the veligers had settled and they depleted the beds during a short period of

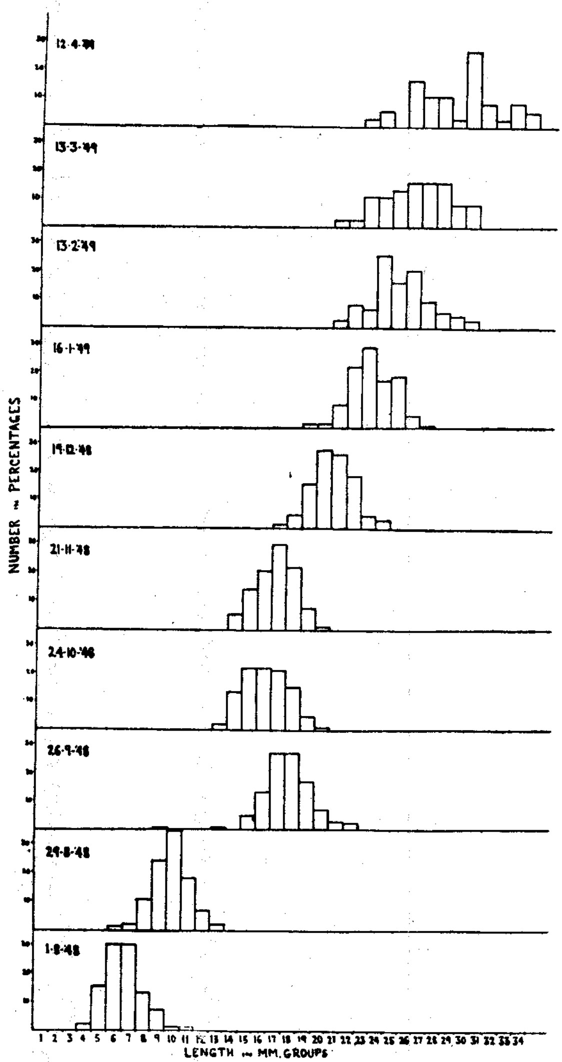

Fig. 4—Histograms representing length frequencies in population samples of clams from bed B.

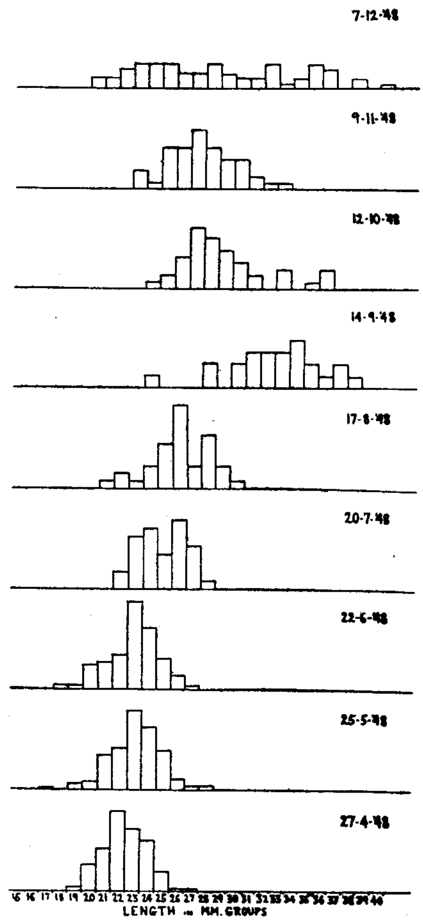

Fig. 5—Histograms representing length frequencies in population samples of clams from bed C.

indiscriminate collection. The effect of the removal of a significant part (which is unknown and varies) of the population by collectors every day, is conspicuous in the irregularity of data from the river bed. Moreover during the rainy season when the water level in the river rose, collections over this bed became difficult.

The data obtained by this method have been classified into millimetre groups (tables 4 & 5) and the frequencies are represented by histograms (figures 4 & 5). Two factors need to be borne in mind in the interpretation of these histograms, namely, the effects of (a) fishing and (b) spawning on the size groups in successive samples. Since the collectors do not reject even small clams, in the case of a dense bed like bed B, fishing may be said to affect the size groups more or less proportionately. But spawning would mask growth because of large additions to the lower size groups. This is clearly seen in the month of August on bed B, which is a month of spawning in the backwater. The mode is at 5.75 mm. (as is clear when the clams are grouped in half millimetre groups) on the 1st of August and shifts to 8.25 mm. by 15th. This represents a growth of 2.5 mm. in two weeks. From 15th to 29th August the mode shifts from 8.25 to 9.75 mm. which is a growth of 1.5 mm. in two weeks. A growth of 5 mm. for clams 5.75 mm. long and 3 mm. for clams 8.25 mm. long in one month in the backwater, is much lower than what is expected. This is because their growth has been partly masked by large additions to the lower size groups, which is confirmed by the fact that with the cessation of spawning by the end of August, the mode shows a much larger growth in the very next sample on 12th September. The 9.75 mm. group shifts to 15.75 mm. in two weeks, which means a growth of 12 mm. in one month.

Yet another factor which influences growth is crowding. It is well known that crowding affects growth adversely and the phenomenal growth in the first two weeks of September is partly due to the fall in density of the clam bed. This factor is also responsible for the growth during 12th to 26th September being less than that expected even though the masking effect of spawning was practically absent during this period. Most of the larger size groups of clams present on 26th September have been fished out by 10th October. Hence this sample is the result of the growth of the smaller size groups represented by only a few on 26th September. Growth is very slow in October, the mode shifting from the 15 mm. group to the 16 mm. group by the beginning of November. By 21st November it shifts to the 17 mm. group and reaches the 19 mm. group on 5th December. By 19th December it is in 21 mm. group and on 16th January it is in the 23 mm. group. Now the sample shows two distinct modes, one at 23 and the other at 25 mm., which advance to 24 and 26 mm. respectively by middle of February. This month a small mode appears at 22 mm. All the three modes are indistinguishable in March but reappear in April at 26, 30 and 33 mm.

In bed C spawning did not occur during the period of study, but fishing by handpicking was being done. Considering the lower density of the bed it is natural to expect a higher rate of growth than that in the backwater, but the growth is actually very slow. The data are very much affected by the discrimination inherent in fishing by handpicking, but nevertheless they give a rough idea. The mode shifts from 22 to 23 mm. during April-May, stays at 23 mm. till 22nd June, shifts to 24 mm. by 20th July, to 26 mm. by 17th August and 27 mm. by 12th October. The sample collected on 14th September does not fit into the picture, which is due perhaps to an error in sampling. The mode stays at 27 mm. through October and November and moves to 28 mm. by December.

A comparison between the two beds at Adyar shows that growth in this clam is much more rapid in the backwater than in the river, where the clams have increased in length from 22 mm. at the end of April 1948, to 28 mm. by the beginning of December 1948. But in the backwater, clams of the same size have grown from 22.5 to 29.5 mm. in three months (middle of January to middle of April 1949). Thus the observed difference in growth rate does not seem to be due to the slowing down of growth with increase in size.

Temperature, Salinity and Rainfall. Salinity and temperature are two factors well known to affect growth. Hamai (1935) working on Japanese clams (*Meretrix meretrix*) has established an inverse relation between relative growth and temperature, while with regard to salinity

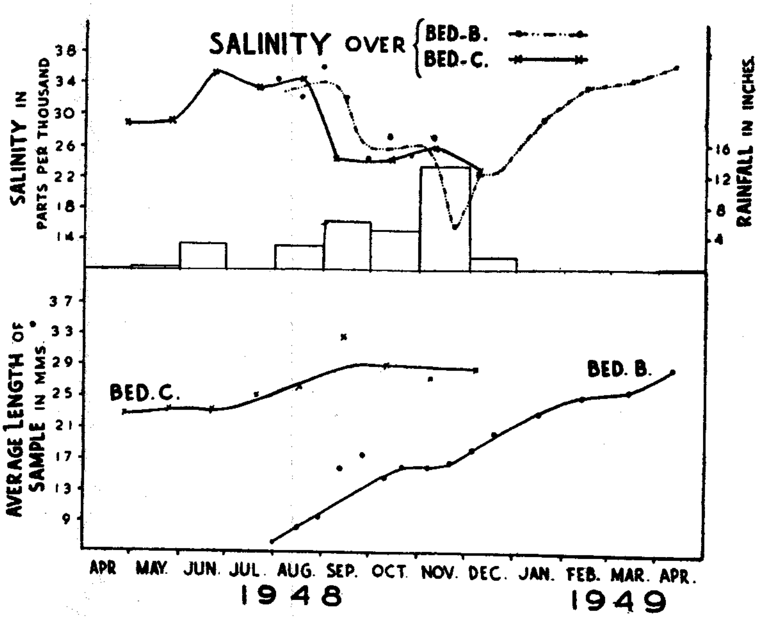

Fig. 6—Graph representing Salinity and Growth of populations on beds B and C, and Rainfall.

he only extends the view that "it may be supposed that salinity affects growth in some way". But no work has been done on the influence of environmental factors on growth of lamellibranchs in Indian waters, except the studies by Paul (1942) and Rao (1951a). Paul (1942) observed a rapid rate of growth and earlier attainment of maturity in most of the sedentary animals of the Madras harbour, which he attributed to the high rate of metabolic activities in the tropics. Rao (1951a) has discussed the effect of salinity and temperature on the growth of *Katelysia*. He observed that a higher salinity is the probable factor in inducing growth.

It would be seen from figure 6 that monthly rainfall and the consequent changes in salinity exert a distinct influence on growth in *M. casta*. Out of a total of 34.54 inches of rain in the year 1948, 17.96 inches fell in two months, October and November (table 1). As a result the salinity of the backwater was the minimum for the year (15.65 $^{o}/_{oo}$) by the 21st of November. This period coincides with the almost complete cessation of growth in the backwater bed. The effect on the clams in the river bed is also similar. Growth was already slower there, but it comes to almost a standstill during September, October and November. The effect of rainfall and the consequent lowering in salinity, is felt much earlier and for a longer period in the river, as is only to be expected. However the fact that a period of 'no growth' occurs in the backwater bed during February-March also, indicates that the effect of salinity on growth is probably only indirect and lies in stimulating the clam to sexual activity. During the period of proliferation of reproductive tissue which culminates in spawning at the highest and lowest salinities, there is probably a fall in shell secretion and hence the slackening of growth. The fact that spawning occurred in the bed in October-November 1948, is confirmed by the appearance of a distinct and separate mode in the collection of April 1949 at about 26 mm. Clams spawned in October-November 1948 are about five months old in April 1949 and as has been already shown, 26 mm. is just the size they are expected to grow to, in this period.

Organic matter—It appears unlikely that the difference in salinity between the two beds, would by itself account for the large difference in the rate of growth. Kreger (1940) who studied the ecology of *Cardium edule* in the Zuider Zee, has shown that "an inverse relation exists between the coarseness of the sand and the quantity of flocky material" over the soil and that the amount of this material may be considered an average measure of the quantity of organic matter available as food. Judging from the obvious difference in the soil of the two beds at Adyar, it is clear that in the backwater there is a greater quantity of available food. The flow of water during the rainy season is comparatively greater in the river. During October 1948, a phytoplankton bloom (mostly *Peridinia* and *Anabaenopsis*) which seems to have been washed down to the backwater, was observed. Throughout the greater part of the year, when the water is more or less stagnant over both the beds, the available suspended food material in the river would settle down on and become attached to the dense algal mass and become unavailable to the clams (Kreger, 1940). This could not happen in the backwater as there was no vegetation on this bed. Thus the more rapid growth of clams in the backwater is attributable to the availability of more of organic food material at the bottom and the absence of impeding vegetation, which robs the water of suspended food material.

(c) *Growth in the laboratory and salinity tolerance.* In order to study the growth of the clams under laboratory conditions, a hundred clams ranging in length from 23 to 43 mm. were collected from the river bed, in August 1947. They were placed in two equal groups of fifty each in circular wooden tubs. The bottom of the tubs was covered to a depth of 5 cm. with mud brought from the clam bed. One of the tubs marked No. 1, was then filled with a mixture of sea water and tap water in the proportion of about 1:2 by volume so as to obtain a salinity of 11.5 $^{o}/_{oo}$. The other tub marked No. 2, was filled with a mixture of sea water and tap water in the ratio 2:1 by volume so as to obtain a salinity of 23 $^{o}/_{oo}$. The length, breadth and depth of the two groups of clams were carefully measured, the clams were numbered serially with Indian ink as already described and placed in the two tubs. The soil in the tubs was renewed once a week and the water was renewed every alternate day, care being taken to maintain the correct salinities in the respective tubs. The clams were collected regularly every month and measured, the numbering being renewed whenever necessary.

There was heavy mortality in tub No. 2, since in about five days forty of the clams died. The dead clams were removed and the water changed whenever death occurred, so that the other clams were not affected. The remaining ten clams in this tub lived for six months till the end of the experiment, except for one which died on 22nd September. In tub No. 1 the mortality was very much lower and till the end of the experiment only twelve clams died. At the end of six months the maximum growth observed was 0.3 mm. in length. In another experiment clams were collected at a very young stage (7–15 mm. in length) and reared in the laboratory in water of the same salinity and provided with an abundant supply of mud. At the end of four months the maximum growth observed was 0.4 mm. in length. Comparing these data with their growth under natural conditions and making allowance for the possible margin of error in the measurements, it can be reasonably concluded that the clams did not grow under the experimental conditions. These results stress the importance of the availability of food for growth to occur, since Coe and Fox (1942) who kept the California sea-mussel in a running water aquarium and Coe (1945) who kept the California bay-mussel in the aquarium for a year found that no growth occurred, but when special efforts were made to provide large amounts of micro-organisms and detritus, growth occurred one third to half as fast as in nature.

The differential mortality of clams in the two beds throws light on the salinity tolerance of these clams. They have been observed to thrive well in Adyar, in places where the salinity is very low (estimated salinity: 6.67 $^{o}/_{oo}$) and also in places where it is even higher than that of sea water estimated salinity: 38.49 $^{o}/_{oo}$). The clams used in the experiment were collected from a river bed, where the salinity was only 12.86 $^{o}/_{oo}$. They were kept in tubs 1 & 2, where the salinities were 11.5 $^{o}/_{oo}$ and 23 $^{o}/_{oo}$ respectively. The survival of more than 75% of the clams in tub No. 1 is due to the fact that they suffered practically no alteration in the salinity of their environment, while the mortality of 80% of those in tub No. 2 within five days may be attributed to the immediate and large increase in salinity. Similar phenomena due to lowering of salinity occur in nature, as has been recorded by Hornell (1917) on the west coast of India during the heavy monsoon period when rivers are flooded. But at Adyar, especially for the past six years during which period the monsoon has been failing more or less, such flooding which brings about a sudden and large decrease in salinity and consequent large scale mortality has not been observed. *M. casta* appears to be able to withstand salinities within a wide range provided the change from a very high to a very low salinity or vice versa is gradual. Steep changes of salinity when they are sudden, bring about a high rate of mortality.

Growth in Weight

Over a hundred clams were collected, representing almost all size groups from 1 to 56 mm. in length from the backwater. They were left in clean brackish water for half an hour, with a change of water after 15 minutes. The clams circulated the water and got rid of all extraneous matter. They were then washed well in running water and dried. After measuring their length and weighing them, they were boiled open. The shells were thoroughly cleaned of all the soft parts without breaking the hinge ligament, washed in tap water, dried overnight and weighed the next day. Clams below 10 mm. were measured using the vernier scale on the microscope stage and weighed on an aperiodic balance. The data are plotted in figure 7. For obvious reasons, the data on clams under 10 mm. have been plotted on a different scale. The curves represent the increase in total weight and shell weight of clams from the time of setting to the maximum size attained at Adyar.

The growth in weight may be considered to occur in four clearly marked stages, for the sake of convenience (fig. 7.) During the first stage, which begins at setting and extends till the clams reach a length of 19–20 mm., the rate of increase is the smallest. At the end of this

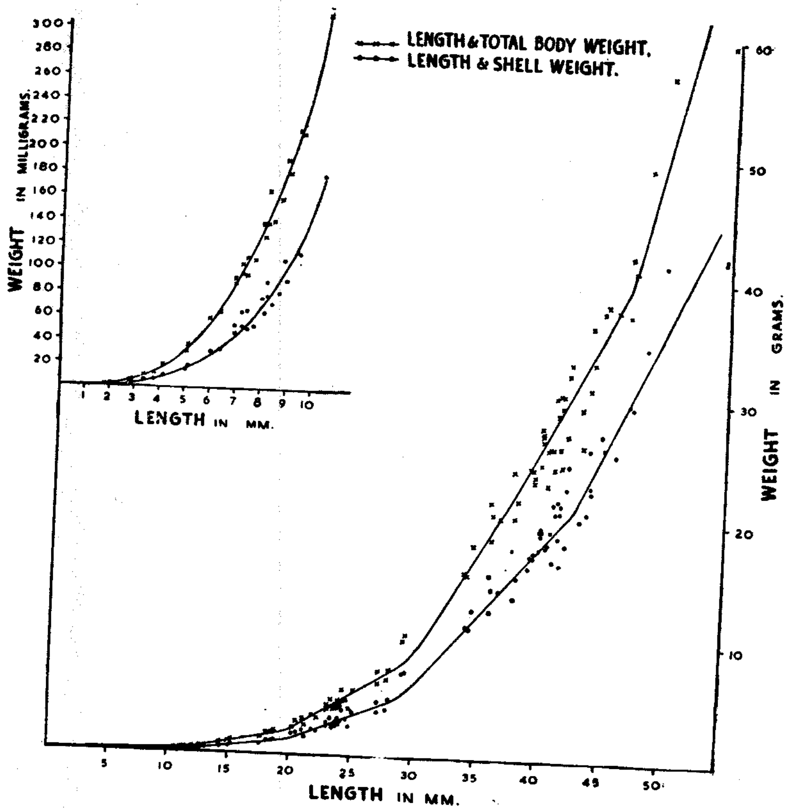

Fig. 7—Graph showing relation between :
(a) Length and Total body weight and
(b) Length and Shell weight, in *M. casta*.

stage the total body weight is 2 grams and the shell weight 1.6 grams. The second stage extends till the clam reaches a length of 29 mm. and shows a higher rate of growth. At the end of this stage the clam weighs 7.8 grams and the shell 5.2 grams. The third stage is of different durations as far as the total body weight and shell weights are concerned. This stage of growth in body weight extends till the clam reaches a length of 47 mm., when it weighs 40 grams. The shell increases by 15.6 grams to reach a weight of 20.8 grams at 42 mm. length during the third stage. The fourth stage is the one showing the highest increase and there is practically little growth in length during this stage. The total body weight reaches 72.5 grams at a length of 55 mm. and the shell weights 47 grams, at this length.

Rai (1932) has recorded a weight of 4 ounces for clams (*Meretrix meretrix*) of average size (60-70 mm. in length) at Bombay. *M. casta* does not grow beyond 55-60 mm., but as is clear from figure 7, the rate of growth in *M. casta* in its fourth stage is such that it will weigh about 130 grams at 65 mm. length. In Japanese waters *M. meretrix* grows in weight in the same cyclical manner as already mentioned for length, reaching 2.2, 7.8, 16, 19.7 and 35 grams at 20, 31, 40, 44 and 55 mm. length respectively (Hamai 1935). Thus at a length of 55 mm., *M. meretrix* in Japanese waters weighs only half as much as *M. casta* at Adyar. The relation between short diameter and weight in the Ceylon Pearl Oyster given by Malpas (1933) is similar to that between length and weight in *M. casta* till about 40 mm., after which the clam increases in weight much more rapidly than the oyster.

The relation between growth in weight of the entire clam and that of the shell is interesting. The shell in *M. casta* weighs only as much as 50% of the total body weight at the beginning of the first stage but becomes 80% at the end of it. The shell comes to weigh a lower percentage of the total weight as the clam grows. At the end of the second stage it weighs 67% of the total weight. The relative rate of increase of the shell falls slightly and then rises till 47 mm., when it weighs 75%. Thereafter the shell weighs proportionately less and less and is only 66% at 54 mm. Thus the fluctuating rate of relative growth of the shell, reaches a maximum for the second time, at the length of 47 mm. This stage (at the age of 1½–2 years) is perhaps the best time to collect shells for the purpose of making lime.

It is noteworthy that the clam and shell weights fall into two distinct groups with a few intermediate values (fig. 7). This heterogeneity of weight in relation to length (which may be taken as an index of the shape) indicates that the clams belong broadly to two distinct shapes, a roundish type and a flat elongated type. This is in conformity with observations on *M. casta* by Hornell (1917) and those on *M. meretrix* by Hamai (1935a). While in the case of shell weight the shape is the only cause for this separation into two groups, in the case of total body weight in addition to this factor, the bulk of body tissue (which depends on the condition of the gonad) has a certain amount of influence. Hence the range of difference between the two groups in total body weight, is higher than that in the case of shell weight.

Growth Rings

Interruptions of growth, which would otherwise be continuous, cause the formation of coaxial rings on shells of bivalves. We owe much of our present knowledge of these rings to Orton (1927), who distinguished 'disturbance rings' from others in *Cardium edule*. Owing to the frequent interruptions of growth (at least twice a year due to spawning alone) a number of rings of varying intensity occur on the shells of *M. casta*. They are particularly crowded after the clam reaches a length of 33 mm.

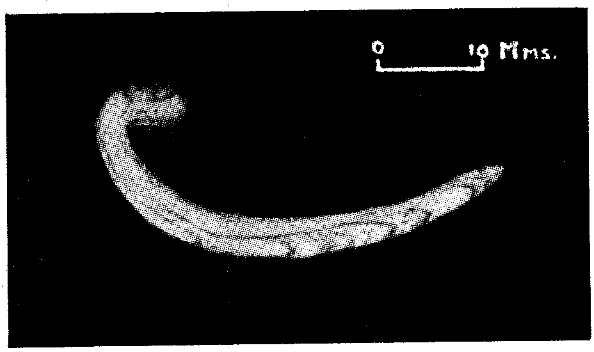

Fig. 8—The cut edge of a shell valve of *M. casta* showing rings.

Rings in *M. casta* are of varying intensity from slender lines which are of the order of 'disturbance rings' to grooves which are up to 2 mm. in breadth. These latter which are like the winter rings formed in colder waters are caused by prolonged suspension of growth probably due to sexual activity. About 45 large clams were collected from the backwater on 4th September 1952 and the rings on their shells measured. The breadth of the shells and the distance of the rings (only the very clear ones) from the umbo along the breadth, are classified into millimetre groups (table 7). The rings appear in a cyclical manner, with an interval of two or three months of growth, which is what is expected from the distribution of spawning peaks in a year. In the older clams the earlier rings are rubbed out or appear very faint. Some of the earliest rings are seen at 10 and 15 mm. which is just after the clams attain sexual maturity as is shown later on. The rings can be clearly seen if a valve is cut through its breadth and the cut edge examined after grinding to smoothness (fig. 8). Rao (1951a) noted the regular occurrence of rings in *Katelysia opima* and has shown how they indicate the age of the clam. But in *M. casta* rings do not occur with such regularity nor do they appear to be annual.

General Considerations

Breeding habits. Clams with ripe eggs and sperms have been collected by the author during all months of the year but there is no doubt that reproductive activity attains its peaks in certain months. The clams in bed B, when sampling was started there on 1st August, were 4–11 mm. in length with an average of 6.3 mm. (table 4). This indicates spawning activity in the month of July. It has been the observation during three years (1948, 1951 and 1952) that seed clams of 1-4 mm. are available in the backwater throughout the month of August, which indicates the continuation of spawning activity till the end of August. As has been already shown, this period of spawning activity ends by the beginning of September. Early in January 1946, an intensely packed bed was observed on the western side of the small bridge on San Thome High Road (bed D in fig. 1), consisting of clams ranging from 10 to 25 mm. in length with an average of 18.5 mm. Since these clams are only about two months old, it indicates a spawning activity at the end of October. Veliger larvae of the clam at various stages have been collected from the beds in May and June 1948 and towards the end of March 1949 in the backwater. Spawning has been induced in clams in the laboratory. Clams collected from near the bar in September, when the salinity was 27 ‰ were kept under observation in water of salinity 22 ‰ made up by dissolving common salt in tap water. A clam 31 mm. long spawned profusely in 3-4 minutes. Spawning was also seen in clams 40 mm. long. Similar experiments seem to indicate that in *M. casta* spawning occurs in the salinity ranges of 20-25 ‰ in October November and of 30-37 ‰ the summer months. Further observations will no doubt be necessary to confirm this.

It is clear that the period of active spawning does not remain constant from year to year in the same environment nor does it coincide in the two environments studied. Inconstancy in the onset and duration of the rainy season (table 1), which controls the salinity of the water accounts for this. The poor rainfall since 1946, on account of which the drop in salinity has been small, and the short period during which the sand bar remained open, explain the close similarity between the curves representing salinity in the river and the backwater (fig. 6). *M. casta* shows a peak of spawning activity in July and August, another in October-November and a third, the period of most intense and prolonged activity, in the summer months beginning in March and extending into April and sometimes May, in the backwater. The peak in October-November follows the opening of the bar and the summer peak the closing of it. The summer peak in normal years extends and most probably merges with the one in July and August. But in certain years (1943, 1944, 1949 and 1952) when there has been an abnormally high rainfall (over 10 inches) in March, April or May the salinity is slightly lowered for a short time and the peak from March to August is broken up into one in March-April and another in July-August. In the river the peak is in the summer months and again in September-November.

Hornell (1922) observed that spawning in *M. casta* appeared to take place twice a year during April-May and again in September. Rai (1932) mentions that the principal breeding season of *M. meretrix* lasts from March to June, but if weather conditions are favourable and the temperature above 82°F., they breed all the year round except during the monsoon season. Observations on the breeding habits of brackish water animals of Madras have led Panikkar and Aiyar (1939) to classify them into four types. It is clear from the above account that *M. casta* shows "discontinuous breeding all through the year, breeding often taking place irregularly mostly determined by the rains." Paul (1942) who has discussed in detail the influence of temperature and salinity on breeding in tropical marine animals, concludes that temperature is not the all-important factor governing breeding. He has given instances where breeding was correlated with salinity. Observations in the field and laboratory experiments on the effect of salinity on spawning in the backwater oyster at Adyar by Rao (1951), have shown that the optimum range of salinity for spawning of both sexes is 22 to 26 $^{\circ}/_{oo}$ and spawning of males occurred in the field in the salinity range 32.45-37.94 $^{\circ}/_{oo}$. He records two breeding periods, November-December and March-April, for the oyster in the backwater. Rao (195a) in his recent studies on the breeding habits of *Katelysia opima* in the Adyar estuary, records that this clam spawns once a year, commencing in late December and spawning throughout January. As has already been shown *M. casta* spawns at least twice a year.

Age and Size at Sexual maturity. Veliger larvae of the clam have been reared in the laboratory for a few days and the size of setting has been found to be 208 microns in length and 183 microns in breadth, when it is only 4 to 5 days old. In order to determine the size at sexual maturity clams of 2 to 17 mm. were collected and one clam of each millimetre group serially sectioned. The study of the stained sections as well as examination of live clams revealed that the gonad follicles do not begin to appear till the clam reaches a length of 5 mm. The follicles are fully formed at a size of 7 mm. The smallest clam in which ripening sexual products were observed was 9 mm. long. But the ova at this stage are small and the clam is not ready to spawn till it is about 10 mm. long. Ripe ova and sperms have been observed in clams 10.2 mm. long. It may hence be considered that the size at sexual maturity is about 11 mm. in length which is an age of about one month. That the clam does spawn if conditions are favourable when it reaches this size, is shown by the occurrence of rings at a breadth of 9.5 mm.

The age and size at sexual maturity of *Ostrea madrasensis* and *Mytilus viridis* have been studied by Paul (1942). He records that sexual maturity is reached in 21 days after attachment at a size of 12.5 by 12 mm. in the oyster and in 48 days after attachment at a size of 15.5 mm. length and 9.4 mm. breadth in the mussel. Rao (1951a) has recorded that sexual maturity is attained in the clam *Katelysia opima* in two to three months when they are just over 12 mm. long. *M. casta* at Adyar reaches sexual maturity at a much smaller size than the mussel and at a little smaller size than the oyster and the clam.

Longevity and Mortality. The largest clam obtained in collections during the past seven years (56.3 mm. length, 49.1 mm. breadth and 35.7 mm. depth) was collected in the backwater near the spot marked

A in figure 1, in June 1947. The clam reaches 56.5 mm. length in about three years. Clams more than 50 mm. long have been collected about half a dozen times, but they are rarely allowed to live to such an age, since more than 95% of the clams are fished before they reach a length of 30 mm. This is shown very clearly by the data in table 4. Beginning with a bed of clams (average size: 6.3 mm. length) which showed a density of 150 clams per square foot, the density has fallen to about 40 per square yard by the time they reach an average size of 28.4 mm. in length. Thus the maximum length to which 97% of the clams can hope to live is 30 mm., that is an age of 6 months. About 50% of the clams live only up to a length of 16 mm., which is an age of two months.

Clam beds at Adyar about one month old, show a small percentage of dead shells. On a bed spotted in January 1946 (bed D in fig. 1), 35-45 valves were obtained per square foot. Taking the average of the two square feet, where the number of live clams were 566 and 300, this forms only about 4.5%. A similar percentage of clams die even in later stages as shown by the presence of larger valves on older beds. This natural rate of mortality may be ascribed to a variety of reasons like competition for food, the relative inability of a few to withstand crowding, variations in salinity and temperature, accidental desiccation on mud flats and so on.

Large scale mortality has been observed occasionally at Adyar. During the summer months when the 'marginal zone' (Panikkar and Aiyar 1937) of the backwater, consisting of mud flats are left exposed and drying, the clams that occur there desiccate and die in large numbers. This is aided by the putrefaction of large masses of algae and animals caught up within them. This was observed on the mud flat surrounding the large island in the river mouth in March 1948 and also at Ennore, ten miles north of Madras. Hornell (1917) records heavy mortality owing to flooding on the west coast of India and Rai (1932) infers that the poor yield of clams (*M. meretrix*) in some years on the Bombay coast is owing to excessive rainfall, the consequent flooding and heavy mortality. For the past six years rainfall has been far below normal in Madras, and the fact that no such large scale destruction due to rains has been observed at Adyar, is due probably to this.

An interesting observation made at Ennore is worth recording. In this area widespread mortality was observed among clams under 16 mm. in length, on a large bed in July and August 1948. It was noticed that the gastropod *Natica* which had bored a fine circular hole 1-2 mm. in diameter on the shells, had destroyed the young clams. On a conservative estimate from the number of perforated shells, at least 50% of the clams of this bed were destroyed in this manner. Apart from these causes, man is the chief agency in the large scale destruction of these clams.

Clam beds and Fishing. In the Adyar watermass, clam beds occur almost in any part of the backwater and even higher up the river beyond the Elphinstone bridge to a distance of about two miles from the sea coast. They occur at all times of the year at one place or other. The beds are of varying densities according to the intensity of spawning, which explains the appearance of denser beds in the summer months. One of the most dense beds observed during the present study, was on the western side of the small bridge in 1946 (bed D in fig. 1). In January, it was noted to extend nearly 100 yards in length from the bridge and for about 10 yards in breadth from almost the water's edge on the southern bank. The density of the bed was 626, 390 and 480 individuals per square foot for the months of January, February and March respectively. Calculating on an average of 500 clams per square foot, this bed consisted of about four and a half million clams. Since it was observed that the density of the bed was higher near the bank than the middle of the backwater where there was a greater depth of water (about 2 feet), clams from two spots, one near the bank and the other 15 feet away from the bank, were collected. There were 566 clams (10.7 to 20.8 mm. in length) to the square foot near the bank and 300 clams (9.8 to 22.1 mm. in length) to the square foot in deeper water. Thus the density of a clam bed is found to be higher in the shallower than in the deeper regions of the bed. The depth of water in the backwater is generally lower than that in the river which may be the reason why the beds in the river are comparatively less dense than those in the backwater.

As far as the area is concerned this bed is one of the smallest observed at Adyar. Beds in the river are usually more extensive than those in the backwater, probably because of greater space available. Beds have been observed in the river which are 350 yards long and 150 yards broad. Some of the biggest beds extend up to 10 acres in area and contain approximately 50 million clams.

Clam fishing is done on almost all days of the year. But the summer months (March to July) form the period of good fishing, owing to factors such as smaller depth of water, greater occurrence of clams and weather free from rain and wind. When the depth of water is small, on dense beds wicker baskets are used to scoop clams but if the density of a bed is low, the soil is scooped up with the hand and sifted for clams. If the depth of water is great, the clams are searched for with the toes and obtained by diving. Nets or implements for digging are not used, unlike the practice on the Bombay coast (Rai 1932), because the soil is loose and contains soft mud. Clam collection is held in contempt by 'fishermen' (those who catch fish, prawns and crabs) and is done only by the so-called low class women and children who accompany them. Both subsistence fishing and fishing for trade exist, as described below.

1. The poor people living on the banks of the Adyar backwater gather

clams enough for their daily needs. To many of them clams are a delicacy preferable even to fish, so that they are prepared to dive for them in deep waters. There are also a few middle class families in San Thome and Adyar, who get their supplies on regular order.

2. The second and larger type of fishing is done by groups of women who fish them in large numbers for sale. They fish for 3 to 4 hours at a stretch during mid-day. On days of good fishing as many as 25 to 30 women have been observed on one bed, each removing 2 to 3 wicker baskets of clams. A wicker basket would contain about 3,000 clams of average size. If they are able to sell the catch, the average earning for a woman per day is about Rs. 1-8.

The shells are kept as such up to two days, a portion being broken open now and then according to demand. There is no regular market for clam meat. The shells are deftly opened with a knife or stone, the washed meat is put in fresh water in pots and the swollen meat with the liquid is hawked and sold at 6 pies per 'ollock' (cigarette tin used as a measure). Among the three small hamlets on the beach, just north of the backwater, in Dumingkuppam almost every house has a stock of clams and they sell them at 4 annas for about 10 pounds. No measure is used in such sale and the price is merely estimated.

There can be no doubt that the present methods of clam fishing at Adyar and even at Ennore are ruinous and wasteful of this natural resource. This would be realised from the fact that about 50% of the clams are fished within two months of spawning, when they are only 16 mm. long. Their total weight is only about 1.25 grams and the shell weight only 0.8 gram at this stage. As such their value either as food or for making lime is practically nil. Even at the size of 30 mm. length their total weight is less than 10 grams and the shell weight only about 6 grams. Thus six months and barely one month are the maximum and minimum ages of the commercially fished clam at Adyar. It is fortunate that in spite of such indiscriminate fishing the species has not been wiped out at Adyar, as it has happened a few years ago in the Cooum river* in Madras and also at Pulicat lake, about 50 miles north of Madras. Among the factors which have enabled the clam to survive such conditions of large scale indiscriminate fishing, the most important are :

1. The high rate of growth, especially during the younger stages.
2. The accelerated early development and abbreviated larval stage.
3. The early attainment of sexual maturity.
4. Discontinuous breeding occurring throughout the year with at least two peaks of sexual activity and spawning.
5. Tolerance to a wide range of salinity.

* The Cooum estuary is repopulated and clam fishing is being done now.

It would be readily recognised that some form of control over fishing is very necessary in the interests of conservation. One possible solution is to declare the clam beds as government property by legislation, as has been done in the case of oyster beds in Madras and to auction the right of collection periodically with a restriction against the fishing of clams below 35 mm. length. It is also desirable to set apart at least one clam bed for purposes of exhaustive study and experimentation.

Summary

1. The study of growth in size of *M. casta* has been attempted by three different methods. Marked clams left in the natural habitat indicate that if growth is uninterrupted, they would attain 43 mm. in length and 35.2 mm. in breadth in one year. However analysis of periodical population samples has shown that under natural conditions growth is suspended during at least two periods in a year and hence clams spawned in August 1948 in the backwater, reach a length of 29.5 mm. by beginning of April 1949. Comparison of population samples from two beds, one in the river and the other in the backwater, has shown that conditions for growth in *M. casta* are much more favourable in the backwater than in the river. Rearing clams under laboratory conditions for six months has shown that they do not grow, presumably due to inadequate food supplies.

2. The study of growth in weight of the entire body and shell alone has shown that at a length of 55 mm. the entire clam weighs 72.5 grams and the shell 47 grams. The shell weighs 75% of the total body weight at a length of 47 mm.

3. Peaks of breeding activity have been recorded twice a year, one in March-May and another in October-November. The frequency of occurrence of growth rings has been shown to coincide with the distribution of spawning peaks.

4. The clam attains sexual maturity at a length of 11 mm.

5. The largest clam collected (56.3 mm. in length) was probably three years old. But normally about 97% of the clams are fished even before they reach a length of 30 mm., as has been shown from the monthly samples from one of the beds. The percentage of natural mortality has been estimated to be 4.5 and instances of mortality due to desiccation and one case of destruction by *Natica* are recorded. Steep changes of salinity bring about a high rate of mortality.

6. Clam beds have been described, some of the largest at Adyar extending to 10 acres in area and having 50 million clams. The present methods of fishing and marketing of clams at Adyar are described.

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TABLE 1—Monthly rainfall (in inches) for a few years.

(Recorded at the King Institute of Preventive Medicine, Guindy and published with the kind permission of the Director).

	1943	1944	1948	1949	1950	1951	1952
January	4.05	0.12	1.47	—	0.26	0.3	0.31
February	—	0.58	0.78	—	0.38	—	0.63
March	—	11.41	—	—	0.81	0.07	—
April	0.67	—	0.2	0.19	—	1.98	—
May	12.49	—	0.34	10.43	2.57	0.05	15.46
June	1.29	4.15	3.21	3.59	2.61	1.67	1.87
July	4.58	6.11	—	2.29	2.86	3.09	0.79
August	8.89	4.38	2.98	6.27	8.04	6.83	4.21
September	4.81	4.8	6.11	5.44	8.65	1.8	1.84
October	32.99	9.87	4.87	5.29	6.39	4.52	9.07
November	17.52	23.02	13.09	4.91	5.92	10.04	0.99
December	4.41	11.33	1.49	—	0.26	0.33	8.77
Total	91.7	75.77	34.54	38.41	38.75	30.68	43.94

TABLE 2—Measurements of marked clams left in the natural habitat.

(All measurements are given in millimetres. The first line of measurement against each clam gives the length, while the second line gives the breadth).

Clam number	Reading on 22-11-'47	Reading on 22-12-'47	Reading on 23-1-'48	Reading on 23-2-'48
5	20.3 16.2		29.8 24.2	
7	18.9 15.8	23.6 19.2		
9	19.0 15.2	23.4 19.2		
25	17.3 14.4	23.1 19.8	28.2 23.4	
38	17.4 14.5	26.2 21.4		
50	18.4 15.0	25.6 20.8		
52	16.4 13.7	23.0 19.2		

TABLE 2—(*continued*)

Clam number	Reading on 22-11-'47	Reading on 22-12-'47	Reading on 23-1-'48	Reading on 23-2-'48
53	19.6 17.0	24.5 21.7		
58	17.3 14.1	24.8 20.5		
62	17.7 15.0	22.7 19.7		
64	16.3 13.9	23.1 19.5	27.3 23.0	28.2 23.8
65	15.0 12.3	21.7 18.0		
75	17.3 14.5	23.2 19.4		
77	29.2 24.5	31.6 26.5	33.8 28.2	
79	39.1 33.0	40.6 34.2		
83	30.2 26.6	32.2 28.2		
102		23.2 18.7	27.9 22.8	32.1 26.5
103		23.8 19.1	28.7 23.0	31.2 25.2
108		25.2 21.2	27.6 23.1	32.6 28.0
111		23.7 19.0	29.1 23.9	
113		46.3 39.1	47.0 39.1	
201			27.6 23.2	28.5 23.8
203			28.6 24.1	32.8 27.6
204			29.2 24.6	33.2 27.8
206			27.1 22.9	31.6 26.9
207			32.2 25.9	35.7 27.8
211			27.9 23.2	32.9 27.2
212			27.3 24.5	32.9 29.2
			Reading on 29-1-'48.	Reading on 29-2-'48.
215			26.7 22.9	30.4 25.8

Table 3.—Growth in length and breadth in one month, observed in marked clams left in the natural habitat.
(All measuremens are given in milimetres. The horizontal lines show groups adopted for graduation).

LENGTH

Initial measurement.	Average	Growth in one month	Average
15.0		6.7	
16.3		6.8	
16.4		6.6	
17.3	16.71	5.8	6.85
17.3		5.9	
17.3		7.4	
17.4		8.8	
17.7	18.05	5.0	6.1
18.4		7.2	
18.9		4.7	
19.0		4.4	
19.6		4.9	
23.1	21.8	4.2	4.78
23.1		5.1	
23.2		4.7	
23.7		5.4	
23.8		4.9	
25.2		2.4	
26.7	26.57	3.7	2.87
27.1		4.5	
27.3		0.9	
27.3		5.6	
27.6		0.9	
27.6	27.66	5.0	4.14
27.9		4 2	
27.9		5.0	
28.6		4.2	
28.7	28.93	2.5	
29.2		2.4	3.23
29.2		4.0	
30.2		2.0	
31.6	31.33	2.2	2.56
32.2		3.5	
39.1	39.1	1.5	1.5
46.3	46.3	0.7	0.7

BREADTH

Initial measurement.	Average	Growth in one month	Average
12.3		5.7	
13.7	13.5	5.5	5.8
13.9		5.6	
14.1		6.4	
14.4		5.4	
14.5		4.9	
14.5		6.9	
15.0	14.76	4.7	5.28
15.0		5.8	
15.2		4.0	
15.8		3.4	
17.0	17.63	4.7	4.28
18.7		4.1	
19.0		4.9	
19.1		3.9	
19.5	19.47	3.5	3.67
19.8		3.6	
21.2	22.0	1.9	2.8
22.8		3.7	
22.9		2.9	
22.9		4.0	
23.0		0.8	
23.0	23.04	2.2	2.77
23.1		4.9	
23.2		0.6	
23.2		4.0	
24.1		3.5	
24.5		2.0	
24.5		4.7	
24.6	25.36	3.2	2.53
25.9		1.9	
26.5		1.7	
26.6		1.6	
33.0	36.05	1.2	0.6
39.1		0.0	

TABLE 4—Size frequencies of random samples from the backwater bed (bed B), with Salinity and monthly Rainfall

Length groups (in mms.)	1-8-'48	15-8-'48	29-8-'48	12-9-'48	26-9-'48	10-10-'48	24-10-'48	7-11-'48	21-11-'48	5-12-'48	19-12-'48	16-1-'49	13-2-'49	13-3-'49	10-4-'49
	Date of collection														
4	3														
5	23														
6	45	7	2												
7	45	18	3												
8	20	37	15												
9	11	41	35		1										
10	2	21	50		..										
11	2	6	26		..	2		2							
12		1	10		..	10		..							
13			3	1	1	19	2	3							
14				2	..	43	14	12	4						
15				7	9	51	23	25	11	1					
16				15	25	28	23	45	16	4					
17				7	51	19	22	44	23	15	1				
18				5	51	3	16	7	17	22	3				
19				1	32	1	5	5	6	20	10	2			
20					13		1	2	1	9	18	2			
21					5			..		7	17	11	2	1	
22					4			..		2	12	30	6	1	
23								..			3	39	5	4	1
24								1			2	23	19	4	2
25												25	12	5	..
26												6	15	6	6
27													7	6	4
28													4	6	4
29													3	3	1
30													2	3	10
31															3
32															1
33															3
34															2
Total number of clams	151	131	144	38	192	176	106	146	78	80	66	139	75	39	37
Sample average (in mms.)	6.29	8.12	9.38	15.74	17.3	14.35	15.74	15.74	16.3	18.1	20.18	22.8	24.72	25.66	28.39
Salinity in °/₀₀	34.1	31.98	35.87	31.82	24.15	27.0	24.75	27.05	15.65	22.2	22.74	29.15	33.15	33.92	35.92
Monthly rainfall in inches	2.98			6.11		4.87		13.09		1.49		nil	nil	nil	0.19

TABLE 5—Size frequencies of random samples from the river bed (bed C) with salinities

	Date of collection								
	27-4-'48	25-5-'48	22-6-'48	20-7-'48	17-8-'48	14-9-'48	12-10-'48	9-11-'48	7-12-'48
Length group (in mms.)									
17		1							
18		..	1						
19	3	5	1						
20	22	6	7						2
21	34	27	8		1				2
22	66	32	10	2	2				4
23	51	62	26	6	1			3	5
24	42	49	18	7	3	1	1	1	5
25	16	30	9	4	6	..	2	7	5
26	2	8	4	8	11	..	5	7	3
27	2	3	1	5	3	..	10	10	3
28		3		1	7	2	8	7	5
29					3	..	6	5	3
30					1	2	4	5	2
31						3	2	2	2
32						3	..	1	5
33						3	3	1	1
34						4	..		2
35						2	1		5
36						1	3		4
37						2			..
38						1			2
39									..
40									1
Total number of clams.	238	226	85	33	38	24	45	49	61
Sample average (in mms.)	22.5	23.13	22.95	24.88	26.1	32.51	28.8	27.31	28.43
Salinity in ‰	28.73	28.82	35.13	* 33.06	34.17	24.15	23.91	25.3	22.61

* The salinity on this bed was 38.47 ‰ on 6th July, 1948, the maximum value recorded here.

TABLE 6—Distribution of rings on the shell of *M. casta.*

(The breadth of shells and the distance of rings from the umbo along the breadth of shells have been grouped into millimetre groups. The numbers given below indicate the frequency of their occurrence).

Breadth (in mms.)	Distance of rings from umbo. (in mms.)																															
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
29							1	1				2					2	1															
30							1	1				2					1	1															
31											1				1																		
33	1				1					2	1			3	2			1															
34						1							2		4		1	3		3	4	1	3										
35						1	2				1	1		2	2	3	2	1		1	1	2	2	1									
36															1	1	1						1										
37																	4			1			4			1	1						
38																	3	1	1			1	2	1	2		1	1					
39																1	1							2			2						
40																		1				1			1			1					
45																2												2					2
Total frequency	1				1	2	4	2		2	3	5	2	5	10	7	15	9	1	5	5	5	12	4	3	1	4	4					2