STUDIES ON THE CLAM, *MERETRIX CASTA* (CHEMNITZ), OFF COCHIN BARMOUTH

BY

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THESIS

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CERTIFICATE

This is to certify that this thesis is an authentic record of the work carried out by Mr.K.I.Mohammed Salih, M.Sc., under my supervision in the Department of Marine Sciences of the University of Cochin and that no part thereof has been presented before for any other degree in any University.

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CONTENTS

INTRODUCTION

Three species of Meretrix, viz., M.meretrix (Linn.), M.Atkinsonia (Dunker) and M.casta (Chemnitz), have been reported from the continental waters of India. M.casta (Chemnitz) is widely distributed along both the west and east coasts of India. Numerous varieties and local races are available due to the marked susceptibility of the animals to environmental conditions. Hornell (1917) has recognised two variations from the form, described by Chemnitz and by Lamarck under the name casta, considered to be the type of the species. These are M.casta var.crum (Hanley) and M.casta var.sainparaensis (Preston). M.casta var.sainparaensis is found only in the sub fossil form. Variety crum (Hanley) differs from the type (a) in having a more pointed outline of posterior angle of the shell; (b) in the frequent presence of radial banding; (c) in having narrower and more elongated form of the hinge and (d) in having escutcheon with a flattened surface as opposed to the convex form in the type. Hornell (1917) has repeatedly stressed that no clear line of distinction can be drawn between the types and either of the varieties as a host of intermediate forms "merging so insensibly into one another" are found.

M. casta populations on the east coast remain true to the type within narrow limits compared to the extent of

variations found in the populations on the west coast. According to Hornell (1917), variability is intensified along the west coast due to two factors: (a) the much more diversified conditions under which the species exists on the west coast, and (b) the vastly greater numbers of individuals involved. M.casta var. gryna (Hanley) is common along the west coast, but is rare on the east coast, where the type predominates.

M.casta, strictly comparable to type form, has been observed by Hornell (1917) in the estuary of the Baliapatam river in North Malabar. M.casta (Chemnitz) has also been reported from the west coast by Silas and Alagarswami (1967), Seshappa (1967) and Parulekar et al. (1973).

In the area under investigation off Cochin bar-mouth, population of M.casta closely follows the description given for the type M.casta (Chemnitz) by Hornell (1917) and Sathyamoorthi (1966).

M.casta has considerable economic importance. It is used as a subsistence food by fisherman community in some localities as it forms a cheap source of protein food. It has also considerable commercial importance as a source of raw material for lime and cement industry. The thickness of the shell makes it especially suitable in this respect.

Although M.casta occurs extensively in the estuaries and backwaters of both coasts, its beds show a discontinuous distribution. Beds are found most commonly in isolated patches in the shallow regions of the backwaters and in the vicinity of the barmouth. Off Cochin, the clam bed occurs in waters of depth of about 2.5 m.

In spite of the possibilities this species holds forth, both as a raw material for lime industry and as a source of food, its utilisation at present is primitive. Any rational exploitation of this resource should presuppose a thorough knowledge of its biology, ecology, behaviour and distribution. Our knowledge about these aspects of the species is scarce. What we do know, we owe to the work of a handful of authors. Among them, Hornell is the foremost. His is practically the only work on M.casta prior to 1950. We owe to him an extensive literature on various categories of Indian Molluscs as well as a revision of the Indian species of Meretrix. He was the first to focus attention on the importance of Meretrix species as a source of lime. In 1916, he published a paper on the utilisation of shells in the lime industry. Hornell (1917a) noted that M. casta "is probably the most important food molluscs of Madras Presidency". Rai (1932) pointed out M. casta as the species of prime fishery importance among bivalves of the Bombay coast.

Abraham(1953) made a detailed study of the biology of M. gaudichaudi. His report includes observations on the environment, growth, breeding habits, longevity and mortality of the species in the Adayar backwaters. His paper has served as a pioneer work and starting point for subsequent work on the species.

In the sixties and early seventies, Durve(1963, 1964, 1965, 1970 and 1971) published a series of papers on M. gaudichaudi, focusing on the rate of filtration, seasonal gonadal changes, dimensional relationship, growth and experimental transplantation. Seshappa(1967) studied the probable growth rate and spawning periods of M. gaudichaudi collected from Beypore and Korapuzha estuaries. Mention should also be made of the work of Silas and Alagarswami (1966) on an instance of parasitism by the pea crab, Pinnotheres sp. on M.gaudichaudi.

Studies on the related species, M.margaritifera, have been made in the Japanese waters by Hamai (1934a, 1934b, 1936).

For the most part, work on M. gaudichaudi has been limited to the east coast of India. Exceptions are those of Seshappa(1967) who made observations on the growth rate of M. gaudichaudi in the Beypore and Korapuzha estuaries and of Parulekar, et al.(1973) who gave an account of the ecology of clam beds in Mandovi, Cumbarjua canal and Zuary estuarine

systems of Goa. Thus information on *M. gaudichaudi* with special reference to conditions obtaining on the west coast is still largely wanting.

Although many aspects of the biology of clams have been the subject of study by various authors, no attempt has so far been made to make a thorough investigation of a selected population of a particular species through several seasons. Thus our knowledge of the biology of clams remains fragmentary. The present study seeks to fill in the major gaps of our knowledge of the biology of an economically important clam species. Any rational exploitation of this species as an economic resource should be based on a thorough knowledge of its biology. Such knowledge presupposes information on the density of populations in the regions under study, the changes the density undergoes through various seasons, the rate of growth, the breeding habits and the breeding seasons.

It is the object of the present study to contribute so much information as possible on the biology and economy of *M. gaudichaudi* on the south-west coast of India. It includes investigations on the growth of the species in three dimensions, length-weight relationship, reaction to changing environmental parameters, seasonal gonadal changes and spawning. Observations are made on the rate of oxygen

consumption and salinity tolerance. An analysis of the biochemical composition of the species is also undertaken. Every attempt was made to make the observations as regular and as continuous as possible, so as to obtain a truly representative picture of the selected population.

MATERIALS AND METHODS

Hydrography

Bottom water samples for the determination of salinity were collected with an indigenous water sampler fabricated in the Department of Marine Sciences. Modified Mohr-Knudsen method was followed for the estimation of salinity. The bottom temperatures were noted immediately after retrieving the water sample.

Growth

The material for the studies on growth was collected from the clam bed off Cochin bar mouth during the period from March 1973 to March 1974. The collections were made at fortnightly intervals with a van Veen grab (.05 m^2) and the sediments containing the clams were passed through a large sieve of mesh size 1 mm.square, so that even the smallest clams could be obtained. The growth in the three dimensions, viz., length, height and depth have been studied. The method of averages as described by Durve(1970) was used for the purpose. The length is

defined here as the greatest dimension along the anterio-posterior axis, height as the maximum distance between the hinge and the opposite end of the shell and depth as the greatest distance between the outer surfaces of the two valves measured in a direction perpendicular to the anterio-posterior axis. The two fortnightly samples were combined for each month and the average values of the three linear dimensions were determined. The difference between two consecutive values gives the average rate of growth for each month.

It has been observed that the growth of the clams takes place along all the three dimensions, but the rates of increment differed from one another. Therefore it was necessary to treat the three dimensions separately.

The data regarding the average values for length, height and depth as well as the average increment of the clams for each month from March 1973 to March 1974 are given in table 3. These data were further analysed to find out the theoretical pattern of growth of M.casta using Von-Bertalanffy's growth equation: $l_t = l_\infty\left[1-e^{-k(t-t_0)}\right]$, where l_t is the length attained at time t, l_∞ is the theoretical maximum length, k is the growth parameter and t_0 is the time at which the animal has zero length. This equation was used for all the three stocks. The quantities, l_∞ and k were estimated separately using the least square method

from the reduced form, $l_t = l_\infty (1-e^{-k}) + e^{-k} . l_t$ giving a linear relation between the length at time t and $(l_t + 1)$. The Ford-Walford plot of (l_{t+1}) against l_t was also tried for three stocks to get the estimates of l_∞. By using the estimated values of 'k' and 'l_∞', t_0 was estimated from the Von-Bertalanffy's model as the average of t_0 obtained giving different values for 't'. The fitted Bertalanffy's models for the three stocks are given below.

First stock $l_t = 39.2253 \left[1-e^{-0.4202(t + 4.8474)}\right]$ (1)

Second stock $l_t = 42.1818 \left[1-e^{-.2330(t + 1.8006)}\right]$ (2)

Third stock $l_t = 54.1826 \left[1-e^{-.1659(t + 5.8560)}\right]$ (3)

<u>Relation between different dimensions and total weight.</u>

The relationship between different dimensions of the animal was studied by using suitable mathematical models. A preliminary plot of each of the logarithms of height(H), depth(D) and total weight(W) against logarithms of length(L) gave out linear form. Hence the allometric relations,

$H = a_1 L^{b_1}$ (1)

$D = a_2 L^{b_2}$ (2)

$W = a_3 L^{b_3}$ (3)

were used to study the relation of length and height,

length and depth, and length and total weight, respectively. The constants 'a' and 'b' were found out using the least square method after taking the logarithm on both sides and converting the equation into a linear form. The plots of logarithmic values together with the fitted lines are given in Pl.3, figs. 2, 3, 4. The linear relations of logarithmic values are as follows:-

$$\text{Log } H = -.3646 + 1.1773 \log L \quad (1)$$

$$\text{Log } D = -.0103 + 0.7836 \log L \quad (2)$$

$$\text{Log } W = -2.8111 + 2.5060 \log L \quad (3)$$

The estimated values of 'a' and 'b' substituted in the respective models led to the following equations.

$$H = (0.4319)L^{1.1773} \quad (1)$$

$$D = (1.024)L^{0.7836} \quad (2)$$

$$W = (0.0015)L^{2.5060} \quad (3)$$

Similar mathematical models have been made by Parulekar et al.(1973) on M.casta collected from two localities from the west coast of India.

Seasonal gonadal studies.

Random samples of adult clams were collected at fortnightly intervals from the clam bed for a period of two years from March 1973 to February 1975. As it was not possible to obtain the clams of the same size throughout the period of observations, adult clams varying in shell

length 10-36 mm. have been used for the histological study of the gonads. Fresh gonad smears of individual clams were studied under microscope to determine the sex and to know the state of the gonad. Changes in the histological state of gonads during different seasons were studied by examining microtome sections of thickness 8μ. Sections were stained with Delafield's haematoxylene and counter-stained with eosin. Along with the studies on the histological state of the gonads, the percentage edibility of the clams of both sexes and indeterminates was also determined as observed by Durve(1964). A total of 1166 clams were used for the purpose. The clams were weighed individually correct to 0.01 gm. and their meat was preserved separately in 5% sea water formalin for ten days. The extraneous water was removed by using filter paper after washing away the formalin and the clams were weighed individually. The ratios of the meat weight to whole weight were then calculated to find out its variations due to sexual activity.

Biochemical composition

The biochemical investigations on M.casta were undertaken using the samples collected during one year (1973 to 1974). Samples were collected from the site at an interval of thirty days and brought to the laboratory within an hour. A toothed dredge was used for the collection of specimens for biochemical analysis.

The collected samples falling within the range of 20 mm. to 35 mm.in length were treated differently to suit the nature of investigation. Although Okazaki and Kobayashi (1929), Kusumoto et al.(1934) and others observed sex-wise differences in the chemical composition, in the present analysis, however, no distinction was made between sexes of the individuals and only samples as obtained during different months of the year were analysed. The seasonal variations of organic constituents (protein, glycogen and fat) in the body entire and the selected component parts, viz., gonad and adductor muscles were estimated. The seasonal variations of ash and ions were determined in relation to the body entire only. The specimens were forced open using a stainless steel scalpel and the soft parts were removed from the shell. The tissues were washed (except in the case of those specimens used for the moisture estimations where washing is done to a minimum) in distilled water, followed by de-ionised water. Since the component organs dissected from individual specimens were too small for analyses, the concerned organs from a sufficient number of individuals were dissected out and analysed collectively. The method employed for the estimations of each constituent is outlined below.

Estimation of water content: The soft parts in their entirety or component parts, whichever may be the case, were washed

with a minimum amount of distilled water and then dried within the folds of a filter paper. A certain amount of the wet material is weighed accurately. This weighed material is dried in an air oven at a temperature of 95 to 100°C. for twenty-four hours. The dried material is again weighed to constant weights. The difference in weights between the wet material and dried material gives the moisture content which is expressed as percentage of water on wet weight basis. The dried material is pulverised using a glass mortar and pestle. The powder is sealed in polythene bags and kept in desiccator over calcium chloride. These samples are later used for glycogen, protein, fat and calorie estimations.

Estimation of Glycogen: The method adopted for the estimation of glycogen was that of Vendo-Kley(1951) and is briefly described below.

One gram of the powdered material is treated with 10 ml. of 5% ice cold trichloro-acetic acid containing 0.1% silver sulphate. The solution is filtered and made up to 100 ml. One ml. of the aliquot is mixed with 3 ml. of concentrated sulphuric acid. This mixture is heated over a water bath for seven minutes and the colour intensity is measured at 515 mμ filter. The concentration of the sample was then determined from the standard graph.

Estimation of Protein: Only total nitrogen has been determined and from its value the crude protein has been analysed, using the formula, Protein = total nitrogen x 6.25. Since into this estimation non-protein nitrogen also enters, the values obtained for protein will be higher than the actual values.

For the estimations of total nitrogen, micro Kjeldahl's method as described in the official methods of analysis of the association of official analytical chemists (William Horwitz, 1970) was used. Nitrogen in a weighed amount of dry tissue is converted into ammonium sulphate by heating with concentrated sulphuric acid in the presence of a catalyst. The sample containing ammonium sulphate is treated with strong alkali (40% sodium hydroxide) which causes ammonia to be expelled into a buffer containing Tashiro's indicator. On titration against dilute sulphuric acid (0.02N) the buffer regains its original colour. The estimation was done in triplicate and the mean of comparable estimation gives the reported value of total nitrogen.

Estimation of Fat: For fat estimation the Soxhlet ether extraction method was used. The method consists in extracting the fat using the non-polar solvent, diethyl ether. A weighed amount of fairly powdered dry material is treated with diethyl ether in a Soxhlet's apparatus.

Labar, ether is evaporated by warming under reduced pressure. The estimation was repeated two or more times as needed.

This method has a limitation in that the non-polar solvent extracts mainly the stored lipid while being generally ineffective in extracting structural lipids. So the value of the fat given by the method will be slightly lower than the actual value.

Estimation of Calorific Content: Food value was estimated for the entire animal in relation to season, but it was not attempted to relate the food value of the component organs to seasons. The method followed for the estimation of the food value of the entire animal was that of Karzinkin and Tarkovskaya (1936). A known weight of the dried sample is oxidised with a mixture of potassium iodate and concentrated sulphuric acid. Unreacted iodate is back titrated with sodium thiosulphate (0.1N). The calorific values are calculated by the method given by them and the values are expressed as k.cal/gm dry weight.

For comparison, food value was also estimated, using the calorific equivalents of protein (5.65 k.cal./g) glycogen (4.2 k.cal./g) and fat (9.45 k.cal./g). This method, however, yielded values higher than those obtained with the Karzinkin and Tarkovskaya Method.

Estimation of Inorganic Constituents: Among the inorganic constituents estimated were ash, iron, copper, calcium and magnesium. Dry ashing was the method followed in the estimation of ash content. Ash content of the entire body (excluding shells) was determined.

In dry ashing, a weighed amount of dry material is taken in a silica crucible and is placed in an electric muffle furnace. Slowly the temperature is raised to 500°C., and held there for four to six hours. Clean ash of negligibly low carbon content is obtained. The percentage of ash was calculated in terms of dry weight of the tissues.

Preparation of solution for the estimation of ions: The ash obtained is mixed with 5 ml. of concentrated hydrochloric acid heated nearly to dryness. This is extracted with water and made up to a convenient volume. The residue in the crucible is extracted with a mixture of 2:1 hydrochloric acid and nitric acid and added to the original aliquot. The solution is then made up to a convenient volume. This extract of ash was subsequently used for the estimation of minerals.

Estimation of Iron: Iron was estimated colorimetrically by the method of Strickland and Parsons(1968) using dipiridil as well as bathophenanthrolene. The method involves the complexing of iron with dipiridil at pH 4 to 4.5 in

aqueous solution. When the iron present in the sample was too little, the estimation was done by complexing it with bathophenanthroline, after extraction with isoamyl alcohol.

Estimation of Copper: Copper was estimated colorimetrically by the method described by Strickland and Parsons (1968) by complexing it with diethyl dithiocarbamate, which is practically specific for copper. Extraction was done with carbon tetra chloride. The complex is stable enough to permit ten estimations at a stretch.

Estimations of Calcium and Magnesium: Calcium and magnesium present in the sample were determined by EDTA method as described by Vogel (1969). An aliquot of the sample solution was treated with NH_3-NH_4Cl buffer to (pH 10) and then with little NH_2-OH-HCl (hydroxyl amine hydrochloride) and KCN. It was then titrated against standard EDTA solution using Eriochrome-Black-T as indicator.

The same aliquot was treated with diethylamine (pH 12.5) which precipitated magnesium quantitatively. It was then titrated against EDTA using Calcone indicator. Titration using Eriochrome-Black-T gives the total calcium and magnesium. By substracting the amount of calcium determined by calcone indicator, the magnesium content was calculated.

Salinity tolerance

The specimens for studying the salinity tolerance were collected from the clam bed and immediately introduced in water collected from the collection site and brought to the laboratory. These specimens were subsequently kept in troughs containing water of the same salinity to get the animals acclimatised to laboratory conditions. Experiments were conducted with three size groups viz., 8-15 mm.length (small clams), 20-30 mm.length (medium sized clams), and 32-38 mm.length (large clams) during the months of their availability.

Saline water higher than 34‰ was obtained by evaporation of sea water and lower salinities were obtained by adding the required quantity of fresh water to it. A constant number of individuals(15) from each size group was transferred into troughs containing water of salinities 0‰, 5‰, 10‰, 15‰, 20‰, 25‰, 30‰, 35‰, and 40‰. Each trough contained three litres of filtered water. The clams were kept under observation for fifteen days. The water in the troughs was changed once in every twenty-four hours. The number of casualties in each size group for each salinity was noted. The animal was considered dead if it failed to close its valves or not to react when touched with a needle. Salinities which caused more than 50% mortality during the course of fifteen days

have been considered beyond the range of tolerance of the species. Two sets of experiments have been conducted for each size group. The combined data are given in the tables.

The lethal salinities of clams of all the three size groups (10 members in each case) were determined by experimenting with different concentrations (1‰ difference) of lower salinities in which the clams showed more than 50% mortality. The average temperature of water in the troughs during the experiments was 28 C.with a variation of $\pm 2^{\circ}$C.

Oxygen consumption

Specimens of M.casta collected from the clam bed were taken to the laboratory. In the laboratory the clams were sorted into different size groups and members of each size group were kept in glass troughs (12" dia.) containing air saturated sea water of different salinities which range from 5‰ to 40‰ at 5‰ intervals, for 48 hours. This is to acclimate the animals to the experimental conditions.

Wide-mouthed pyrex bottles of 270 ml. capacity were used as respiratory chambers. The sea water used for experiments was filtered using whatmann No. 42 filter paper and was air saturated to an oxygen pressure of about 160 mm.Hg.

The water of different salinities for the experiment was prepared either by dilution of sea water with

distilled water or by evaporation. The salinity of the water samples was determined by modified Mohr-Knudsen method. Oxygen in the water samples was estimated using Winkler technique, Strickland and Parsons (1968). After 48 hours' acclimation individual *M. gaudichaudi*, which was cleaned thoroughly of the lingering algae and dirt was carefully transferred to the respiratory chamber containing filtered, air saturated sea water of the respective salinity. The surface of the water was then covered with a thin layer liquid paraffin. The respiratory chambers were kept immersed in a water bath and a temperature of 29°C.-1°C.was maintained throughout the experiment. A control bottle without *M. gaudichaudi* was also kept immersed in the bath to check on the initial oxygen concentration which was found not to change during the course of the experiment. For longer animals the duration of the experiment was restricted to 2 hours. But for smaller animals it was extended by one more hour. The soft parts of the clam were weighed to the nearest milligram immediately after the experiment. Differences in oxygen content between control and experimental bottles were estimated and are taken as the amount of O_2 consumed and is expressed as total oxygen consumption in ml. per animal per hour body wet flesh weight. The initial oxygen concentration in all cases was that of fully saturated sea water at the appropriate salinity and the fall in concentration in no case exceeded 25%; difference in the oxygen tension was not considered to have had any effect.

Experiments on the oxygen consumption were conducted as and when the different size groups of M. cephalus were available. Naturally it extended over a period of several months as all the different size groups were not available at any particular time.

Using the statistical method of least squares, parameters involved in the relations between oxygen consumption and body weight in each of the eight salinity media were found out. Analysis of variance and Student's 't' test were used for comparison of the regression values obtained during experiments in the different salinity media and to find out whether deviations are significant statistically.

BIOLOGY OF M.ERETRIX CASTA

M.casta is a common species of backwater clam along both the east and west coasts of India. In Kerala it is found in all the estuaries, although its distribution is restricted to the barmouths and their vicinity. Eventhough the value of clams as a rich source of protein is well-known, its great potential in this respect has so far not been fully exploited.

Our knowledge of the biology of Indian bivalves is based on the work of a handful of authors. Most of these authors concentrated on growth studies. Orton(1927) reported the rate of growth of Cardium edule. Minkworth (1931) gave an account of the growth of Paphia undulata. Studies on the biology of Ostrea madrasensis and Mytilus viridis were made by Paul(1942). Rao(1951a) studied the growth of Katelysia opima. The growth of the wedge-clam, Donax cuneatus was observed by Nair(1955). Durve and Bal (1962) described the growth processes of the oyster, Crassostrea gryphoides. Rao et al.(1962) gave an account of the biology and fishery of Solen kempi. Alagarswami(1966) dealt with the growth of Donax faba and Narasimham(1968) on some aspects of the biology and fishery of the cockle, Anadara granosa.

Studies on the genus Meretrix have been few and

limited in scope. On the east coast M.casta was made the subject of investigation by Durve and Abraham. Abraham (1953) reported on certain aspects of the biology of M. casta. Durve (1970) studied the growth of M.casta in the marine fish farm at Mandapam Camp. On the west coast, M.casta was studied by Parulekar et al.(1973) and Seshappa (1973). Other reports on Meretrix came from Hornell(1917, 1921), Durve (1963), Durve and Dharmaraja(1965).

The brief resume of the work done on Meretrix and other bivalves given above emphasises the need for more exhaustive and more sustained investigations on the biology and fisheries potential of this important group of aquatic organisms. The present study is an attempt in this direction with respect to species that can, by intelligent exploitation, be made into a rich source of much needed animal protein and an important industrial raw material.

Description of the species

(Pl.2. Figs.1, 2, 3, 4 and 5)

M.casta (Chemnitz) has thick triangularly ovate shell. Shell is usually smooth and coloured lightly yellowish brown. Along the posterior margin, it is dark grey. Radial bands are sometimes found. Radial bands, if present, are usually two to three in number. They are more prominent in young specimens. In older ones, they tend to

disappear. The lunule is not well defined and is almost obsolete and the ligament is usually short. The shell is elongate posteriorly. The anterior lower margin is rounded, while the posterior lower margin is slightly angular.

The hinge area is thick with three cardinal teeth and a tooth in front of the cardinals on the left valve. A corresponding depression is present on the right valve. The pallial groove has only a slight indentation below the posterior adductor impression. The inside of the shell is white with a violet tinge on and around the posterior adductor impression. The details described above are similar in all essential respects to the type, M. casta (Chemnitz) described by Hornell (1917) and by Satyamurthy (1936).

The morphological difference between M. casta (Chemnitz) and M. casta var grus (Hanley) has been given in the introduction. The annual average percentage occurrence of specimens identical with description of M. casta var grus as given by Hornell (1917) was less than 20% in the bed under investigation. A fewer number of intermediate forms which defy inclusion in either the type or the var grus were also present. The type M.casta (Chemnitz) which follows the description given above was most abundant in the bed, constituting roughly 60% of the population.

Description of the environment

The region from where the materials for the present study have been collected, forms part of the upper continental shelf of the Arabian Sea on the northern side of the entrance into the Cochin harmouth. It lies between latitudes 9° 28' and 10° 00' N and longitudes 76° 13' and 76° 31' E. (Pl.1, fig.1). The average depth of water over the clam bed is 2.5 m. and it has an area of approximately 1.5 sq.km. The bottom sediment is composed of sand, silt and mud, the percentage of sand being predominantly higher than the other two. Fragments of molluscan shells, mostly of bivalves, gastropods and scaphopods also contribute to the composition of the sediment, which is subjected to wide seasonal variations. Although technically the clam beds form part of the upper continental shelf, its environmental conditions show seasonal variations, evidently because of its close proximity to the Cochin gut, which forms a permanent outlet for the egress of enormous volume of fresh water discharged into the Cochin backwater system by five major rivers. Achencoil, Pamba, Manimala, Meenachil and Muvattupuzha.

Siltation during the monsoon, which is a constant menace to the Cochin Harbour, poses a serious threat to the clam bed also. As the flood water which is heavily laden with silt is discharged into the sea through the

Cochin gut, the silt spreads out laterally on the seaward side of the gut to be deposited in the shallow regions which form the natural habitat of the clams. But very often the clam beds have been seen to respond to the threat of siltation by making limited shifts in their positions. However, it has not been possible to make a thorough study of such shifts.

The formation of mud bank is a natural phenomenon which is likely to alter the composition of the bottom sediments of the clam beds. The mud banks which take shape during the monsoon season are characterised by calm water saturated with fine bottom mud. Although several of them appear along the coast during rough monsoon weather at different places, almost regularly from year to year, none has ever been known to have formed in the Cochin barmouth area. The nearest one is that which forms at Malipuram/ Narakkal, north of Cochin barmouth. Although the position of the mud banks is subjected to variation from year to year, the Malipuram/Narakkal mud bank has never come close to the Cochin barmouth as to cause any serious effect on the clam bed.

The current speeds over the clam bed also vary a great deal with the tides and seasons. They are especially powerful during the monsoons. Since no reliable data regarding the speeds of current over the clam beds are

available, no attempt has been made to establish any specific relationship between them and the clams. However, it is believed that the currents have a direct physical effect over the clam bed in so far as they are strong enough to sweep away at least a percentage of the population.

Tides in the area are of mixed diurnal type with an average range of about 90 cm. with a highest known tide of 1.75 m. Spring tides often have a range of 1.1 m. During the freshet season the effect of tidal currents is very much reduced. Average rainfall in this area is about 3300 mm. Active rainfall occurs during the south west monsoon which extends from June to September. This is followed by the less intense north east monsoon which lasts from October to December. The hydrological parameters of the clam bed are largely controlled by the freshets discharged into the Arabian Sea from the Cochin backwater system.

That clams in general are extremely sensitive to seasonal variation in environmental conditions has been established by many previous workers. Among them, mention may be made of Hornell(1917), Orton(1927), Panikkar and Aiyar(1937), Rao(1951), Abraham(1953), Nair(1955), Narve (1970), and Parulekar et al.(1973). Although hydrological conditions which control the distribution of organisms are

many, the most important of them are temperature and salinity.

Temperature:

Temperature as a physical parameter is more significant in the temperate region than in the tropics where seasonal variations are less pronounced. The seasonal variations in the bottom temperature over the clam bed during the whole period of investigation are shown in Pl.3, Fig.1 and Table I.

TABLE I

Distribution of average bottom temperature and bottom salinity of the waters over the clam bed in different months from March 1972 to March 1974.

Months	Temperature 0^{o}	Salinity ‰
March (1972)	27.80	32.39
April	30.23	34.33
May	27.50	23.30
June	26.10	13.29
July	25.38	6.82
August	23.60	2.30
September	26.65	23.24
October	28.40	28.30
November	27.12	30.16
December	27.10	29.25
January (1973)	26.70	29.38
February	29.30	33.80
March	29.00	33.28
April	30.12	33.71
May	29.28	35.28
June	26.97	26.10
July	25.22	10.11
August	23.13	5.28
September	25.26	7.28
October	27.19	28.00
November	27.22	28.25
December	27.45	28.10
January (1974)	28.92	30.25
February	29.31	32.18
March	30.11	33.27

It may be seen from the table that the temperature reaches the maximum in April and with the onset of the south west monsoon, either by the middle of May or by the beginning of June the temperature gradually falls. As the intensity of the monsoon increases, the temperature shows a progressive decrease until it reaches a minimum value of 28.60°C. in August. This is followed by a progressive increase till October. From November to January the temperature shows a slight decrease, after which it again begins to increase till the maximum value is attained in April.

Salinity:

Salinity is by far the most important hydrological factor which governs the distribution of marine and estuarine animals. Observations on the distribution of salinity over the clam bed are given in Table I and represented graphically by Pl.3, fig.1. An examination of the curve will reveal that the seasonal variation in the bottom salinity displays a trend similar to that of bottom temperature. The salinity reaches the maximum value of 34.33‰ in April. With the onset of the south west monsoon, the salinity gradually falls until August, when the minimum value of 2.3‰ is attained. During September, a sudden rise in bottom salinity is observed and this is followed by a gradual increase till May, although a

slight fall is noticed during November-January period. This decline in bottom salinity observed during these months could be attributed to the effect of discharge of fresh water over the clam bed during the less intensive north east monsoon.

Population Density:

A Van Veen grab with an effective sampling area of 0.05 m^2 was used for the collection of clams for studying the population density. The population density of clams per m^2 was obtained by multiplying the number of clams collected every month by 20. It is assumed that the relative efficiency of the grab remains constant and the number collected gives a measure of the density of populations in the bed. Records of seasonal variations in the population density and the biomass are set out in Table II. The biomass was determined by taking the wet weight of the whole animal with the shell in the sample collected from 0.05 m^2 and after that the values were converted into meter square. Determination of the wet weight of molluscs is difficult, for it gives erroneous values, since the mantle cavity water will also be included. Hence the mantle cavity water was sucked up with filter paper, after which the animals were weighed.

TABLE II

Table depicting the population density and biomass* of *Meretrix casta* for a period of two years, January 1971 to December 1972.

Months	Number of clams/.05 m^2.	Number of clams/m^2.	Biomass/.05 m^2 (gm. wet weight).	Biomass/m^2 (gm. wet weight).
January (1971)	280	5600	125.72	2514.40
February	230	4600	135.56	2711.16
March	284	5080	155.92	3078.46
April	302	6040	214.15	4283.10
May	132	2640	125.50	2509.96
June	75	1500	71.305	1426.10
July	49	980	46.586	931.72
August	67	1340	84.50	1690.04
September	142	2840	90.72	1814.40
October	310	6200	7.982	159.64
November	343	6860	22.336	446.72
December	180	3600	72.517	1450.34
January (1972)	280	5600	164.325	3286.50
February	230	4600	239.802	4796.04
March	354	7080	336.564	6731.28
April	328	6560	512.049	10240.98
May	128	2560	213.152	4263.04
June	98	1960	163.194	3263.88
July	70	1400	247.23	4944.60
August	82	1640	8.898	177.96
September	315	6300	11.723	234.46
October	217	4340	69.981	1399.62
November	228	4560	222.80	4455.0
December	240	4800	242.31	4845.0

* Wet weight of animal with shell.

It may be seen from the table that there is a fall in the population density during the active south-west monsoon period which extends from June to August. During 1971-1972, the lowest density was observed in July; in the succeeding year also this density of population attained the minimum

value in July. With the reduction in the intensity of the south-west monsoon, which occurs in September, there is a sharp increase in the density of population. Thus it may be seen that in 1971 the number of clams per unit area has increased from 67 in August to 142 in September. The increase in 1972 in the respective months was from 82 to 315. The sudden spurt in the density of population observed immediately after the abatement of the south-west monsoon rains, could be attributed to the intensive spawning and the consequent recruitment of young clams to the population.

An examination of Table II will show that the trend of variation in the biomass does not follow the variation in density. This is because the high population density largely depends on young individuals whose biomass, when compared to that of adults, is very low. Thus in October and November, 1971, the biomass is found to be only 159.61 and 446.72 gm. wet weight/m^2 when the density of population is as high as 6200 and 6860/m^2 respectively. In the month of April, during the same year, the biomass shows a high value of 4283.10/m^2. This inverse proportion between the biomass and population density can only be due to the variation in the size composition of the population during these months. It may be noted in this connection that in October and November the bulk of the population was contributed by juveniles, whereas in April it was formed entirely by large adult individuals. This trend was noticed in the year 1972 also.

Growth

Growth in length: The trends in the rate of growth in length, height and depth of the three stocks of clams are represented graphically by Pl.4, figs. 2, 3 and 4. The clams obtained in the samples at the commencement of the study in March 1972 belonged to a single stock, which continued to persist till September 1972 without showing the recruitment of any fresh stock. Table III shows that the average length of this stock on 1st March 1972 was 32.50 mm.

TABLE III

Average growth and growth increment per month in length, height and depth of Moraitrix costa for a period of two years from March 1972 to March 1974

	Months	Average length (mm.)	Growth increment (mm.)	Average height (mm.)	Growth increment (mm.)	Average depth (mm.)	Growth increment. (mm.)
First stock (1972)	March	32.50	2.03	29.50	1.45	19.20	1.08
	30th March	34.53	2.07	30.95	1.65	20.28	1.06
	April	36.60	1.20	32.50	0.90	21.34	0.65
	May	37.80	0.80	33.40	0.60	21.99	0.45
	June	38.00	0.20	34.00	0.30	22.44	0.30
	July	38.20	0.15	34.30	0.20	22.74	0.20
	August	38.35	1.06	34.50	0.30	22.94	0.35
	September	39.10	-	35.30	-	23.29	-
	October	9.76	5.92	7.30	4.70	5.80	3.61
	November	15.68	6.00	12.00	4.76	9.41	2.11
	December	21.68	5.04	16.76	3.85	11.52	1.51
Second stock (1973)	January	26.72	4.13	20.61	2.82	13.03	1.72
	February	30.86	3.10	23.43	1.72	14.75	1.10
	March	33.95	2.02	25.15	1.70	15.85	1.00
	April	36.00	2.00	26.85	0.40	16.85	0.30
	May	38.00	0.70	27.25	0.20	17.15	0.20
	June	38.70	0.10	27.45	0.15	17.35	0.10
	July	38.80	0.05	27.65	0.10	17.15	0.10
	August	38.85	-	27.75	-	17.55	-
	September	10.78	5.12	6.80	4.50	5.04	2.46
	October	15.90	5.56	11.30	4.55	7.49	2.30
	November	21.46	5.04	15.85	4.03	9.79	1.90
	December	26.50	4.32	19.88	2.71	11.69	1.70
Third stock (1974)	January	30.82	3.10	22.59	1.49	13.39	1.15
	February	33.92	3.08	24.08	1.40	14.54	1.00
	March	36.00	-	25.48	-	15.54	-

By 30th March 1972, the mean length had shifted to 34.53 mm., showing an increase of 2.03 mm.in a month. By the end of April 1972, the mean length has shifted to 36.60 mm., representing an increment of 2.07 mm., indicating thereby that the rates of growth during March and April were almost uniform. In May 1972, there was a slackening in the rate of growth, the average rate of increment being 1.20 mm., slightly less than that of the previous month. During the subsequent months from May to July, there was a progressive decrease in the rate of growth, as shown by the descending order of the average values, viz., 0.80 mm., 0.20 mm., and 0.15 mm. However, in August 1972, the mean length increased from 38.36 mm. to 39.10 mm., registering an increase of 0.75 mm. Thereafter, this stock completely disappeared from the sample, which from October 1972, was substituted by a fresh stock, which is evidently the result of spawning during second week of September 1972.

The average length of the second stock obtained during October 1972 was 9.76 mm. This stock attained an average length of 15.68 mm. by November, thereby indicating an increase in length of 5.92 mm. in one month. The rate of growth during November is 6.0 mm., which is slightly higher than that in the previous month. From December onwards the growth rates decrease steadily. The class obtained during December 1972 with an average length of 21.68 mm.has grown to 28 mm. by May 1973, registering an increment of

16.32 mm. in six months, the rate of growth during successive months from December 1972 onwards being 5.04 mm., 4.13 mm., 3.10 mm., 2.02 mm., 2.0 mm., and 0.70 mm. respectively. June to August is a period of retarded growth, the total average increment in length during this period being as negligible as 0.15 mm. In September 1973, the second stock has completely disappeared from the samples and a new stock of average length 10.78 mm. has been found to be recruited. This stock is probably the result of spawning in late August 1973.

Growth in height: An examination of table-III will show that the trend in the rates of growth in height closely follows that of length. Thus the first sample which shows an average height of 29.80 mm. on 1st March 1972, increases to 30.96 mm., indicating a growth of 1.46 mm. by the end of this month. The rate of increment in height is found to be a little higher (1.66 mm.) during the next month. Thereafter, growth in height progressively decreases till July 1972 when the average total height attained by the clam is 34.30 mm. Although there is a slight increase in the rate of growth in August, 1972, the stock has completely disappeared by the end of this month.

The next group of samples showed an average height of 7.30 mm. in October 1972. The growth in height of this group during the next two months was almost uniform, the rates of increment being 4.70 mm. and 4.76 mm. respectively.

From January 1973 onwards, it showed a marked decrease in the rates of increment from 2.82 mm. in January.

The third stock which made its appearance by the end of September 1973, showed an average height of 6.80 mm. The growth in height of this stock during September and October 1973, as in the case of the previous stock, was almost uniform, the rates of increment being 4.80 mm. and 4.85 mm., respectively. From November to February, it showed a gradual decline in the rates of increment.

Growth in depth: The average depth of the clams on 1st March 1972 was 19.20 mm. This has increased to 23.29 mm. at the end of September, 1972, thus showing a total increment of 4.09 mm. in seven months. It is seen from table III that the rates of increment during the first two months are uniform and closely follow the pattern described for the other two dimensions, namely, length and height. From April 1972 to July 1972, there is a steady decrease in the rates of growth in depth. But the ratios between the average depth and rate of increment are found to be slightly higher than those for length.

The trend in the rates of growth in depth of the second and third stock is exactly identical to that described for length and height. A comparison of the actual values for the three dimensions, namely, length, height and depth with the corresponding theoretical values determined

by Von-Bertalanffy's growth equation as summarised in Table IV will show that they almost agree each other.

TABLE IV

Table showing the average observed growth and average calculated growth in three dimensions (length, height and depth) of 3 different stocks of H-hilsa.

Months	Average length (mm.)		Average height (mm.)		Average depth (mm.)	
	observed value.	calculated value*	observed value.	calculated value*	observed value.	calculated value*
(1972)						
1st March	32.50	33.4239	29.50	29.49	19.20	19.19
30th "	34.63	34.8388	30.95	31.11	20.28	20.37
April	36.60	36.1723	32.80	32.21	21.34	21.18
May	37.80	37.8321	33.40	33.30	21.99	21.98
June	38.00	38.3204	34.00	34.07	22.44	22.47
July	38.30	38.4618	34.30	34.53	22.74	22.80
August	38.36	38.5831	34.50	34.75	22.94	23.03
September	39.10	38.6817	35.30	34.90	23.59	23.18
October	9.76				5.80	
November	15.66	16.76	12.00	12.89	9.41	10.67
December	21.08	21.42	16.76	16.41	11.52	11.63
(1973)						
January	26.78	26.15	20.61	19.98	13.03	13.36
February	30.65	30.12	23.43	22.86	14.76	14.45
March	33.95	33.37	25.15	24.96	15.69	15.69
April	36.00	35.81	26.85	26.27	16.86	16.49
May	38.00	37.42	27.28	27.54	17.15	17.21
June	38.79	38.59	27.45	27.84	17.38	17.43
July	38.89	39.56	27.68	27.99	17.45	17.57
August	38.96	39.63	27.76	28.14	17.55	17.66
September	10.78				6.04	
October	15.90	16.67	11.30	11.92	7.49	7.63
November	21.46	21.19	15.85	15.81	9.79	9.69
December	26.50	25.90	19.86	19.14	11.69	11.63
(1974)						
January	30.83	30.26	22.89	22.36	13.39	13.22
February	33.98	33.67	24.08	25.72	14.84	15.62
March	36.00	-	25.48	-	15.84	-

*growth as determined by Von-Bertalanffy's growth equation.

Of all three dimensions, namely, length, height and depth, the highest increment is shown by length (Table V). It is evident from Table V that the total percentage increase in length is 238.05%, whereas that of the depth is lowest, being 202.68%. The total percentage increase in height has been found to be 220.13%. These values refer to the second stock which represents a generation, the growth of which has been traced from the early stages up to the period of spawning.

TABLE V

Average growth in length, height, depth, total and the percentage increase of the second stock of [illegible]

Months	Average length (mm.)	Average height (mm.)	Average depth (mm.)
October (1972)	9.76	7.30	5.80
November	15.68	12.00	9.41
December	21.68	16.76	11.88
January (1973)	26.72	20.61	13.03
February	30.85	23.45	14.75
March	33.95	25.15	15.85
April	36.00	26.65	16.65
May	36.00	27.25	17.15
June	38.70	27.45	17.35
July	38.80	27.65	17.45
August	38.85	27.76	17.55
Total increase	29.09	20.46	11.76
Percentage increase.	238.05	220.13	202.58

Seasonal gonadal studies and spawning in *M.casta*.

Studies on sexuality and seasonal gonadal changes were undertaken by various workers. (Loosanoff: 1936a, 1936b, 1937a; Loosanoff and Davis: 1950; Davis and Chanley, 1956). Their work was mainly concerned with the hard clam, *Venus mercinaria*. Coe and Harry J.Turner (1938) studied the development of the gonads and gametes in the soft shell clam *Mya arenaria*. The reproductive cycle and the spawning in the same clam have been studied by Stickney(1952) and Rogers (1959). Studies related to breeding of the clams *Meretrix meretrix*, *Katelysia opima*, *M.casta* and *Paphia laterisulcata* and the mussel,*Mytilus viridis* were made by Hornell(1922), Rao (1951), Abraham(1953), Nagabhushanam and Dharma(1975) and Nagabhushanam and Nano(1975) respectively. Durve(1964) made some observations on the seasonal gonadal changes and spawning of *M.casta* from the Marine Fish Farm at Mandapam Camp.

A sound knowledge of the seasonal gonadal studies and spawning is important for the rational exploitation of the commercially important clam. The aim of the investigation is to find out the exact period of spawning of the clams in the waters under study and to see whether the spawning period agrees with the time of occurrence of the juvenile clams observed during growth studies.

Sexes are separate in *M.casta*. No instance of

hermaphroditism has been noted during the course of study. Hence the development of the gonads of males and females has been treated separately.

In order to find out the exact state of the gonads in different periods of the year, the investigatory phase has been divided into five stages based on the gonadal activities. The months in which the respective stages of gonads occurred in the samples are given against the five stages.

Stage I: Individuals with gonads showing gametogenetic activities (January second half to May second half).

Stage II: Individuals with fully ripe gonads (June first half to July second half).

Stage III: Individuals with partially spawned gonads (August first half to August second half).

Stage IV: Individuals with fully spawned gonads (September first half to October second half).

Stage V: Individuals with sex indistinguishable (November first half to January first half).

Males: From an analysis of the monthly variations in the percentage compositions of *M. cantra* in different maturity stages during 1973-1976, it is seen that almost all male class show gametogenetic activity from January second half to May second half. (Table VI).

TABLE VI

Monthly variations in the percentage composition of M.esculenta in different maturity stages during the period from March 1973 to February 1974 (Males)

Months	Numbers	Stage I	Stage II	Stage III	Stage IV	Stage V
March *(1973)	93	100	-	-	-	-
**	105	100	-	-	-	-
April *	132	100	-	-	-	-
**	120	100	-	-	-	-
May *	162	100	-	-	-	-
**	160	94.8	5.6	-	-	-
June *	78	8.82	91.18	-	-	-
**	43	5.23	94.77	-	-	-
July *	31	-	100	-	-	-
**	[illegible]	-	[illegible]	-	-	-
August *	[illegible]	-	-	[illegible]	-	-
**	[illegible]	-	-	[illegible]	-	-
September *	[illegible]	-	-	-	[illegible]	-
**	[illegible]	-	-	-	[illegible]	-
October *	[illegible]	-	-	-	[illegible]	-
**	[illegible]	-	-	-	[illegible]	-
November *	[illegible]	-	-	-	-	[illegible]
**	[illegible]	-	-	-	-	[illegible]
December *	[illegible]	-	-	-	-	[illegible]
**	[illegible]	-	-	-	-	[illegible]
Jan. *(1974)	[illegible]	-	-	-	-	100
**	128	90.71	9.29	-	-	-
February *	[illegible]	[illegible]	-	-	-	-
**	[illegible]	[illegible]	-	-	-	-
March *	[illegible]	[illegible]	-	-	-	-
**	[illegible]	[illegible]	-	-	-	-
April *	[illegible]	[illegible]	-	-	-	-
**	[illegible]	[illegible]	-	-	-	-
May *	[illegible]	[illegible]	-	-	-	-
**	[illegible]	-	[illegible]	-	-	-
June *	[illegible]	-	[illegible]	-	-	-
**	[illegible]	-	[illegible]	-	-	-
July *	[illegible]	-	[illegible]	-	-	-
**	[illegible]	-	[illegible]	-	-	-
August *	[illegible]	-	-	[illegible]	-	-
**	[illegible]	-	-	[illegible]	-	-
Sept. *	[illegible]	-	-	-	[illegible]	-
**	[illegible]	-	-	-	[illegible]	-
October *	[illegible]	-	-	-	[illegible]	-
**	[illegible]	-	-	-	[illegible]	-
November *	[illegible]	-	-	-	-	[illegible]
**	[illegible]	-	-	-	-	[illegible]
December *	[illegible]	-	-	-	-	[illegible]
**	[illegible]	-	-	-	-	[illegible]
Jan. *(1975)	[illegible]	-	-	-	-	[illegible]
**	[illegible]	[illegible].90	-	-	-	19.10
Feb. *	[illegible]	[illegible]	-	-	-	-
**	121	100	-	-	-	-

*First half of the month. **Second half of the month.

In late January the gonads of the male clams show ramification. The gonad follicles appear and after forming three or four rows of germ cells, numerous spermatogonia begin to grow rapidly. Further, in the lumen of the follicles spermatocytes and spermatids can also be seen. In no section of gonad obtained in January could be seen fully developed spermatozoa (Pl.5, fig.1). It is found that different follicles of the gonad of the same individual contain sex cells in varying quantities and also in varying stages of development.

From late February onwards, the proliferations of the follicles become more apparent and the sexes can be easily distinguished. Spermatogenesis proceeds at a rapid rate and in many follicles fully developed spermatozoa are seen in the centre of the lumen although their number is comparatively less (Pl.5, fig.2). Clams with resting phase were not represented during this stage. More advanced stages of spermatogenesis are seen in the gonads examined from March to May first half. An early stage of spermatogenesis is seen in a few follicles. The lumen of most of the follicles is packed with secondary spermatocytes, spermatids and

connective tissues in between the follicles are very much reduced. The branches of anastomosing follicles reach the region of digestive gland.

Spawning starts at the beginning of August and it continues till the end of the month. Individuals with partially spawned gonads are seen till the second half of August (Pl.6, fig.4). Some follicles have already discharged their contents, while in other follicles spermatogenesis still continues and the lumen is filled with spermatozoa. This suggests that an individual clam takes several days or even weeks for the completion of spawning. Gonads of partially spawned clams are shrunk.

Fully spawned individuals occur in the samples from September to October second half. Their gonads are characterized by the shrinkage of the gonadal follicles (Pl.6, fig.5). Specimens with fully developed gonads are also observed but their numbers are few, suggesting that different individuals do not spawn at the same time.

Females: There is no considerable difference in the occurrence of the different maturity stages during the different months between the males and females (Tables VI & VII).

TABLE VII

Monthly variations in the percentage composition of M.malabaricus in different maturity stages during the period from March 1973 to February 1976 (Females).

Months	Num-bers.	Stage I	Stage II	Stage III	Stage IV	Stage V
March *(1973)	72	100	-	-	-	-
**	89	100	-	-	-	-
April *	120	100	-	-	-	-
**	128	100	-	-	-	-
May *	134	100	-	-	-	-
**	144	100	-	-	-	-
June	89	10.34	89.66	-	-	-
**	80	8	92	-	-	-
July	42	-	100	-	-	-
**	35	-	100	-	-	-
August	30	-	5	95	-	-
**	50	-	-	100	-	-
Sept. *	43	-	-	-	100	-
**	46	-	-	2	98	-
October *	88	-	-	-	100	-
**	82	-	-	-	100	-
November *	80	-	-	-	-	100
**	93	-	-	-	-	100
December *	77	-	-	-	-	100
**	85	-	-	-	-	100
Jan. *(1974)	95	-	-	-	-	100
**	92	90	10	-	-	-
Feb. *	72	92.28	7.72	-	-	-
**	72	100	-	-	-	-
March *	83	100	-	-	-	-
**	84	100	-	-	-	-
April *	115	100	-	-	-	-
**	138	100	-	-	-	-
May *	152	100	-	-	-	-
**	85	-	100	-	-	-
June *	83	-	100	-	-	-
**	49	-	100	-	-	-
July *	28	-	100	-	-	-
**	30	-	-	100	-	-
August *	26	-	-	100	-	-
**	56	-	-	6	94	-
Sept. *	72	-	-	7.75	92.25	-
**	87	-	-	7	93	-
October *	80	-	-	-	100	-
**	91	-	-	-	-	100
November *	74	-	-	-	-	100
**	125	-	-	-	-	100
December *	122	-	-	-	-	100
**	122	80.90	-	-	-	19.10
Jan. *(1975)	90	100	-	-	-	-
**	112	100	-	-	-	-
Feb. *	90	100	-	-	-	-
**	112	100	-	-	-	-

* First half of the month. **Second half of the month.

Slow oogenetic activities become apparent by the beginning of January second half. Majority of the specimens obtained in the latter half of February showed various stages of oogenetic activity. From March to the end of May, all specimens in the samples exhibited gonadal activities. The follicles show all stages of oogenesis, viz., oogonia, oocytes and mature ova (Pl.6, fig.1). The growth and proliferation of ova are very rapid. All the follicles do not begin to produce ova at the same time.

Clams with well developed gonads (light yellow to yellow in colour) were obtained during June. Some of the specimens obtained in early June showed late stages of oogenesis. In fully ripe ovaries the follicles are completely distended, the vesicular connective tissue thereby becoming very much reduced and the entire lumen is packed with mature ova. (Pl.6, fig.2).

As in the males, spawning starts in the females also from the beginning of August. A good number of specimens obtained during this period showed partially spawned gonads. Discharge of ova from the different follicles is not uniform, suggesting the long duration taken by an individual clam for spawning. Phagocytic cells appear in the partially spawned follicles and the gonads show shrinkage. (Pl.6, fig.3). Partially spawned individuals occur in the samples till the end of August.

Fully spawned females are seen in the sample from September first half to October second half. (Pl.6, fig A). A few unspawned ova are found to remain and the number of phagocytic cells increases steadily within the follicles. These cells apparently devour the residual gametes in the follicles. Tranter(1958b) observed three different types of phagocytic cells (cell types A,B,C) in Pinctada albina during the resting phase. In the present study the phagocytic cells are found in the spent follicles and resemble closely to his cell type A. The occurrence of phagocytic cells is a general feature and is encountered in the post-spawning stages and rarely during the early stages of gametogenesis. Clams with considerable shrinkage of follicles occur in the samples till the end of October, by which time some of the clams become sexually indeterminate.

Indeterminate gonad: Clams in which sex could not be determined occurred in the samples from the first half of November onwards upto the end of January first half. All the specimens examined upto the first half of January were indeterminate, while their number gradually decreased and by the beginning of February gametogenetic activity had begun and sexes could be easily identified in all the specimens.

During the two years of observation on M.casta in the clam bed off Cochin backwater, gonadal activity was found to be initiated at a rise in salinity of 30.25‰ (Table VIII) observed in January when the winter monsoon's effect on this region has subsided. The rate of gonadal development becomes

TABLE VIII

Average monthly bottom temperature and bottom salinity of the waters over the clam bed during March 1973 to February 1975

Months	Salinity ‰	Temperature °C.
March 1973	33.28	29.00
April	33.71	30.12
May	35.28	29.28
June	26.10	26.97
July	10.11	25.22
August	5.28	23.13
September	7.28	25.28
October	28.0	27.19
November	28.25	27.22
December	28.10	27.45
January 1974	30.25	28.92
February	32.18	29.31
March	33.27	30.11
April	34.18	32.70
May	35.21	32.90
June	26.29	26.71
July	8.76	24.18
August	3.23	23.71
September	4.37	23.93
October	28.15	26.53
November	28.90	28.22
December	28.23	28.41
January 1975	30.10	29.75
February	32.32	31.20

faster as the salinity increases and all the clams collected during April and May showed vigorous gonadal activity. It is possible that changes in salinity of the environment may have some effect on the development of gonads.

Percentage edibility: The total average percentage edibility of males, females and indeterminates collected during March 1973 to February 1976 is given in Table II. It would be seen that the total average percentage edibility varies from 11.54 to 16.41. The highest values for both males (15.77 - 16.21) and females (15.90 - 16.62) were obtained during the months of June and July and the lowest values (11.20 - 11.77 for males; 11.89 - 12.82 for females) were recorded in October. The trend in the variation of percentage edibility of both males and females during both the years are more or less similar.

TABLE IX

Monthly variations in the percentage edibility of the males, females and indeterminate M. casta during the period from March 1973 to February 1975

Months	No.	Males %	No.	Females %	No.	Indeterminate %	Average %
March 1973	30	14.19	18	14.41	-	-	14.30
April	48	14.60	28	14.40	-	-	14.50
May	56	14.93	27	15.01	-	-	14.97
June	13	15.77	7	15.90	-	-	15.83
July	10	16.21	12	16.62	-	-	16.41
August	12	14.01	18	14.21	-	-	14.11
September	20	13.31	25	14.11	-	-	11.71
October	11	11.20	23	11.89	-	-	11.54
November	-	-	-	-	40	12.47	12.47
December	-	-	-	-	40	12.88	12.88
Jan. 1974	15	12.10	15	12.30	26	13.22	12.54
February	22	12.86	20	12.49	-	-	12.45
March	43	13.38	13	13.01	-	-	13.19
April	45	13.95	20	13.45	-	-	13.70
May	53	14.29	18	13.98	-	-	14.13
June	19	15.38	21	14.58	-	-	14.98
July	13	15.79	16	15.62	-	-	15.70
August	11	13.81	22	15.13	-	-	14.47
September	21	12.16	27	14.29	-	-	13.22
October	15	11.77	18	12.01	-	-	11.89
November	-	-	-	-	38	12.22	12.22
December	-	-	-	-	52	12.83	12.83
Jan. 1975	22	12.89	17	12.44	25	12.86	12.73
February	26	12.93	24	12.90	-	-	12.91

Spawning activity: The periodicity of spawning was studied by examining histological preparations of gonads during the periods of study as well as by studying the percentage edibility variations during different seasons of the year. Stage II gonads (fully ripe) were obtained during the months of June and July at which the percentage edibility in both the sexes was also high. Sections of gonads observed during the following months showed follicles from which the genital products had already been discharged. The spawning in both males and females is slow and it continues in a limited number of clams upto the end of October. Concurrent with the release of sperms and ova, the percentage edibility shows a gradual drop, until the lower value is reached in October when the clams are fully spawned. So it can be inferred that the discharge of the genital products accounts for the drop in percentage edibility. Sections of gonads of specimens taken in later part of October upto the early part of January were sexually unidentifiable. During this period recovery of spent individuals is taking place. The sections showed an increasing amount of vesicular connective tissues; consequently the percentage edibility also shows a gradual rise.

BIOCHEMICAL COMPOSITION OF M. CASTA

Biochemical investigations on bivalves are important from the point of view of both pure biology and applied biology. An understanding of the physiological mechanisms of an animal presupposes a knowledge of the chemical constituents of its body, as well as the transformations these chemical constituents undergo within the body. Such an investigation is also essential for the understanding of the balance that exists between the animal and its environment. In such economically important animal groups as the clams, a knowledge of the chemical composition of the body is important not only for the evaluation of their utility for food or other purposes, but also for a more balanced utilisation of the resource. Seasonal variations in the composition of the animal in association with the seasonal variation in the environment should be studied in order to arrive at the efficient means of culture and conservation.

Although the importance of chemical investigations on bivalves was recognised very early, attempts at such investigations were comparatively rare until the latter half of the present century. Though a considerable body of literature on the chemical composition of molluscs exists, only a small proportion of these literature pertains to bivalves and, out of these, most of them relate to temperate species. One of the drawbacks of the earlier studies

on the chemical compositions of the molluscs was that the authors made their analyses, often making a mash of the entire body. Bergmann(1962) has pointed out that in studies where a particular chemical constituent is of special interest, such an analysis is effective. But in the molluscs which contain an ample digestive tract full of food, this procedure introduces some error unless the animal is first starved. Furthermore, for a study of the physiology of an animal, the biochemical constitution of each of the component organs of the body would be more informative than an analysis of the entire body. These points were stressed by Giese(1959) who has outlined a scheme for the investigation of the biochemical investigation of the component body. In the same paper he sums up the available knowledge on the organic constituents in the molluscs.

Vinogradov(1953), in his classic monograph on the elementary chemical composition of marine organisms,sums up the biochemical work done on the molluscan body during a century and a half. He also gives an excellent historical introduction to the subject. But in recent years, there has been growing criticism against Vinogradov on the ground that "much of the work referred to by him was conducted long ago by questionable experimental techniques which would not be regarded now as valid", Krishnamoorthy(1969). Granting the justice of this criticism,it should, however,

be admitted that Vinogradov's work stands as a monumental start in the investigation of the chemical composition of organisms.

Joshi and Bal (1965) observed the chemical composition of the clam, Katelysia marmorata. Rahman (1965) gave an account of the nitrogen content of the lamellibranch, Donax cuneatus. The same author gave a more general account of the chemical composition of the same species, the following year (Rahman, 1966). Durve and Bal (1961) studied the chemical composition of the Oyster Crassostrea gryphoides. Krishnamoorthy (1969) investigated the distribution of iron in the tissues of some bivalve molluscs. Nagabhushanam and Mantale (1972) have studied the chemical composition of the oyster, Crassostrea gryphoides. Suryanarayanan and Alexander (1972) have gauged the nutritional value of five species of bivalves. As a part of the ecology of two sandy beaches in the south-west coast of India, Ansell et al. (1973) gave an account of the biochemical composition of four common invertebrates including two species of the genus Donax. These are some of the more important biochemical investigations on the molluscan body conducted in India. It should be noted that so far no attempt has been made to make a systematic study of the chemical composition of a species of Marcia. It is not surprising that the information we have is too sketchy to be incorporated into any meaningful

pattern of understanding.

The work on Indian species of bivalves should be viewed against the background of investigations on temperate species by a growing body of scientists from many disciplines and with varying interest, whose methods have been followed by the Indian investigators. The more important among these investigations are those of William(1969), Durkin (1971), Stuvesson and Reyment (1971), Perrine et al. (1971), Takahashi and Hori (1971), Graham (1972), Crenshaw (1972), Ansell et al.(1973), Bryan (1973), Ansell (1974a, b, c & d), Dalhaye & Gernet (1975), Parameswaran & Visvanathan (1976). These authors have studied the organic and inorganic constituents of the molluscan body and their seasonal variations in varying detail. In spite of the considerable body of work done, we are far from being able to arrive at a satisfactory understanding of the chemical complexity of the molluscan organisation.

The present investigations comprise the study of both the organic and inorganic constituents in the body entire of *M. gaudia* as well as in selected component organs. An attempt has also been made to trace the seasonal variations of some of the elements. The object of the investigation is to understand the chemical transformations in the body of *M. gaudia* associated with the great variability of its environment, especially with the monsoons.

a) Seasonal variations of organic constituents in the body entire of *M.casta*.

Seasonal variations in water content, glycogen, protein and fat have been studied. The calorific value has been calculated from the values of organic constituents, using appropriate conversion factors and also estimating the calorific content directly by the wet oxidation method of Karzinkin and Tarkovskaya (1964).

Considerable work on the seasonal variation in organic constituents in temperate bivalves has been done by several authors. Among these, mention may be made of Fraga (1956) in *Mytilus edulis*, Fugi (1967) in *Corbicula japonica*, Galtsoff (1964) in oysters, and Giese, *et al.* (1967) in *Tivela stultorum*. But in the tropical waters inhabited by *M. casta*, seasonal variation in hydrological factors are felt to much less degree. Here the determining factor is the monsoons, especially the south-west one which forms the great climatic event of the year. The monsoons bring abrupt radical changes in the ambient water. Such changes can be expected to cause equally radical changes in the physiology of the animal.

Water content: The water content in the body of M. gaeta expressed as percentage of wet body weight shows marked variation during the course of the year (Table X, Pl.8, fig.1).

TABLE - X

Seasonal variations of water content in the body entire of M.gaeta

Months	% of water/gm.wet weight
January 1973	72.68
February	71.10
March	70.98
April	70.88
May	70.86
June	78.90
July	80.26
August	80.37
September	76.10
October	75.04
November	75.00
December	74.68
Average	74.89
Standard Deviation	± 3.86

During the winter monsoon period and in the interval preceding the summer monsoon, the water content of the body

remains more or less steady at about 70%. At the onset of the summer monsoon in June, the water content rises rapidly to 78.90% and continues more or less at that level up to the end of August. As the monsoon wears off during September and October, the water content falls to about 75% and remains more or less at that level for the rest of the year.

Glycogen content: During January to May, the glycogen content increases from 4.41% to 8.70% (Table-XI, Pl.8, fig.2).

TABLE - XI

Seasonal variation of glycogen in the body entire of *M. cephalus*.

Months	% glycogen/gm. Dry weight
January 1973	4.41
February	6.03
March	6.07
April	8.78
May	8.70
June	4.41
July	3.44
August	3.49
September	6.16
October	6.94
November	7.83
December	7.68
Average	6.14
Standard Deviation	± 1.787

The maximum value of 8.78 was obtained during April. From June to August is a period of rapid decrease. During the rest of the year the value gradually rose to 7.66%.

Protein content: Protein shows a seasonal trend similar to that of glycogen (Table-XII, Pl.8, fig.3), increasing from a value of 45.18% of the dry weight in January to 70.06% in April, the latter being the maximum value obtained during the year. At the onset of the south-west monsoon in June, the value plummets downward to 40%.

TABLE - XII

Seasonal variations of protein in the body entire of M.canta.

Months	% Protein/gm. Dry weight (P = N x 6.25)
January 1973	45.18
February	50.50
March	68.75
April	70.06
May	69.10
June	40.00
July	38.00
August	38.06
September	42.12
October	47.31
November	55.00
December	60.68
Average	41.98
Standard Deviation	± 34.64

The value continues to fall during July and August and from September onwards, the value shows an upward trend reaching 60.66% during December.

Fat content: As in the case of Glycogen and Protein, the fat value is higher during January to April, increasing from 5.10% to 7.23% of the dry weight (Table-XIII, Pl.8, fig.4).

TABLE - XIII

Seasonal variation of fat in the body entire of M.gaeta

Months	% fat/gm. Dry weight
January 1973	5.10
February	5.58
March	6.06
April	7.23
May	4.12
June	2.10
July	2.58
August	1.98
September	1.25
October	1.19
November	5.67
December	6.92
Average	4.14
Standard Deviation	± 4.25

At the onset of the summer monsoon, when the water content of the body rises to 78.90%, the fat value plunges down to 2.20%. A slight increase in fat content observed in July (2.68%) does not significantly alter the low level of fat during the whole of the south-west monsoon period. During August-September, the value continues to fall, coming down to 1.19% by October. In November and December, the fat value registers abrupt increases, the value being 5.37% and 6.92% respectively.

Calorific value: During the early part of the year from January to April, when the water content remains more or less steady at about 70%, the calorific value (experimental) rises from 3.01 K cal/gm to as high as 4.98 K.cal/gm dry weight. (Table-XIV, Pl.8, fig.6).

TABLE - XIV

Seasonal variation of calorific content in the body entire of *M.vagina*

Month	K.cal/gm dry wt. (calculated value)	K.cal/gm dry wt. (Experimental)
January 1973	3.24	3.01
February	3.68	3.28
March	4.75	4.16
April	5.04	4.98
May	4.70	4.75
June	2.66	2.21
July	2.58	2.13
August	2.41	2.18
September	2.78	2.43
October	3.08	2.61
November	3.98	3.61
December	4.40	4.29
Average	3.60	3.31
Standard Deviation	± 0.9262	± 1.0161

At the onset of summer monsoon in June, the water content rises abruptly to 78.90% and the calorific value drops abruptly to 2.21 K.cal/gm. During July and August, when the water content shows slight increase, the calorific value remains at about this low level. It starts increasing only when the water content shows a decreasing trend

in September. From September onwards the calorific values rise steadily.

b) Seasonal variation of organic constituents in the component parts of M. senhousia.

Giese (1969) has pointed out the drawbacks in treating the entire animal as a single unit in biochemical studies. For one thing, the procedure introduces some confusion when the animal contains an ample digestive tract, unless it is first starved and the method is adequate only when a particular constituent is of special interest. For a study of the physiology of an animal, the biochemical constitution of each of the component organs of the body is more informative than analysis of the entire body.

From this point of view, the molluscan body can be divided into a number of units such as the foot, the mantle, the gonad and the adductor muscles, etc. Ideally all these units must be analysed separately and in detail. In the present study, however, analysis has had to be limited to two component organs, namely, the gonad and the adductor muscle. These two components constitute a major proportion of the body in M. senhousia. The objective in their detailed analysis was to find out whether the seasonal variations in their biochemical constituents compare with the variations in the body treated as a whole.

Water content in the gonad: From January to May, the water content in the gonad shows a slight decrease from 75.17% to 74%. (Table-XV, Pl.7, fig.1).

TABLE - XV

Seasonal variation of water content in the gonad

Months	% water/gm. wet weight
January 1973	75.17
February	75.00
March	74.89
April	74.23
May	74.00
June	80.13
July	80.56
August	83.20
September	77.08
October	78.56
November	78.80
December	78.05
Average	77.43
Standard Deviation	±4.64

Thus the water content is about 3% higher than that for the entire body during the same period, but the trend compares with that of the whole body in being more or less steady at certain level. In June, there is a sharp increase

in water content to 80.13% and by August it has reached 83.10%. This is obviously due to the lowering of salinity during the monsoon season. From August onwards there is a decline in the water content. By October it has come down to 78.56% and remains at about that level for the rest of the year.

Glycogen content in the gonad: During the pre-monsoon period from January to April, the glycogen value of the gonad increases from 4.80% to 5.63%, the latter being the maximum value observed for the gonad in M. costa (Table-XVI, Pl.7, fig.2).

TABLE - XVI

Seasonal variation of glycogen in the gonad

Months	% glycogen/gm. Dry weight
January 1973	4.80
February	5.12
March	5.58
April	5.63
May	4.01
June	2.18
July	2.06
August	2.01
September	3.11
October	3.85
November	4.01
December	3.60
Average	3.83
Standard Deviation	± 2.95

During June to July at the onset of the summer monsoon, the glycogen value plunges to about 2% and continues at that level through August; thereafter in response to lowering of water level the value rises to a second peak of about 4% in November. In December the value falls to 3.60%

Protein content in the gonad: Protein is remarkable in that in the gonad it shows a trend similar to that in the body entire (Table-XVII, Pl.7, fig.3), while in the latter, protein shows a clear inverse relationship with water content, rising when the latter is low and falling when the latter is high.(Pl.8a)

TABLE - XVII

Seasonal variation of protein in the gonad

Month	% protein/gm. dry weight
January 1973	56.23
February	57.01
March	58.43
April	58.75
May	59.08
June	60.00
July	60.63
August	55.13
September	63.66
October	69.79
November	74.20
December	66.26
Average	60.01
Standard Deviation	± 8.10

In the gonad there is no such clear-cut relationship between water and protein contents. During January to May, protein content rises from 56.23% to 69.06%. In June, at the onset of the monsoon, the protein content shows a sharp plunge to 30%, but thence forward through the rest of the monsoon period, spawning and post-spawning stages, protein content in the gonad continues to rise until it reaches a maximum value of 74.20% in November. In December, it falls to 68.26%.

Fat content in the gonad: Fat values of the gonad rise from 5.12% in January to the maximum value of 6.8% in February (Table-XVIII, Pl.7, fig.A).

TABLE - XVIII

Seasonal variations of fat in the gonad

Months	% Fat/gm. dry weight
January 1973	5.12
February	6.80
March	6.00
April	6.12
May	6.06
June	4.13
July	4.10
August	3.47
September	1.82
October	1.70
November	1.92
December	2.10
Average	4.11
Standard Deviation	± 1.82

In March, the value falls to 6% and remains more or less at that level during April and May. It plunges down to 4.13% in June at the onset of monsoon. The value remains at about that level for July also. During September the value decreases to 1.82%. Thenceforth, in October, the value falls. In November and December, however, it registers a slight increase.

Calorific value in the gonad: The calorific value of the gonad does not vary as greatly as that of body entire. The minimum value (experimental) is 3.09 K.cal/gm and the maximum is 4.68 K.cal/gm. (Table-XIX, Pl.7, fig.6).

TABLE - XIX

Seasonal variation of the calorific content in the gonad

Months	K.cal/gm dry weight	
	(calculated) Values	(experimental) values
January 1973	3.89	3.10
February	4.10	4.10
March	4.13	4.13
April	4.16	4.01
May	4.10	4.01
June	3.33	3.09
July	3.36	3.30
August	3.86	3.87
September	3.93	3.27
October	4.30	4.12
November	4.28	4.68
December	4.24	3.98
Average	3.972	3.686
Standard Deviation	± 0.2237	± 0.4667

The value is 3.10 K.cal/gm in January, but rises to and remains steady at about 4 K.cal/gm during February to May. At the onset of the monsoon in June, the value falls to a minimum of 3.09 K.cal/gm, but in August it rises to 3.87 K.cal/gm and continues to rise in the succeeding months to the maximum value of 4.66 K.cal/gm in November. In December the value falls to 3.98 K.cal/gm.

Water content in adductor muscles: From January to May the water content in the adductor muscles varies from 71.05% to 69.98%. (Table-XX, Pl.9, fig.1).

TABLE - XX

Seasonal variations of water content in the adductor muscles

Months	% water/gm. Wet weight
January 1973	71.06
February	71.00
March	70.38
April	70.01
May	69.98
June	77.00
July	80.20
August	80.15
September	76.00
October	76.04
November	76.00
December	73.00
Average	74.06
Standard Deviation	± 17.00

The water-content compares well with that for the body entire during the same period. As in the case of the

gonad and the body entire, from June onwards the water-content in the adductor muscles is on the rise, reaching a maximum of about 80% in July and August. Thereafter, in September and October, the water content falls to about 75%, and it remains at that level during November also. In December, the value falls to 73%

Glycogen content in the adductor muscles: With respect to the glycogen content in the adductor muscles, the year can be divided into two distinct periods - a pre-monsoon period during which the value is falling steadily and a post-monsoon period during which the value is rising equally steadily.

TABLE - XXI

Seasonal variation of glycogen in the adductor muscles

Months	% glycogen/gm. dry weight
January 1973	3.80
February	3.01
March	2.86
April	2.27
May	2.15
June	1.63
July	0.98
August	0.87
September	2.71
October	3.27
November	3.85
December	2.88
Average	2.46
Standard Deviation	± 1.46

The value attains a minimum (ca.1%) during the monsoons and maximum (3.85%) during November (Table-XXI, Pl.9, fig.2)

Protein content in the Adductor muscles: Variations in protein content paralled those of glycogen with a pre-monsoonal period during which the value falls steadily and here the fall continues steadily to 44.33% up to the end of the south-west monsoon, and post-monsoon period during which the value rises to a maximum of 63.30%. (Table-XXII, Pl.9, fig.3).

TABLE - XXII

Seasonal variations of protein in the adductor muscles

Months	% Protein/gm. Dry weight (P = Total nitrogen x 6.25)
January 1973	61.56
February	59.00
March	58.09
April	57.06
May	56.31
June	50.69
July	48.32
August	44.33
September	55.69
October	59.19
November	62.92
December	63.30
Average	56.42
Standard Deviation	± 5.830

Fat content in the adductor muscles: Fat value rises from January (4.18%) to May (6.05%). It decreases to 0.72% in June and continues to fall to 0.4% in August (Table-XXIII, Pl.9, fig.4).

TABLE - XXIII

Seasonal variation of fat in the Adductor Muscles

Months	% Fat/gm. dry weight
January 1973	4.18
February	4.49
March	5.19
April	5.86
May	6.05
June	0.72
July	0.66
August	0.40
September	2.10
October	2.41
November	3.01
December	3.83
Average	3.21
Standard Deviation	± 1.93

Calorific value of the Adductor Muscles: The calorific values (experimental) show a progressive increase from 3.08 to 3.78 K.cal/gm during January to April. In May,

it falls to 2.41 K.cal/gm and continues at about that level without significant variations until September when it starts rising and comes to 3.85 and 3.91 K.cal/gm in November and December. (Table-XXIV, Pl.9, fig.8).

TABLE - XXIV

Seasonal variations of calorific content in the edible mussels

Months	K.cal/gm dry weight	
	(Calculated value)	(Experimental value)
January 1973	4.06	3.06
February	3.91	3.42
March	3.92	3.57
April	3.90	3.75
May	2.73	2.41
June	2.97	2.80
July	2.86	2.63
August	2.64	2.41
September	3.84	3.19
October	3.73	3.49
November	4.06	3.86
December	4.09	3.91
Average	3.86	3.2926
Standard Deviation	± 0.186	± 0.5329

e) Seasonal variations of ions in the body entire of H. spatula.

In view of the relative paucity of information on the distribution of trace elements in Holuroea, as part of the present investigation of the chemical composition of H.spatula, a series of analyses of the body entire with respect to seasons were undertaken. The elements chosen for the study were iron, copper, calcium and magnesium. The levels of various elements are expressed in terms of percentage dry weight.

Ash: The ash value expressed as percentage of dry weight varies from 5.76% in June at the beginning of the south-west monsoon to 6.35% in November just before the beginning of the north-east monsoon (Table XXV, Fig.D, fig.1). The range in ash value is not as great as the range in organic constituents. The monsoons with their effect of raising the water level of the body do not seem to have as great an effect on the inorganic constituents.

TABLE - XIV

Seasonal variation of ash in the body entire of H.canis

Months	%ash/gm dry wt.	Range	Standard deviation	%ater/gm. wet weight
January 1973	6.28	6.22-6.32	± 0.043	72.68
February	6.24	6.20-6.28	± 0.037	71.10
March	6.34	6.32-6.36	± 0.017	70.98
April	5.86	5.86-5.86	± 0.0048	70.93
May	5.89	5.85-5.92	± 0.029	70.86
June	5.76	5.66-5.81	± 0.057	78.90
July	5.80	5.75-5.87	± 0.053	80.25
August	6.23	6.2 -6.5	± 0.0205	80.37
September	6.29	6.26-6.35	± 0.040	78.10
October	6.25	6.23-6.28	± 0.024	75.04
November	6.35	6.32-6.38	± 0.022	75.00
December	6.30	6.00-6.30	± 0.082	73.08
Average	6.12			74.89
Standard deviation	±0.214			± 3.56

* Data are based on the analyses of three samples of H. canis.

Iron: The pattern of distribution of iron seems to be closely related to the monsoons. It is highest during the south-west monsoons (June to August), being of the order of 0.1126 to 0.1163% (Table-XXVI, Pl.10, fig.2). During the pre-monsoon and post-monsoon periods, the values are considerably low, being not more than 0.1065%. A slight increase in the iron content is observed during the winter monsoon also, the average value being around 0.1086%. The relation between iron content and salinity is clear. When the salinity is at its lowest (0.30%.), during August, the iron content is at its highest with a value of 0.1163%. When the salinity is at its maximum (36%.) in April, the iron content is at its minimum, being 0.0136%.

TABLE - XXVI

Seasonal variations of iron in the body entire of *M. senhousia*

Months	%Iron/gm dry wt.	Range	Standard deviation	Salinity ‰
January 1973	0.1009	.1002-0.1016	± 0.00065	33.0
February	0.1004	.1002-0.1009	± 0.00032	32.4
March	0.0261	.0254-0.0268	± 0.00055	34.4
April	0.0134	.0130-0.0139	± 0.00046	35.0
May	0.0174	.0169-0.0181	± 0.00064	23.3
June	0.1136	.1123-0.1131	± 0.00032	13.26
July	0.1280	.1270-0.1292	± 0.00089	6.88
August	0.1663	.1648-0.1671	± 0.00054	2.30
September	0.1033	.1021-0.1031	± 0.00056	23.4
October	0.1045	.1038-0.1051	± 0.00055	28.9
November	0.1078	.1070-0.1086	± 0.00063	30.0
December	0.1006	.1078-0.1097	± 0.00064	20.2
Average	0.008			
Standard deviation	± .044			

• Data are based on three samples of *M. senhousia*.

Copper: The value of copper is lower than that of iron throughout the year (Table-XVII. Pl.XD, fig.3) and the pattern of its seasonal variation parallel that of iron. Copper also shows its maximum value at the height of the south-west monsoon when the salinity is at its lowest. The maximum value of copper, 0.013%, is obtained in August when salinity is at its minimum of 2.3%. and the minimum copper value of 0.002% is obtained during April when the salinity is at a maximum of 38%. As in the case of iron, there is a slight increase in the value of copper during winter monsoon also.

TABLE - XXVII

Seasonal variation of copper in the body entire of *M. smithi*

Months	Copper/ gm. dry wt.	Range	Standard deviation	Salinity ‰
January 1973	0.009	.018-.001	± .0078	33.0
February	0.009	.011-.007	± .0017	32.4
March	0.007	.018-.001	± .0065	34.4
April	0.003	.0029-.0018	± .0018	35.0
May	0.012	.019-.005	± .0059	23.3
June	0.016	.018-.009	± .0040	13.28
July	0.016	.018-.013	± .0024	6.82
August	0.018	.028-.008	± .0062	2.30
September	0.013	.021-.007	± .0060	23.40
October	0.010	.010-.016	± .0023	28.90
November	0.012	.016-.009	± .0029	30.0
December.	0.010	.013-.008	± .0021	29.20
Average	0.010			
Standard deviation	± .005			

* Data are based on three samples of *M. smithi*

Calcium: The relation between the monsoon and the concentration of ions in the tissues of M.dussumieri is reversed in the case of calcium. At the height of the south-west monsoon, the calcium content is generally at its lowest (Table-XXVIII, Pl.XI, fig.4). The minimum value of calcium, 0.106% being observed in July. The maximum value of 0.670% is obtained during May. Calcium, however, does not show as clear-cut a relationship to salinity as does iron and copper, while the latter two give their maximum values during August when the salinity is at its minimum. Calcium shows its maximum value during May when the salinity is considerably lower than its maximum value.

TABLE - XXVIII

Seasonal variation of calcium in the body entire of *M. smithi*

Months	%Calcium/ gm.dry wt.	Range	Standard deviation	Salinity ‰.
January 1973	0.312	.309-.315	±.0029	33.0
February	0.637	.631-.649	±.0063	32.4
March	0.645	.638-.650	±.0063	34.4
April	0.665	.650-.668	±.0132	36.0
May	0.670	.660-.681	±.0060	23.3
June	0.206	.200-.218	±.0062	13.28
July	0.106	.096-.119	±.0093	6.82
August	0.216	.207-.227	±.0061	2.30
September	0.229	.206-.241	±.0163	23.40
October	0.230	.201-.257	±.0366	30.90
November	0.263	.210-.268	±.0263	40.00
December	0.267	.231-.291	±.0259	30.20
Average	0.360			
Standard deviation	± .207			

* Data are based on three samples of *M. smithi*.

Magnesium: The relationship between calcium and magnesium is the same as in the case of iron and copper. Although the absolute values of magnesium are lower than those of calcium in the corresponding months, the variation of magnesium during the year parallels that of calcium. Magnesium values are at their lowest just after the south-west monsoon (Table-XXIX, Pl.XI, fig.6), the value in September being 0.060%. The highest value of 0.234% is obtained in April when the salinity is at its highest.

TABLE - XXIX

Seasonal variation of Magnesium in the body entire of *M. gadia*.

Months	Magnesium/ gm. dry wt.	Range	Standard deviation	Salinity ‰
January '73	0.060	.125-.061	± .029	33.0
February	0.202	.265-.176	± .038	32.4
March	0.113	.161-.090	± .020	34.4
April	0.234	.234-.198	± .049	36.0
May	0.166	.191-.151	± .017	23.3
June	0.090	.120-.068	± .022	13.28
July	0.038	.066-.018	± .019	6.62
August	0.107	.131-.091	± .017	2.30
September	0.060	.069-.039	± .016	23.40
October	0.063	.081-.043	± .016	28.90
November	0.066	.081-.051	± .020	30.00
December	0.094	.108-.079	± .0068	20.70
Average	0.113			
Standard deviation	± .069			

*Data are based on the analyses of three samples of *M. gadia*

SALINITY TOLERANCE OF M. CASTA

As pointed out earlier, the environment of the clam bed outside the Cochin gut is particularly a variable one. For most of the year the water over the clam bed maintains a salinity not lower than that of brackish water. But wide variations of salinity do occur owing to the influence of fresh water discharge from the Ernakulam channel especially during the south-west monsoon period. This being the case, the violent fall in salinity caused by the south-west monsoon should pose a critical problem to the clams. The clams subjected to such a wide range of salinity should have developed an efficient salinity tolerating mechanism for survival. A series of experiments were conducted in the laboratory to investigate the degree of tolerance attained by the clam, M.casta.

Salinity tolerance of Tapes nuralis was studied by Blum (1922). Atwood and Johnson (1934) have conducted similar experiments on Donkia squilla. Some observations on the salinity tolerance of M. casta were made by Abraham (1953). A decrease in activity of Macrobia alleata in salinities below 6‰ was noted by Nagabhushanam (1956). Experiments on the salinity tolerance of marine and brackish water lamellibranchs have been conducted by Davis (1950) and Stickney (1964). Several other bivalve species have been studied by Schleiper et al.(1960) and Neuhoft (1961).

Vernberg et al.(1963) observed that altered salinity differentially influenced the lethal limits of isolated gill sections from various molluscs occupying different estuarine habitats. Cheriyan (1966) studied the salinity tolerance of Mausitiorn hadleri. Balaparameswara Rao and Ganapathi (1972) noted that sea water of salinities below 20.84‰ and above 37.39‰ are critical to the limpet Collisma radiata. Sundaram and Sheffie (1975) studied the salinity tolerance of Crassostrea madrasensis, Meretrix meretrix and Perna viridis collected from the Ennore estuary. A detailed study of the adaptability of M. casta to different salinities has not been studied so far.

Tables XXX - XXXV give the data on the salinity tolerance studies carried out on 3 different size groups of M. casta, during the present investigation.

It can be seen that in the small clams (Table XXX), 100% mortality occurred in four days' time in fresh water medium, whereas the medium sized and large clams did not survive the same for not more than three days. In water of salinity 5‰, the small clams survived without any mortality for three days. But mortality began to take place on the fourth day and at the end of the tenth day, 73.30% of the clams died.

TABLE - XXX

Rate of mortality of *M. casta* in salinities ranging from 0‰ to 40‰. (small clams 8-15 mm.in length)

No.of days.	Salinity in ‰.								
	0	5	10	15	20	25	30	35	40
1	20.00	-	-	-	-	-	-	-	-
2	13.33	-	-	-	-	-	-	-	-
3	26.66	-	-	-	-	-	-	-	-
4	13.33	26.66	-	-	-	-	-	-	-
5	-	6.66	-	-	-	-	-	-	-
6	-	6.66	13.33	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-
8	-	13.33	20.00	6.66	-	-	-	-	-
9	-	13.33	6.66	13.33	-	-	-	-	-
10	-	6.66	6.66	13.33	13.33	-	-	-	-
11	-	-	6.66	6.66	-	-	-	-	-
12	-	-	-	-	6.66	13.33	-	-	20.00
13	-	-	-	-	6.66	-	-	13.33	13.33
14	-	-	-	-	-	13.33	6.66	6.66	13.33
15	-	-	-	-	6.66	-	13.33	13.33	13.33
Total % mortality	99.98	73.30	53.31	39.98	33.31	26.66	19.99	33.32	80.00

In the medium sized clams (Table-XXX) mortality was initiated on the first day itself and it continued up to the sixth day in water of salinity 5‰. 20.02% of the clams survived the period of observation.

TABLE - XXXI

Percentage mortality of H. costa in salinities ranging from 0‰ to 40‰.. (Medium sized clams: 20-30 mm. in length

No.of days	Salinities in ‰								
	0	5	10	15	20	25	30	35	40
1	83.33	40.00	-	-	-	-	-	-	-
2	33.33	13.33	-	-	-	-	-	-	-
3	13.33	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-
5	-	6.66	-	13.33	-	-	-	-	-
6	-	19.99	26.66	13.33	6.66	-	-	-	-
7	-	-	13.33	19.99	13.33	-	-	-	-
8	-	-	6.66	6.66	6.66	-	-	-	-
9	-	-	-	-	-	-	-	-	-
10	-	-	13.33	-	-	-	-	-	13.33
11	-	-	-	-	-	6.66	-	-	19.99
12	-	-	-	-	13.33	6.66	-	19.99	-
13	-	-	-	-	-	19.33	13.33	6.66	19.99
14	-	-	-	-	-	6.66	13.33	13.33	6.66
15	-	-	-	-	-	-	6.66	-	6.66
Total Mortality	99.99	79.98	99.98	92.31	99.98	93.31	93.32	99.98	96.63

But in the same salinity complete mortality occurred for the large sized clams (Table-XXXI) by the end of the fourth day.

TABLE - XXXII

Rate of mortality of *M. gaudichaudii* in different salinities ranging from 0‰ to 40‰ (Large clone; 32-36 mm. in length)

No. of days.	Salinities in ‰.								
	0	5	10	15	20	25	30	35	40
1	53.33	53.33	-	-	-	-	-	-	-
2	33.33	26.66	26.66	-	-	-	-	-	-
3	13.33	6.66	13.33	-	-	-	-	-	-
4	-	13.33	-	19.99	-	-	-	-	-
5	-	-	-	6.66	-	-	-	-	-
6	-	-	19.99	6.66	13.33	-	-	-	-
7	-	-	6.66	-	13.33	-	-	-	-
8	-	-	-	13.33	6.66	-	-	-	-
9	-	-	-	13.33	6.66	6.66	-	-	33.33
10	-	-	-	-	-	6.66	-	-	-
11	-	-	-	-	-	13.33	-	-	19.99
12	-	-	-	-	-	6.66	-	-	13.33
13	-	-	-	-	-	6.66	13.33	19.99	-
14	-	-	-	-	-	-	6.66	6.66	6.66
15	-	-	-	-	-	-	6.66	---	--
Total Mortality	99.00	99.99	66.64	99.97	99.99	39.97	26.65	26.65	74.31

For the small and medium sized clams there was no mortality at the end of the fifth day in 10‰ salinity, and 46.69% and 40.02 of the clams respectively survived the period of observation. In the same salinity, mortality began to take place on the second day and 33.36% of the large clams survived. Small sized clams in water of salinity 15‰ did not show any mortality till the end of the seventh day and 60.02% of the clams were able to tolerate this salinity and survived for eleven days. In medium and large sized clams there was no mortality for three days, 46.69% and 40.03% of the clams respectively survived in the same salinity. In 20‰ salinity there was no mortality at all for small clams during the first nine days of the experiment and at the end of the period of experiment, 66.69% were found to tolerate the medium. Medium sized and large clams did not exhibit any mortality for the first five days and at the end of fifteen days, 60.02% of them tolerated 20‰ salinity medium. There was no mortality for the small sized clams for the first eleven days in 25‰ salinity; 73.34% of them tolerated the period of observations in the medium. In the same medium medium sized clams survived for ten days and at the end of the period, 66.69% of them were found to tolerate the medium and survived. Large sized clams also showed almost the same pattern of tolerance, 60.03% of them surviving at the end of the period. 80.01% of small clams tolerated 30‰ salinity for fifteen days, there being no mortality at all for the

first twelve days of the experiment and 66.69% of them tolerated 30‰ salinity medium. In the same medium all the large clams survived the first twelve days of the experiment and at the end of fifteen days, 73.35% of them were alive. Small clams showed appreciable tolerance to water of salinity 35‰. Mortality started only on the thirteenth day and at the end of the fifteenth day 66.68% were found to have survived. In the case of medium sized clams mortality started on the twelfth day and at the end of the period of observation, 60.02% were alive. 73.35% of large clams tolerated 35‰ salinity medium. 40.01% of small clams survived the fifteen-day period in 40‰ salinity. In the same salinity, medium sized clams underwent mortality from the tenth day and only 33.37% of them survived. Large clams showed a lesser degree of tolerance; mortality beginning on the ninth day and only 25.69% of them survived the fifteen-day period.

Table-XXXIII shows that small clams tolerate salinities ranging from 6‰ to 10‰. It can also be seen from the Table that there was not more than 50% mortality in salinities upto 7‰. In the next lower salinity, survival was only 40%.at the end of ten days. In the succeeding salinities of 5‰, 4‰, and 3‰, rate of mortality increased to 70%, 80% and 100% respectively, thereby indicating that the lethal salinity for small clams is 6‰.

TABLE - XXXIII

Determination of lower lethal limit of salinity of M.gaeta in salinities ranging from 10‰ - 3‰ (small clams)

No. of days.	Salinities in ‰							
	3	4	5	6	7	8	9	10
1	10	-	-	-	-	-	-	-
2	20	-	-	-	-	-	-	-
3	20	20	-	-	-	-	-	-
4	10	10	20	20	10	10	-	-
5	40	-	10	-	-	20	20	20
6	-	-	10	20	30	10	10	10
7	-	20	-	10	10	-	20	10
8	-	-	10	-	-	10	-	10
9	-	10	20	-	-	-	-	-
10	-	20	-	10	-	-	-	-
Total Mortality	100	80	70	60	50	50	50	50

Table-XXXIV shows the trend of mortality of medium sized clams in different salinities varying from 15‰ to 4‰. It is clear from the table that 50% of the clams could withstand low salinities upto 11‰. In 10‰ and 9‰ salinities 60% of the clams perished. In 8‰, 7‰ and 6‰ salinities there was 70% mortality and in 5‰, 80%. In the lowest salinity of 4‰, 100% of the clams perished at the end of the third day. This shows that the lethal salinity for

medium sized clams is 10%.

TABLE - XXXIV

Determination of lower lethal limit of salinity of M.casta (medium sized clams) in salinities ranging from 15%. to 4%..

No.of days.	Salinities in %.											
	4	5	6	7	8	9	10	11	12	13	14	15
1	30	30	-	-	-	-	-	-	-	-	-	-
2	30	20	-	-	-	10	-	-	-	-	-	-
3	40	-	40	30	-	-	-	-	-	-	10	-
4	-	-	20	20	20	10	-	20	-	10	-	-
5	-	20	-	10	20	20	30	10	20	10	20	10
6	-	10	10	-	10	10	10	10	10	-	10	20
7	-	-	-	10	10	10	20	-	-	20	10	-
8	-	-	-	-	10	-	-	10	20	10	-	10
9	-	-	-	-	-	-	-	-	-	-	-	10
10	-	-	-	-	-	-	-	-	-	-	-	-
Total % mortality.	100	80	70	70	70	70	60	60	60	60	60	60

Table-XXXV shows the tolerance of large clams in salinities ranging from 15%. to 7%.. It may be seen from the table that there was not more than 60% mortality in 15%. and 14%. salinities. In 13%. and 12%. salinity, mortality was 60% and clams could not survive in 11%., 10%, and 9%. salinities. Twenty per cent of the clams survived the ten-day period in 8%. salinity and 100% of the clams perished at

the end of the fourth day in 7‰ salinity. This shows that the lethal salinity for large clams is 13‰.

TABLE - XXXV

Determination of lower limit of lethal salinity of M.casta (large) in salinities ranging from 15‰ to 7‰.

No.of days	Salinities in ‰.								
	7	8	9	10	11	12	13	14	15
1	30	10	-	-	10	-	-	-	-
2	10	10	10	-	20	-	-	-	-
3	30	30	20	20	-	10	20	-	-
4	30	30	30	10	10	30	-	10	20
5	-	-	10	30	30	10	20	20	-
6	-	-	-	10	-	-	10	10	10
7	-	-	-	-	-	10	-	-	10
8	-	-	-	-	-	-	10	-	10
9	-	-	-	-	-	-	-	10	-
10	-	-	-	-	-	-	-	-	-
Total mortality	100	80	70	70	70	60	60	60	60

OXYGEN CONSUMPTION IN M. CASTA

Oxygen utilisation is a measurement of energy metabolism of an organism. Though considerable amount of data has accumulated on the oxygen consumption in a wide range of organisms from bacteria through protozoans to large mammals, investigations in certain groups have remained quite insufficient. Mollusca is perhaps the most diverse in form and physiology than any other invertebrate phylum. Among molluscs, Bivalvia is known to show greatest variability in respiratory rate.

The rate at which organisms consume oxygen is modified by both environmental and intra-organismic factors and not all animals are influenced in the same manner. Therefore it is difficult to generalise, and hence oxygen consumption in relation to various influencing factors, should be determined for each species.

The influence of body weight on the rate of oxygen consumption has been reported by many authors in diverse animal groups. In general, the metabolism has been shown to be proportional to a fractional power of the body. If O_2 is the total metabolism or oxygen consumed per unit time W, the body weight, then

$$O_2 = aW^b \text{ or, } \log O_2 = \log a + b \log W$$

The formula implies that for a constant value of

a and b there is a linear relationship between log O_2 and log W. The constant a denotes the level of logarithmic regression line (intercept on y axis or metabolism axis) and b gives the slope of logarithmic regression line (i.e., the rate at which oxygen consumption changes with size). The weight specific metabolic rate or rate of oxygen consumption per unit weight of tissue per unit time is expressed (as pointed out by Bertalanffy, 1957) by the modified form

$$\frac{O_2}{W} = a\, W^{(b-1)} \text{ or, } \log \frac{O_2}{W} = (b-1) \log W + \log a$$

Significant contributions on the size dependence of oxygen consumption in poikilotherms are by Weymouth et al. (1944), Zeuthen (1953, 1955), Prosser (1955), Bertalanffy (1957), Hemmingsen (1960), Kleule and Ludwig (1956), Kruger (1960), Kuenzler (1961), Read (1962), Von Brand et al. (1968). More recently size dependence in oxygen consumption has been shown in the gastropod Turbo intercostalis (Menke) by Ganapati and Rama Sastry (1973) and in the bivalves Gonaria gallaei (Reclus), Donax vittatus (da costa) and Cardium edule by Mangapathi Rao et al. (1974), Ansell (1973) and ela Vahl (1972) respectively.

Biological significance of b value has been discussed by most of the authors. Bertalanffy (1957) postulated the existence of three metabolic types, according to the relationship between metabolic rate and body size, first with metabolic rate proportional to surface area in compliance

with surface area rule, when b value is 0.67, second with metabolic rate proportional to weight when b value is 1 and the third type with metabolic rate intermediate between proportionality to weight and surface area. Clams according to him belonged to the first metabolic type when oxygen consumption per unit weight decreases with increase in body size but remains constant per unit surface (2/3 body weight). In some molluscs b is about 0.67 (Von Brand et al., 1948; Bathamwe 1956). But great variations have been shown to exist and the value for b has been found to vary from 0.45 to 1.00, i.e., less than proportional to surface to nearly directly proportional to weight (Kleule and Ludwig, 1956; Kruger, 1960; Kuenzler 1961; Read 1962; Mangapathi Rao et al.1974; Ansell 1972; Ganapati and Rama Sastry 1972; Olewahl, 1972).

That in molluscs the oxygen uptake is influenced by the osmotic pressure of the environment has been reported by a number of investigators. Their responses to salinity changes are not however uniform. Schlieper(1929) observed that the gills of Mytilus edulis have a higher respiration rate in more dilute media while both Bouxin (1931) and Maloeuf (1938) arrived at a different conclusion observing a decrease in the oxygen consumption in hypo and hypertonic sea water. Hopkins (1946) and Schlieper (1929) showed that isolated gills of Venus mercenaria when transferred from sea water to isotonic NaCl showed an increase in oxygen

consumption. Hiscock(1963) studied the oxygen consumption in Hydrilla australis and found that oxygen consumption decreases as the chloride concentration of the external medium rises from 0.25 to 5.0 ml. Lumbye(1966) found that Theodoxus fluviatilis living in brackish and fresh water has the same oxygen consumption in 11‰ salinity or in fresh water. But in Potamopyrgus jenkins which also occurs in both habitats the above author found that animals from brackish water have a greater oxygen uptake than those from sea water. More recently Kanada(1973) studied the effect of salinity on the oxygen consumption of clams. He observed an increase in oxygen consumption of Katelysia opima with decrease in salinity from 30‰ to 6‰. He further observed that in the case of Meretrix meretrix, changes from 30‰ to 6‰ has little effect on the oxygen consumption.

From the preceding review it is obvious that in molluscs there is diversity with regard to their size related respiration and does not stick to a general pattern. It is also evident that molluscs in general and bivalves in particular behave differently with regard to their oxygen consumption in various salinity media.

These aspects of M. gaimardi, which have so far been ignored, have been examined.

a. Oxygen consumption in relation to body weight in 5‰ salinity.

Oxygen uptake and metabolic rate for different

sizes of M. costa are given in Table-XXXVI. Oxygen consumption and metabolic rate varied from 0.1230 ml.O_2/hr. to 0.8218 ml.O_2/hr. and from 1.7382 to 0.5721 ml.O_2/hr./gm respectively, depending on the size of the animal. Body weights for 16 animals used for the experiments ranged from 0.0711 gm. to 0.8913 gm.

When the logarithms of body weight were plotted against the logarithms of the oxygen consumption, the points were found to cluster around a straight line with positive slope (Pl.11, fig.1). Hence the model $\log O_2 = \log a + b \log W$ was used.

This is derived from the allometric form $O_2 = aW^b$, where O_2 is the hourly oxygen consumption and W is the wet flesh weight in grams. a and b are constants and give the level of the regression line (intercept on the metabolism axis) and slope of the regression line respectively.

But the log metabolic rate, i.e., the oxygen uptake per unit body weight per hour when plotted against the log weight was showing a downward linear trend (Pl.11,fig.2). Thus the form $\log O_2 - \log W = \log a + b \log W - \log W$ leading to $\frac{O_2}{W} = aW^{b-1}$ was used to study the relationship between metabolic rate and body weight. In both the cases the constants a and b were estimated using the method of least squares.

TABLE -XXXVI

Oxygen consumption and metabolic rate in relation to body weight in *M. gaimardi* acclimated in 6‰ salinity.

Sl. No.	Weight of animal in gm.	Oxygen consumption ($ml.O_2/hr.$)	Metabolic rate ($ml.O_2/hr./gm$)
1	0.0711	0.1230	1.7299
2	0.0760	0.1321	1.7382
3	0.0860	0.1421	1.6167
4	0.1180	0.1536	1.3016
5	0.2218	0.1897	0.8552
6	0.3706	0.2716	0.7328
7	0.4171	0.2939	0.7046
8	0.5630	0.3221	0.5721
9	0.6179	0.3330	0.5360
10	0.6701	0.4112	0.6136
11	0.7211	0.4616	0.6401
12	0.7503	0.4960	0.6610
13	0.8284	0.5216	0.6319
14	0.8630	0.5201	0.6026
15	0.8721	0.4901	0.5619
16	0.8913	0.5100	0.5721

The calculated values for a, b and b-1 are -0.3426, 0.4237 and -0.5763 respectively.

b. <u>Oxygen consumption in relation to body weight in 10‰ salinity.</u>

Oxygen uptake and metabolic rate for 17 animals ranging in wet flesh weight from 0.0413 gm. to 0.7219 gm. in 10‰ salinity are given in Table-XXXVII. The oxygen consumption of the different sizes varied from 0.1730 to 0.6980 ml.O_2/hr. and the metabolic rate from 4.1388 to 0.7963 ml. O_2/hr/gm. The log oxygen uptake when plotted against body weight showed a highly positive correlation (Pl.11,fig.3) and log metabolic rate against log body weight showed a negative relation (Pl.11, fig.4) as in the previous case in 5‰ salinity. The calculated b value is 0.4276 and the estimate of a is -0.1514, b-1 value is -0.5724.

TABLE -XXXVII

Oxygen consumption and metabolic rate in relation to body weight in *M. cephia* acclimated in 10‰ salinity.

Sl. No.	Weight of animal in gm.	Oxygen consumption (ml.O_2/hr)	Metabolic rate (ml.O_2/hr/gm)
1	0.0418	0.1730	4.1388
2	0.0527	0.1890	3.5863
3	0.0569	0.2010	3.5307
4	0.0721	0.2521	3.4965
5	0.0782	0.2603	3.3298
6	0.0933	0.2500	2.6795
7	0.0971	0.3486	3.5901
8	0.2139	0.3902	1.8423
9	0.2517	0.3611	1.4346
10	0.3486	0.3723	1.0680
11	0.4419	0.5171	1.1702
12	0.4816	0.5210	1.0818
13	0.5219	0.5419	1.0383
14	0.5963	0.6206	1.0846
15	0.6260	0.5126	0.8162
16	0.7191	0.5719	0.7953
17	0.7219	0.5960	0.8284

c. <u>Oxygen consumption in relation to body weight in 15‰ salinity</u>.

The oxygen consumption and metabolic rate in 16

animals varied from 0.1293 to 0.5601 ml.O_2/hr.and from 3.4271 to 0.6734 ml.O_2/hr./gm, respectively, depending on the size of the animals (Table-XXXVIII). Wet flesh weight of the animals ranged from 0.0473 to 0.7721 gm. The estimate of b is 0.4636 and that of a is -0.1923 (Fl.12,figs.1 and 2). b-1 is -0.5364.

TABLE-XXXVIII

Oxygen consumption and metabolic rate in relation to body weight in M. *cephs* acclimated in 15‰ salinity.

Sl. No.	Weight of animal in gm.	Oxygen consumption (ml.O_2/hr)	Metabolic rate (ml.O_2/hr./gm.)
1	0.0473	0.1621	3.4271
2	0.0481	0.1293	2.6985
3	0.0517	0.1163	2.2504
4	0.0527	0.1408	2.6717
5	0.0958	0.2263	2.2634
6	0.1231	0.2760	2.2563
7	0.2741	0.2936	1.0719
8	0.2960	0.3723	1.2578
9	0.3016	0.4018	1.3322
10	0.4476	0.4623	1.0328
11	0.5283	0.5334	1.0097
12	0.5606	0.4926	0.8787
13	0.7103	0.5178	0.7290
14	0.7231	0.5107	0.7063
15	0.7360	0.4970	0.6734
16	0.7721	0.5601	0.7254

4. Oxygen consumption in relation to body weight in 20‰ salinity.

Oxygen consumption and metabolic rate varied from

0.1212 to 0.4361 ml.O_2/hr. and from 1.6136 to 0.4063 ml.O_2/hr./gm. as shown in Table XXXIX. 17 animals with range in wet weight from 0.0088 gm. to 0.8706 gm. were used for the experiment. The b value and b-1 value obtained are 0.4769 and -0.5231 respectively, while estimate for a is -0.4109 (Pl.12, figs.3 and 4).

TABLE - XXXIX

Oxygen consumption and metabolic rate in relation to body weight in M.maha acclimated in 20‰ salinity.

Sl.No.	Weight of animal in gm.	Oxygen consumption (ml.O_2/hr)	Metabolic rate (ml.O_2/hr/gm)
1	0.0828	0.1206	1.6136
2	0.0830	0.1218	1.3617
3	0.0880	0.1401	1.5064
4	0.1366	0.1696	1.2041
5	0.6350	0.1681	0.6516
6	0.3060	0.1925	0.6816
7	0.4102	0.2241	0.5463
8	0.5075	0.2960	0.5832
9	0.6763	0.3201	0.4719
10	0.7130	0.3380	0.4711
11	0.7297	0.3021	0.4140
12	0.7401	0.4361	0.5892
13	0.7828	0.3462	0.4838
14	0.7880	0.3113	0.4063
15	0.8132	0.3811	0.4657
16	0.8704	0.3732	0.4287
17	0.8706	0.4242	0.4872

e. Oxygen consumption in relation to body weight in 35‰ salinity.

18 animals ranging from 0.0340 to 0.6122 gm. gave a range in oxygen consumption from 0.0881 to 0.5671 ml.O_2/hr.

and in metabolic rate from 3.9718 to 0.8975 ml.O_2/hr./gm. (Table-XL). The b and b-1 values obtained are 0.5190 and -0.4820. The estimate for a is -0.1771 (Fig.13, figs.1 & 2)

TABLE - XL

Oxygen consumption and metabolic rate in relation to body weight in *M.gaimardi* acclimated in 25‰ salinity.

Sl.No.	Weight of animal in gm.	Oxygen consumption (ml.O_2/hr)	Metabolic rate (ml.O_2/hr./gm.)
1.	0.0210	0.0831	3.8708
2	0.0226	0.0832	3.2867
3	0.0255	0.1125	3.9718
4	0.0279	0.1392	3.8728
5	0.0488	0.1897	3.0676
6	0.0492	0.1528	3.0936
7	0.0542	0.1671	3.0773
8	0.0560	0.1512	2.7000
9	0.0561	0.1597	2.7457
10	0.0761	0.1800	2.2370
11	0.0782	0.1627	2.1382
12	0.0898	0.1695	1.8961
13	0.1410	0.2660	0.9007
14	0.2832	0.2917	1.0275
15	0.2921	0.2628	0.8998
16	0.5100	0.4968	0.9741
17	0.6806	0.6211	0.8975
18	0.6138	0.5671	0.9248

f. Oxygen consumption in relation to body weight in 30‰ salinity.

18 animals gave a range in the oxygen consumption from 0.0893 to 0.8728 ml.O_2/hr.and in metabolic rate from 3.9812 to 0.9063 ml.O_2/hr./gm. (Table-XLI). The wet weight

of the animals ranged from 0.0280 to 0.6190 gm. The b value is 0.5305 and b-1 value is -0.4696. a has a value of -0.1563 (Pl.13, figs.3 & 4).

TABLE - XLI

Oxygen consumption and metabolic rate in relation to body weight in M.edulis acclimated in 30‰ salinity.

Sl.No.	Weight of animal in gm.	Oxygen consumption ($ml.O_2/hr$)	Metabolic rate ($ml.O_2/hr./gm$)
1	0.0280	0.0893	3.1893
2	0.0298	0.0948	3.1812
3	0.0372	0.1161	3.9832
4	0.0481	0.1561	3.2468
5	0.0497	0.1512	3.0423
6	0.0561	0.1689	3.0107
7	0.0568	0.1543	2.7166
8	0.0590	0.1610	2.7288
9	0.0750	0.1695	2.2600
10	0.0782	0.1663	2.0997
11	0.0809	0.1715	1.9313
12	0.1429	0.2691	1.8831
13	0.3818	0.3948	1.0327
14	0.3929	0.3631	0.9242
15	0.5121	0.5010	0.9783
16	0.5824	0.5290	0.9083
17	0.6161	0.5719	0.9286
18	0.6190	0.5728	0.9254

5. Oxygen consumption in relation to body weight in 35‰ salinity.

In 17 animals examined in this salinity, oxygen consumption varied from 0.1190 to 0.8361 $ml.O_2/hr$, while metabolic rate varied from 1.9286 to 0.8493 $ml.O_2/hr/gm$. (Table XLII). The range in wet flesh weight of the animals is from

0.0815 to 0.8860 gm. The b, b-1 and a values are 0.7499, -0.2501 and -0.0175 respectively. (Pl.14, figs.1 & 2).

TABLE - XLII

Oxygen consumption and metabolic rate in relation to body weight in M.gaudichaudi acclimated in 35‰ salinity.

Sl.No.	Weight of animal in gm.	Oxygen consumption ($ml.O_2/hr$)	Metabolic rate ($ml.O_2/hr./gm$)
1.	0.0815	0.1120	1.3742
2	0.0857	0.1217	1.4201
3	0.0921	0.1306	1.4180
4	0.1249	0.2410	1.9296
5	0.2260	0.3819	1.6750
6	0.3349	0.4129	1.2329
7	0.3861	0.6265	1.6276
8	0.4642	0.8961	1.2841
9	0.5217	0.6646	1.2739
10	0.6710	0.6818	1.0161
11	0.7106	0.6526	0.9184
12	0.7268	0.8101	1.1150
13	0.7618	0.6917	0.9080
14	0.7665	0.6987	0.9423
15	0.8196	0.7790	0.9510
16	0.8315	0.8173	0.9829
17	0.8860	0.8361	0.9439

h. Oxygen consumption in relation to body weight in 40‰ salinity.

Oxygen consumption varied from 0.1483 to 0.9604 ml. O_2/hr. and metabolic rate from 3.4812 to 0.7473 $ml.O_2/hr/gm$, in 17 animals ranging from 0.0426 to 0.8208 gm. in wet flesh weight (Table-XLIII).

TABLE - XLIII

Oxygen consumption and metabolic rate in relation to body weight in *M.gaudichaudi* acclimated in 40‰ salinity

Sl.No.	Weight of animal in gm.	Oxygen consumption (ml.O_2/hr)	Metabolic rate (ml.O_2/hr/gm.)
1	0.0426	0.1483	3.4832
2	0.0666	0.1527	2.7027
3	0.0389	0.1625	2.7689
4	0.0813	0.1708	2.1009
5	0.0826	0.1774	2.1480
6	0.1132	0.2981	2.6334
7	0.2178	0.3014	1.3838
8	0.2643	0.2140	0.8062
9	0.4681	0.4296	0.9178
10	0.4923	0.3721	0.7558
11	0.5033	0.3974	0.7869
12	0.5178	0.5863	1.1323
13	0.6285	0.6178	0.9830
14	0.6800	0.6301	0.7472
15	0.7103	0.5966	0.8385
16	0.7214	0.9804	0.9670
17	0.9106	0.6806	0.7473

The b, b-1 and a values are 0.5136, -0.4864 and -0.1611 respectively (Pl.14, figs.3 & 4). The regression coefficients of the logarithms of oxygen uptake against the logarithms of body weight in different salinity media together

with corresponding log a and b-1 values are given in Table-XLIV.

TABLE - XLIV

Showing the regression coefficients of the logarithms of oxygen uptake against the logarithms of body weight in different salinity media together with corresponding log a and (b-1) values.

Salinity media in ‰	b-Values	log.a values	(b-1)values
5	0.4237	- .3426	- .5763
10	0.4276	- .1514	- .5724
15	0.4636	- .1923	- .5364
20	0.4769	- .4109	- .5231
25	0.5180	- .1771	- .4820
30	0.5305	- .1563	- .4695
35	0.7499	- .0176	- .2501
40	0.5136	- .1611	- .4864

The significance of difference among regression coefficients is verified using analysis of variance and the results are presented in Table-XLV.

TABLE - XLV

Analysis of variance showing the significance of regression coefficients obtained in eight salinity media.

Salinity in ‰	Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	F	Probability
5	Total	0.9069	16	-		
	Regression	0.4337	1	0.4337	12.8325	.006-.01
	Residual	0.4732	15	0.0338		
10	Total	0.7706	16	-		
	Regression	0.5902	1	0.5902	49.0897	< .001
	Residual	0.1804	15	0.0120		
15	Total	0.7969	16	-		
	Regression	0.7279	1	0.7279	149.9182	< .001
	Residual	0.0680	14	0.0049		
20	Total	0.5908	16	-		
	Regression	0.5423	1	0.5423	167.7118	< .001
	Residual	0.0485	15	0.0032		
25	Total	1.0454	17	-		
	Regression	1.0299	1	1.0299	1066.9434	< .001
	Residual	0.0154	16	0.0010		
30	Total	1.1958	17	-		
	Regression	1.1624	1	1.1624	556.8695	< .001
	Residual	0.0334	16	0.0021		
35	Total	1.4360	16	-		
	Regression	1.3020	1	1.3020	17.7064	.001-.002
	Residual	1.1029	15	0.0736		
40	Total	0.9845	16	-		
	Regression	0.9253	1	0.9253	13.0480	.006-.01
	Residual	1.0640	15	0.0709		

The slopes in the different media were then compared, using Analysis of Covariance method (Zar,1974) and the results are given in Table - XLVI.

TABLE - XLVI

Analysis of co-variance for testing the difference between slopes of regression lines obtained in each of the eight salinity media.

	Σx^2	Σxy	Σy^2	Residual sum of squares	Residual degrees of freedom.
Regression 1	5.5974	1.6681	0.9969	0.4722	16
Regression 2	3.2276	1.3882	0.7706	0.1804	16
Regression 3	3.3863	1.5700	0.7369	0.0660	16
Regression 4	2.3080	1.1373	0.5908	0.0486	16
Regression 5	3.9265	2.0012	1.0454	0.0154	16
Regression 6	4.1306	2.1922	1.1968	0.0334	16
Regression 7	2.3182	1.7862	1.4360	0.1340	16
Regression 8	3.8076	1.8016	0.9848	0.0692	16
Pooled Regression	-	-	-	1.0121	120
Common Regression	28.4404	13.3758	7.7259	1.4397	120
Total Regression.	83.4725	55.7229	42.3368	5.1231	136

The calculated value of F (7.2442) is found to be significant at 5% level (Table value of F at 5% for 7 and 120 degrees of freedom is 2.09) thereby showing that all the slopes are not equal. Hence a pair-wise comparison is called

for. A pair-wise comparison of the b values using students' t test shows that the b values obtained in 5‰ and 35‰, 10‰ and 35‰, 15‰ and 35‰, 20‰ and 35‰, 25‰ and 35‰, 30‰ and 35‰ and 35‰ and 40‰ salinity are significantly different at 5% level (Table-XLVII).

TABLE - XLVII

Results of pair-wise comparisons of regression coefficients obtained in different salinity media

Comparing media in ‰	t	Degrees of freedom.	Probability
5-10	0.0372	29	P > .50*
5-15	0.4169	28	P > .50*
5-20	0.5129	29	P > .50*
5-25	1.1193	30	.20 < P < .50*
5-30	1.2570	30	.20 < P < .50*
5-35	2.6890	29	.005 < P < .01
5-40	0.9743	29	.20 < P < .50*
10-15	0.8000	29	P > .50*
10-20	0.6610	30	P > .50*
10-25	1.5106	31	.10 < P < .20*
10-30	1.6679	31	.10 < P < .20*
10-35	3.6856	30	P > .001
10-40	1.2876	30	.20 < P < .50*
15-20	0.2462	29	P > .50*
15-25	1.3881	30	.10 < P < .20*
15-30	1.5697	30	.10 < P < .20*
15-35	4.6649	29	P > .001
15-40	0.9930	29	.20 < P < .50*
20-25	1.1007	31	.20 < P < .50*
20-30	1.2623	31	.20 < P < .50*
20-35	3.7838	30	P > .001
20-40	0.6681	30	P > .50*
25-30	0.4830	32	P > .50*
25-35	4.0841	31	P > .001
25-40	0.2838	31	P > .50*
30-35	3.6367	31	P > .001
30-40	0.4269	31	P > .50*
35-40	3.4774	30	.002 < P < .005

*Probability not significant at 5% level.

DISCUSSION

Growth and Spawning:

From the foregoing account it may be seen that the study of the rate of growth of M. gaeta presently undertaken is based on three different stocks, which have been obtained at three different times during the period of investigation. It is evident that the first stock which contributed to the initial sample taken on 1st March 1972 belonged to the 1971 year class. This stock continued to persist in the sample till September 1972 without showing any new recruitment during the period. From October 1972 to August 1973, the samples were constituted by an entirely different stock, there being no representation of the first stock at any time during the above period. Like the first stock the second stock also abruptly ceased to represent in the samples from September 1973 onwards. The samples obtained during the rest of the period of investigation were composed of a third stock, quite different from the first and the second. Of the above three stocks the duration of existence of the first was limited to eight months, that of the second to eleven months and the third to seven months. So far none of the stocks was found to show an uninterrupted representation in the samples from the beginning to the end, the second stock which had the maximum duration of existence was taken as a modal which can provide a complete picture

of the growth pattern of *M. gaudia* from the time of spawning till it completes nearly the first year of its life.

It may be seen from Table-III that the pattern of growth in all the three dimensions, viz., length, height and depth, is similar for all the stocks. Growth rate is phenomenally rapid during the early period of the clam's life. Thus the second stock which is the result of spawning of the first stock by the end of August 1972 shows an average increment of 5.92 mm. and 6 mm. during the first and second months of its life. Similarly the third stock registers an increment of 5.12 mm. and 5.53 mm. during the first and second months of its life respectively, indicating an average increment of 5.34 mm. per month. As growth progresses, the rate of increment in length as well as height and depth progressively decreases especially during the second half of its life. This points towards an exponential pattern of growth, which is guaranteed by the use of Von-Bertalanffy's growth model. As the clams approach sexual maturity, the decrease in rate of growth becomes very conspicuous. The minimum rate of growth coincides with spawning which normally occurs some time between August and September.

That the rate of growth of clams is very high during the early stages of their life and that it falls steadily as the organism approaches the maximum size of the species have been shown by many previous authors. Newcombe (1935)

observed this phenomenon in the soft shelled clam, Mya arenaria. A similar observation on the earlier rapid growth of Donax faba has been made by Alagaraswami(1966). Abraham (1933) and Durve(1970) have recorded a similar trend of growth in M. casta from the Adyar backwaters and Mandapam fish farm respectively.

Table-III shows that the second stock of clams which appeared in the sample of October 1972 as juveniles of average length 9.76 mm.,show the maximum length of 38.85 mm. by the end of August 1973, by which time they have completed nearly one year. The theoretical maximum length (l_∞) value as derived from Ford-Walford fit (Pl.4,fig.1) is found to be 42.18 mm.for the second stock. Since the difference between the theoretical maximum and the observed maximum is only 3.33 mm., it can be reasonably assumed that the clam, M. casta of the Cochin backwater attains the maximum size during the first year of its life itself. The rate of growth of this stock could not be traced further because they completely disappeared from the samples since August 1973. Whether they continued to survive or not is a matter of speculation.

The decrease in the rate of growth towards the later stages of life is controlled by inherent mechanisms, but within the limits set by such mechanisms, the environmental conditions would also play a significant role in determining

the rate of growth. It is clear that no animal, however young it might be, would grow rapidly if it is placed in a hostile environment.

The spawning activities of M. gasta and the growth pattern right from the juvenile stage up to the maximum size, viewed against the background of environmental conditions will make this point clear. Regular observations of gonadal condition of M. gasta show that it spawns only once during the year and that the spawning season is so adjusted that the environmental conditions are quite conducive to the survival and rapid growth of the larvae and the seed clams. It may be noted in this connection that M. gasta is neither a marine nor a fresh-water animal. All previous authors have listed it as a true brackish water form, which is capable of tolerating wide fluctuations in the environmental conditions. This fact has been clearly pointed out by Durve (1970) in his observations on M. gasta in the Marine Fish Farm at Mandapam Camp. He found that the rate of growth of this clam was very slow when compared to the rate of growth of the same species in other environmental conditions. He attributed the slow rate of growth to the high salinity conditions of the Marine Fish Farm. It is evident from this that salinity is a dominant factor which governs the rate of growth of M. gasta.

In the present investigation also it has been found

that salinity is the most dominant environmental factor which determines the rate of growth of this species of clam. Thus it may be seen that during the south-west monsoon when the salinity is reduced to the minimum value of 2.30‰, the total increase in the length of the clam is almost negligible. The maximum dilution of water over the clam bed occurs during the peak period of the monsoon,viz., July and August when the rate of growth in length is almost imperceptible as indicated by the increment values of 0.10 cm.and 0.06 cm.respectively.

The effect of monsoon on the biology of M. casta has been pointed out by Abraham (1953). He observed that in the Adyar backwater on the Madras coast the period of heavy rainfall coincides with the period of almost complete cessation of growth in the clams. He maintains that fall in salinity below a certain level is detrimental to the clams. He has also reported that the clams in the Adyar backwater with a salinity lower than that of the backwater grow at a slower pace. However, the above author believes that the effect of lowered salinity on the growth rate of clams is only indirect, consisting in the stimulation of reproductive activity. The population of M. casta studied by him has two spawning seasons, one during the period of lower salinity and the other during the period of higher salinity. The present investigation reveals that the clams collected

off the Cochin barmouth region has only one spawning season which coincides with the period of low salinity.

Durve (1970) found that the clam M. casta from the Marine Fish Farm at Mandapam showed a period of growth retardation during May to September which is exactly the period when the clams occurring off Cochin barmouth also show a retardation in the rate of growth. What is interesting is that here it is caused by lowering of salinity, whereas in the Marine Fish Farm, the retardation of growth is a result of hyper-saline conditions. This difference, although remarkable, is not surprising, since the clams in the fish farm live in a truly marine environment where salinity seldom falls below 30‰.

Durve (1970) related the slackening of growth to the lowering of filtration rate at high salinities. Metabolic rate as measured by oxygen consumption during the present study in M. casta is found to be low at reduced salinities as well. (Discussed later). The retardation of growth in clams off the Cochin barmouth region during the monsoon season when the salinity is extremely low, may therefore be explained in terms of reduction in the metabolic rate rather than to the lowering of the rate of shell secretion as assumed by Abraham (1953).

The availability of food is another ecological factor which plays a dominant role in the biology of animals

The south-west coast of India is characterised by the richness of phytoplankton which constitute the food of the larvae. It is of interest to note that in M. gaeta the spawning period is so adjusted that the larvae hatch out into an environment which can satisfy their nutritional requirements. The spat make use of this favourable environment and grow at a rapid pace. During the first three months of their life they show a phenomenal growth up to 21.68 mm. in length showing an increment of 5.92, 6 and 5.04 mm per month. By the end of May the clams attain a length of 38.0 mm. Thus, within a short span of eleven months, they gain a size comparable to that of their parents. Observations on the gonads indicate that they are sexually mature by this time, but spawning is delayed until the salinity falls to an optimum level (2.30‰ in August 1972).

Although temperature is one of the factors which determines the biology of animals in high latitudes, it cannot be expected to have the same effect in tropical waters. Table-I which gives the temperature values over the clam bed during the whole period of investigation, will provide sufficient evidence in support of this view. The magnitude of variation is not as great as in the temperate regions to have any profound influence on the biology of clams. The range of temperature is very low when compared to that of salinity. Even during the south-west monsoon

when the salinity shows the reduction as low as 3‰ or even still less, the temperature does not fall below 29°C. Durve (1970) also dismisses the possibility of temperature being an effective determining factor in the growth of *M. casta*.

Durve (1970) has observed a marked spurt in the growth of clams after what he describes as "the resting period" during May to September. The present study of the clam does not, however, show such an improvement in the rate of growth during the corresponding period. This is evidently due to the heavy rainfall during this period and the consequent decrease in salinity. Moreover, the clams off Cochin barmouth attain the maximum size limit before the monsoon sets in. However, during one or two months prior to spawning, the clams show a slight improvement in the rate of growth in all the three dimensions.

Durve's values for growth are considerably less than those of Abraham (1953) and those obtained during the present study. This is not surprising since Durve's observations were based on material collected from an artificial environment. The growth values obtained for the clams off Cochin barmouth are in perfect agreement with those of Abraham (1953). This is only natural since Abraham studied a clam population in a habitat comparable in broad details with the environment off Cochin barmouth. The two

populations are subjected to almost similar influences.

Abraham (1963) reported that the clams grew to about 15 mm. in length by the end of two months of their life. An examination of the rate of growth of the second stock as given in Table-III will show that the clams attain an average increment of 6 mm. by the end of November and 5.04 mm. by the end of December 1972. It would therefore appear that the clams off Cochin barmouth grow at a slightly slower rate than those in the Adyar estuary. But it may be remembered in this connection that the observations of Abraham were based on numbered clams, whereas the present study on the rate of growth is based on averages of random samples. Allowing for this difference and for differences in the environments, the values do show fair agreement.

Towards the end of the growth phase of the second stock the clams recorded an average length of 30.85 mm. Spawning occurred at this stage and the new year class (1973 year class) entered the population and the progress of growth of the previous year class could no longer be followed. Abraham (1963) found that his numbered clams grew to a length of 43 mm. in twelve months. The clams observed by him in Adyar backwater therefore had a higher growth rate than these off Cochin barmouth. Here again, due allowance should be given for differences in the methods of

investigation.

The values obtained in the present study as well as those reported by Abraham (1953), Durve (1970) and Parulekar et al.(1973) on M. casta are invariably higher than those obtained by Hamai (1936) for M. meretrix in Japanese waters. But Hamai was studying clams in temperate waters where the pattern of growth is cyclical, the higher rate of growth being limited to the period from May to September when the salinity drops and temperature rises. In those waters the deciding factor is obviously the temperature and not the salinity. The higher rates of growth, recorded in the various species of clams including the present one from tropical waters provide further illustration of the established fact that organisms grow more rapidly in tropical waters than in the temperate waters.

In the present observations the highest percentage of growth is shown by the length. Durve(1970), on the other hand, has reported that the greatest percentage of growth is indicated in the depth of the animal and that the rate of increment in this dimension is almost equal to height. The present observation, however, does not agree with the above two views in so far as the maximum growth has been noted along the anterio -posterior axis which is described as length.

Different authors have different views regarding

the spawning period of M. gaeta. Hornell (1922) found that M. gaeta spawns twice a year, viz., April to May and September. Panikkar (1939) holds that it breeds discontinuously throughout the year and spawning activity is often influenced by the rains. According to Abraham (1963), the peak period of spawning activity of the species is July and August. This is followed by another spawning period in October and November and a third one in summer months beginning with March and ending with April. Durve (1964) found that M.gaeta is a continuous breeder in the Mandapam fish farm with a break for a few months. Pamulekar et al.(1973) reported that M. gaeta breeds round the year in the clam beds of Bassein whereas at Ribandar the breeding is suspended during April to June. Nagabhushanam and Deshmukh(1973)indicate that Meretrix meretrix from the Kalbadevi estuary at Ratnagiri had a single spawning season from September to November, the peak of spawning being in October.

The samples collected in October 1972, for the present study consisted of clams ranging in shell length from 7 to 18 mm.,with an average value of 9.76 mm. It has not been found possible, by direct observation to determine the exact date of first setting either in 1972 or 1973. Abraham (1963) has shown that M. gaeta is about two months old when it has a shell length of 15 mm. Assuming that the rate of growth of M. gaeta off the Cochin backwaters is identical with

that observed by Abraham (1953), it follows that the 9.76 mm. group represented in the collection of October 1972 is more than one month old and that spawning must have taken place some time during late August.

Durve (1964) studied the gonadal changes and spawning in M. casta and found that no sex change occurs for the clam. During the present observations also no instance of sex change has been noted. Coe (1943) has pointed out that only less than 4% of the described species of bivalves deviate from a strictly dioecious condition. Loosanoff (1937a) observed that the primary gonads of Venus mercinaria of 4-6 mm. is clearly bisexual with a tendency towards potandric nature. Partial or functional hermaphroditism has not been noted in the adult clams by the present author. It is also noteworthy that there is no wide fluctuations in the number of males and females in the samples observed during any time of the year.

The production of sperms and ova begins by the second half of January. Before this the gonads were inactive. This proves that gonadal activity does not begin in M.casta immediately after spawning. Loosanoff (1937a) observed the initiation of gametogenesis immediately after spawning in Venus mercinaria. Gonadal inactivity in adult M.casta after the spawning season for a period of about four months from July to October was noted by Durve(1964). He could not

attribute any environmental factor for stimulating gonadal activity because there was no appreciable change of temperature or salinity in the Marine Fish Farm at Mandapam between the resting phase period and the starting of gonadal activity. Loosanoff (1937b) observed that temperature influenced considerably the development of sex cells and spawning in the case of Venus mercinaria. Under temperate conditions the main stimulus for spawning is the increase in temperature (Stafford, 1913; Churchill, 1919; Nelson 1921, 1928a, 1928b; Prytherch, 1928 and Galtsoff 1930, 1932). Nelson (op.cit) found that the maturing process also depends upon the temperature. Under tropical conditions of Indian coasts, Rao (1951) and Durve (1966) found that the temperature is not influencing the spawning in the oysters, Crassostrea madrasensis and C. gryphoides. There is no appreciable change of temperature (27.45°C - 29.75°C) occurring in the later part of January from the preceding months when gonadal activity begins in both males and females of M. cephalus observed during the present study. It may be presumed that temperature is not a stimulus for initiating gonadal activity in M. cephalus in the region under investigation.

Adult clams show no gonadal activity during the months of November to January first half when owing to the influence of winter monsoons comparatively low salinities

(28.25 to 28.10‰) were observed. Durve (1964) observed that the hypersaline water (45‰) may be the cause for the retardation of sexual activity in M. casta, during July to mid October in the Marine Fish Farm at Mandapam.

It has been found that lowering of salinity in the clam bed is one of the causes for spawning in both males and females of M. casta. It is possible that there may be other environmental factors influencing the spawning. Abraham (1953) observed that low salinity in the Adyar backwaters near Madras caused spawning in M. casta. Nagabhushanam and Dhamne(1975) found that the estuarine clam Paphia laterisulcata spawns during the months of September to March in Kalbadevi estuary at Ratnagiri. This continuous spawning has been reported to be controlled by the salinity and temperature over the clam bed in that region. Salinity in that region is comparatively low owing to the influence of the north-east monsoon. Nagabhushanam and Mane(1978) observed that the salinity in the Khatia Creek at Ratnagiri which varies from 3‰ to 31.5‰ played an important role over the reproduction of estuarine mussel, Mytilus viridis. Durve (1965) found that the lowering of salinity to an optimum level influenced the spawning in Crassostrea cucullata. Lowering of salinity to an optimum level between 28.58‰ and 13.15‰ stimulated spawning in oysters, Durve (1965). It can be seen from Tables VI and VII that fully ripe individuals dominate the samples during the months of June and

July. In these months there is a drop in salinity in the clam bed region owing to the influence of the south-west monsoon. But fully mature individuals do not start or initiate spawning in this period when the salinity value varied from 26.29‰ to 8.76‰. The examination of gonads of males and females collected during August and September showed spawned gonads during which time the lowest salinity values were observed (3.23‰ - 4.37‰). This indicates that optimum level of salinity necessary to stimulate spawning may be within the range of 4.37‰ - 3.23‰. It may be added that as the season advances, clams become more responsive to stimulation and spawn even at high salinities than at the beginning of the season. It has been found that the total average percentage edibility is at its lowest during the month of October when all the individuals are fully spawned. Durve(1964) observed no considerable change in the percentage edibility in the clam M. casta collected from the Marine Fish Farm at Mandapam. The reason for the same is that the clams in the marine fish farm bred continuously. His values for the percentage edibility is considerably low (4.22 - 5.98) when compared with the values obtained in the present observations on M. casta (Table-IX). Percentage edibility of the clams from Madras coast recorded by Venkita Raman and Chari (1951) also showed similar high values.

Durve (1964) correlated the drop in average percentage edibility value with spawning in oyster and further noted a fall in the glycogen content value during the spawning period. During the present observations the biochemical composition of the clam was studied. It has been found that the lowest values of fat recorded in the body entire of M. casta was during the spawning season and just after this period. An examination of Table-XII shows that 9.76 mm. average size group was present in varying numbers in October 1972. This fact indicates that spawning has taken place in August and lends support to the duration of spawning period arrived at by gonadal study.

Biochemical Composition:

During monsoon period, the water level of the body entire increases from 70% of the wet weight to 80% (Table-X, Pl.8, fig.1). This dilution of the body fluids has a marked effect on the level of organic constituents in the body. All the three organic constituents studied, viz., glycogen, protein and fat show an inverse relationship with the water content.(Pl.8a, fig.1). As the water level rises, the level of all the three organic constituents falls and as the water level begins to fall, the level of organic constituents begin to rise. The glycogen value during the monsoon period falls to 3.44% of the dry weight.(Table-XI, Pl.8,figure 2). During the same period the protein value

plummets downward from a pre-maximum of 70% to a minimum monsoon value of 38% in August (Table X-II, Pl. 8, fig.3). Fat also shows the same trend. It falls from a pre-monsoon value of 7.23% to monsoon value of 2% (Table X-III, Pl.8, fig.4). Fat differs from protein and glycogen in that its value continues to fall during the post-monsoon period up to October. The value begins to rise only during November and December. This difference in the seasonal trend of fat may be the result of spawned individuals present in the samples taken for fat analysis.

The winter monsoon is a less fierce event than the summer monsoon. Moreover, on the west coast of India, where the present study was conducted, it is a less wet event than on the east coast. Even so, it appears to have an effect, though not a fatal one, on the constitution of the clam body. During the winter monsoon period, the levels of glycogen, protein and fat are lower than during the transitional period (March-April) between the two monsoons. The glycogen value during January is only 4.41% which is not so far above the August value of 3.49%. Similarly, the protein value during January of 45.1% and the fat value during January of 5.1% are not as different from their corresponding values during August of 38.2% and 1.98% as from the corresponding value during April, the latter being 70% and 7.23% respectively. In fact, the highest values of

all three constituents (glycogen 6.78%, protein 70% and fat 7.23%) are obtained during April. Although during the post-monsoon period, the values of all the three constituents show significant increase over their monsoon values (glycogen 7.68%, protein 60.68% and fat 6.82%) during December. The post-monsoon values never reach up to the values obtained in April.

Variations of organic constituents in the body entire of other bivalves have been studied by a number of other authors. Among those should be mentioned Venkitaraman and Chari (1961), Chidambaram and Dinamani(1961), Durve and Bal(1961), Joshi and Bal (1966), Ansell and Trevallion(1967), Ansell et al.(1972a), Ansell (1972), Ansell et al.(1973), and Ansell (1974a, b, c and d).

Ansell as well as other authors noted the rapid increase in the water content of bivalve tissues at the time of spawning. Most of their observations were on temperate species and may not be entirely comparable with conditions in the tropical species. Even so, it seems that the seasonal trend in M. casta shows a slight parallel with the seasonal trend in temperate species. Although the water level in M. casta falls from its high monsoonal value, during the post-monsoon period, it does not fall as low as during the pre-monsoon period. During October and November the water level in M. casta is 78% of the wet body weight.

which is 6% higher than during April. The failure of the water level to fall to the normal pre-monsoon level may be related to spawning which in M. casta takes place during August second half to October. The failure of glycogen and protein to rise to pre-monsoon level during October to November may also be related to the failure of water level to fall to the pre-monsoon level during these months. However, in tropical waters, the variation in water level seems to be controlled more by monsoon than by the sexual conditions of the clams.

The inverse relation which organic constituents hold to water level in M. casta have been observed by Venkitaraman and Chari (1951), Fraga (1956), Durve and Bal (1965) in other bivalves.

The period of June to August when glycogen level is at its lowest corresponds roughly with the period of maximum water content. The upward trend of glycogen during September to October which is the spawning period of M. casta, is in agreement with Ansell's (1974d) observation of the rise in carbohydrate contents in Lima hians of the Clyde sea during the spawning period. In contrast Ansell (1974a) himself found that in Abra alba the carbohydrate level reached a peak in July just before spawning and rapidly decreased during spawning in the same month. In Tellina pulchella, on the other hand, Ansell (1974c) did not find a

marked seasonal trend in carbohydrate level. Joshi and Bal (1966) found that in Katelysia marmorata, the glycogen gives the highest value in June, before the development of the gonads. From June onwards to January there is a gradual decrease in glycogen value initially due to rise in water level during the rainy season and later on due to spawning.

Obviously there are great differences among bivalves in the relation glycogen holds to spawning. Perhaps in M. casta, the rise in glycogen content during the spawning season may not have direct relation to spawning. The rise may only be an indication of resumption of normal metabolic activity consequent on the draining of excess water from the tissues and on the rise in salinity of the surrounding water.

Humphry (1941) thinks that in oysters the glycogen acts as reserve food material and is used in the development of gonad. Glycogen content rises from February and remains high from April to June when the clams remain sexually inactive. Glycogen content of the clam thus appears to be influenced by water level and sexual maturity. The decrease in glycogen content in M. casta during monsoon may be the result of it being utilised by the animal to sustain itself during the unfavourable condition. An intimate association of glycogen with the period of sexual activity has been

observed in oysters by Okazaki and Kobayashi(1929) and Narve and Bal(1961).

In *M. casta*, protein levels are apparently on the increase during the spawning period (September-October). This observation is in disagreement with Ansell(1974c) in *Nucula sulcata* where protenacious nitrogen content falls with spawning. In *Abra alba* and *Lima hians* also Ansell observed that nitrogen increases steadily to a pre-spawning maximum. Spawning leads to a fall in the value, but situation in *M. casta* may not indicate as great a discrepancy as at first appeared. It should be remembered that spawning in *M. casta* is preceded by the drastic lowering in protein level associated with the monsoons. As soon as the monsoons are over and the salinity of the medium shows a trend back to normal sea, the physiology of the clam must begin to recuperate. The increase in the levels of protein is an indication of the improved metabolism in a more favourable environment. But spawning acts as check to the rate of increase in protein levels. It is quite conceivable that, but for spawning the protein level would have increased at a faster rate. In the case of temperate species which Ansell studied, spawning is not preceded by such drastically unfavourable hydrological condition as *M. casta* is subjected to. In these temperate species, the pre-spawning period shows maximum protein values and it is natural that the increased

energy requirements of spawning should have an unfavourable effect on the protein level. Although the present observations do not agree with Ansell (1974) with respect to the significance of spawning, they do agree with him in the inverse relationship of protein value to water level.

Joshi and Bal (1965) observed that in Katelysia opimastra, the protein value reaches maximum in May, thereafter falling to minimum in September. Spawning according to them in this species takes place some time during October to January. Here therefore spawning does not seem to have any distinct relation to protein level. Moreover, these authors found a reciprocal relationship between glycogen and protein during certain periods. Similar observations have been made by Masumoto et al.(1954), and Durve and Bal (1961) in oysters. No such reciprocal relationship has been observed in M. casta during the present study. Here the trends of the two constituents are quite similar.

Fat shows a fall in level with both the monsoon and spawning (Table-XIII, pl.8, fig.4). Both the decreases can be explained as a reaction to the increasing water content of the body which happens both with monsoons and spawning. These observations are in agreement with those of Ansell (1974a, b, c) in Abra alba, Lima hians and Nucula nucleus, in all of which major decreases in fat level are associated

with spawning. In Katelysia marmorata, Joshi and Bal (1965) and in oysters, Chidambaram and Dinamani (1951) found a similar relationship. In Katelysia marmorata, fat accumulates in the gonad during the formation of gametes as it does in those of the oyster, as observed by Pease (1932). Relationship between the seasonal cycle and fat value is recorded by Venkitaraman and Chari (1951), Durve and Bal (1961) and by Nevi (1964) in Corbicula manadei.

Joshi and Bal (1965) found in Katelysia marmorata there is an inverse relationship between the water level and calorific content. Their observations agree with the present ones in that during the monsoon seasons when the water level is high, the calorific value falls (Table XIV, Pl.8, fig.6). From the second half of October to second half of January, during which period the spawning occurs in this species, there is again a fall in the percentage of organic constituents and this contributes to the decrease in the calorific value of the clam. Joshi and Bal's (1965) observation that variation in the calorific value due to changes in the proportion of protein, glycogen and fat holds good for the present study also. The inverse relationship of the organic constituents with the water level is reflected in the calorific contents.

Ansell (1974a) found very little seasonal fluctuations in calorific contents in Chlamys septemradiata. On the

other hand, in Lima lima he found that the calorific content follows the seasonal cycle of the tissue weight. In Area alba he found that the calorific content decreased from September to a minimum in April and increased rapidly to a pre-spawning peak in July.

Comparison of calculated calorific content with values obtained by direct analyses using the method of Krumholz and Tarkowskaya(1956) shows that the actual values are somewhat lower than the calculated value (Table-XIV). The discrepancy must result from errors in the conversion factors for the three organic constituents. An alternative possibility is that in the wet oxidation method used, the incomplete oxidation of the organic material might have failed to take place.

The water level in the gonad is higher throughout the year than in the body entire, the trend in seasonal variations for the gonad being similar to that for the whole body (Pl.V, fig.1). The fact that during September-October, when the salinity of the water is steadily rising, the water level continues to be higher than during the pre-monsoon period, may be related to spawning which in M.gracilis takes place during this period.

Ansell (1974d) has found in Chlamys septemradiata the lowest water content (77%) in the ripe gonad during June and that considerable increase occurred with spawning.

The value of 77% obtained for this species contrasts with the value of 77.08% obtained for M. senhousia (Table-XV,Pl.7, fig.1) during September, when the latter's gonads had spent. But this value is not the lowest value obtained in M. senhousia. Lowest value is obtained during the pre-monsoon period.

As in the case of body entire, in the gonad also glycogen shows an inverse relationship with water content. The glycogen content of the gonad is much lower than that for the entire body. The minimum glycogen values for the body entire is 3.44% and the maximum is 8.78%. The values are 2.01% and 5.83% respectively for the gonad.

Ansell (1974d) too found that in Chlamys senhousia, the gonad contained relatively little carbohydrate. In contrast, Giese (1959) reports that for Mytilus californianus the carbohydrate level is very high in the gonads for a considerable part of the year. In this species, carbohydrate must play a more important role than fat as a storage material. The gonads show little carbohydrate storage when mature gametes are present, suggesting a massive conversion of carbohydrate into gamete tissues. In M. senhousia, on the other hand, glycogen does not seem to have much significance as a storage material in the gonad.

M. senhousia differs from Chlamys senhousiana in that protein value does not fall during spawning. This observation

for *M. casta* is in agreement with that of Giese(1969) in *Thyela chiliensum* that while there is variation in protein level from month to month, it appears to have no relation to the reproductive season. The variation must depend upon differences in nutrient conditions or other environmental factors. The protein levels of gonad in *M. casta* are quite variable and are highest when it is gravid which presumably reflects the high protein contents of the maturing gametes. In contrast, immature gonads contain large stores of nutrient reserves such as glycogen and fat.

Variation in the fat content of the gonad is in general agreement with the variation of this constituent in the body entire. The initial fall in fat value due to monsoon is clearly marked in both cases. The continuing fall during the period of spawning is also common for gonad and body entire. Fat has great importance as storage material in gonad and its depletion during spawning is quite natural. However, in the body entire the fat values fall lower than in the gonad, down to 1% in contrast to 1.8% in the gonad.

Ansell (1974d) observed great accumulation of fat material in the maturing gonads in *Chlamys septemradiata*, but in *M. casta*, during maturation, the fat content is observed to fall. The difference can, however, be explained by differences in climatic circumstances between the two

species. The fall in the fat value in M. senhousia during maturation is a result of the influence of the monsoons. Giese (1959) has also observed increase in the fat content of gonad at the time of maturity in Tivela stultorum.

The calorific content of the gonad shows a pattern of variation similar to that of the body entire, although the range in the gonad is not as wide as in the body entire. During the post-monsoon period the calorific content of the gonad increases due to the maturing of gonads and the main contribution to the calorific value comes from the protein and the glycogen which are on the increase at this time in contrast to fat which is falling (Pl.7, fig.5). Ansell (1974d) has found that the relatively higher calorific content of the gonad at maturity is due to the higher protein content. He also found that the calorific value of the gonad at maturity is ten times higher than the minimum value.

Variation in the water content in the adductor muscle is similar to that in the body entire and the gonad. Ansell (1974d) found little seasonal trend in the adductor muscles of Chlamys septemradiata. For most of the year, the value of water content varied between 79% and 82%. This is to be expected as the adductor muscle is an organ whose importance to the animal does not vary during the year. In vital organs, the levels of the major components tend to remain constant within limits comparable with its functioning unless forced to change by external forces. In the

temperate waters inhabited by clams, the cycle of the seasons controls the biology of the animal, but the responses to changes in the environment are limited to more specialised organs than the adductor muscles. In such organs, for example, as the gonad which passes through changes (in size as well as in importance) during the course of the year, there are changes in the levels of the constituents. The adductor muscle passes no such change except in size and therefore its water level remains constant percentage-wise. The same would have been the case with the adductor muscles of M. gaditana except that the extreme lowering of salinity during the monsoon leads to a break-up of the osmoregulatory mechanism of the animal flooding all the organs of the body including the adductor muscles with water.

The monsoonal depression in the values of glycogen is explainable in terms of the inverse relationship between the biochemical constituents and the water level. The pre-monsoonal decline of protein and glycogen in the adductor muscles cannot be attributed to any obvious cause. Comely (1974) and Ansell (1974d) have found that in Chlamys opercularis there is decline in the glycogen value of the adductor muscle during the growth of the gonad. But in M. gaditana, the decline in the values does not coincide with the growth of the gonad. If we try to relate the decline to a carry-over effect of the winter monsoon, the question arises as to why this monsoon had no such effect on the gonad and the body

entire. In contrast to protein and glycogen, fat is on the rise during the pre-monsoon period.

The steady value of the calorific content of the adductor muscles during the pre-monsoon period must be maintained by fat which is on the rise during the period, while protein and glycogen are on the decline (Table-XXIV,Pl.9, fig.8). Ansell (1974d) found in Chlamys septemradiata that the calorific content of the adductor muscle showed very little variation throughout the year. The curve for the calorific content in M. casta shows that this would have been the case in this animal also with the value remaining steady at about 4 k.cal/gm, but for the depression in the middle of the year caused by the monsoons.

The inorganic constituents studied here differ considerably among themselves in the pattern of their seasonal variations. The two groups of ions - iron and copper, calcium and magnesium show a more or less distinct relationship to the monsoons in their seasonal trends, although they show opposite reactions to the monsoons.

In view of the fact that the mechanism whereby the concentration of trace metals take place in living things is still not clear. Goldberg(1961) has highlighted an increasing interest in the biosphere, particularly in relation to the trace element uptake by marine organisms. It is difficult to explain the seasonal trends of inorganic

constituents observed in *M. edulis*. An explanation of these trends in terms of the effect of monsoons on the metabolism of the species can, however, be attempted. Whether iron and copper have an essential role in the metabolism of the species and whether they can ever become limiting factors is not clearly known. *M. edulis* lacks haemoglobin, Krishnamoorthi (1969). So iron cannot be an essential component of oxygen transport system of the animal. Several authors have reported the levels of several elements in bivalves, particularly in *Mytilus* spp. Robert and Rumsby (1965) examined the levels of several elements in *Mytilus* from New Zealand waters and found that iron was by far the most abundant trace element estimated on a $\mu g/g$ dry-weight basis. Collins and Riley (1971) found similar high iron levels in samples from the English Channel. Robbins (1967), (1969) and Krishnamoorthy (1969) have also carried out certain laboratory studies based on the accumulation of iron in *Mytilus* from sea water. Pentreath (1973) has reported a very low level of iron in the body entire of *Mytilus edulis*, but of the component parts studied, he recorded a high level of iron in the digestive gland. Similar high concentration of iron in the digestive gland has been reported by Bryan (1973) in *Patina pellucida* and *Thlamys opercularis*. Iron and copper are likely to be accumulated in the body of the animal as metabolic by-products or by simple absorption from the medium.

As organic constituents are used up during the unfavourable condition created by the monsoons and while the water level of the body rises drastically, the dry-weight of the animal decreases. The iron and copper contents are not used up in any way and their level expressed as a percentage of the dry weight rises. This rising of their level therefore does not indicate any increase in their absolute values, but indicates only the decrease in the dry weight which depends to a great degree on the organic constituents which are being fast used up.

Bryan (1973) has tried to relate the seasonal variation of trace metals to the availability of food in the clam, Chlamys opercularis and the oyster, Pinkna maximus. He found that the concentration of trace metals is in general lower during seasons of high productivity. He suggested that during such seasons the amount of the metals in the medium is exhausted by flourishing phytoplankton populations, leaving very little to be absorbed by other organisms. Moreover, during such high productivity seasons the amount of trace metals available to the animals for the phytoplankton themselves is less than during the other seasons, since the amount of such metals available in the medium is limited. It would be difficult to apply Bryan's suggestions to M.gamia since productivity conditions in the tropical waters are quite dissimilar to those of temperate waters. However, it should be admitted that the levels of iron and copper are

low in *M. gaudia* when the living conditions of the animal are favourable.

Calcium is an essential inorganic constituent for *M. gaudia* which has a calcareous shell. The calcium obtained by the animal is used by it to secrete the shell and very little is likely to be stored in the softer parts. It is not surprising, therefore, that during the monsoons the calcium level of the body falls (Table-XXVIII). During these periods of low salinity the metabolism of the animal as measured by oxygen consumption in low salinity is considerably impaired, and consequently the animal's mechanism for obtaining calcium should also be under a disadvantage. It would be difficult to explain the seasonal trend of magnesium without more information on the role of the element in the molluscan metabolism.

Salinity tolerance

The greatest climatic event in the tropical region inhabited by *M. gaudia* is the south-west monsoon. The two most important hydrological effects brought about by the monsoons is the lowering of salinity and the lowering of temperature. The monsoon season affects the clam bed unfavourably is proved by the fact that after the monsoons the clam beds are strewn with empty shells of clams especially those of larger sizes. Only a small proportion of the original population survive to spawn during September-October.

The losses in the clam bed must be attributed as much to simple smothering by silt and sweeping away by freshet flows as to the hydrological differences caused by the monsoons. The lowering of temperature caused by the monsoons, does not lower the temperature as low as to prevent normal physiological functioning of the clams. So the mortality described during the monsoons must be the result of the lowering of salinity.

The salinity at the clam bed (Table-I) which is about 25.38 - 35.28‰ during the pre-monsoon period in 1973 shows a marked decrease during the monsoons. It falls to as low as 6.28‰ during August at the height of the monsoons. The effect of the monsoon on the clam bed is to plunge it into a hypersaline medium. The clam, M. casta, at the Cochin gut is in general adapted to a greatly variable environment and provided with a very effective osmoregulatory mechanism. But the clam finds it difficult to cope up with such an abrupt change in the medium as occurs during the monsoons. Obviously the osmoregulatory mechanism of the animal must break down during the period with fatal physiological consequences by the hydrological alteration of the medium.

Nunes (1953a and 1964d) has pointed out that the salinity ranges occupied in the sea are not necessarily the same as those tolerated for prolonged period in the laboratory. Field observations and laboratory studies on tolerance

of *M. casta* made during the present investigation support this point of view. In the natural environment, the clams were found to be more tolerant to variation in salinity than in the laboratory. It has been found that in both cases increasing salinity has never caused so disastrous an effect on the population as done by decrease in salinity.

It is clear that under laboratory conditions, the higher and lower limits of salinity which the small clams (8-15 mm.in length) can tolerate are 36‰ and 15‰ respectively, as adjudged by 50% survival at the end of 15 days. In medium sized (20-30 mm.in length) as well as large clams (32-38 mm. in length), the tolerance range is between 35‰ and 20‰ salinity. This shows that the small clams are more capable of withstanding a wider variation in salinity than in large ones. But in the natural environment, clams of all size groups were found to be tolerating salinities from 2.30‰ to 35.28‰, although there is mortality occurring for a small number of large clams.

The increase in salinity above 35.28‰ is never met with under natural conditions. What may upset the normal activities and survival of the clams is therefore not high salinity, but the prolonged low salinity conditions during the monsoon period. Experiments conducted on salinity tolerance of the clams show that majority of them can hardly survive in salinity below 15‰. But observations of clams under natural conditions show that mass mortality never

occurs, although a small percentage of large clams perish during the monsoon season. The only logical explanation that could be attributed to this conflicting observation is that under natural conditions the clams get acclimatised below the lethal level since dilution by river water is a slow and gradual process, whereas under laboratory conditions the change to low salinities is effected suddenly and abruptly. Abraham (1953) observed that clams collected from 12.86‰ salinity, when transferred to 23‰ salinity underwent considerable mortality within 5 days.

It is clear from the present observations that salinity tolerance capacity of M. gaudia decreases with increase in size.

Oxygen consumption

The results of the experiments show that oxygen consumption and metabolic rate in M. gaudia are size-dependent in all the eight concentrations of the media ranging from 5‰ to 40‰ at 5‰ intervals. The total oxygen consumption in unit time is less in small animals, while more in large animals and the metabolic rate or weight specific oxygen consumption shows the opposite trend. These findings are in general agreement with the observations by earlier workers on the size dependence of metabolism in molluscs and other animal groups. (Weymouth et al. 1944; Zeuthen 1953,

1966; Prosser 1966; Bertallanffy 1957; Hemmingsen 1960; Kainle and Ludwig 1966; Kruger 1960; Mangler 1961; Read 1962; Van Brand et al. 1948; Ganapati and Ramasastry 1972; Mangapathi Rao et al. 1974; Ansell 1973; Ola Vahl 1972; Rathnam 1966; Davies 1967; Duerr 1967; Loveland and Chu 1969; Kennedy and Mihursky 1972).

The extent of dependence of metabolism on size varies from salinity to salinity as evidenced by the different b values obtained. b has a value as low as 0.4237 in 5‰., while it is as large as 0.7499 in 35‰. salinity.

Ludwig and Krywienczyk (1966) correlating metabolism with the respiratory mechanism showed that in gill breathers which include bivalves, oxygen consumption is proportional to surface. Bertallanffy (1957) recognised the existence of three metabolic types with respect to their relation between metabolic rate and body size. In the first type, metabolic rate is proportional to surface or the 2/3 power of body weight. In the second type, the metabolic rate is proportional to weight and in the third type, metabolic rate is intermediate between proportionality to weight and to surface area. He categorised clams in that metabolic type where respiration is proportional to surface, suggesting a value of 0.67 for b.

The values of b obtained in *M. casta* acclimated in

5‰., 10‰., 15‰., 20‰., 25‰., 30‰., 35‰. and 40‰.salinity are 0.4237, 0.4276, 0.4636, 0.4769, 0.5180, 0.5308, 0.7499 and 0.5136. Great variations exist and the range in the b value extends from 0.4237 to 0.7499. Thus the metabolic rate varies from less than proportional to surface to intermediate between proportionality to weight and surface area. In 35‰. salinity, the b value is more than 0.67 which is required by surface law but less than weight proportionality. In the salinity media 25‰. and 35‰. the b values are nearer to the two-third power of respective body weight. It can be seen that in the rest the b values are much different from 0.67 which is required for surface law of Bertallanffy (1957).

It is difficult to compare, but in a rough way, the present values with the b values reported for bivalves by earlier workers, as experimental conditions, factors considered and previous environmental history of the experimental animals were grossly different. Kennedy and Mihursky (1972) have reviewed the values of b recorded in literature for bivalves which range from 0.31 to 0.96. These authors have further recorded values of b for Mya arenaria, Macoma balthica and Mulinia lateralis ranging from 0.235 to 0.864. Ansell (in prep.) has compared values of b determined at 10°C. for sixteen species of bivalves from west coast of Scotland to obtain a common value of 0.703 for b. Ola Vahl (1973) determined the b value for Arctica islandica as 0.75 which is close to b value obtained for M. casina in 35‰.

salinity. The same author established a value of 0.77 for b in the case of Cardium edule. It can be seen that many of the b values mentioned are significantly close to the estimates of b for poikilotherms by Zeuthen (1953) and Hemmingsen (1960) which are 0.75 and 0.73 respectively. The present values of b are much lower than these estimates with the exception of 0.7499, the b value obtained in 35‰ salinity. Mangapathi Rao et al.(1974) recently gave 0.5845 as the b value for Mytilopsis sallei at a temperature of 29.0 ± 0.5°C in salinity of 35‰. Under almost similar conditions of temperature of 29.0 ± 1 C and salinity of 35‰, a b value of 0.7499 was obtained in the case of M. opalia.

The above discussion of the b values in particular together with the present results seem to suggest that great variations occur in the value of b among the bivalves and in the particular species concerned. This makes it difficult to assign a particular b value as a group or even species characteristic.

SUMMARY

Studies on the biology of the backwater clam, Katelysia opima (Chemnitz) have been undertaken based on regular collections from the clam bed off Cochin barmouth during 1972-1974. The relationship between different dimensions of the shell of the clam to length and total weight, growth in three dimensions, viz., length, height and depth, seasonal variations in numerical abundance and biomass of the population, seasonal gonadal changes and spawning, biochemical composition, salinity tolerance and oxygen consumption are dealt with in the present work. The hydrological data and the nature of the substratum at the clam bed were also recorded at the time of collection of samples.

The analysis of the data showed that the numerical density of K. opima in the clam bed off Cochin barmouth is at its lowest during active south-west monsoon season. However, improvement in the density occurred immediately after the abatement of the south-west monsoon rains owing to the recruitment of young clams. The highest biomass (including shell on wet weight basis) observed was 10240.96 gm/m^2 in April 1972.

Though K. opima occurs near and off the barmouth, its preference seems to be a substratum consisting of fine sand mixed with a very small percentage of silt and mud. The salinity in the clam bed varied from 2.30‰ to 36.36‰,

whereas the variation in temperature was from 23.13°C to 30.23°C.

Biometric relations between height(H) and length (L), depth(D) and length, total weight(W) and length have been studied using the method of least squares. The regression of the respective dimensions obtained were as follows:

$$\log H = -.3646 + 1.1773 \log L$$

$$\log D = -.0109 + 0.7836 \log L$$

$$\log W = -2.6111 + 2.8060 \log L$$

Growth in three dimensions, viz., length, height and depth has been studied in three different stocks which have been obtained at three different periods during March 1972 to March 1974. Similarity has been observed in the growth patterns among different dimensions. Actual growth rate when compared with values computed by using von Bertalanffy's growth equation showed agreement. A rapid growth rate of 5.32 mm. and 6 mm. in length has been obtained for the second stock during the first two months (October-November), while in the third stock the rate of growth for the first two months (September-October) was 5.12 mm. and 5.86 mm.respectively. Minimum monthly average growth of 0.08 mm. in length has been recorded during the monsoon season for the second stock when the metabolic rate was least.

Sexes are separate in M. <u>gracilis</u>. Maturity of gonads

has been traced noticing variations in percentage edibility and through cytological preparations. Gametes which started development during the second half of January have reached maturity during the period from June to second half of July. Spawning started by the second half of August and continued till the end of October.

Salinity has been observed to have an important role in the development of gonads and spawning. Gonadal activity was found to be initiated by a rise in salinity in the environment in January and the rate of gonadal development became faster in the following months as salinity increased.

Seasonal variations in water content, glycogen, protein, fat and calorific value in the body entire and in selected component parts (gonad and adductor muscles) have been studied. It was found that the water content of the body entire increased from a normal of 70% of the wet weight to 80% during the south-west monsoon period. Corresponding to the dilution of body fluids there was a reduction in the value of glycogen, protein and fat. Consequently the calorific value also got reduced. During the winter monsoon period, the levels of glycogen, protein and fat were found to be lower than those during the transitional period (March-April) between the two monsoons. The highest values of all the three constituents were obtained in April.

It was observed that the water content in the gonad was higher throughout the year than that in the body entire. Glycogen in the gonad showed an inverse relationship with water content. Protein content of the gonads was found to be highest when they were gravid, while glycogen and fat dominated the immature gonads. It was found that there was an increase in the calorific content of the gonads during the post-monsoon period owing to the increase in glycogen and protein content. During this period fat content showed a decrease.

Variation in the water content of the adductor muscle was found to be similar to that in the body entire and in the gonad. The glycogen and protein content showed a steady fall during the pre-monsoon period and an equally steady rise during the post-monsoon period. The trend was opposite in the case of fat.

The concentration of inorganic constituents, viz., ash, iron, copper, calcium and magnesium in the body entire of *M. gamia* with respect to seasons was studied. The lowest ash value (5.76%) was recorded in June and the highest value (6.36%) was obtained in November. An inverse relationship between iron content and salinity of the ambient water has been noticed. The trend of concentration of copper was similar to that of iron, showing a negative correlation with salinity. The value of copper was less

than that of iron throughout the year. The absolute values of magnesium were less than those of calcium throughout the year. The distribution of calcium and magnesium in the tissues of M. casta showed an opposite trend to iron and copper. An explanation of the seasonal trends of ions in terms of the effect of monsoons on the metabolism of the species has been attempted. It has been found that during the unfavourable conditions created by the monsoon the organic constituents were used up and while the water content of the body raised drastically, the dry weight of the animal proportionally decreased.

Experiments on salinity tolerance were conducted with three different size groups of clams, viz., 8-15 mm. in length (small clams), 20-30 mm.in length (medium sized clams), and 32-38 mm. in length (large clams) in different salinity media ranging from 0‰ to 40‰ at 5‰ salinity intervals. The lethal salinities of all the three size groups were determined. The experiment showed that the higher and the lower limits of salinity which the small clams could tolerate were 35‰ and 15‰ salinity respectively, while in the medium sized and large clams the tolerance range was between 35‰ and 20‰ salinity. This proved that the small clams were capable of withstanding a greater variation in salinity than the larger ones.

The total and weight specific oxygen consumption were size dependent in all the eight concentrations ranging

from 5‰ to 40‰ at 5‰ intervals. The value of b varied from one salinity to another which showed that the extent of dependence of metabolism on size was different in different salinity media. The metabolic rate varied from less than proportional to surface to intermediate between proportionality to weight and surface area. A review of the literature showed that great variation existed in the value of b among bivalves. The b values obtained for M. gaditana in the present study in different salinities were well within the range of b values reported for bivalves by earlier workers.

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* Not referred to in original.

PLATE. 1

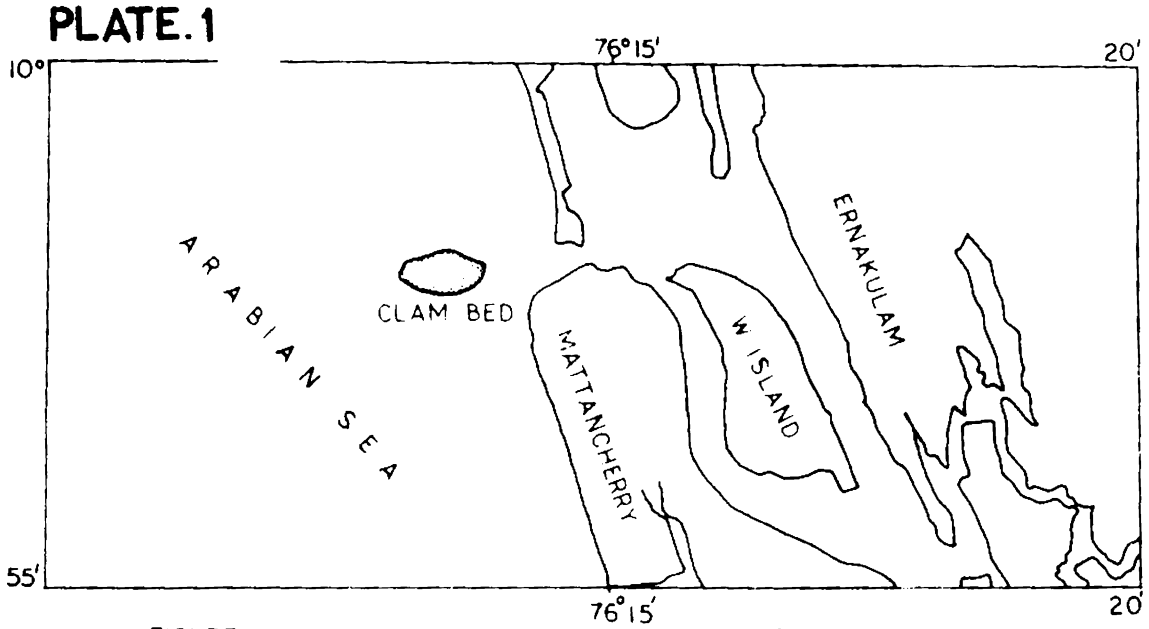

FIGURE 1. MAP SHOWING THE LOCATION OF THE CLAM BED

PLATE 2

Figure 1. Showing the different sizes of M. gaspia.

Figure 2. Posterior view of M. gaspia showing the hinge ligament (I)

Figure 3. Anterior view of M. gaspia showing the lunule (II)

Figure 4. Left valve of M. gaspia showing the posterio-lateral tooth (III),
Central cardinal tooth (IV), and
anterior cardinal tooth (V).

Figure 5. Right valve of M. gaspia showing the corresponding depressions of the teeth of the left valve.

PLATE 2.

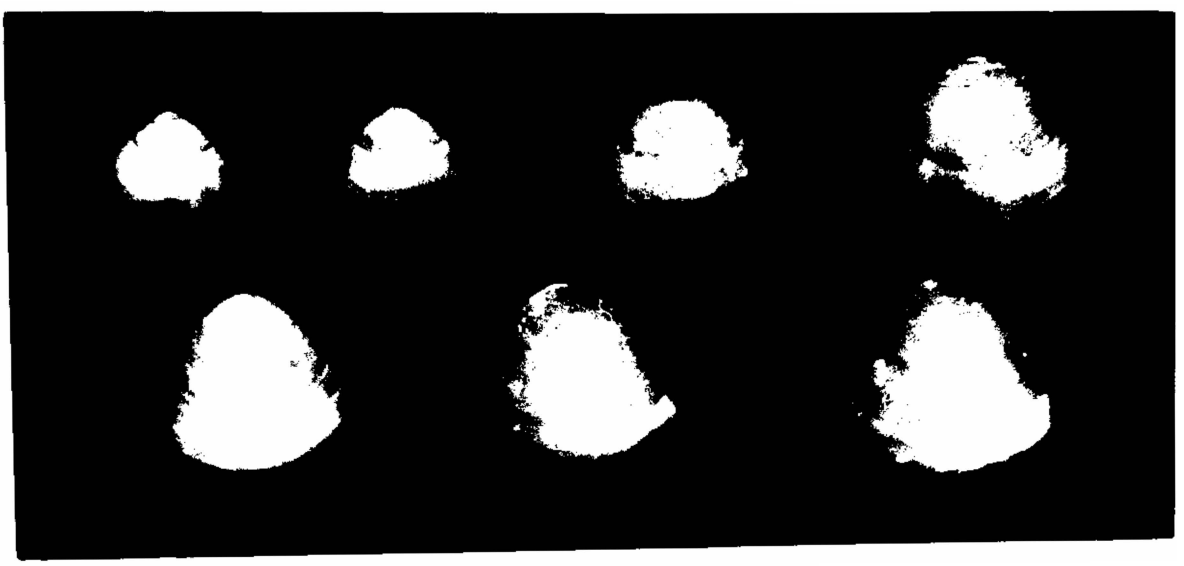

FIG 1.

FIG 2.

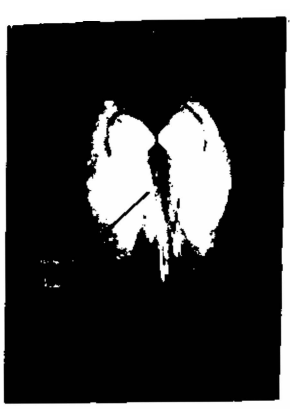

FIG 3.

FIG 4.

FIG 5.

PLATE 3.

Figure 1. Distribution of bottom temperature and bottom salinity of the waters over the clam bed for a period from March 1972 to March 1974.

Figure 2. Relation between shell length and height of different sizes of *M. gaeta*.

Figure 3. Relation between shell length and depth of different sizes of *M. gaeta*.

Figure 4. Relation between shell length and total weight of *M. gaeta*.

PLATE. 3

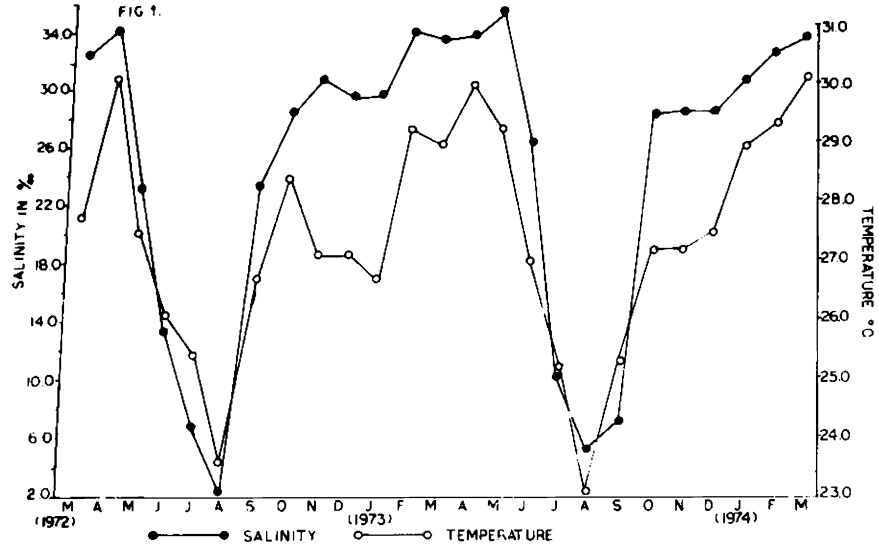
FIG 1.
SALINITY IN ‰
TEMPERATURE °C
M A M J J A S O N D J F M A M J J A S O N D J F M
(1972)
(1973)
(1974)
SALINITY
TEMPERATURE

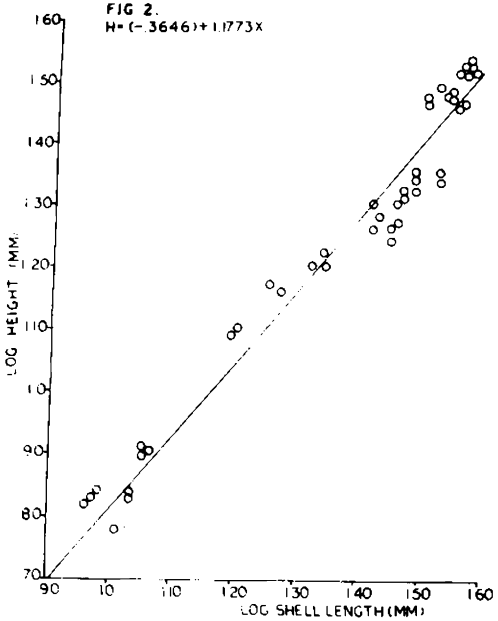
FIG 2.
H=(-.3646)+1.1773X
LOG HEIGHT (MM)
LOG SHELL LENGTH (MM)

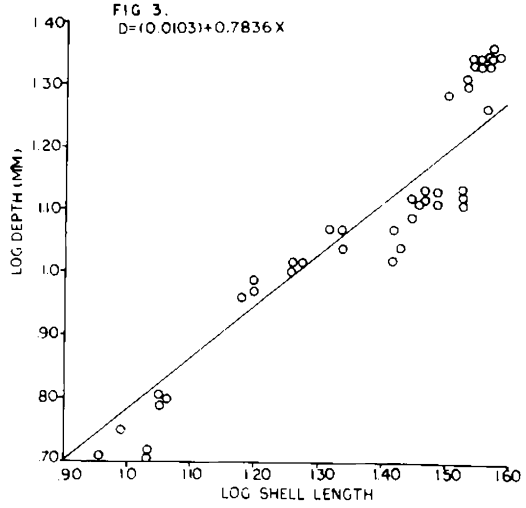
FIG 3.
D=(0.0103)+0.7836X
LOG DEPTH (MM)
LOG SHELL LENGTH

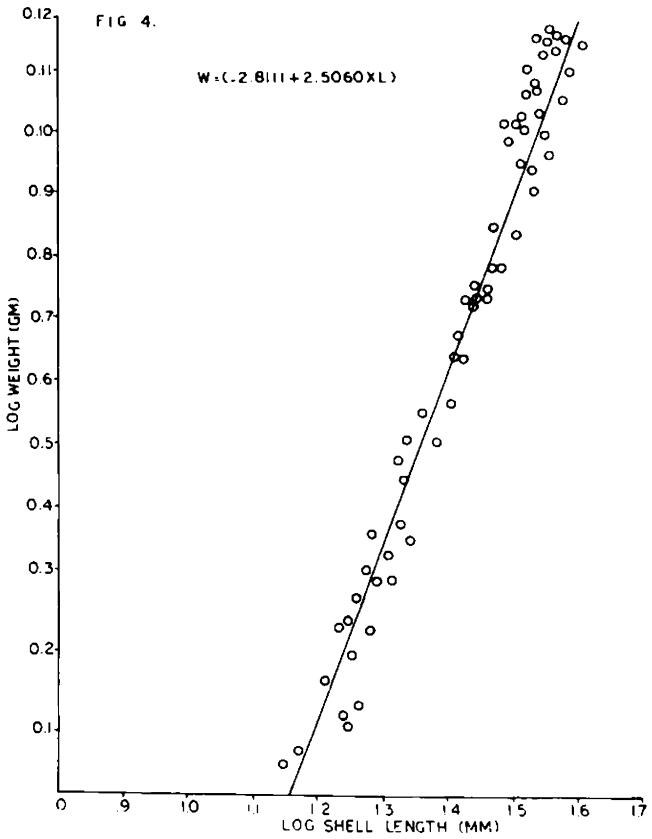
FIG 4.
W=(-2.8111+2.5060XL)
LOG WEIGHT (GM)
LOG SHELL LENGTH (MM)

PLATE 4.

Figure 1. Showing the relation between length (mm) at time 't' and length (mm) at time t+1 in *H. gaskia*.

Figure 2. The pattern of growth in length of the three different stocks of *H. gaskia* during the period March 1972 to March 1974.

Figure 3. The pattern of growth in height of the three different stocks of *H. gaskia* during the period March 1972 to March 1974.

Figure 4. The pattern of growth in depth of the three stocks of *H. gaskia* during the period March 1972 to March 1974.

PLATE. 4

FIG. 1

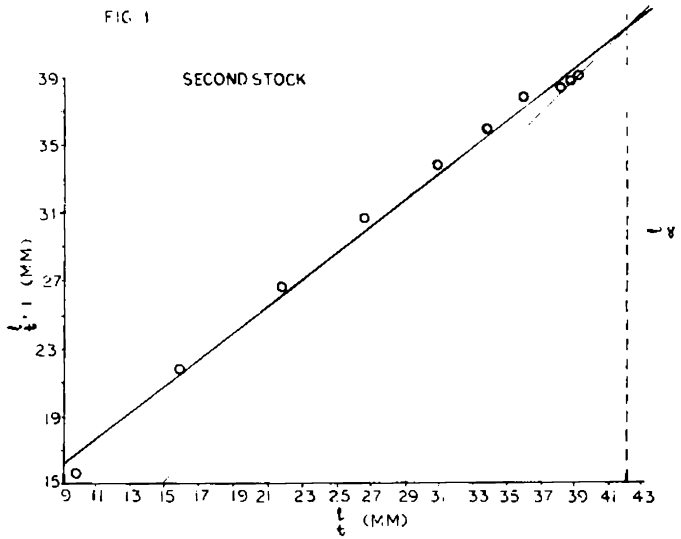

FIG. 2

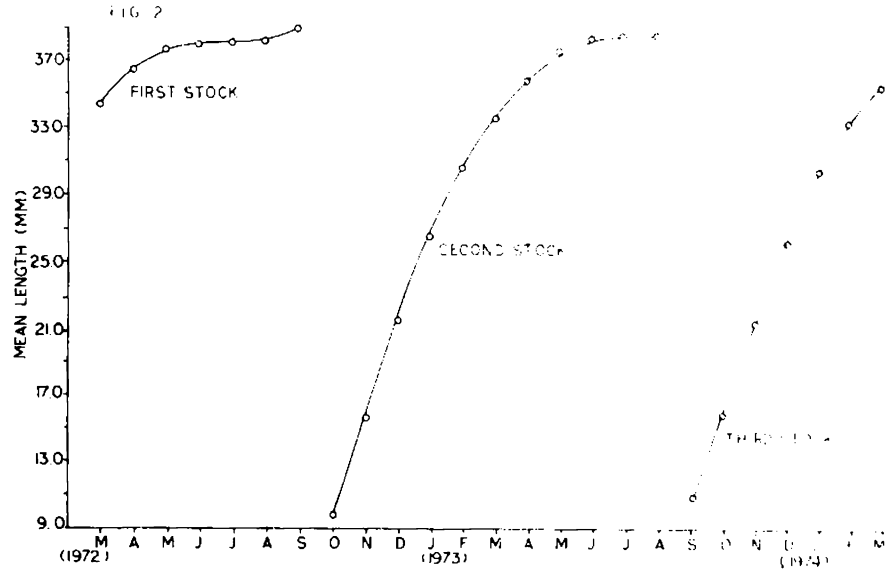

FIG. 3

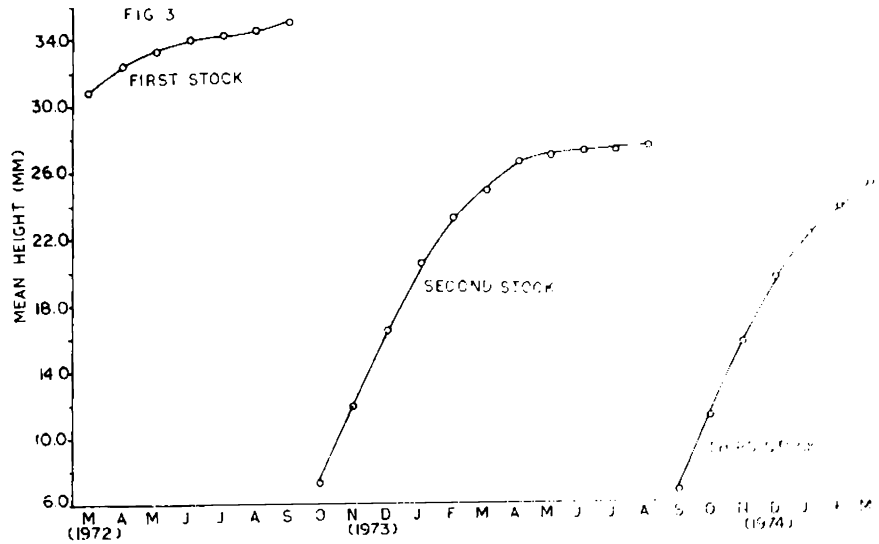

FIG. 4.

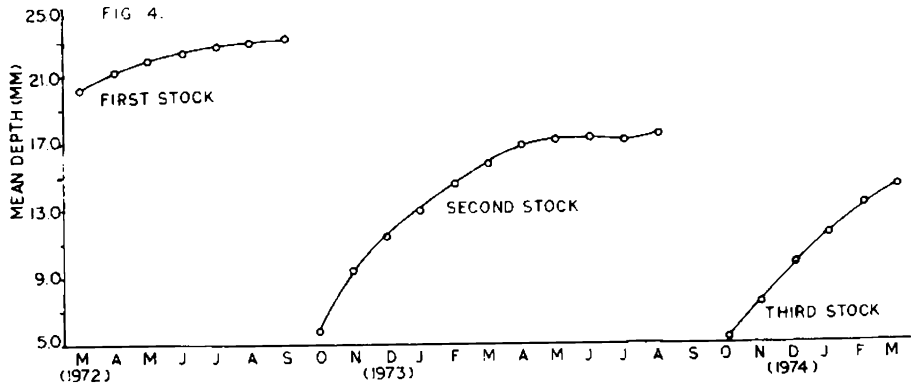

PLATE 5.

Figure 1.* Section of gonad of a male clam showing the early stages of spermatogenesis (follicles are packed with primary and secondary spermatocytes in various stages of development).

Figure 2.* Section of gonad of a male clam showing the late stages of spermatogenesis with comparatively lesser number of spermatozoa occupying at the centre of the follicle.

Figure 3.* Section of gonad of a male clam showing the follicles packed with fully developed sperms.

Figure 4.* Section of gonad of a partially spawned male clam.

Figure 5.* Section of gonad of a fully spawned male clam.

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*All sections are 8 μ thick. The magnification of each figure: 225 x.

PLATE 5.

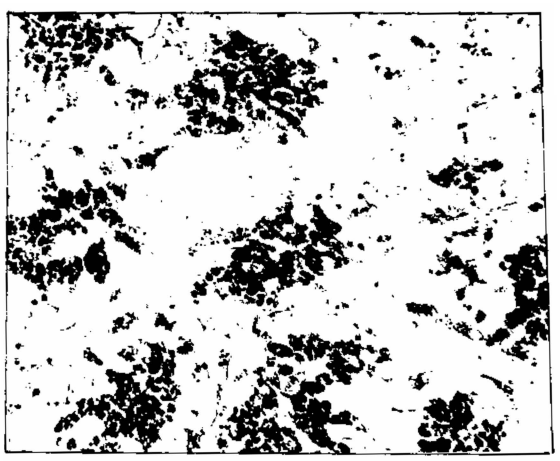

FIG 1.

FIG 2.

FIG 3.

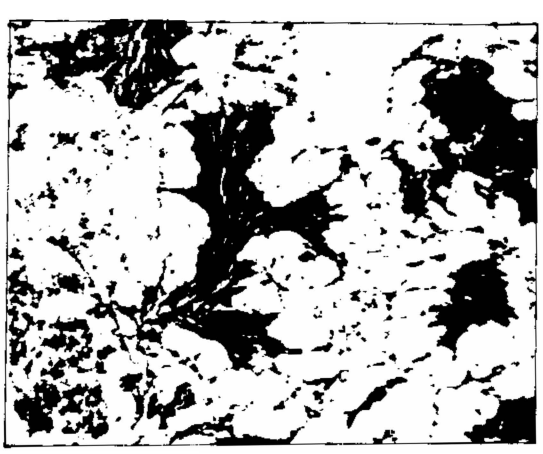

FIG 4.

FIG 5.

PLATE 6.

Figure 1.* Section of gonad of a female clam showing the different stages of oogenesis (oogonia are seen attached to the follicular wall).

Figure 2.* Section of gonad of a female clam with fully ripe ovaries packed with mature ova.

Figure 3.* Section of gonad of a partially spawned female clam. The follicle is seen to be invaded by fewer number of phagocytic cells.

Figure 4.* Section of gonad of a completely spawned female clam.

Figure 5.* Section of gonad of a fully spawned female clam. The lumen of the follicle is invaded by phagocytic cells in varying numbers.

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*All sections are 8 μ thick. The magnification of each figure: 225 x.

PLATE 6.

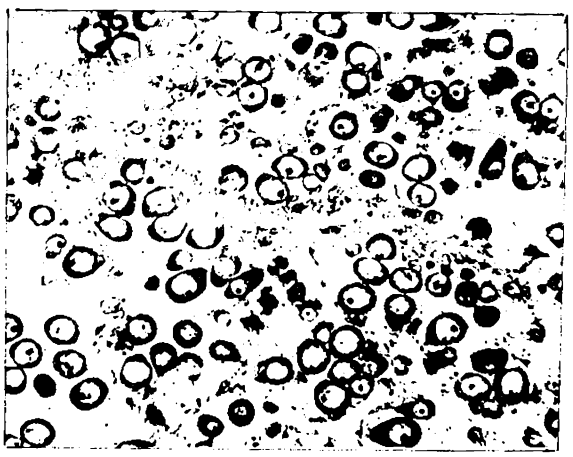


FIG 1.

FIG 2.

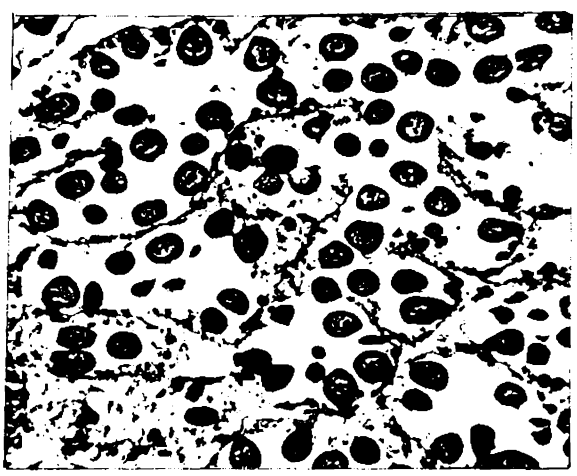
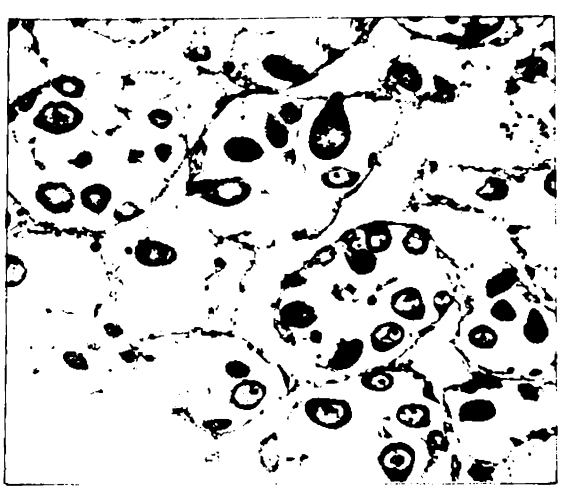


FIG 3.



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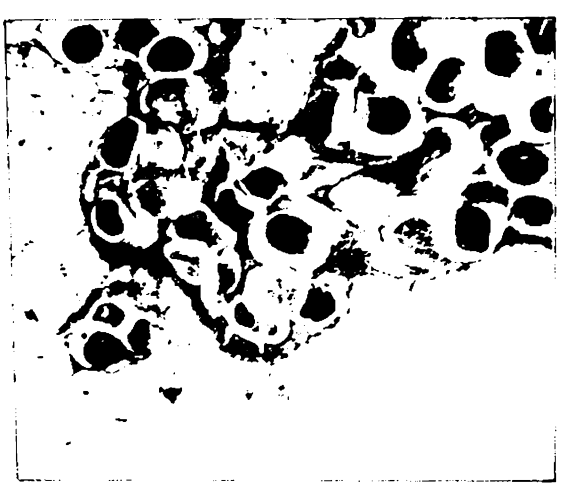


FIG 5.

PLATE. 7

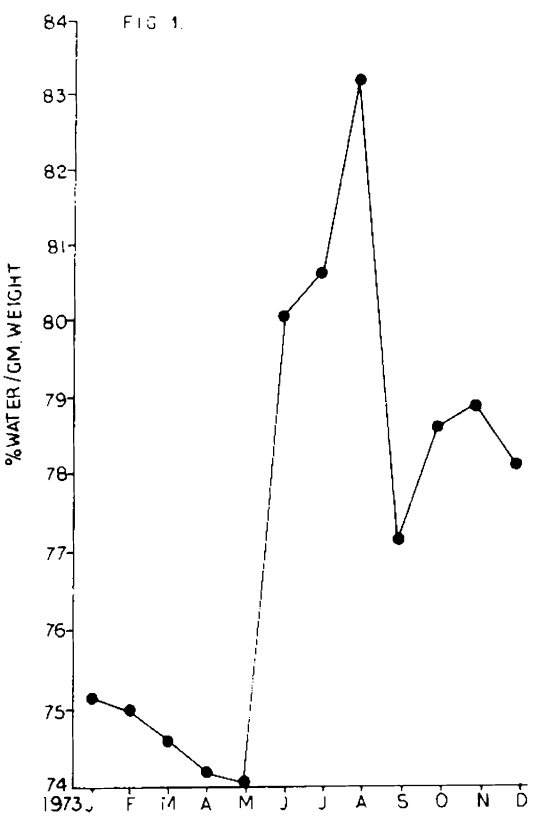


FIG 1.
%WATER/GM.WEIGHT
84
83
82
81
80
79
78
77
76
75
74
1973J F M A M J J A S O N D

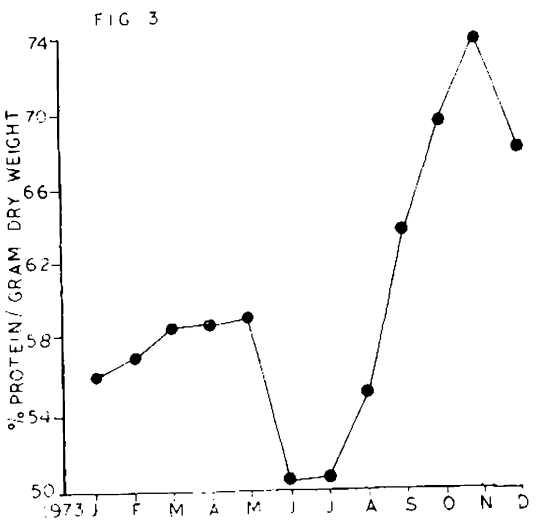


FIG 3
% PROTEIN/GRAM DRY WEIGHT
74
70
66
62
58
54
50
1973J F M A M J J A S O N D

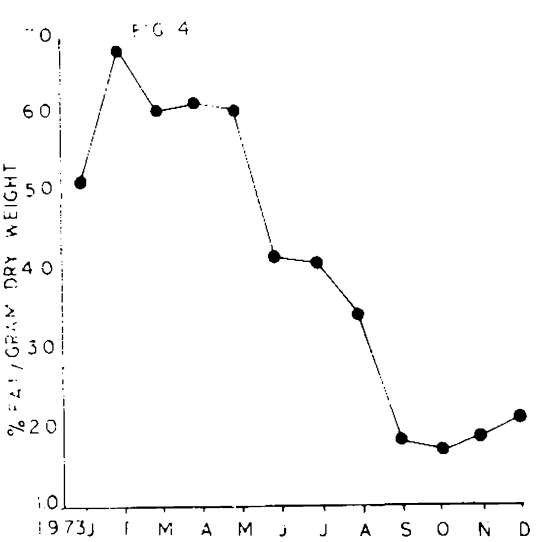


FIG 4
60
50
40
30
20
1973J F M A M J J A S O N D

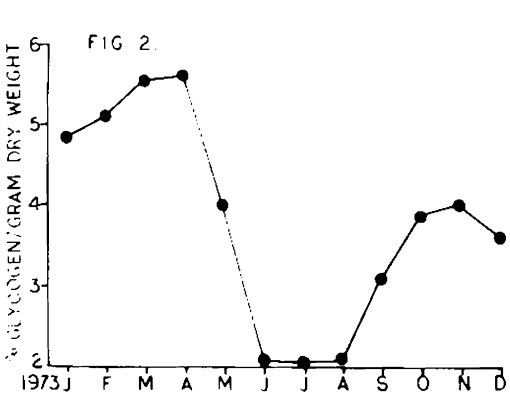


FIG 2.
6
5
4
3
2
1973J F M A M J J A S O N D

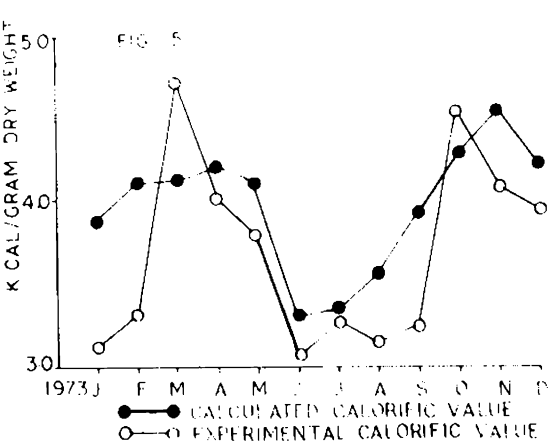

K CAL/GRAM DRY WEIGHT
50
40
30
1973J F M A M J J A S O N D
CALCULATED CALORIFIC VALUE
EXPERIMENTAL CALORIFIC VALUE

PLATE 8.

Figure 1. Water content in the body entire of *M. gaaba* for the year 1973-1974.

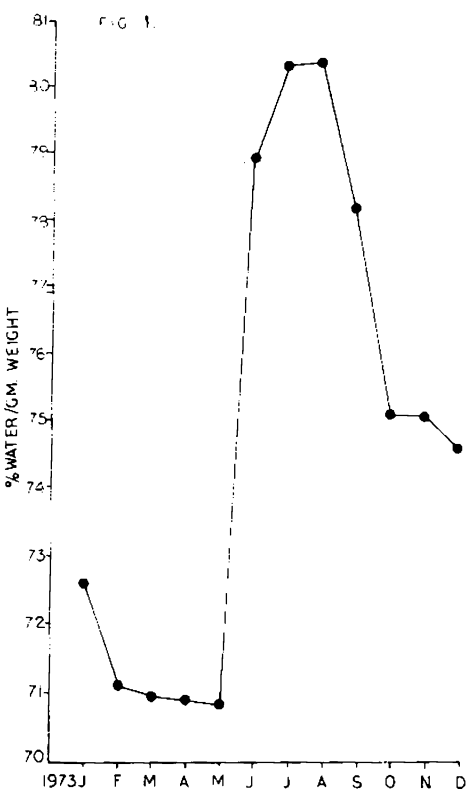
Figure 2. Glycogen content in the body entire of *M. gaaba* for the year 1973-1974.

Figure 3. Protein content in the body entire of *M. gaaba* for the year 1973-1974.

Figure 4. Fat content in the body entire of *M. gaaba* for the year 1973-1974.

Figure 5. Calorific content in the body entire of *M. gaaba* for the year 1973-1974.

PLATE. 8


% WATER/GM. WEIGHT
81
80
79
78
77
76
75
74
73
72
71
70
1973J F M A M J J A S O N D

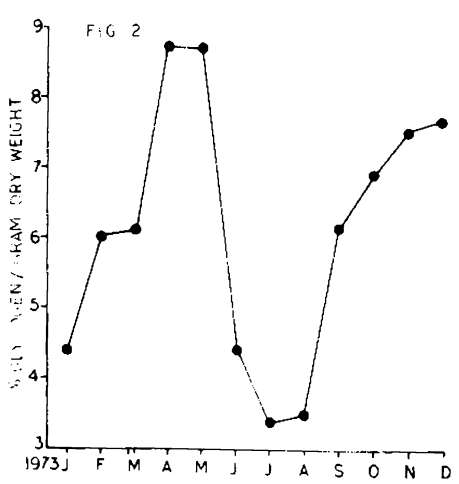


FIG 2
9
8
7
6
5
4
3
1973J F M A M J J A S O N D

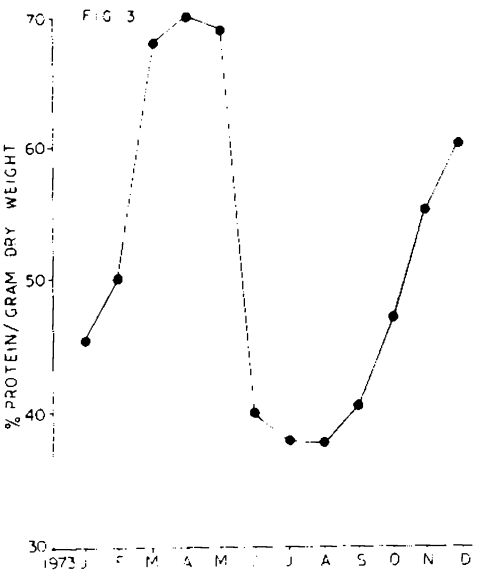
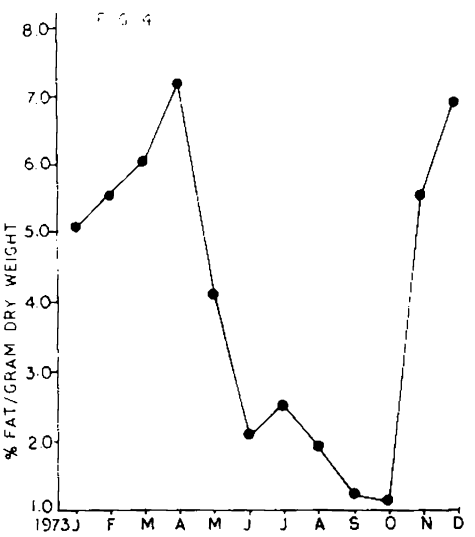


FIG 3
% PROTEIN/GRAM DRY WEIGHT
70
60
50
40
30
1973J F M A M J A S O N D


8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
1973J F M A M J J A S O N D

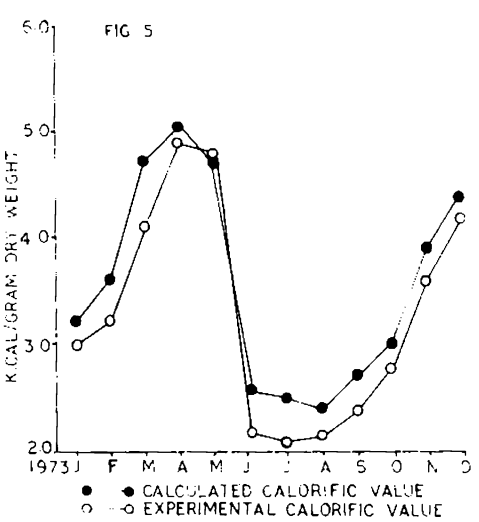


FIG 5
K.CAL/GRAM DRY WEIGHT
5.0
4.0
3.0
2.0
1973J F M A M J J A S O N D
CALCULATED CALORIFIC VALUE
EXPERIMENTAL CALORIFIC VALUE

PLATE 8a.

Figure 1. Relation between water content, glycogen, protein and fat in the body entire of *L. gracilis*.

FIG. 1

PLATE. 8a

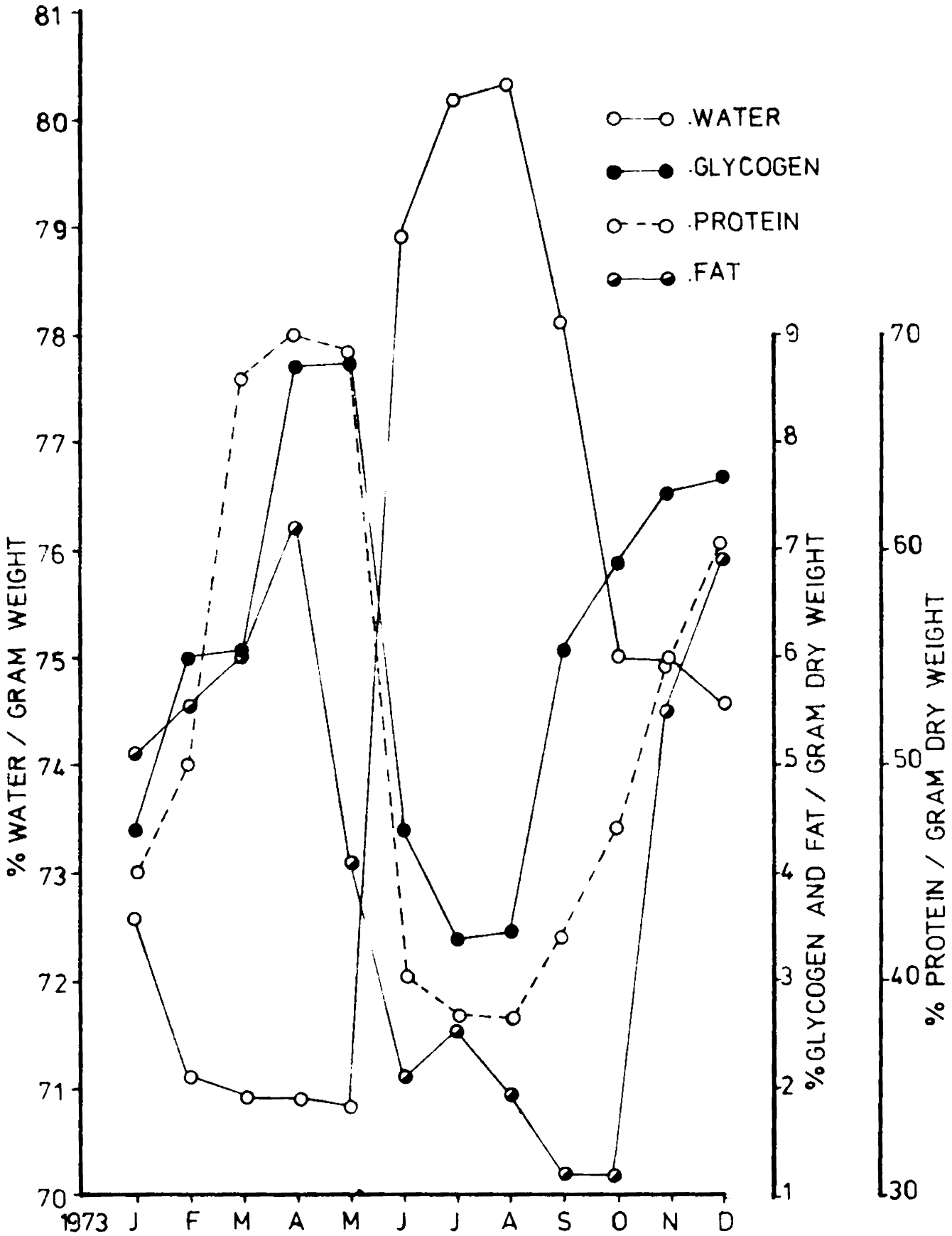


PLATE 9.

Figure 1. Water content in the adductor muscle of *M. gaaba* for the year 1973-1974.

Figure 2. Glycogen content in the adductor muscle of *M. gaaba* for the year 1973-1974.

Figure 3. Protein content in the adductor muscle of *M. gaaba* for the year 1973-1974.

Figure 4. Fat content in the adductor muscle of *M. gaaba* for the year 1973-1974.

Figure 5. Calorific content in the adductor muscle of *M. gaaba* for the year 1973-1974.

PLATE. 9

FIG 1

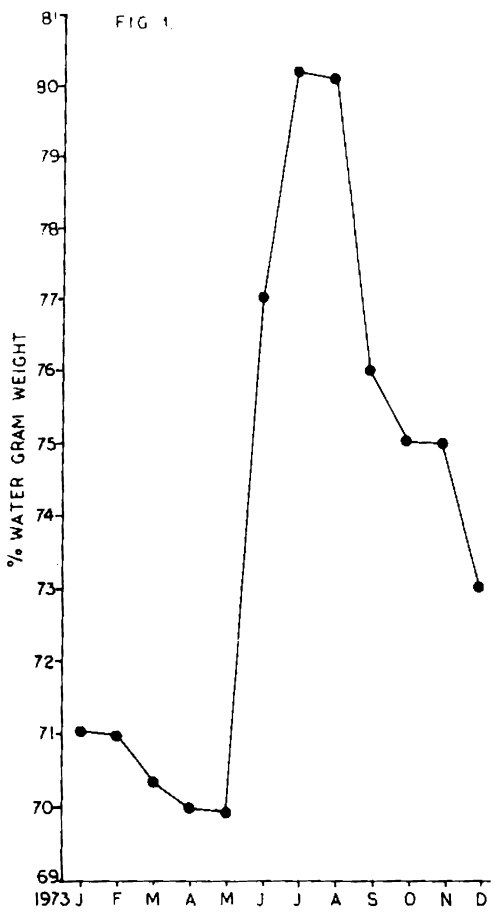


FIG 2

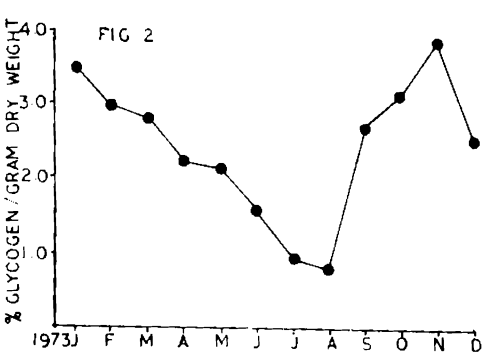


FIG 3

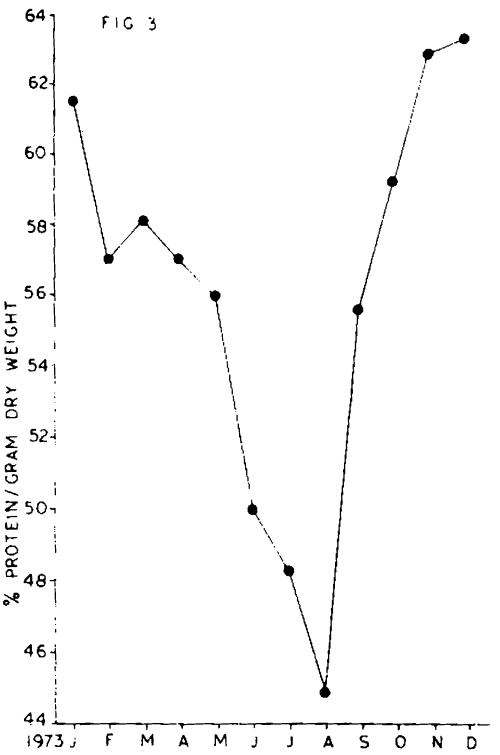


FIG 4

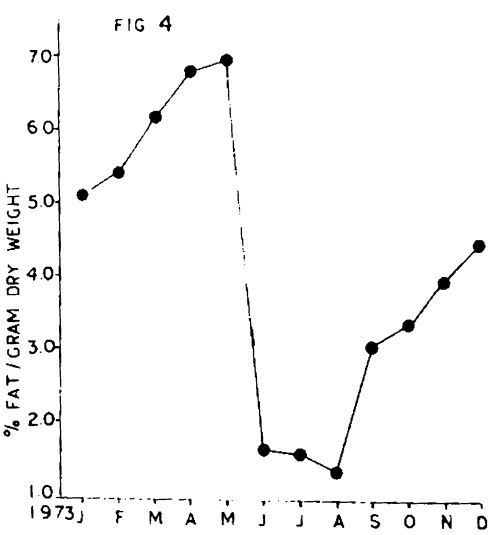


FIG 5

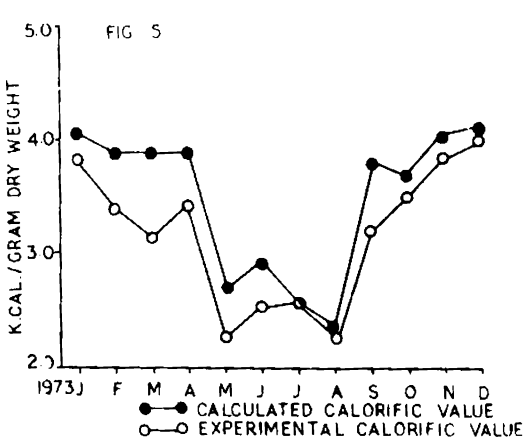


PLATE XD.

Figure 1. Ash content in the body entire of *M.cephalus* for the year 1973-1974.

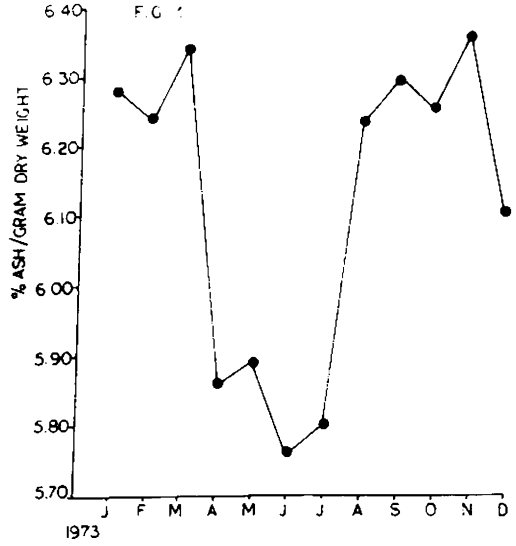
Figure 2. Iron content in the body entire of *M.cephalus* for the year 1973-1974.

Figure 3. Copper content in the body entire of *M.cephalus* for the year 1973-1974.

Figure 4. Calcium content in the body entire of *M. cephalus* for the year 1973-1974.

Figure 5. Magnesium content in the body entire of *M. cephalus* for the year 1973-1974.

PLATE. 10


6.40
6.30
6.20
6.10
6.00
5.90
5.80
5.70
% ASH/GRAM DRY WEIGHT
J F M A M J J A S O N D
1973

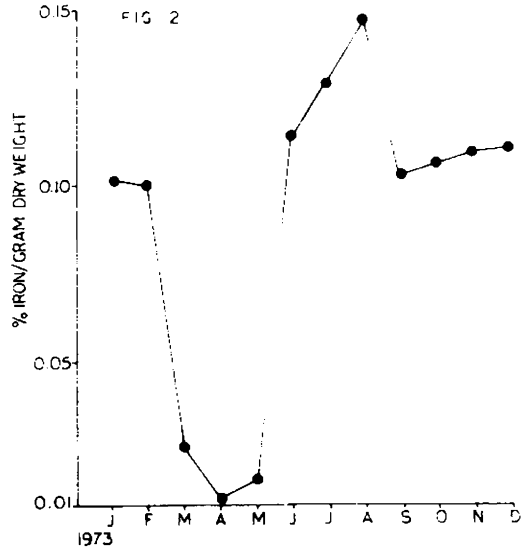


FIG 2
0.15
0.10
0.05
0.01
% IRON/GRAM DRY WEIGHT
J F M A M J J A S O N D
1973

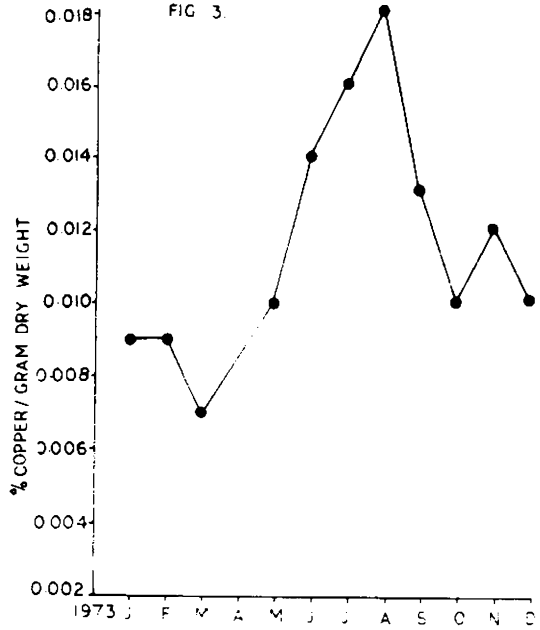


FIG 3.
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
% COPPER / GRAM DRY WEIGHT
1973 J F M A M J J A S O N D

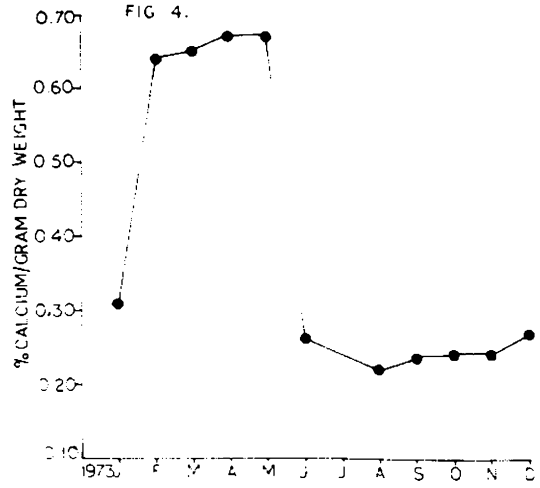


FIG 4.
0.70
0.60
0.50
0.40
0.30
0.20
0.10
% CALCIUM/GRAM DRY WEIGHT
1973

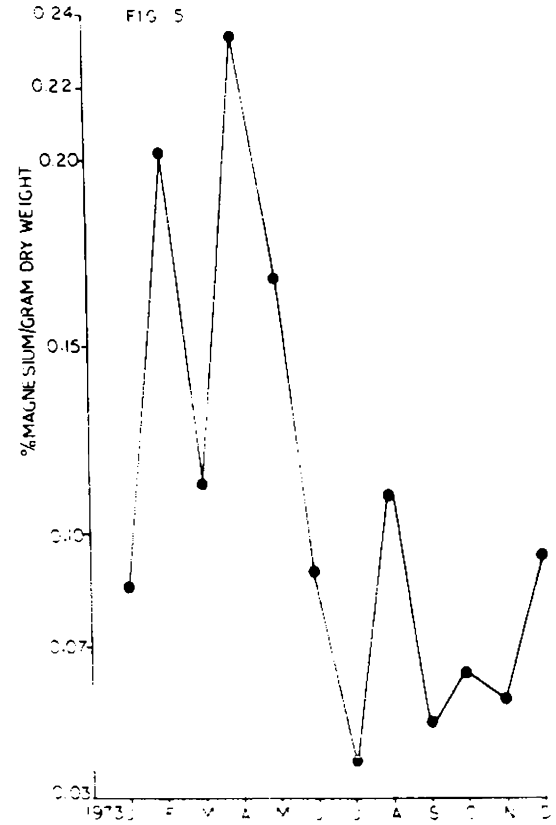


FIG 5
0.24
0.22
0.20
0.15
0.07
0.03
% MAGNESIUM/GRAM DRY WEIGHT
1973

PLATE 11.

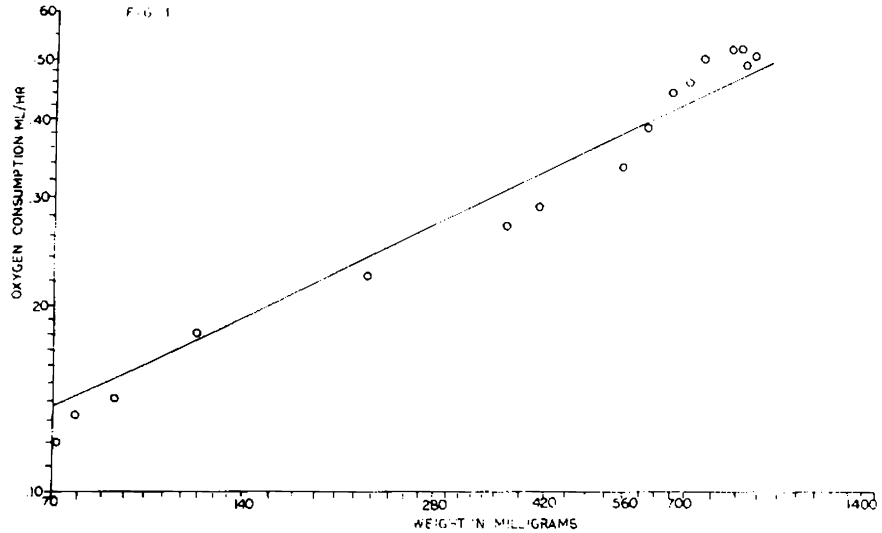
Figure 1. Relationship between Oxygen uptake and body weight in *M. cepia* in 5% salinity medium at 160 mm.Hg.pressure.
'b' value = 0.4237.

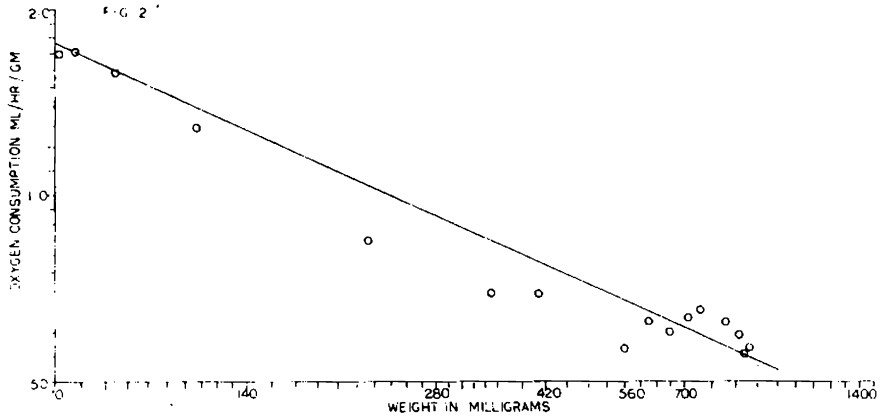
Figure 2. Metabolic rate and body weight in *M.cepia* in 5% salinity medium at 160 mm.Hg.pressure.
'b-1' value = -.5763.

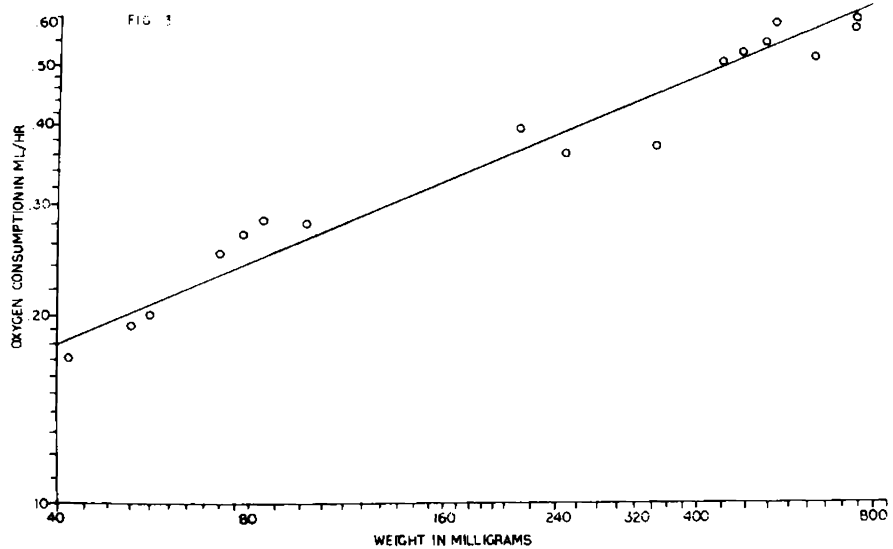
Figure 3. Relationship between Oxygen uptake and body weight in *M.cepia* in 10% salinity medium at 160 mm.Hg.pressure.
'b' value = 0.4276.

Figure 4. Metabolic rate and body weight in *M.cepia* in 10% salinity medium at 160 mm.Hg.pressure.
'b-1' value = -.3724.

PLATE. II


OXYGEN CONSUMPTION ML/HR
.60
.50
.40
.30
.20
.10
70
140
280
420
560
700
1400
WEIGHT IN MILLIGRAMS


OXYGEN CONSUMPTION ML/HR/GM
2.0
1.0
.50
140
280
420
560
700
1400
WEIGHT IN MILLIGRAMS


OXYGEN CONSUMPTION IN ML/HR
.60
.50
.40
.30
.20
.10
40
80
160
240
320
400
800
WEIGHT IN MILLIGRAMS

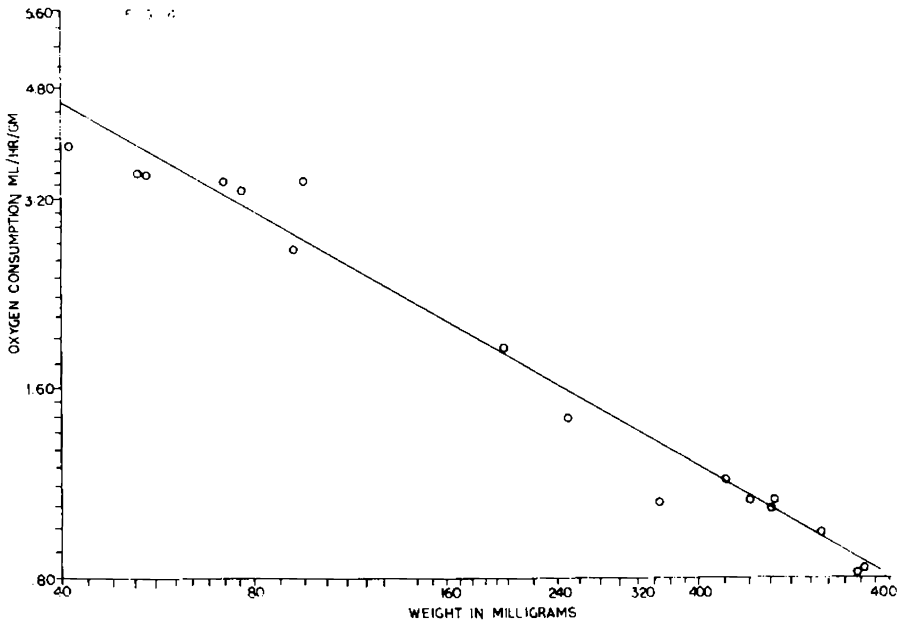

OXYGEN CONSUMPTION ML/HR/GM
5.60
4.80
3.20
1.60
.80
40
80
160
240
320
400
WEIGHT IN MILLIGRAMS

PLATE XX.

Figure 1. Relationship between Oxygen uptake and body weight in *M. gamia* in 15‰ salinity medium at 160 mm. Hg.pressure.
'b' value = 0.4636.

Figure 2. Metabolic rate and body weight in *M.gamia* in 15‰ salinity medium at 160 mm. Hg.pressure.
'b-1' value = -.6364.

Figure 3. Relationship between Oxygen uptake and body weight in *M. gamia* in 20‰ salinity medium at 160 mm.Hg. pressure.
'b' value = 0.4769.

Figure 4. Metabolic rate and body weight in *M. gamia* in 20‰ salinity medium at 160 mm.Hg.pressure.
'b-1' value = -.6231.

PLATE. 12

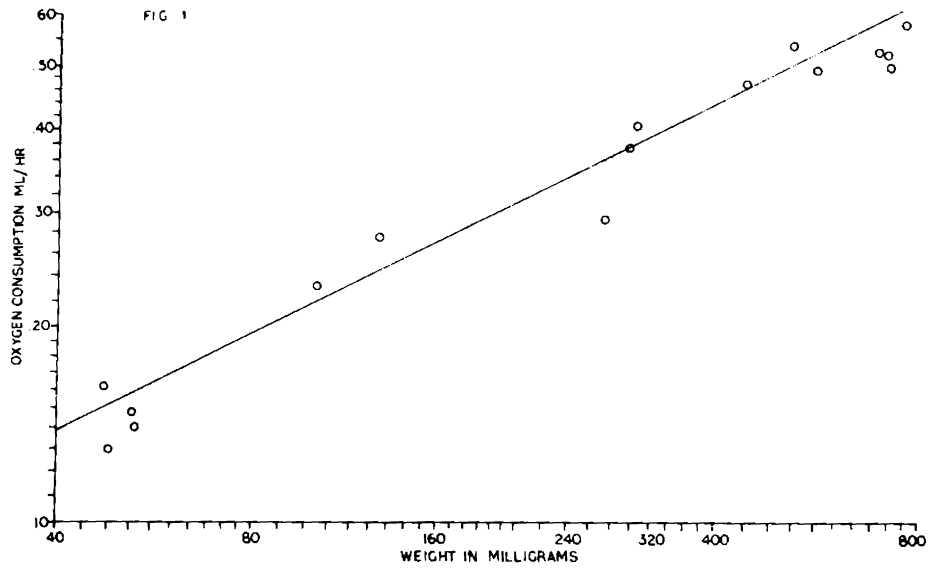


FIG 1
OXYGEN CONSUMPTION ML/HR
60
50
40
30
20
10
40
80
160
240
320
400
800
WEIGHT IN MILLIGRAMS

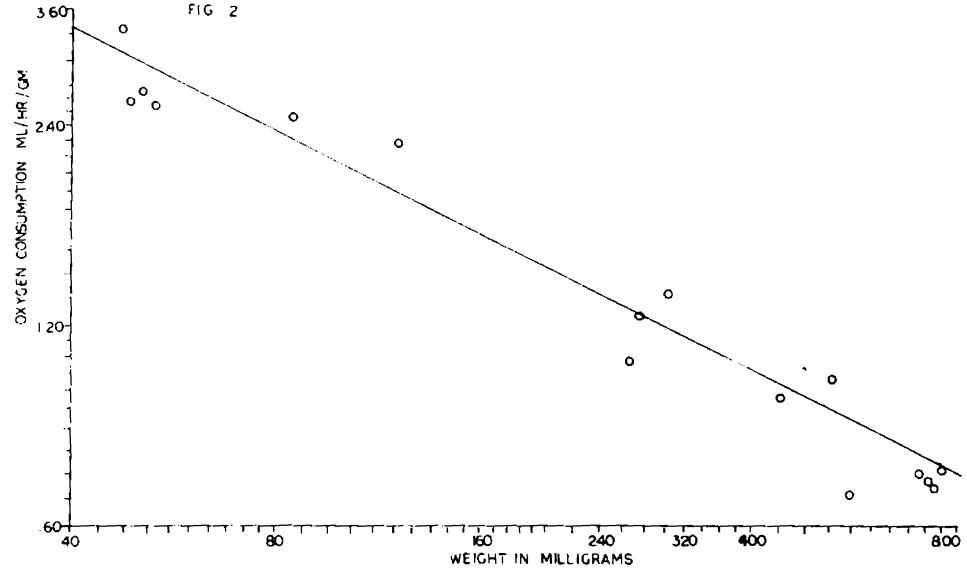


FIG 2
OXYGEN CONSUMPTION ML/HR/GM
360
240
120
60
40
80
160
240
320
400
800
WEIGHT IN MILLIGRAMS

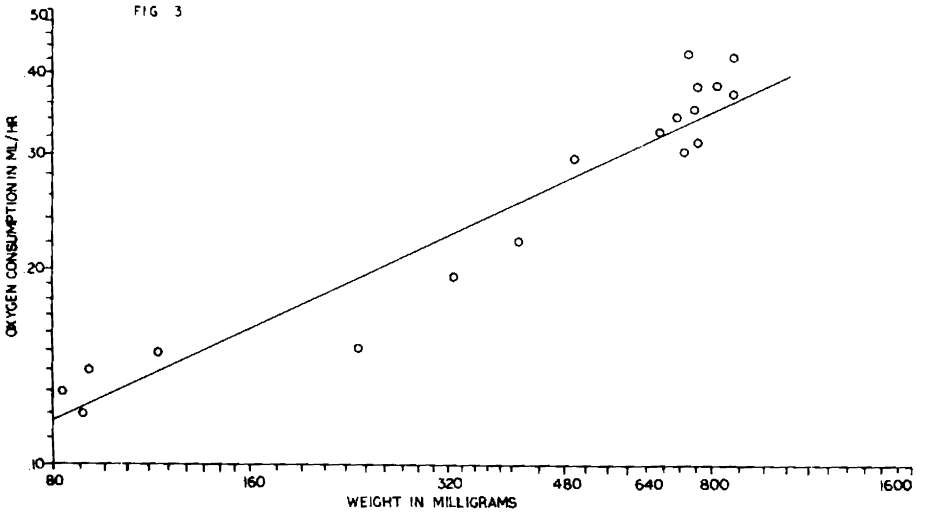


FIG 3
OXYGEN CONSUMPTION IN ML/HR
50
40
30
20
10
80
160
320
480
640
800
1600
WEIGHT IN MILLIGRAMS

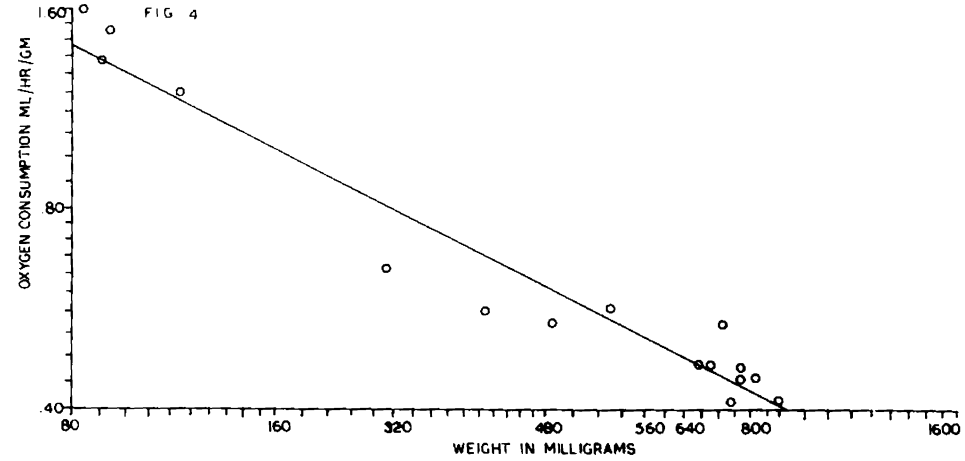


FIG 4
OXYGEN CONSUMPTION ML/HR/GM
160
80
40
80
160
320
480
560
640
800
1600
WEIGHT IN MILLIGRAMS

PLATE 19.

Figure 1. Relationship between oxygen uptake and body weight in *M. gamia* in 25% salinity medium at 160 mm. Hg. pressure.
'b' value = 0.6180.

Figure 2. Metabolic rate and body weight in *M. gamia* in 25% salinity medium at 160 mm.Hg.pressure.
'b-1' value = -.4820.

Figure 3. Relationship between Oxygen uptake and body weight in *M. gamia* in 30% salinity medium at 160 mm.Hg.pressure.
'b' value = 0.6306.

Figure 4. Metabolic rate and body weight in *M.gamia* in 30% salinity medium at 160 mm.Hg. pressure.
'b-1' value = -.4696.

PLATE. 13

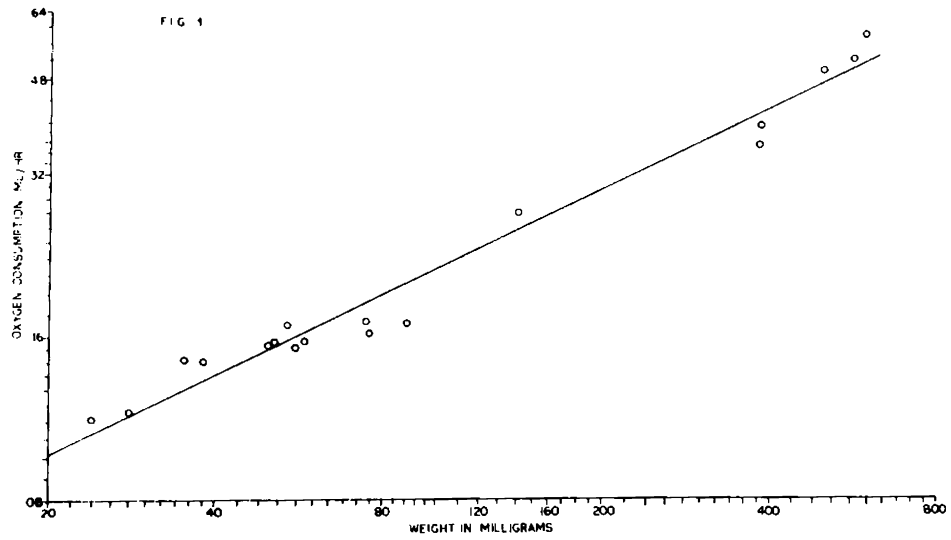


FIG 1
64
48
32
16
20
40
80
120
160
200
400
800
WEIGHT IN MILLIGRAMS

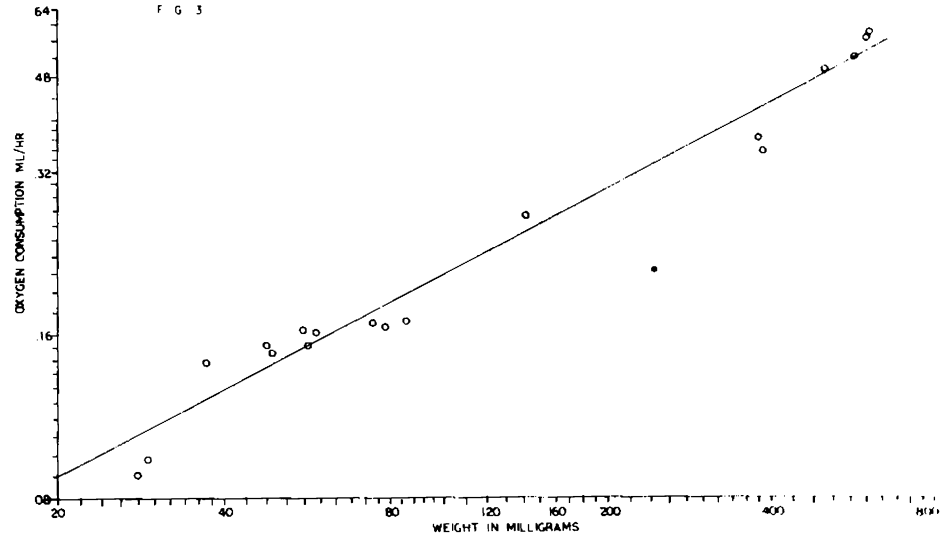


FIG 3
64
48
32
16
20
40
80
120
160
200
400
WEIGHT IN MILLIGRAMS

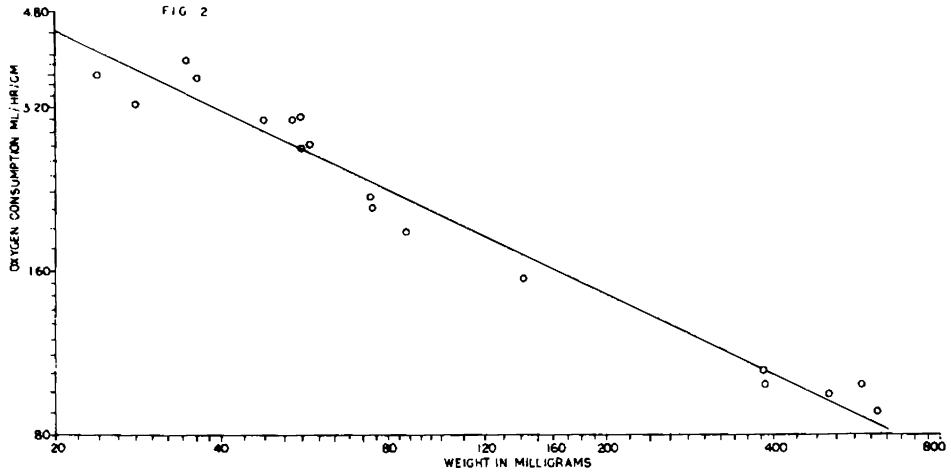


FIG 2
OXYGEN CONSUMPTION ML/HR/GM
480
320
160
80
20
40
80
120
160
200
400
800
WEIGHT IN MILLIGRAMS

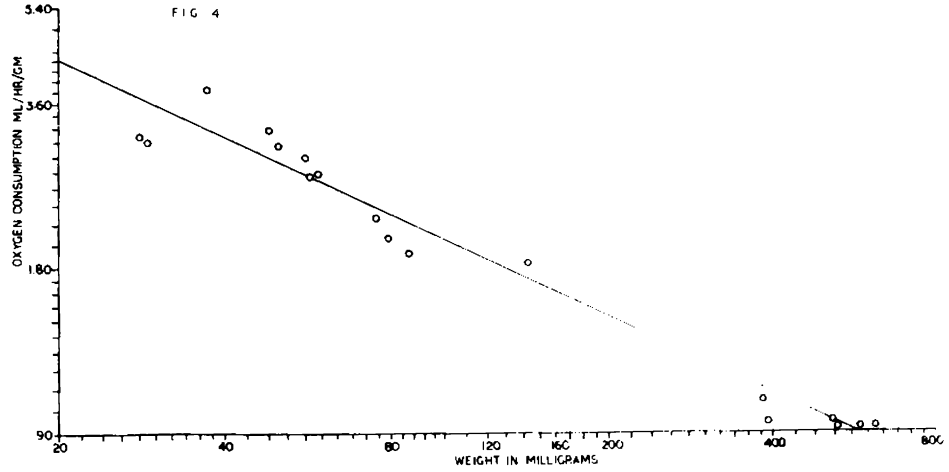


FIG 4
OXYGEN CONSUMPTION ML/HR/GM
540
360
180
90
20
40
80
120
160
200
400
WEIGHT IN MILLIGRAMS

PLATE 14.

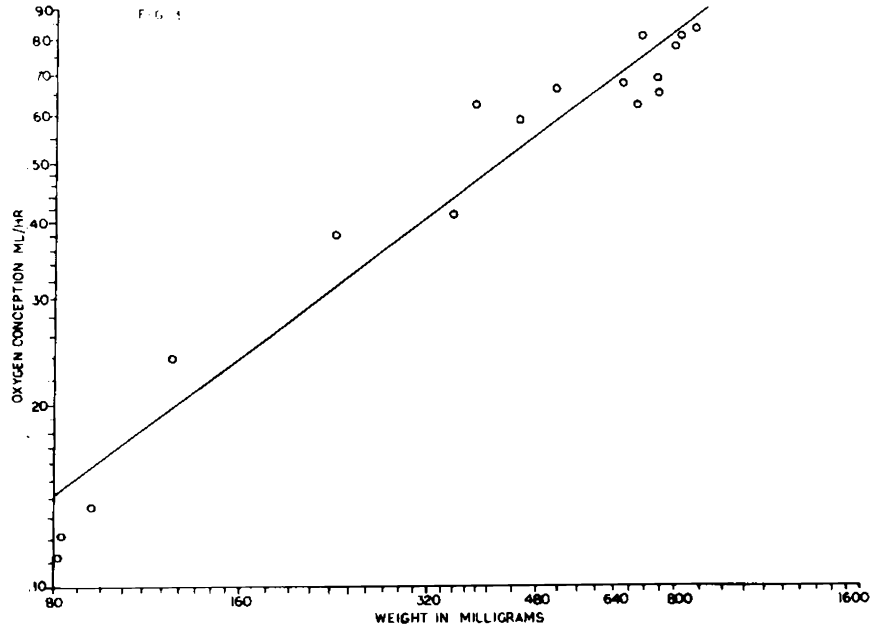
Figure 1. Relationship between oxygen uptake and body weight in M. gamia in 35‰ salinity medium at 160 mm.Hg. pressure.
'b' value = 0.7439.

Figure 2. Metabolic rate and body weight in M.gamia in 35‰ salinity medium at 160 mm. Hg.pressure.
'b-1' value = -.2601.

Figure 3. Relationship between oxygen uptake and body weight in M. gamia in 40‰ salinity medium at 160 mm. Hg.pressure.
'b' value = 0.6136.

Figure 4. Metabolic rate and body weight in M.gamia in 40‰ salinity medium at 160 mm. Hg.pressure.
'b-1' value = -.4864.

PLATE. 14


OXYGEN CONCEPTION ML/HR
WEIGHT IN MILLIGRAMS

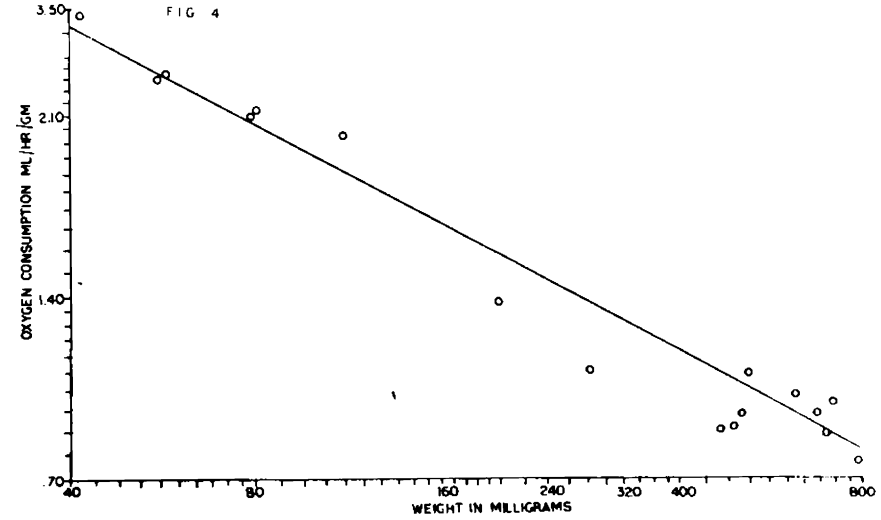


FIG 4
OXYGEN CONSUMPTION ML/HR/GM
WEIGHT IN MILLIGRAMS

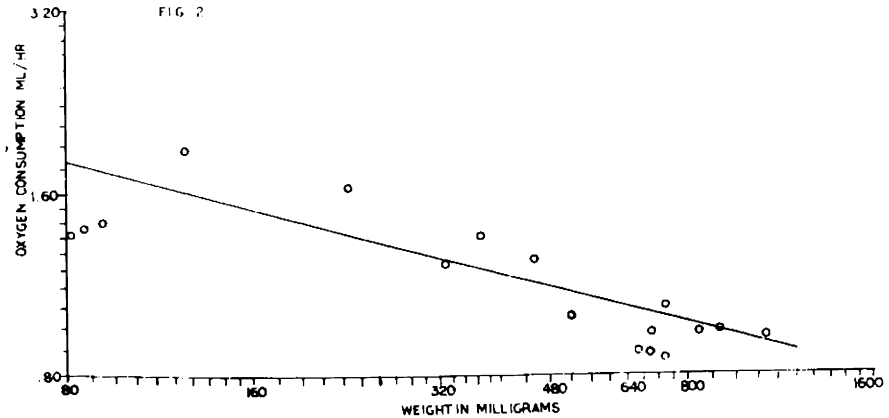


FIG 2
OXYGEN CONSUMPTION ML/HR
WEIGHT IN MILLIGRAMS

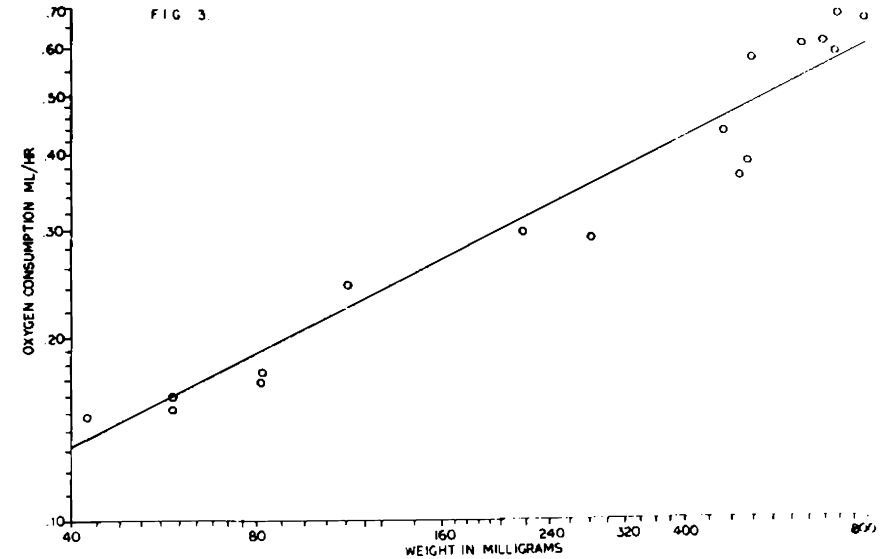


FIG 3
OXYGEN CONSUMPTION ML/HR
WEIGHT IN MILLIGRAMS