STUDIES ON THE BENTHOS OF THE MUD BANK REGIONS OF THE KERALA COAST

By

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THESIS

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

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C O N T E N T S

C H A P T E R - I

INTRODUCTION

It is generally recognised that a detailed understanding of the bottom fauna is necessary to obtain a comprehensive picture of the fishery potential in an area. Bottom fauna is roughly divided into (a) animals that live much of their lives in the upper layers of the water and descend to the bottom for breeding, feeding or resting as contrasted with (b) animals that spend most of their lives on the bottom; and finally (c) burrowers (Allee et. al. 1961). The first group includes bottom dwelling fishes, many crustaceans and other mobile invertebrates. The second and third categories correspond to Petersen's epifauna and infauna respectively (Petersen 1913).

The above situation makes it necessary to consider two separate entities in the environment - the substratum, and the water overlying it - in an ecological study of the bottom fauna. For the first category of animals the condition of the bottom water may be the most important factor. In the case of animals which live on the bottom and are constantly in contact with the bottom water (epifauna) for their feeding, respiration etc., the nature of the substratum as well as that of the overlying water are of equal importance. As far as the burrowers (infauna) which spend most of their life within the substratum are concerned, the physical and chemical nature of the sediment may be of greater significance than to the epifauna.

Benthic animals are divided into three categories according to size (1) macrobenthos (2) meiobenthos and (3) microbenthos (Mare 1942). Although the terms macrobenthos, meiobenthos and microbenthos are now in common use, the prefix mega (meaning large, great) is preferred to macro (meaning long, large), by some investigators (Carriker 1967). Long animals, although their body diameter may be smaller than the mesh size used for separating larger animals from the sediment, will be retained in the sieve by virtue of their length and will be included in this category in most of the investigations. Thus the term macrobenthos is preferred in the present study.

The above distinction of benthos into three size groups is rather arbitrary and vague and varies according to the workers and according to the type of substratum under investigation. The lower size limit of macrobenthos depends upon the mesh size of the finest sieve used and usually varies between 3.0 and 0.5 mm. according to different workers. The upper limit of meiobenthos depends upon the mesh size of the sieve used for separating macrobenthos from meiobenthos. This generally falls between 0.5 and 1.0 mm. In most of the meiobenthos investigations it is necessary to have a lower size limit to eliminate the fine sediment in the process of extraction of organisms. This lower limit is between 0.04 and 0.1 mm. (McIntyre 1969). The smallest size groupe, microbenthos, includes those organisms that are not retained in the finest sieve used for meiobenthos separation and includes bacteria and most protozoa. Because of the variation in the mesh size of the sieves used by different workers, there is no strict definition to separate the three categories of benthos and they serve only as an indication of the way the investigators have found it convenient to sample a continuous size spectrum (McIntyre loc. cit.).

The history of quantitative investigation of bottom fauna is rather recent. It is only in the early years of the 20th century C.G. Joh Petersen made extensive investigations in Danish waters, to study the importance of bottom fauna in the marine economy. This has initiated a number of other investigations on bottom fauna in different parts of the world. But most of these studies were restricted to macrobenthos owing to the relative ease in the investigation. Since the work of Remane in Kiel Bay (Remane 1933), the meiobenthos have been subjected to detailed investigations. With the realisation of the importance of these smaller sized metazoans, meiobenthos studies have gained momentum.

There is very little information on the subtidal bottom fauna of the shelf regions in the seas around India. What little is known is restricted to macrobenthos. The paucity of the work on bottom fauna and the importance of mud banks in the fishery of the South West Coast of India has initiated the present study. Attempts have been made to obtain a picture of the bottom fauna of a mud bank region of the Kerala Coast. The difficulties involved in the sampling and analysis, especially the availability of a suitable vessel during the S.W. Monsoon, resulted in the work being restriricted mainly to the Narakal mud bank region 6 Km. north of Cochin.

Detailed sampling was conducted using grab, dredge and to a small extent beam trawl, to assess the qualitative and quantitative nature of the macrobenthos. Important species contributing to the fauna are identified and the standing crop estimated for different seasons. The meiobenthos was studied using core samples taken from the grab. Animals were identified to the major taxa. Standing crop of meiobenthos and the quantitative importance of different groups were also studied. The data collected have been interpreted and discussed.

As an understanding of the physico-chemical aspects of the environment is essential in order to obtain a true picture of the benthos, attempts were made in this direction. Environmental parameters such as temperature of the sediment, salinity, temperature, and dissolved oxygen in the overlying water were studied during the period of benthos investigation. Monthly observations on the dissolved inorganic and organic phosphorus in the area of investigation have been made. The physico-chemical

nature of the sediment was also studied. Influence of these ecological variables on the bottom fauna is discussed.

C H A P T E R -- II

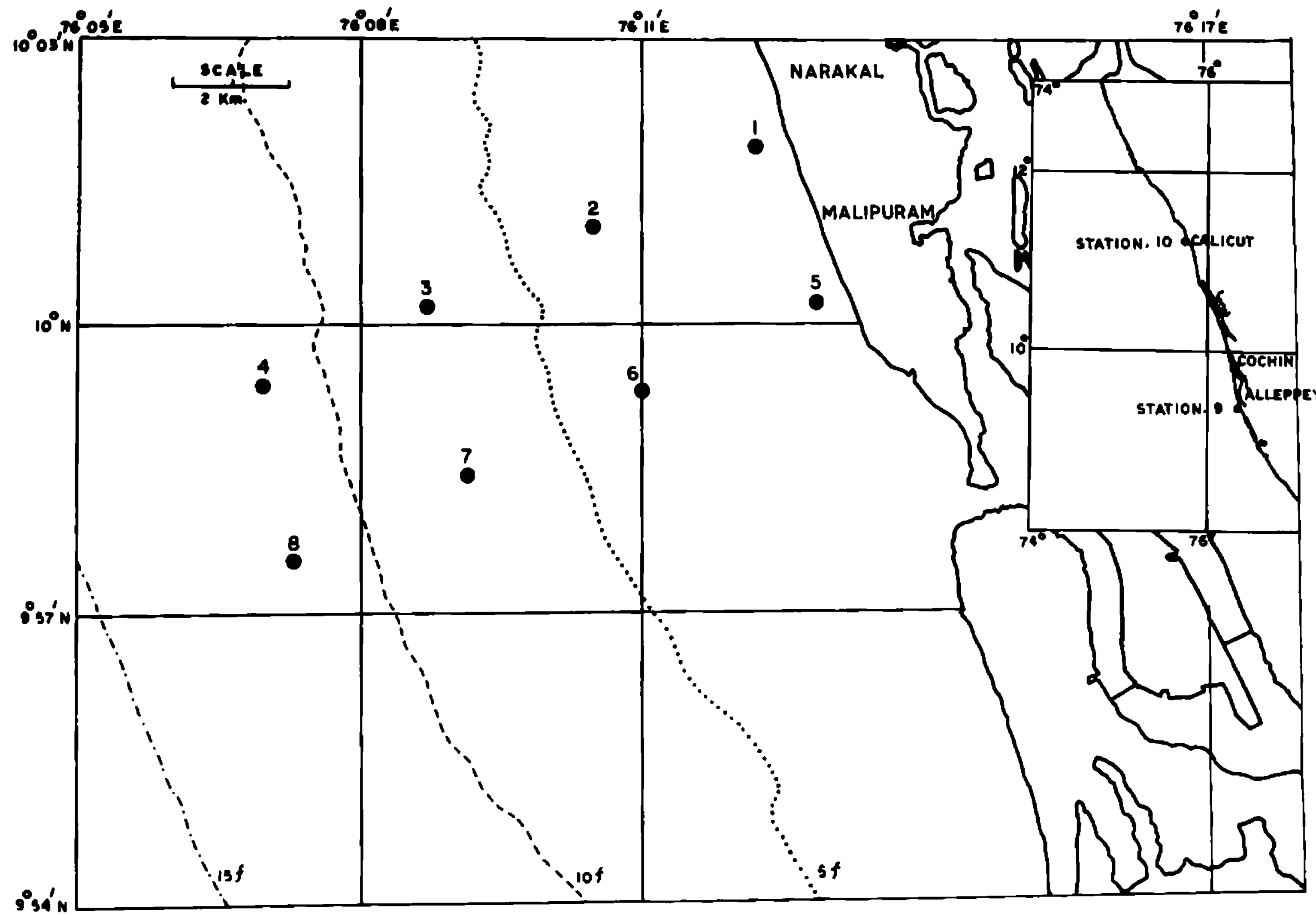
MATERIAL AND METHODS

The materials for the present study were collected from February 1966 to February 1968, from eight stations located on two traverses running about 2 Km. apart at right angles to the coast from a mud bank region off Narakal (Fig. 1). For the region as a whole the nature of the substratum was muddy. The stations in each traverse were 3 Km. apart and stations 1 and 5 which were nearest to the coast in each traverse were about half Km. from the low water mark. The depth of these two stations was 4 m. The second set of stations (Stations 2 and 6) were at 8 m. depth, the third set (Stations 3 and 7) at 14 m, and the last set (Stations 4 and 8) at 21 m. depth. The stations nearest to the coast were fixed with the help of land bearings and the others towards the sea by dead reckoning.

Each of the eight stations mentioned above was sampled once a month. In addition to this, samples were collected from two other mud bank regions, one off Alleppy (Station 9), and one off Calicut (Station 10) to study the nature of meiobenthos. The main effort however was restricted to the first eight stations. In addition to the bottom fauna collection, samples for hydrographical and phosphate studies were simultaneously taken from each station. Sediment samples were also taken from each

Fig. 1. Map showing the positions of the stations.

Station No.	Latitude	Longitude	Depth
1.	10^{o} 1.8'N.	70^{o}. 12.2'E.	4 m.
2	10^{o} 1.0'N.	76^{o}. 10.5'E.	8 m.
3	10^{o} 0.2'N.	76^{o}. 8.8'E.	14 m.
4	9^{o}59.3'N.	76^{o}. 7.0'E.	21 m.
5	10^{o} 0.2'N.	76^{o}. 12.8'E.	5 m.
6	9^{o}59.3'N.	76^{o}. 11.0'E.	8 m.
7	9^{o}58.4N.	76^{o}. 9.1'E.	14 m.
8	9^{o}57.6'N.	76^{o}. 7.3'E.	21 m.
9	9^{o}22.0'N.	76^{o}. 21.8'E	4 m.
10	11^{o}21.6'N.	75^{o}. 45.0'E	4 m.



76° 05' E
76° 08' E
76° 11' E
76° 17' E
10° 03' N
10° N
9° 57' N
9° 54' N
SCALE
2 Km.
NARAKAL
MALIPURAM
1
2
3
4
5
6
7
8
15 f
10 f
5 f
74°
76°
12°
10°
STATION. 10
CALICUT
COCHIN
ALLEPPEY
STATION. 9

station at frequent intervals in order to study the physico-chemical nature of the bottom. The detailed techniques employed in each case are given below.

HYDROGRAPHY

Surface water temperature and bottom sediment temperature were observed at each station at monthly intervals with the exception of June 1967. In December 1966 and January 1967 observations were taken only on one traverse. As sampling of the stations in each traverse was done as far as possible on the successive days and the distance between the traverses is only 2 Km., the data from stations of identical depths are averaged while plotting the graph.

Water temperature was recorded using an ordinary centigrade thermometer. The sediment temperature was taken by inserting the thermometer in the centre of the grab sample, as soon as the sample was taken aboard. The bottom water temperature was not taken for the present study, because observations on the same region during different months showed that there was only a small difference between the bottom water temperature and sediment temperature (Hridayanathan, unpublished).

Together with temperature observations, water samples for dissolved oxygen and salinity data were collected from the surface and bottom. The bottom water samples were collected by lowering a Nansen bottle as close to the bottom as possible. Chlorinity of the water was estimated using the Mohr method

(Barnes 1959) and salinity calculated using Knudsen's table. Dissolved oxygen in the water was estimated using the Winkler method (Barnes 1959).

PHOSPHORUS

Samples for inorganic phosphorus were collected from May 1966 onwards and unusually high values were obtained during July 1966. This initiated the study of total phosphorus. Thus the present data is from May 1966 to February 1968 for inorganic phosphorus with the exception of June 1967, and from October 1966 to February 1968 for total phosphorus with the exception of March and June 1967.

Surface water samples were collected using an ordinary plastic bucket and bottom water using Nansen bottles as close to the bottom as possible. Samples were preserved by adding a few drops of chloroform, and analyses were conducted within a few hours. Inorganic phosphorus estimation was done by filtered sea water and total phosphorus on unfiltered sea water which had been allowed to settle for 24 hours to remove the excess turbidity. The term inorganic phosphorus is used here to designate that part of phosphorus held in solution in sea water which had reacted with acidified molybdate in five minutes. The term organic phosphorus is used to describe that part of phosphorus which has not reacted to the molybdate in five minutes but was estimated by the method used for total phosphorus. Analytical methods followed for inorganic and total phosphorus were those of Strickland and Parsons (1965), using a spectrophotometer. For each month mean values of inorganic and total phosphorus were calculated for stations having similar depths and plotted in the graph. Values for organic phosphorus were obtained by subtracting the inorganic phosphorus values from total phosphorus values.

SEDIMENT

A total of 56 samples were taken for the study of the sediment; seven samples from each station at an interval of three months. Samples were taken from a Petersen grab haul. Contents of the grab was mixed and a small sample was taken for analysis. The general features of the sediment like colour, texture and plasticity were logged in the field.

All the sediment samples were subjected to particle size analysis by the combined sieving and pipette method given by Krumbein and Pettijohn (1938). Known quantities of dried sediments were dispersed overnight in 0.025 N solution of sodium hexametaphosphate. The silt clay fractions were separated by washing the dispersed sediments through a 230-mesh sieve (with an aperture of 1/16 mm.). The coarse fractions retained in the sieve were dried and analysed using Standard Endecott sieves. The finer fractions were analysed down to a 0.5 μ. size limit by the pipette method (Krumbein and Pettijohn, 1938).

Organic carbon in the sediment was estimated by the method of El Wakeel & Riley (1956). Prior to analysis the sediment was washed to remove all salts. To get the percentage of organic matter, the organic carbon percentages were multiplied by a factor of 1.724 (Trask, 1938).

BOTTOM FAUNA

Essentially selective sampling of bottom is still the main technique employed in the study of benthos. The inadequacy of the present sampling instruments and the need for innovations had been pointed out by many workers (Birkett 1958, Home 1964). Under-water diving, photography and television are coming into common use, at least in certain regions. But for many workers, grabs, dredges, beam trawls and corers are the main tools even today.

Quantitative samples for macrobenthos were taken with a Petersen grab of 0.1 m^2. Samples were collected every month between January 1966 and February 1968 from stations 1 to 4, and between February 1966 and February 1968 from Stations 5 to 8. However collections were not taken during December 1966 and January 1967 as the research vessel was not available. In June 1967, also, sampling could not be done because of the severe monsoon and uncertain weather. Holme and McIntyre (1971) suggest five samples with a 0.1 m^2 grab for each station for quantitative work. In the present study one of the aims was to determine the influence of mud bank formation on bottom fauna at different depths. For this purpose at least eight stations were found to be necessary. As it was not possible to deal with a large quantity of material within a reasonable period it was decided to take one sample from each station. Thus one grab haul was taken from every station in each month. As the bottom sediment was fine and soft throughout the sampling area the Petersen grab was always able to cut through the bottom easily and came up completely filled with mud. A few dredge hauls were also taken from each station using a dredge of 28 x 47 cm. size. The dredge was used to collect the epifauna and also species which are poorly distributed. A few beam trawl hauls were also taken with this aim.

For separating the animals from the sediment hand sieving was employed. The grab contents were screened through a 1.00 mm. round mesh sieve. So for the present study, all animals retained on the 1.0 mm. sieve have been categoriesd as macrobenthos. Those animals passing the 1.0 mm. sieve but retained on the 62 μ sieve have been studied separately as meiobenthos.

After a cursory examination the residues from the 1.0 mm. sieve were preserved in 5% neutral formalin for further study. In the laboratory all the animals in each sample were picked out and identified as far as possible to species level.

For sampling the meiobenthos an instrument of the type described by Moore and Neill (1930) might have been useful. In the absence of such an instrument taking subsamples from a grab is the next alternative. But according to McIntyre (1971) any instrument that is dropped to the bottom, where there is a flocculent layer, is incapable of bringing a sample that is representative.

In the present study samples for meiobenthos were taken from a grab in the following way. A Van Veen grab of 0.05 m^2. surface area was used. As soon as the grab was hauled up the top plate of the grab was removed and the surface of the deposit was exposed. After making sure the sample was undisturbed, a plastic tube of 10 cm. length and 3.2 cm^2 internal area was pushed in and a core sample was collected. Two or three samples were taken in this way from each station. The top 6 cm. of the core was pushed out from below using a plunger. Each 2 cm. of the core was cut off and placed in a separate plastic container and sufficient filtered sea water added to keep the organisms alive. The subsampling was not done when the sample was very loose (during mud bank formation in stations 1 and 5) and also when samples were collected using a dug-out canoe.

In the laboratory the meiobenthos samples were treated as follows. Core samples were sieved using filtered sea water. The water collected from the representative stations were used for this purpose. First a 1.0 mm. square meshed Endecott sieve was used for separating macrobenthos. The material retained in the sieve was examined carefully and small animals below 1.0 mm. entrapped in it were separated before rejecting the residue. The filtrate was again washed through a 62 μ sieve and the residue was transferred to filtered sea water and observed under a binocular microscope. The small animals collected from 1.0 mm. sieve were also added to this residue. In one sample from each station the live animals were picked out using a needle and fine pipette. After this initial treatment the samples were preserved in an aqueous solution of rose bengal and re-examined to extract the remaining animals. The replicate samples collected were also sieved in the fresh condition and after a cursory examination these were preserved in 5% formalin and the animals extracted at a later date.

The 62 μ sieve filtrate from all the samples was treated as described by McIntyre (1964). The filtrate was diluted using filtered sea water, made upto 2 L., and four subsamples of 100 ml. were taken using a modified Stempel pipette. These were transferred to petri dishes and allowed to settle overnight. The animals were easily located from the traces they left on the smooth mud surface. The total number of animals recovered by this process was very small and most of them were juvenile nematodes.

Wet weight of macrobenthos was taken after preservation in formalin. This includes the weight of hard parts such as shells of molluscs and gut contents. The latter may be of considerable weight especially in the echiuroid, *Ochetostoma septemyotum*. Lovegrove (1966) has shown that preservation can effect changes in biomass, these changes being marked during the first few days of preservation and thereafter an equilibrium is obtained. Wet weight of macrofauna, during the present study, was always taken eight weeks after preservation and is not likely to be influenced by the changes during preservation. The wet ~~wet~~ weight of meiofauna was not taken as it is not likely to give any reliable results. According to Wieser (1960) "no meaning can be attached to the wet weight of small animals determined by direct weighing since evaporation through the body wall takes place too rapidly to allow the definition of a stable state".

Lovegrove (1966) recommended drying the animal tissues at 60° C. for sixteen hours as the best method for determining dry weight of plankton and this procedure was followed for determining the dry weight of macrobenthos. The animals were washed in distilled water to remove extraneous salts and hard parts and gut contents were removed before estimating the dry weight. The dry weight of *Nucula* sp. was taken including the shell. These specimens were too small to remove the shell by normal methods. Attempts to decalcify the shell did not give desired results. Therefore the weight of this species was taken including the shell and treated separately.

Dry weight of each meiobenthic group was determined by drying large numbers of specimens at 60° C. for six hours, and the average weight of a single animal was calculated. The dry weight of nematodes was determined from the calculated wet weight. The ~~wet weight determination~~ specific gravity of nematodes ~~being~~ equals taken as 1.13 (Wieser 1960). As it is not practicable to measure the length and diameter of thousands of nematodes large nematodes were first separated from the sample. Then random samples were taken from the large and small groups and mean length and diameter for each sample determined. The wet weight of each sample was calculated from these data and the dry weight computed, 25% of the wet weight being taken as the dry weight (Wieser 1960, McIntyre 1964)

CHAPTER -- III

THE MUD BANKS

The Kerala State lies in the south west coast of the Indian peninsula. It has a long coast line of about 550 Km. (Fig. 2). Lying almost parallel to the shore and separated by only a narrow stretch of land extend the backwaters, into which six major rivers discharge. The backwaters are connected to the sea at few places, the most important being the Cochin bar mouth.

The climatic condition of the area is mainly governed by rainfall. Round the year the atmospheric temperature varies from 22^{o}C. to 32^{o}C. There is an average rainfall of 3000 cm/year, and according to the rainfall three seasons can be distinguished; (1) Pre-Monsoon (January-April) (2) Monsoon (May-August to September) (3) Post-Monsoon (October to January). The South West Monsoon which commences in late May or early June is the most important. The heavy precipitation decreases by the end of August when the S.W. Monsoon ceases. A weak or moderate North East Monsoon is experienced every year during September-October months.

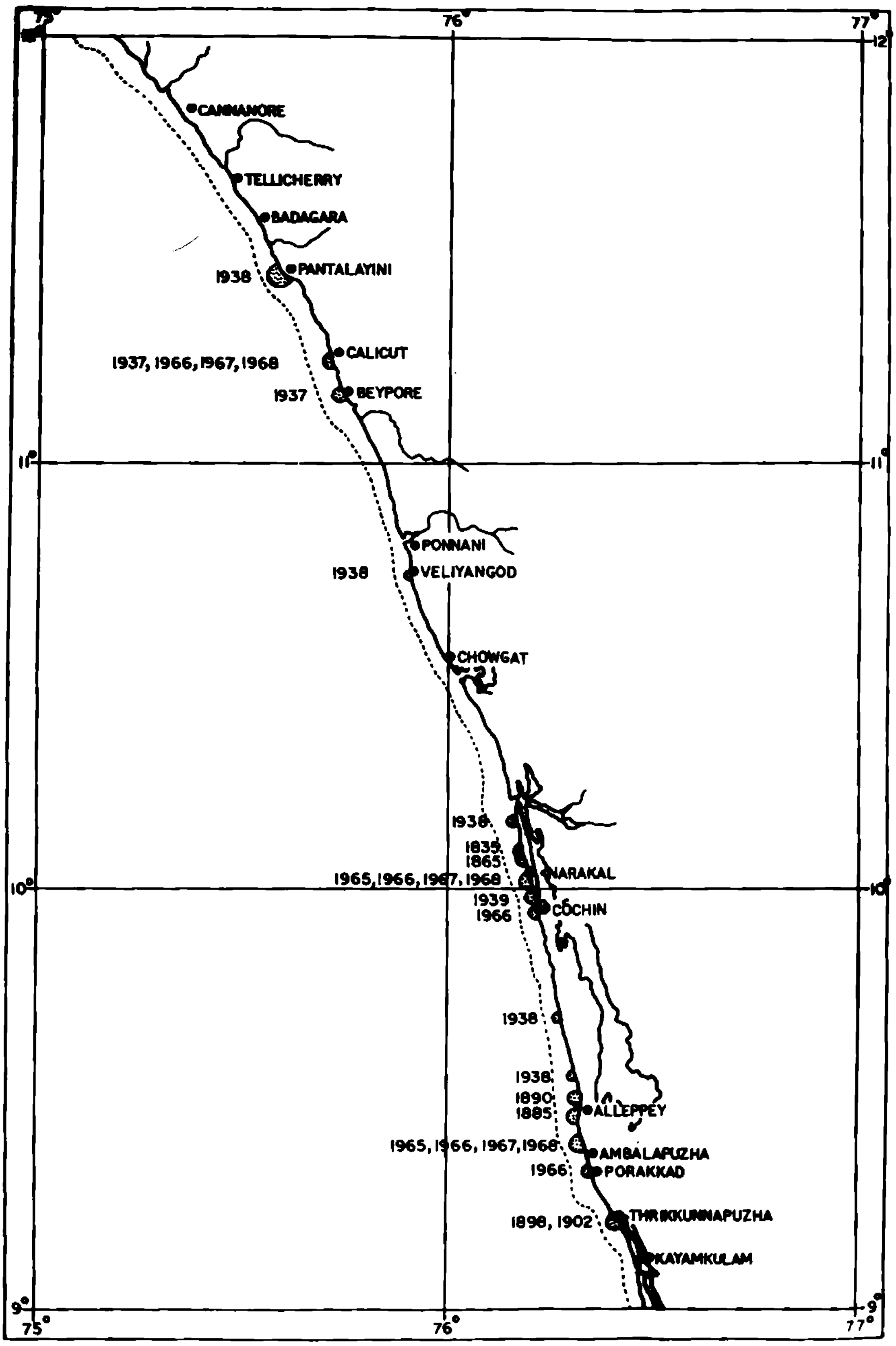
The coast line is mainly sandy with some rocky outcrops. Between Quilon and Tellicherry the sandy intertidal region is followed by muddy substratum just below the tidal belt. This region is also peculiar by the formation of the mud banks, which is an annual phenomenon. During S.W. Monsoon period in the shallow sea adjacent to the coast, smooth-water tracts occur in certain regions, and these are generally referred to as the mud banks. This phenomenon is locally known as the Chakara formation. These banks begin from the shore and, according to King (1881), in Du Cane et al 1938 "extend out to seaward for some miles, presenting a more or less semi-circular or crescentic edge to the long rollers and tumbling waves of monsoony weather". As Shepard (1963) points out, this phenomenon is exclusive to this region and is apparently unique.

Information regarding the mud banks during the past years is rather incomplete. Although mention can be seen in the literature about mud banks as early as in 1775, no detailed investigation was done till recently. An organised attempt was made in 1938 to study the nature and formation of the mud banks by the Cochin Port authorities. This resulted in the consolidation of information available up to 1938 (Bristow 1938), and also threw some light on the origin, movement, and other features regarding the mud banks. The more recent studies include those of Seshappa (1953), Seshappa and Jayaraman (1956), Rama Sastry and Myrland (1959), Hirandani and Gole (1959), Damodaran and Hridayanathan (1966), Udaya Varma and Kurup (1969) and Dora et al (1969). The places at which mud banks were recorded till 1968 are shown in the Fig. 2.

NATURE OF THE MUD BANKS

As mentioned earlier, the apparent feature of the mud

Fig. 2. Positions where mud banks are recorded along the Kerala Coast between 1835 and 1968.


75°
76°
77°
12°
11°
10°
9°
CANNANORE
TELLICHERRY
BADAGARA
1938
PANTALAYINI
1937, 1966, 1967, 1968
CALICUT
1937
BEYPORE
PONNANI
1938
VELIYANGOD
CHOWGAT
1938
1835
1865
1965, 1966, 1967, 1968
NARAKAL
1939
1966
COCHIN
1938
1938
1890
1885
ALLEPPEY
1965, 1966, 1967, 1968
AMBALAPUZHA
1966
PORAKKAD
1898, 1902
THRIKKUNNAPUZHA
KAYAMKULAM
75°
76°
77°

bank formation is the appearance of calm water areas adjacent to the shore. When the S.W. Monsoon is very active the boundaries of the mud bank can be demarcated very clearly. At this stage it is more or less semicircular in appearance, the diameter of which (shore line) is generally about 3 to 4 Km. During the monsoon the whole coast is under the impact of long period waves and heavy breakers, and these calm water areas are immediately noticed as they contrast with other areas.

The bottom sediment in the mud bank region undergoes considerable changes during this period. The sediment, which is mainly composed of fine clay, becomes loose and the top remains more or less in a viscous suspension above the hard bottom. The depth of this loose mud is maximum at the centre of the bank and may be one or two metres. Towards the periphery of the bank this depth decreases (Dora et al 1969).

CALMING EFFECT

How the wave action is minimised in the mud bank regions and how the regions remain calm when the sea is in a highly agitated condition is still a question. No satisfactory explanation has yet been put forward which can fully explain this unique feature. Experiments conducted in the laboratory show that, when loose mud from the mud bank region and mud from outside the mud bank are taken and kept in suspension in sea water, the mud bank sediment is found to take a greater time to settle than the mud from outside the bank.

Earlier observers attributed the calming effect of the mud banks to the presence of oil in the mud and to the elastic nature of the mud. Neither of the above views found favour with the later observers (Keen & Russel in Du Cane et al 1938), who were of the opinion that oil as such is not present in the mud bank region, and even if a little oil is present, a thin film of oil could not produce such a pronounced calming effect as actually observed.

The generally accepted view of this calming effect is that, the mud remaining in suspension is the real cause of the retarded and reduced waves and swell. The mud suspension increases the ratio of viscosity of the medium to its density, and results in making the propagation of the waves rather difficult and their subsequent damping. The S. W. Monsoon swell provides a continuous source of energy to maintain the mud in suspension. The slow settling rate of the mud bank sediment is of importance in this context.

THEORIES OF MUD BANK FORMATION

The factors that are responsible for the formation of mud banks are not clearly known. At three regions along the Kerala Coast, Alleppey, Narakal, and Calicut, formation of the mud banks is an annual phenomenon. In addition to these three, there used to be sporadic appearance of mud banks on other parts of the coast. The former three banks are called the permanent mud banks and the others the temporary mud banks. How mud banks are formed at particular localities at a definite period is still obscure. Because of the paucity of continuous data on the formation of mud banks and lack of detailed studies, most of the explanations given regarding the formation of this unique phenomenon are only vague speculations.

One of the earliest explanations recorded in the compiled report of Du Cane et al (1938) is based on the geographical nature of the coast. According to this, the mud banks are formed by the flow of mud from the backwaters by hydraulic pressure through some subterranean channels in the narrow strip of land that separates the backwaters from the sea. Because of the limited number of outlets into the sea and also owing to the large number of flooding rivers into it, water level rises in the backwaters during the S.W. Monsoon months. The fact that this part of the coast line has a continuous stretch of backwaters separated from the sea by a narrow strip of land, and eyewitness reports of mud volcanoes bursting up in the sea during the rainy season are forwarded in support of this explanation. But after analysing the boring conducted in Alleppy, Willington Island and Cochin, Coggin Brown (Du Cane et al 1938) stated "the character of the sediment as revealed by the boring records is sufficient to rule out the possibility of subterranean channel through them, by means of which some earlier observers sought to explain the origin of the mud banks". The present observation that the Alleppy mud bank was formed before the onset of heavy monsoon in 1966, 1967, and 1968, and the water level in the backwaters during this period was not very much higher than the pre-monsoon level, (not enough to cause an increase in hydraulic pressure), also does not support the above theory. Similarly the Narakal mud bank is situated very close to the Cochin bar mouth and there is no significant difference in level of water in the lake in this region during monsoon.

The second theory attributes the formation of the mud banks to the action of the rivers and coastal currents. All the areas where mud banks made their appearance are within a moderate distance from the mouth of the rivers except at Alleppy, where however, no river now exists, eventhough it is believed that an opening once existed Du Cane et al (1938). Coggin Brown (Du Cane et al 1938) has also pointed out that the location of the mud banks is in the same region of the coastal alluvium, confined approximately to the 272 Km. between Calicut and Quilon. This particular coast line is bordered by alluvial deposits backed by laterite masses which are capable of supplying large quantities of detritus. Littoral currents during S.W. Monsoon carry low salinity water which prevents flocculation of sediments in suspension. Therefore it is possible that the fine sediments brought by the rivers may be carried along the coast for some distance by these currents. When the salinity increases, the flocculation process is enhanced and deposition of the sediments takes place somewhere along the shore. The agitation of these deposits by monsoon waves may be helping them to come in suspension again resulting in the formation of the mud banks.

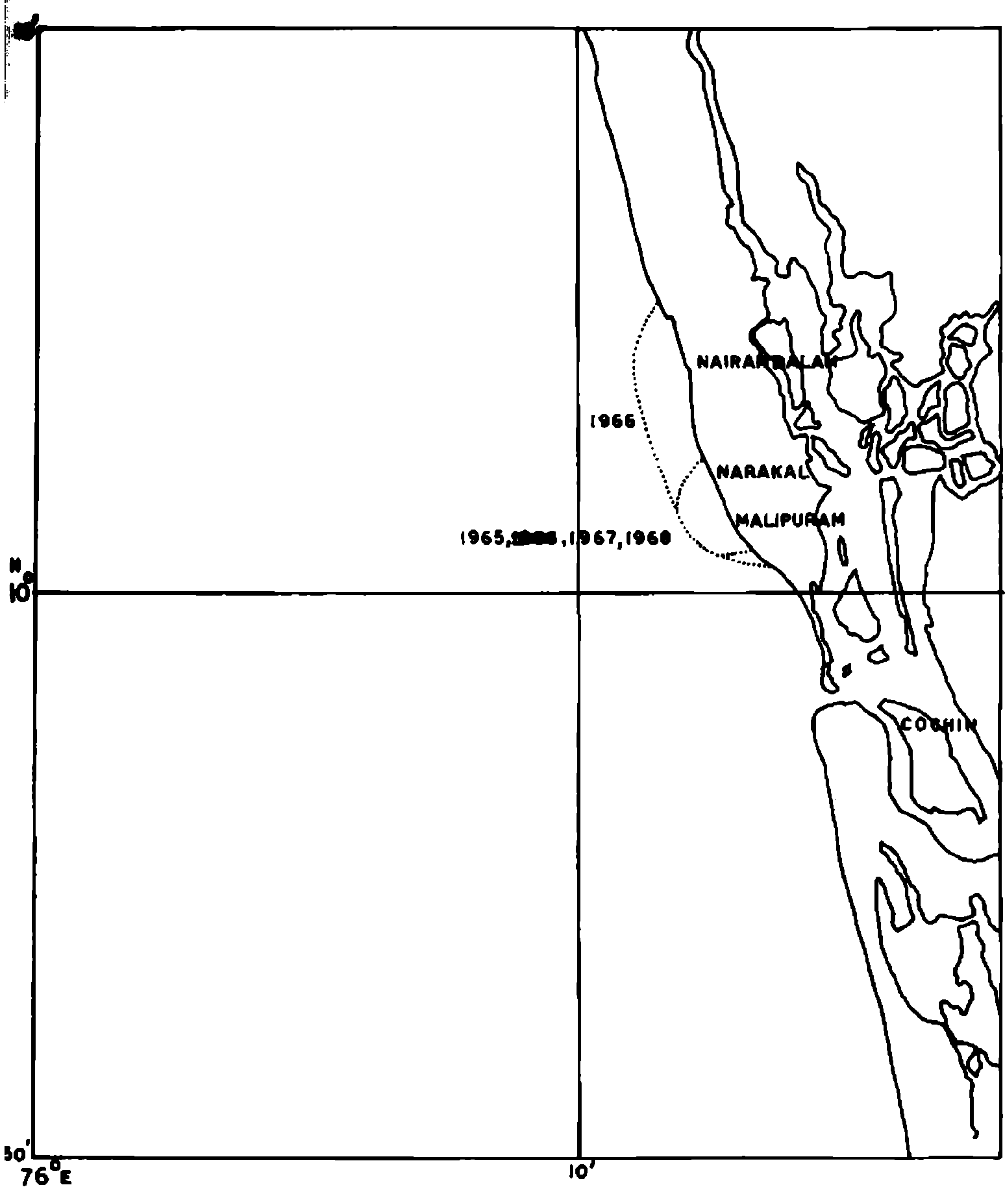
The third theory was forwarded by Ramasastry and Myrland (1959). They attribute the formation of the mud banks to the upwelling of the water near the bottom. According to them the upwelling during the S.W. Monsoon period produces vertical acceleration resulting in the lifting of bottom waters and bottom mud. Hart and Curie (1960) report the formation of temporary mud islands in the Bengula upwelling region, which indicate that the upwelling process can lift the bottom sediments. But Varma & Kurup (1969) stated that "it is doubtful whether an overturning of subsurface water as occurs along this coast can bring up large quantities of mud from the bottom and keep it in suspension for a sufficiently long period".

Varma & Kurup (1969) have given another explanation for the formation of the mud banks. According to this theory the mud banks are formed owing to the effect of higher period waves. These waves in the regions of mud bank formation form rip-currents which can carry finer sediments off shore and prevent onshore transport of sediments by waves. This facilitates localisation of finer sediments at the rip head and, when they settle out diverts the bottom contours offshore. This shift of bottom contour results in the breaking of the waves away from the coast and the formation of calm area near the coast.

NARAKAL MUD BANK, 1965--1968 (Fig. 3)

Off Narakal, the mud bank formation is annual. In 1965 the Narakal mud bank was between Puthuvypu and Nayarambalam, about 13 Km. long. The position of the bank in 1967 and 1968 was similar to that in 1965, the between Narakal and Malipuram. In all these years, the bank made its appearance in the last week of June or in the first week of July. In 1966 although the bank was an extensive one, the loose mud of the bank was only 10 to 15 cm. deep, whereas in 1967 and 1968 the depth of the loose mud in the centre of the bank was about 2 m. During 1966 and 1967 stations 1 and 5 were within the mud bank region.

Fig. 3. Positions of the Narakal mud bank between 1
and 1968.


NAIRAMBALAM
1966
NARAKAL
MALIPURAM
1965,[redacted],1967,1968
N
10°
COCHIN
50'
76°E
10'

CHAPTER -- IV

HYDROGRAPHY

INTRODUCTION

The pioneer works in the field of hydrography as far as Indian waters are concerned are that of Annandale and Kemp (1915) and Sewell (1929). Annandale and Kemp worked on the hydrography of the Chilka Lake on the Orissa Coast and Sewell on the Andaman and Laccadive seas. Later notable works on the east coast of India are those of Jayaraman (1951), Menon (1931) Ramamurthy (1953), Thirupad and Reddi (1959) at Madras; Jayaraman (1954), at Mandapam; Prasad (1951) for east coast waters in general; Ganapati and Rao (1953) Ganapati and Murthy (1954, 1955), Ganapati and Sarma (1958), Lafond (1954, 1958 a, b), Rao and Rao (1962) at Waltair. Along the west coast of India investigations were made by Jayaraman and Gogate (1957) at Bombay and Saurashtra Coast; Jayaraman <u>et</u>. <u>al</u>. (1962) off Bombay; Patil and Ramamritham (1963) in Laccadive offshore waters; Chidambaram and Menon (1945), George (1953), Seshappa and Jayaraman (1956), Subrahmanyam (1959), Sastry and Myrland (1959) off Malabar Coast; Ramamritham and Jayaraman (1960) on the continental shelf waters of Cochin and Menon (1954) at Trivandrum. The backwaters of Cochin were studied by Ramamritham and Jayaraman (1963). Banse (1959, 1968) and Mollie Darbyshire (1967) made observations on South West Coast waters in general. The present account is on the hydrography of the Narakal mud bank region 6 km. north of Cochin during the period May 1966 to February 1968.

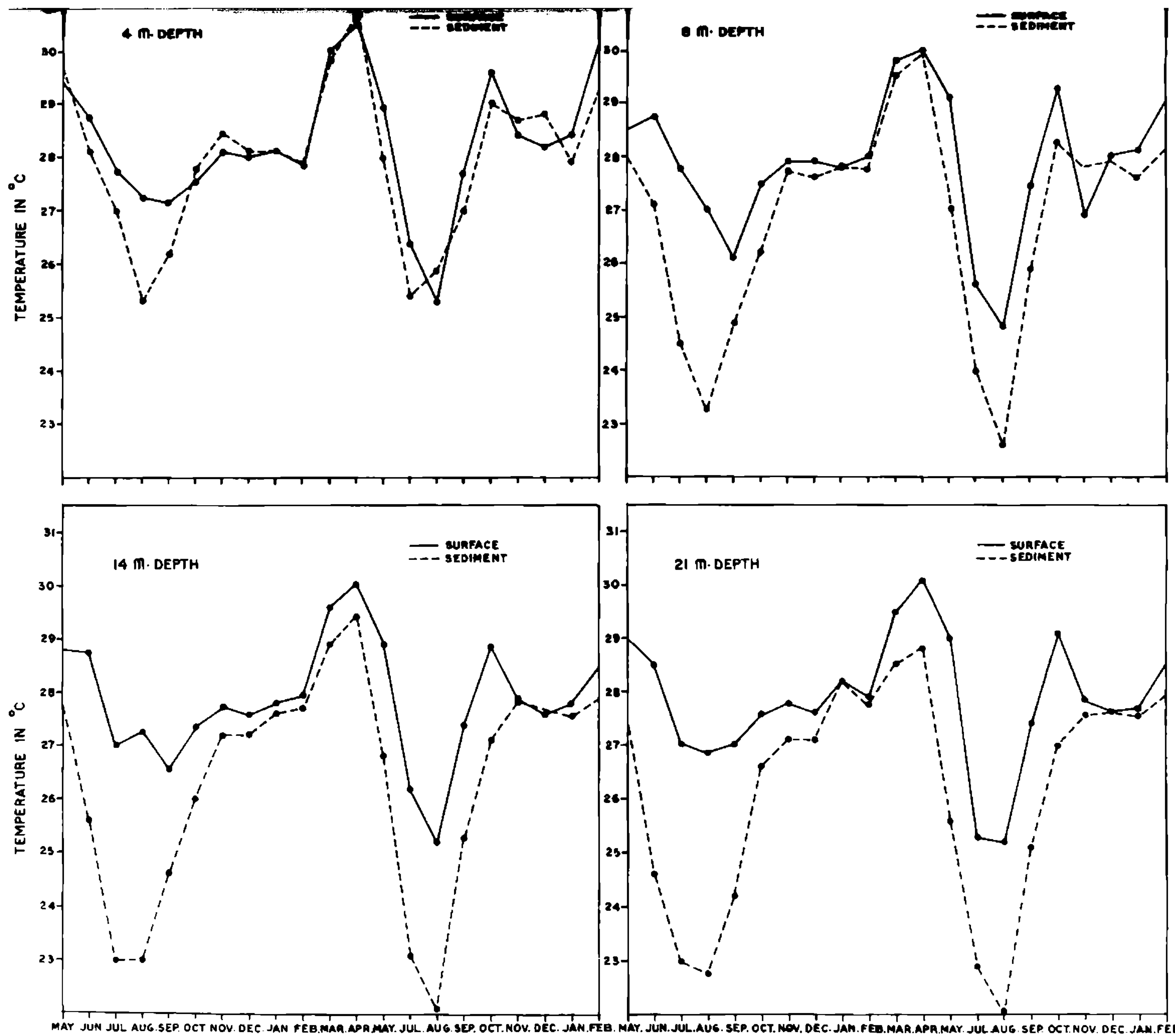
RESULTS AND DISCUSSION

Temperature:- The details of surface water temperature and bottom sediment temperature are given in Fig.4.

In both years the minimum temperature for surface water occurred during the period August-September and for sediment during the period July-August. The maximum temperature of surface water and bottom sediment occurred in April. The period of the S.W. Monsoon coincides with the period of minimum surface water and bottom temperature. The decrease in sediment and surface water temperatures occurred to an equal degree in stations at 4 m. depth. But in all the other stations the decrease in sediment temperature was much greater than in that of the surface water. After the S.W. Monsoon period there was a rapid increase in the sediment and surface water temperature. There was also a slight decrease in both the temperatures during the winter months.

For the region as a whole the pattern of variation of temperature is bimodal. A similar bimodal type of

Fig. 4. Mean surface water and sediment temperature in stations at 4, 8, 14 and 21 m. depth.



4 m· DEPTH
8 m· DEPTH
14 m· DEPTH
21 m· DEPTH
SURFACE
SEDIMENT
TEMPERATURE IN °C
MAY JUN JUL AUG. SEP. OCT NOV. DEC. JAN FEB. MAR. APR. MAY. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB.

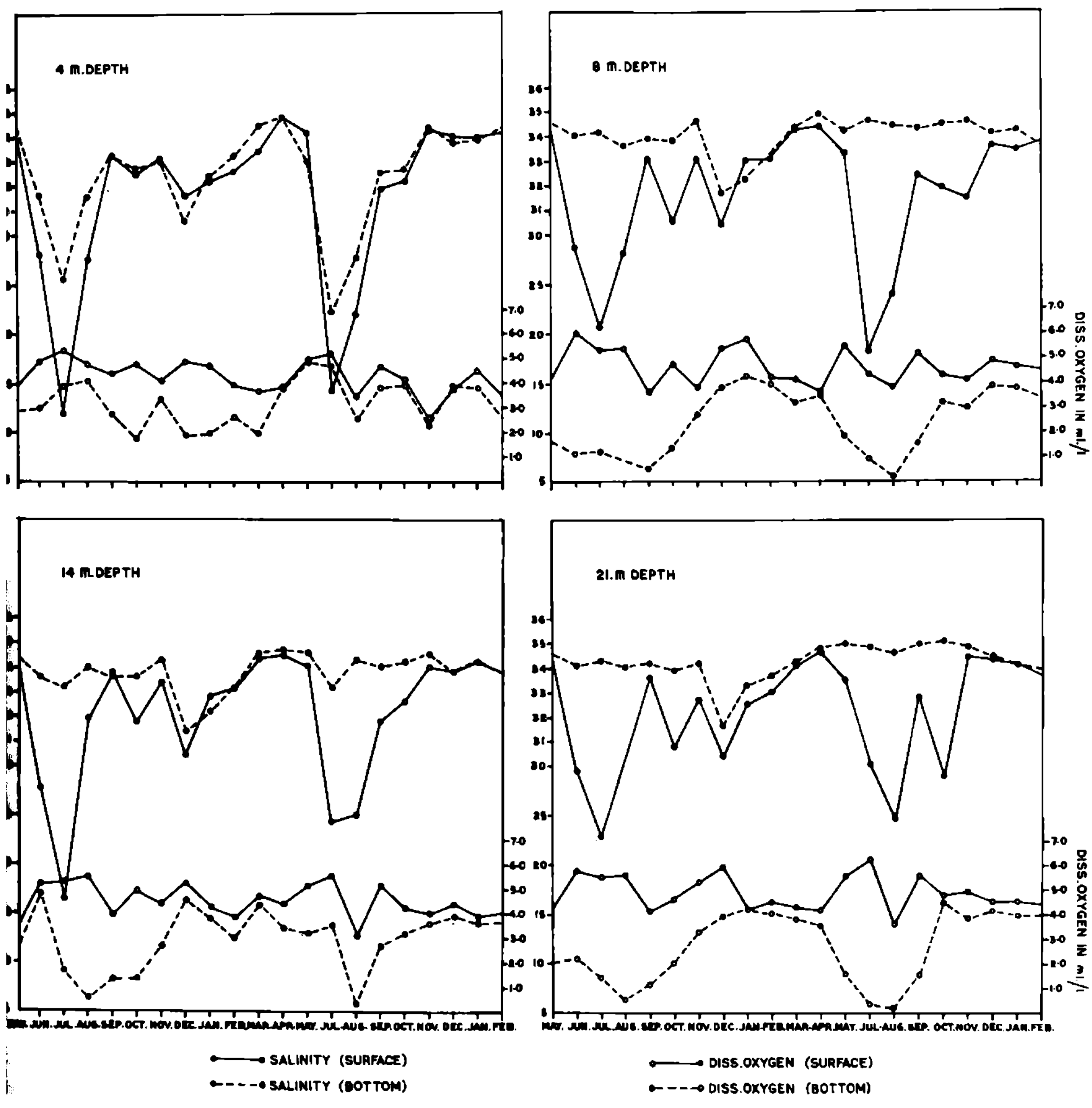
oscillation of temperature was noticed by other workers in the seas around India: Andaman and Laccadive seas, Sewell (1929), off Calicut, Subrahmanyam (1959) and at Mandapam, Prasad (195[illegible]). During April the atmospheric temperature is high and there is practically no rain-fall. This results in high surface water and bottom sediment temperatures during this period. The months of June, July and August can be considered as the active period of S.W. Monsoon in the area under investigation. It can be seen that from the beginning of the monsoon, temperatures show a decrease. During the S.W. Monsoon, upwelling is active along the Kerala Coast (Banse, 1959, 1968; Ramamritham and Jayaraman, 1960; Sastry and Myrland, 1959; Mollie Darbyshire, 1967). In addition to precipitation, the cold water entering on the shelf may contribute to the decrease in temperatures. Thus the sediment temperature shows a fall of about 7.0°C. between April and August 1967 at the 21 m. depth. The rapid decrease in sediment temperature compared with the surface water temperature may be due to the upwelling. The impact of the S.W. Monsoon and upwelling lasts till the end of August and during September-October there is a rapid increase in temperature. The slight decrease in temperatures during December and January may be due to the drop in atmospheric temperature. After this period the atmospheric temperature steadily increases and the pattern is reflected in the sediment and sea water temperatures.

Salinity:- Surface and bottom salinity values are given in Fig. 5.

There is a considerable lowering of salinity in the surface water at all stations during the S.W. Monsoon, and in most of the stations the minimum values are recorded during July. The maximum surface salinity was recorded in April. In the two stations at 4 m. depth the bottom salinity decreased considerably during the monsoon. A small decrease in the bottom salinity is also noticed at 8 m. depth. But in stations at 14 m. and 21 m. depth no salinity decrease was noticed during this period. In fact the bottom salinity showed a slight increase in some of the stations during this period. The minimum bottom salinity at the 4 m. stations occurred during July, but in all the other stations the minimum bottom salinity was recorded in December.

The surface salinity pattern in the area is considerably influenced by rainfall and surface currents. The maximum surface salinity was recorded in April at all the stations and correlates with the period of maximum temperature. With the onset of the S.W. Monsoon the copious precipitation and flood water discharged from the backwaters result in a steep decline in the surface salinity during July. The influence of intermittent rain can again be seen in the surface salinity values during September-October when the coast is under the influence of a moderate N.W. Monsoon

Fig. 5. Mean salinity and dissolved oxygen in the surfa
and bottom water at 4, 8, 14 and 21 m. depth.


4 m.DEPTH
8 m.DEPTH
14 m.DEPTH
21.m DEPTH
DISS. OXYGEN IN ml/l
MAY. JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB.
SALINITY (SURFACE)
SALINITY (BOTTOM)
DISS. OXYGEN (SURFACE)
DISS. OXYGEN (BOTTOM)

The decline of surface salinity values during December can be attributed to two factors. The predominent current along the coast during December and January is from south to north and the low salinity water (coming from the Equatorial region which receives in its course low salinity waters from the Bay of Bengal) is found to occur in the surface layers along the coast during this season (Mollie Darbyshire, 1967). Along with this general decrease in salinity the proximity to the estuarine outlet of the area, and the northerly current which may carry the low salinity water discharged from the estuary to this area may be contributing to the decrease in salinity during this period. This decrease in salinity was more pronounced in December 1966 and January 1967 than in the corresponding months in 1967 and 1968. From January onwards the surface salinity slowly increases to reach an annual peak in April.

Except at shallow water stations (4 m. and to a small extent in 8 m. depth) the bottom salinity is not greatly affected by the monsoons. The S.W. Monsoon correlates with the period of upwelling along the coast, and this in some years starts as early as May (Banse 1968). This may be the reason for the high salinity values found for the bottom water in deeper stations (14 and 21 m.) during this period when the surface salinity is in decline. There is a decrease in bottom salinity during December and

and January, especially in the first year of observation. The fact that surface salinity is low during this period and this is the period of sinking along the coast may explain the presence of low salinity water in the bottom during these months.

Dissolved oxygen:- The values for dissolved oxygen in the surface and bottom waters are given in Fig. No.5

The period of the S.W. Monsoon produced high dissolved oxygen values for the surface water and in general highest values were recorded in July. A reduction in the surface oxygen was noticed during August and September. The dissolved oxygen values again show an increase during winter months especially in December. For the bottom water dissolved oxygen content showed a decrease during the S.W. Monsoon and minimum values were recorded in August. This decrease was not apparent in stations at 4 m. depth, where, because of the shallow depth and possibility of mixing, the bottom water showed an increase with surface water during this period. From September onwards a gradual increase in the dissolved oxygen in the bottom water was noticed in all the stations and this led to high values during December-January.

The surface water had a high oxygen content during May and to some extent in April. Salinity and temperature were high during this period and would not apparently favour an increase in dissolved oxygen. Therefore the high dissolved oxygen content during this period must be due to some other factor. May being early in the period of the S.W. Monsoon, the trade winds are fairly strong and it can bring about agitation and increased dissolution of atmospheric oxygen in the surface layers. Subrahmanyam (1959) working off Calicut attributed the high dissolved oxygen values of the surface water during this period to the impact of trade winds and also to the upwelling of Antarctic bottom water which is rich in oxygen. But the observations on dissolved oxygen of the bottom water showed a decrease in dissolved oxygen in the bottom water from May onwards. This indicates that the increase in dissolved oxygen in the surface water cannot be due to upwelling.

During June and July there was a further increase in dissolved oxygen content in the surface water. The high precipitation, the increase in fresh water influx and decrease in temperature were favourable for an increase in the dissolved oxygen during these months. In addition, the high phytoplankton concentration during this period may also be contributing to increase the oxygen (Subrahmanyam 1959). After this peak there was a decrease in dissolved oxygen values in August-September. Subrahmanyam (1959) working off Calicut attributed this decrease in values to the increase in zooplankton content in the water following the phytoplankton bloom in June-July, and to the increase in detritus and bacterial flora in the coastal waters. Respiration of zooplanktonic organisms, consumption of oxygen by detritus in the upper layers (Sewell

1938), and the utilization of oxygen by bacterial flora (Nash 1947) increase the demand for oxygen and thus decrease the dissolved oxygen present in the water. In addition to these factors, the poorly oxygenated water present near the bottom can also rise to the surface and reduce the oxygen values. After this period the oxygen values again showed an increase and continued in this state until the end of December-January. Low salinity and temperature favour an increase in oxygen content during December-January. Surface oxygen values were low during February-March and to a great extent in April. The high salinity values and atmospheric temperature prevailing during this period do not favour a high dissolved oxygen level.

Dissolved oxygen in the bottom water was low during May and June and there was a marked decline in the values during July and August. Banse (1959, 1968) attributed this decrease to the upwelling waters which are generally poor in oxygen content. The sediment on the continental shelf along the coast is rich in organic matter. The amount of oxygen used for the oxidation of organic matter during the upward movement of the upwelling water further depletes it in oxygen and this water occupies the bottom during this period. Therefore, except in very shallow regions near the coast, the oxygen content of the bottom water remains very low during this period. This seems to be the condition prevailing in the major part of the west coast of India.

Off Bombay nil oxygen values are reported at 10 and 15 m. depth (bottom depth 18 m.) by Gogate (1960). An increase in oxygen content of the bottom water was noticed from September-October onwards with a peak during December-January. December-January is regarded as the period of sinking along the coast and may be the reason for high oxygen values. From February onwards the oxygen values decrease and this trend continues through March into April.

CHAPTER -- V

ANNUAL CYCLE OF PHOSPHORUS

Phosphorus is an important constituent of sea water and vital in the biological economy of the sea. Since Atkins (1923) developed the method of phosphate estimation (The Atkins-Deniges method) a considerable amount of work has been carried out on the role and distribution of phosphates in different seas in various parts of the world.

Investigations on the phosphorus cycle in Indian waters have however been relatively few. Some of the important investigations in the Indian coastal waters are by Bal et. al. (1946) and Jayaraman et. al. (1961) at Bombay, Jayaraman and Seshappa (1957) off Malabar, ~~and~~ George (1953), Rao (1957), Seshappa and Jayaraman (1956) and Subrahmanyam (1959) at Calicut. Jayaraman (1951, 1954) studied the phosphates at Mandapam and Madras on the east coast followed by Thirupad and Reddy (1959) at Madras, and Viswanatham (1959) at Mandapam. Phosphorus studies off Porto-Novo are those of Krishnamurthi (1966) and Ramamurthi et. al. (1965) Off Waltair coast, Ganapati et. al. (1956) studied the vertical distribution of phosphates, and later Rao and Rao (1962) made observations on the diurnal variation.

The benthic organisms are dependent upon the fertility of the overlying water for their food supply, and factors which control the planktonic production in any area are likely to have an indirect influence upon the abundance of the benthic fauna. There is considerable evidence for assuming that phosphate concentration may be a limiting factor in the zooplankton production (Harvey 1950, Armstrong and Harvey 1950). There are also reasons for assuming that changes in phosphate concentrations may influence the quantity of fish present in a given area (Cooper 1948). However Raymong employed experimental methods in a partially enclosed sea loch and the results showed that phosphate concentration does not affect the benthos (Raymont, 1950). But Jones (1956) felt that in an area he studied in the Irish Sea "the only environmental factor so far examined with which changes in the biomass of the benthos may be correlated (where, temperature, salinity, and grade of deposit remain stable) seems to be the concentration of phosphorus in the overlying water".

As there is very little information available on the phosphorus cycle in the inshore waters off Cochin an attempt was made to understand the general trends in the annual cycle of phosphorus in the area and to find out its relation to benthos if any.

RESULTS AND DISCUSSION

Monthly mean values for inorganic and total phosphorus are given in Fig.6. The values for inorganic and organic phosphorus are given in Table No. 1 to 4.

The range of absolute values for inorganic phosphorus during the course of observations was as follows.

TABLE: 1

Average monthly values of inorganic, organic and total phosphorus at 4 m. line

	SURFACE				BOTTOM			
Month	Inorganic phosphorus µg.at./L.	Total Phosphorus µg.at./L.	Organic Phosphorus µg.at./L.	% of Organic Phosphorus	Inorganic Phosphorus µg.at./L.	Total Phosphorus µg.at./L.	Organic Phosphorus µg.at./L.	% of Organic phosphorus
May 1966	1.19	--	--	--	1.74	--	--	--
June '66	1.17	--	--	--	2.16	--	--	--
July '66	1.28	--	--	--	3.75	--	--	--
Aug. '66	2.10	--	--	--	3.49	--	--	--
Sept. '66	0.64	--	--	--	0.53	--	--	--
Oct. '66	0.35	1.58	1.23	77.84	0.39	0.96	0.57	59.37
Nov. '66	0.13	0.95	0.82	86.31	0.18	1.45	1.27	87.58
Dec. '66	0.16	2.32	2.16	93.10	0.60	2.59	1.99	76.83
Jan. '67	0.33	1.83	1.50	81.96	1.26	2.61	1.35	51.72
Feb. '67	0.27	3.10	2.83	--	0.44	3.40	2.96	87.05
March '67	0.34	--	--	--	0.47	--	--	--
April '67	0.31	2.99	2.68	89.63	0.44	3.15	2.71	86.03
May '67	0.94	1.97	1.03	52.28	1.44	2.77	1.33	48.01
July '67	0.64	1.34	0.70	52.23	1.03	2.75	1.72	62.54
Aug. '67	0.11	1.62	1.51	93.21	1.64	2.84	1.20	42.25
Sept. '67	0.39	1.75	1.36	77.71	0.45	2.39	1.94	81.17
Oct. '67	0.19	1.88	1.69	89.89	0.48	2.00	1.52	76.00
Nov. '67	0.20	1.73	1.53	88.43	0.23	1.79	1.56	87.15
Dec. '67	0.06	2.46	2.40	97.56	0.21	2.41	2.20	91.28
Jan. '67	0.26	1.22	0.96	76.88	0.34	2.03	1.69	83.25
Feb. '68	0.63	1.32	0.60	52.27	0.78	1.50	0.72	48.00

TABLE: 2

Average monthly values of inorganic, organic and total phosphorus at 8 m. line

	SURFACE				BOTTOM			
Month	Inorganic Phosphorus µg.at./L.	Total Phosphorus µg.at./L.	Organic Phosphorus µg.at./L.	% of Organic Phosphorus	Inorganic Phosphorus µg.at./L.	Total Phosphorus µg.at./L.	Organic Phosphorus µg.at./L.	% of Organic Phosphorus
May 1966	0.48	--	--	--	0.72	--	--	--
June '66	0.40	--	--	--	0.55	--	--	--
July '66	0.89	--	--	--	4.48	--	--	--
Aug. '66	1.34	--	--	--	3.06	--	--	--
Sept.'66	0.73	--	--	--	0.52	--	--	--
Oct. '66	0.15	1.66	1.51	90.96	0.27	1.06	0.79	74.52
Nov. '66	0.26	1.44	1.18	81.94	0.21	0.95	0.74	77.88
Dec. '66	0.12	1.48	1.36	91.89	0.32	1.63	1.31	80.37
Jan. '67	0.36	1.64	1.28	78.05	0.73	1.91	1.18	61.78
Feb. '67	0.28	3.15	2.87	91.11	0.48	3.24	2.76	85.18
Mar. '67	0.30	--	--	--	0.48	--	--	--
Apr. '67	0.40	2.77	2.37	85.55	0.43	2.74	2.31	84.30
May '67	0.36	1.41	1.05	74.47	1.02	2.62	1.60	61.06
July '67	0.95	2.44	1.49	61.04	1.50	3.34	1.84	55.09
Aug. '67	0.37	2.37	2.00	84.38	2.26	3.20	0.94	29.37
Sept.'67	0.46	1.49	1.03	69.13	0.44	3.35	2.91	86.86
Oct. '67	0.14	1.33	1.19	89.47	0.22	1.55	1.33	85.80
Nov. '67	0.16	1.57	1.41	83.43	0.18	1.62	1.44	88.88
Dec. '67	0.20	1.74	1.54	88.50	0.23	1.70	1.47	86.47
Jan. '68	0.11	0.79	0.68	96.07	0.19	1.26	1.07	84.92
Feb. '68	0.56	1.17	0.61	52.13	0.52	2.09	1.57	77.48

TABLE: 3

Average monthly values of inorganic, organic and total phosphorus at 14 m. line

Month	Inorganic Phosphorus /ug.at./L.	Total Phosphorus /ug.at./L.	Organic Phosphorus /ug.at./L.	% of Organic Phosphorus	Inorganic Phosphorus /ug.at./L.	Total Phosphorus /ug.at./L.	Organic Phosphorus /ug.at./L.	% of Organic Phosphorus
May 1966	1.31	--	--	--	--	--	--	--
June '66	0.58	--	--	--	0.77	--	--	--
July '66	1.19	--	--	--	5.44	--	--	--
Aug. '66	1.26	--	--	--	2.03	--	--	--
Sept.'66	0.44	--	--	--	0.57	--	--	--
Oct. '66	0.25	2.34	2.09	90.86	0.37	1.24	0.87	70.17
Nov. '66	0.13	0.73	0.60	82.02	0.10	0.74	0.64	86.28
Dec. '66	0.15	1.21	1.06	87.60	0.24	1.82	1.58	86.72
Jan. '67	0.10	1.31	1.21	94.52	0.76	1.58	0.82	51.77
Feb. '67	0.42	3.03	2.61	86.14	0.44	3.18	2.74	86.18
Mar. '67	0.35	--	--	--	0.49	--	--	--
Apr. '67	0.14	1.84	1.70	92.39	0.42	2.19	1.77	63.20
May '67	0.52	1.25	0.73	59.70	1.25	2.87	1.62	56.34
July '67	0.76	1.36	0.60	44.13	1.66	3.66	2.00	54.64
Aug. '67	1.28	2.51	1.23	48.98	1.68	2.99	1.31	43.81
Sept.'67	0.29	1.52	1.23	81.45	0.64	3.03	2.39	79.25
Oct. '67	0.34	1.42	1.08	81.49	0.17	1.41	1.24	87.94
Nov. '67	0.17	1.24	1.07	86.30	0.17	1.63	1.46	89.58
Dec. '67	0.25	1.60	1.15	71.71	0.07	1.35	1.18	87.42
Jan. '68	0.09	0.79	0.70	88.59	0.22	1.08	0.86	79.63
Feb. '68	0.34	1.93	1.59	84.29	0.53	2.17	1.64	75.56

TABLE: 4

Average monthly values of inorganic, organic and total phosphorus at 21 m. line

	SURFACE				BOTTOM			
Month	Inorganic Phosphorus µg.at./L.	Total Phosphorus µg.at./L.	Organic Phosphorus µg.at./L.	% of Organic Phosphorus	Inorganic Phosphorus µg.at./L.	Total Phosphorus µg.at./L.	Organic Phosphorus µg.at./L.	% of Organic Phosphorus
May 1966	0.68	--	--	--	1.40	--	--	--
June '66	0.65	--	--	--	1.99	--	--	--
July '66	0.86	--	--	--	5.59	--	--	--
Aug. '66	0.83	--	--	--	2.47	--	--	--
Sept.'66	0.45	--	--	--	0.36	--	--	--
Oct. '66	0.12	1.18	1.06	89.80	0.29	1.14	0.85	75.01
Nov. '66	0.12	1.02	0.90	88.14	0.27	0.60	0.32	53.32
Dec. '66	0.11	1.87	1.76	94.12	0.26	1.80	1.54	85.55
Jan. '67	0.09	2.01	1.92	95.52	0.44	2.36	1.92	80.42
Feb. '67	0.24	2.56	2.32	90.63	0.40	2.71	2.31	85.23
Mar. '67	0.25	--	--	--	0.43	--	--	--
April 67	0.11	2.21	2.10	96.01	0.31	2.00	1.69	84.50
May '67	0.71	1.56	0.85	54.49	1.35	2.62	1.27	48.48
July '67	0.59	1.59	1.00	62.90	1.82	3.05	1.23	40.33
Aug. '67	1.51	2.63	1.12	42.58	1.43	2.59	1.16	44.69
Sept.'67	0.33	1.58	1.25	79.11	0.48	2.41	1.93	80.09
Oct. '67	0.14	1.41	1.27	90.67	0.20	1.67	1.47	88.02
Nov. '67	0.19	1.39	1.20	86.34	0.19	1.73	1.54	89.02
Dec. '67	0.20	1.48	1.28	68.69	0.18	1.42	1.24	86.92
Jan. '68	0.08	0.83	0.75	90.36	0.17	1.13	0.96	84.94
Feb. '68	0.40	2.65	2.25	84.92	0.73	2.38	1.65	69.33

4 m. line

Inorganic phosphorus concentrations in surface water varied between 0.03 µg at./L. and 3.37 µg at./L. the lowest occurring in December 1967 and the highest in June 1966. For bottom water the range was considerably higher. The minimum value recorded was 0.12 µg at./L. in December 1967 and the maximum was 6.05 µg at./L. in July 1966.

8 m. line

The maximum value of 1.39 µg at./L. for surface water was obtained in August 1966. The minimum value of 0.10 µg at./L. was recorded in October 1967 and January 1968. For bottom water the minimum was 0.13 µg at./L. during October 1967, and the maximum 5.39 µg at./L. was in July 1966.

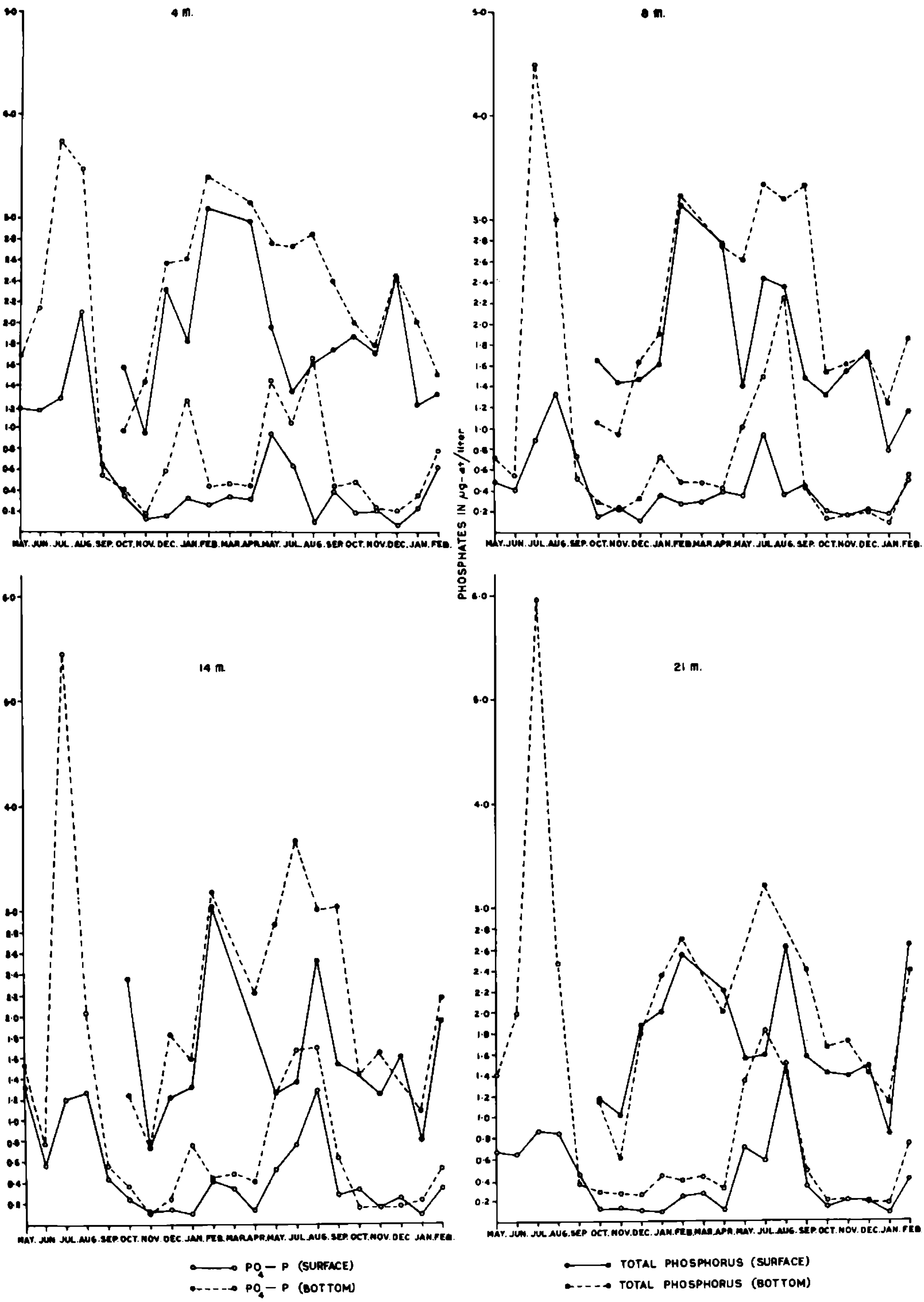
14 m. line

The peak value for surface water of the area was 1.64 µg at./L. and was recorded in July 1966, and the lowest value 0.11 µg at./L. was recorded in both April 1967 and January 1968. For bottom water the maximum was 8.02 µg at./L. in July 1966 and minimum 0.07 µg at./L. in December 1967.

21 m. line

In August 1967, 1.70 µg at./L. marked the highest value for surface water. The lowest value of 0.07 µg at./L. was recorded on two occasions, one in November 1966 and

Fig. 6. Mean values for inorganic and total phosphorus in surface and bottom water at 4, 8, 14 and 21 m. depth.


4 m.
8 m.
14 m.
21 m.
PHOSPHATES IN µg-at/liter
MAY. JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB.
PO4 — P (SURFACE)
PO4 — P (BOTTOM)
TOTAL PHOSPHORUS (SURFACE)
TOTAL PHOSPHORUS (BOTTOM)

the other in January 1968. For bottom water 7.81 μg at./L. was the maximum value and occurred in July 1966. This lowest value for bottom water, 0.14 μg at./L.was obtained in September 1966.

It is evident from the above values that there is a considerable variation in inorganic phosphorus concentration in different months, the maximum occurring during July and August and minimum between October and January. This is true for both surface and bottom waters. It can also be seen that there is a well defined seasonal variation of phosphorus concentration in the area. The period of the S.W. Monsoon coincides with a marked increase in inorganic phosphorus values and the annual peak occurs during the middle or later half of S.W. Monsoon. The N.E. Monsoon months (October, November) mark the period of minimum values. Such an increase of inorganic phosphorus during S.W. Monsoon was also noticed off Calicut (George 1953, Rao 1957, Subrahmanyam 1959). The high values at Cochin are maintained till September. This is followed by a period of minimum values. From January or February onwards an upward trend is again noticed. But a substantial increase in the inorganic phosphorus values begins only from the month of May. Several explanations have been given to account for this pronounced rise during the S.W. Monsoon.

The muddy inshore sediment appears to play a very important role in the phosphorus cycle along the S.W. Coast of India. The role of the bottom sediment as a source of phosphorus has been pointed out by a number of previous workers. The importance of bottom mud in the phosphorus cycle of fresh water environments has been stressed by Mortimer (1941, 1942) in English lakes. Rockford (1951) working on the Australian estuaries indicated a possible exchange of phosphorus between the mud and overlying water. Miller (1952) on Biscane Bay, Florida found that there was a regular enrichment of water with phosphorus from bottom mud every summer. Rittemberg, Emery and Orr (1955) also showed an exchange of phosphorus between the bottom deposit and overlying water in California Basins. An interchange of phosphorus between the off shore sediment and water above was indicated by Cooper (1951). Stephenson (1949) under controlled laboratory conditions found an enrichment of phosphorus content of water in which estuarine mud had been shaken. The above evidence clearly indicates the importance of muddy substratum in the regeneration of phosphorus.

Seshappa and Jayaraman (1956) carried out investigations on the bottom muds of the inshore area off Calicut (4 m. and 19 m. depth) They could obtain high values for interstitial phosphorus during premonsoon months. But during the S.W. Monsoon the interstitial phosphorus values were low with a simultaneous increase in the phosphorus content of the bottom water. Thus they concluded that, "the intense agitation or churning during the monsoon helps to transfer the phosphates from the interstices of the mud, to the overlying water" Thus a cyclical seasonal exchange of phosphorus between sediment and water seem to take place in the S.W. Coast as indicated by Miller (1952) in Biscane Bay.

Another suggested cause of the increase in phosphorus is the large scale mortality of benthic organisms (Seshappa and Jayaraman 1956). The observations on the benthic fauna off Cochin show that mortality does occur during the S.W. Monsoon in shallow waters. But the magnitude of mortality of benthos does not seem to be great enough to cause a large increase in phosphorus values of the water.

The S.W. Monsoon period is the period of phytoplankton bloom along the S.W. Coast of India (Subrahmanyam 1959). The high values for inorganic phosphorus during this period clearly show that there is considerably more of this nutrient in the water than is required for plant growth. In addition to the above mentioned reasons the factors which are considered to be responsible for the maintenance of these high values, during the season of maximum utilization by plants, are rapid regeneration of phosphorus from decomposing plants (Subrahmanyam 1959) and the inshore transport of upwelled water (Panikkar and Jayaraman 1953).

The phosphorus values from October to January are generally poor, and occasionally very low individual values have been obtained. Subrahmanyam (1959), working off Calicut, felt that there is always an abundant supply of phosphorus, present in the water for the growth of phytoplankton. The works of Goldberg et. al. (1951) on Asterionella japonica and Ketchum (1939) on Nitzchia closterium, show that phosphorus values that limit the rate of growth of these two species are 0.25 μg at./L.and 0.55 μg at./L.respectively. The phosphorus concentration in the waters off Cochin falls below this limiting concentration on occasions during the post-monsoon months and may be limiting factor for some species of phytoplankton during this season. However according to Steele (1962) the measurement of only one form of nutrient may not be adequate for comparison with laboratory data and it is also doubtful whether any single nutrient can be used as an index for all latitudes and all seasons. Even if we consider that phosphorus is acting as a limiting nutrient during the above months, this period is not long and there is enough of the nutrient available in the water throughout the other months, to support the phytoplankton production.

The quantity of total phosphorus is much higher than the dissolved inorganic phosphorus. Rao (1957), working off Calicut, found that total phosphorus values are high during June, July, August and also during January to March. The present study is also in agreement with this as far as the general trends of values are concerned. After the high values during the S.W. Monsoon (June, July, August) the total phosphorus values became low during October to December. An increase in the total phosphorus is shown thereafter and high values are obtained during February and March. Again the total phosphorus shows a decline in April-May prior to the increase in inorganic phosphorus in the water. The present values for total phosphorus are considerably lower than the values (1.15 μg at./L. to 9.46 μg at./L. for surface water and 1.85 μg at./L. to 10.43 μg at./L. for the bottom water) obtained at Calicut. The boosting of total phosphorus during the S.W. Monsoon is to a great extent due to the increase in inorganic phosphorus values, as there is a decrease in the percentage of organic phosphorus during this period. The increase in total phosphorus during the post-monsoon period i.e., from November onwards in 1967 is due mainly to increase in organic phosphorus. This increase follows a period of high organic activity in the region ~~and may explain this increase~~. The decrease in the percentage of organic phosphorus during the last half of the pre-monsoon period may be an indication of the conversion of this part to inorganic phosphorus, the concentrations of which begin to show an increase during this period.

CHAPTER -- VI

SEDIMENT

The significance of sediments in the distribution of infaunal invertebrates has been recognised in recent years (Brett 1963, Sanders 1959, Thorson 1957, 1958). The texture and the content of dead organic matter in the substratum are undoubtedly the most important factors as far as the biota are concerned. The character of the sediment at any particular region is determined by (1) factors determining the source of supply of sedimentary material, (2) factors determining the transportation and (3) factors determining the deposition. During the process of transportation and deposition, sediments are subjected to physical and chemical adjustments which are reflected in their character. Thus the sediment of any particular region is a unique assemblage of matter retaining its own character and complexity (Nelson 1962). The nature of the sediment in an area, may also give an indication of the factors operating in the transportation and deposition of sediment in that particular area. This clearly indicates the importance of the study of sediments in understanding the complex of ecological factors significant to benthic organisms.

The texture of the Narakal mud bank sediment was studied by Dora, Damodaran and Josanto (1968). The present study is to investigate the general texture of the sediments and their load of organic matter at the eight stations off Narakal.

RESULTS AND DISCUSSION

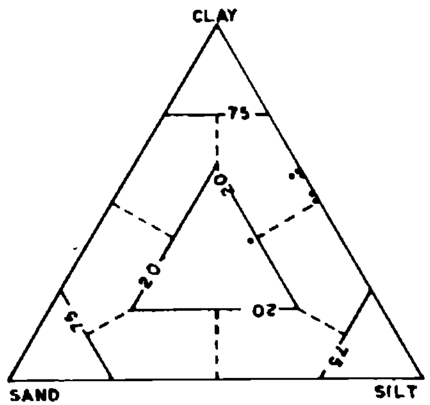
The details of the texture of the sediments are given in Table 5 and Fig. 7.

In general, sediments of the region fall into the category of silty-clay or clayey-silt, and are light reddish or yellowish brown to dark greyish green in colour. A slight black tint was noticed during the period of low oxygen content in the bottom water. This may be caused by the anaerobic condition and the subsequent formation of hydrogen sulphide. If an undisturbed sample is taken from the bottom it can be divided into an upper unconsolidated layer which is brownish and a lower consolidated layer which is more or less greyish green. The upper unconsolidated layer generally extends to a depth of one to two cm.

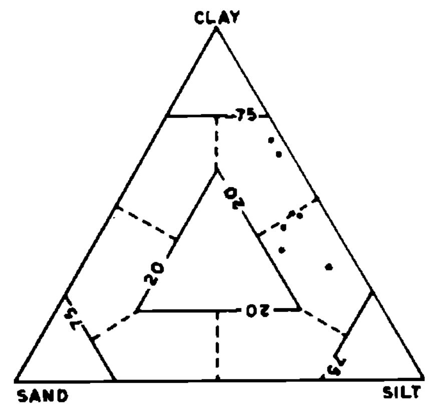
The sediments at stations 1 and 5 can be called silty-clay. Several samples from these stations showed a high percentage of sand. Sediments of stations 2 and 6 were silty-clay or clayey-silt with a little admixture of sand. Sediments at stations 3, 4, 7 and 8 were very fine in nature with very little sand.

From the textural point of view the region can be divided into two: (1) region within 10 m. depth (2) region

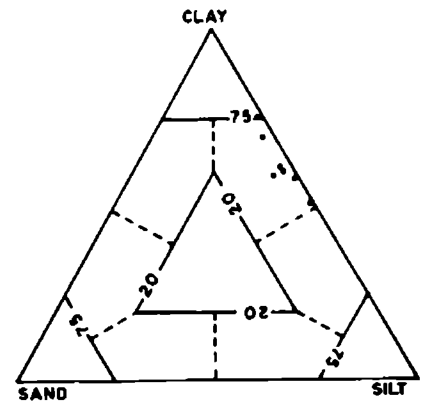
Fig. 7. Sand, silt and clay percentage of the sediment from stations 1 to 8.



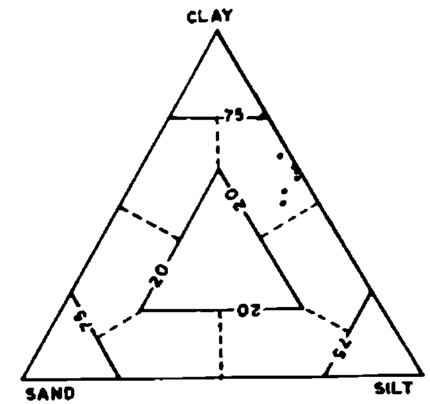
STATION.1



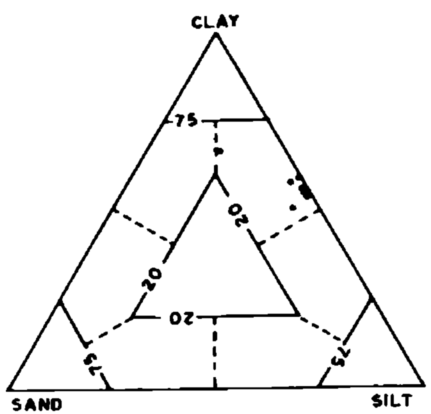
STATION. 2



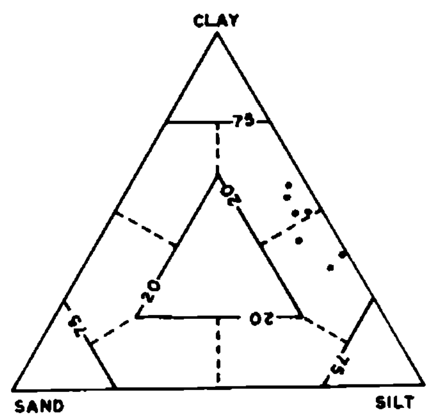
STATION. 3



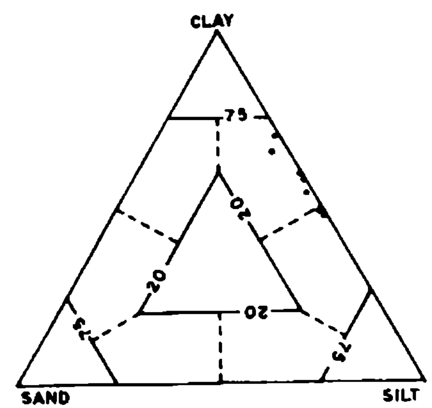
STATION. 4



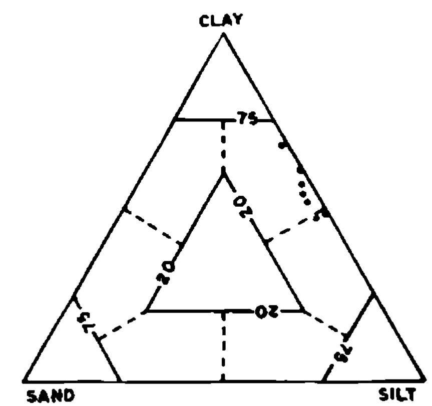
STATION. 5



STATION. 6



STATION. 7



STATION. 8

TABLE: 5

Sand-silt-clay and fine-clay contents in sediments in stations 1 to 8

Date of sampling	Sand %	Silt %	Clay %	% of material finer than 1 µ in diameter.	% of organic matter
			Station: 1		
16-3-1966	22.57	38.14	39.35	28.60	1.97
29-7-1966	--	42.10	57.90	37.95	2.86
20-10-1966	0.84	40.89	58.27	41.36	2.89
30-1-1967	3.57	39.39	57.04	44.00	3.12
27-4-1967	11.26	31.86	56.88	40.01	2.65
26-8-1967	0.78	46.52	53.70	36.70	3.37
22-12-1967	1.32	48.52	50.16	37.35	3.12
			Station: 2		
16-3-1966	3.70	28.36	67.95	47.81	2.55
29-7-1966	26.53	36.42	37.05	29.40	1.97
20-10-1966	12.31	44.04	43.56	37.32	1.82
30-1-1967	8.11	44.58	47.31	39.06	2.36
27-4-1967	3.25	32.62	64.13	51.73	2.01
26-8-1967	7.31	61.50	31.29	27.29	1.65
22-12-1967	6.23	47.05	46.72	29.64	1.73
			Station: 3		
16-3-1966	2.75	27.00	70.25	47.81	3.52

Date of sampling	Sand %	Silt %	Clay %	% of material finer than 1 μ in diameter.	% of organic matter
29-7-1966	6.13	35.72	58.15	47.60	2.35
20-10-1966	3.01	37.07	59.92	44.36	3.21
30-1-1967	2.83	35.75	61.42	45.71	3.42
27-4-1967	1.33	23.42	75.25	48.30	3.69
26-8-1967	0.62	48.33	51.05	40.65	2.98
22-12-1967	1.09	40.81	58.10	46.34	2.86

Station: 4

Date of sampling	Sand %	Silt %	Clay %	% of material finer than 1 μ in diameter.	% of organic matter
16-3-1966	3.60	33.15	63.25	42.15	2.52
29-7-1966	1.60	24.10	74.30	49.20	2.66
20-10-1966	0.89	39.12	59.99	43.18	2.91
30-1-1967	0.94	40.17	58.89	43.96	3.02
27-4-1967	2.09	40.01	57.90	47.20	2.89
26-8-1967	8.87	40.58	50.55	35.60	2.58
22-12-1967	7.62	39.41	52.97	35.86	2.67

Station: 5

Date of sampling	Sand %	Silt %	Clay %	% of material finer than 1 μ in diameter.	% of organic matter
18-4-1966	6.24	43.56	50.20	34.90	2.21
24-6-1966	16.02	17.43	66.55	38.35	1.73
20-9-1966	--	40.70	59.30	44.35	1.92
26-12-1966	1.76	42.49	55.75	43.25	2.31

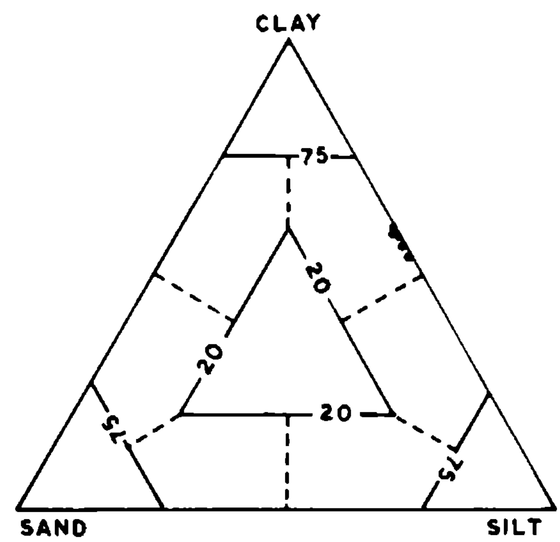
Date of sampling	Sand %	Silt %	Clay %	% of material finer than 1 μ in diameter.	% of organic matter
31-3-1967	1.22	45.46	53.32	47.33	2.65
27-8-1967	0.95	43.75	55.30	39.50	2.61
23-12-1967	2.79	39.05	58.16	40.72	3.23
			Station: 6		
18-4-1966	4.16	39.54	56.30	25.15	2.42
24-6-1966	1.13	61.97	36.90	35.05	2.17
20-9-1966	9.71	49.99	40.30	26.75	1.69
26-12-1966	3.67	47.93	49.40	31.30	1.92
31-3-1967	6.17	40.58	53.25	33.12	2.35
27-8-1967	5.34	61.31	33.35	25.55	1.97
23-12-1967	6.38	44.80	48.82	32.91	2.06
			Station: 7		
18-4-1966	4.07	30.23	65.74	42.45	2.31
24-6-1966	0.89	42.21	56.90	43.35	2.90
20-9-1966	0.79	40.76	58.45	41.45	3.26
26-12-1966	1.69	45.66	52.65	31.45	3.20
31-3-1967	1.67	28.53	69.80	44.98	3.44
27-8-1967	0.08	53.22	46.70	31.70	2.81
23-12-1967	1.47	50.61	47.92	39.62	2.92

Date of sampling	Sand %	Silt %	Clay %	% of material finer than 1 μ in diameter.	% of organic matter
			Station: 8		
18-4-1966	3.02	40.58	56.40	44.75	2.66
24-6-1966	1.29	38.31	60.40	45.65	3.00
20-9-1966	0.44	51.86	47.70	39.25	2.82
26-12-1966	4.04	49.36	46.60	35.55	2.71
31-3-1967	0.89	31.54	67.57	51.10	3.06
27-8-1967	3.86	42.99	53.15	37.15	2.87
23-12-1967	4.12	45.26	50.62	37.10	2.92

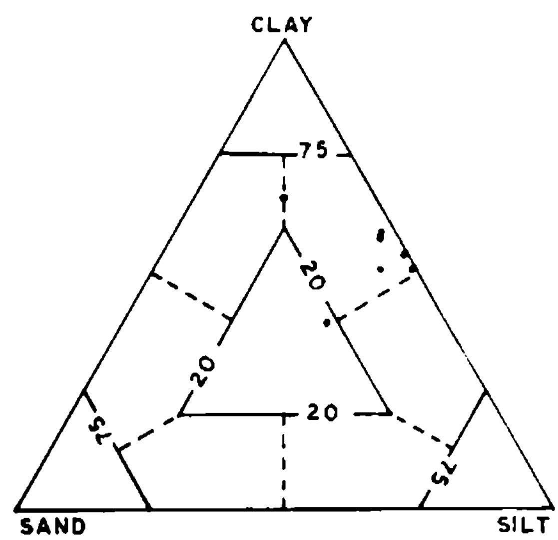
outside 10 m. depth. The stations within 10 m. had fine sediment with a noticeable percentage of sand (excluding the sediment samples from stations 1 and 5 during the active period of the mud bank). These four stations, in comparison with the stations outside the 10 m. line, showed a seasonal variation in the composition of the sediment. Fig. 8 indicates the paucity of sand in the sediments collected from stations 1 and 5 during the active mud bank season. The absence of coarse fraction and higher percentage of clay are the typical characters of the mud bank sediments (Dora et. al. 1968). The sediment samples from the same stations during other periods of the year show a higher amount of sand. The sediments from stations 2 and 6 show the opposite picture. The samples from these stations show a higher percentage of clay when the mudbank is not active and can be classified as silty-clay. But during the mud bank period the sediments of stations 2 and 6 fall into the category of clayey-silt with a good percentage of sand. The decrease in the percentage of finer particles in stations 2 and 6 and an increase in these components in stations 1 and 5 during the mud bank season indicate the likelihood of finer materials from 8 m. depth being transported to 4 m. depth. The samples from stations 3, 4, 7 and 8, although individually different, did not show any marked seasonal difference.

Table 6 shows the composition of the sediment, at

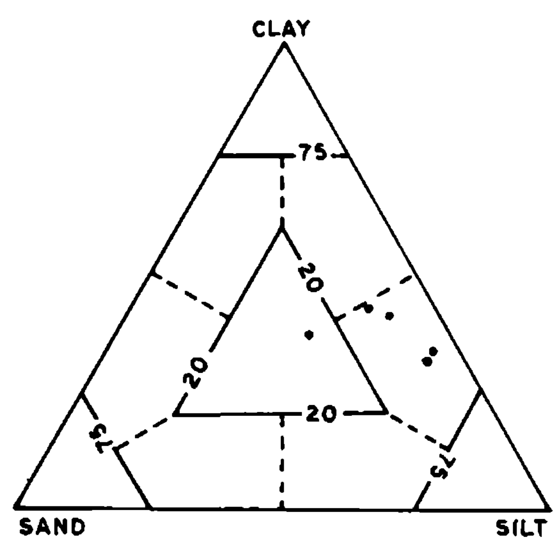
Fig. 8. Seasonal variations in the sand, silt and clay percentage of the sediments at 4 and 8 m. depth.



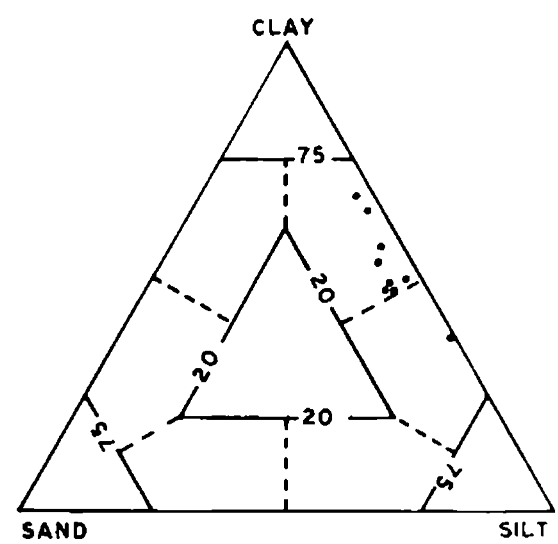
STATIONS I AND 5 MUD BANK (ACTIVE)



STATIONS 1 AND 5 MUD BANK (INACTIVE)



STATIONS 2 AND 6 MUD BANK (ACTIVE)



STATIONS 2 AND 6 MUD BANK (INACTIVE)

TABLE: 6

Composition of the sediment at different depths and % of organic ~~carbon~~ matter

Station No.	Depth of the sediment in cm.	% of sand	% of silt	% of clay	% of organic ~~carbon~~ matter
1	0-2	9.67	42.28	48.05	1.97
1	2-4	20.74	10.86	68.40	2.21
1	4-6	5.79	40.01	54.20	2.23
2	0-2	4.41	26.59	69.00	2.37
2	2-4	3.02	48.23	48.75	2.01
2	4-6	2.32	33.03	64.65	2.28
3	0-2	0.53	16.47	83.00	3.02
3	2-4	2.09	26.21	71.70	3.01
3	4-6	1.36	27.59	71.05	2.89
4	0-2	2.58	39.27	58.15	2.57
4	2-4	1.70	40.35	57.95	2.73
4	4-6	2.01	40.39	57.60	3.01
5	0-2	1.42	43.98	54.60	2.31
5	2-4	1.76	43.64	54.60	2.52
5	4-6	1.48	47.77	50.75	2.23
6	0-2	5.53	39.17	55.30	1.98
6	2-4	0.89	33.36	65.75	2.01
6	4-6	12.09	49.21	38.70	1.65
7	2-4	1.26	35.34	63.40	2.97
7	2-4	1.26	35.34	63.40	2.97
7	4-6	3.55	30.25	66.20	3.02
8	0-2	0.24	19.66	80.10	3.57
8	2-4	0.23	28.57	71.20	2.98
8	4-6	2.19	46.41	51.40	2.71

different depths upto 6 cm., in the eight stations. This indicates a difference in the composition of each 2 cm. section of the sediment, but does not follow any definite pattern. This study has shown that there is a high percentage of clay in the first 2 cm. depth in most of the samples.

The organic matter was determined on sediment samples which had passed through a 0.5 mm. sieve. This was necessary to exclude the large quantity of terrigenous material and also the macrobenthos. The quantity of sand retained in the 0.5 mm. sieve was practially nil and the sediment which passed through a 0.5 mm. sieve was considered as 100%. The sediment was dried and washed to remove salts, which are likely to interfere with the organic matter ~~carbon~~ estimation.

Organic matter ~~carbon~~ content in all the stations was high. All clay minerals except kaolin bind organic matter (Sanders 1956), and the area with a high percentage of clay is capable of having a high proportion of organic matter ~~carbon~~. Since organic matter is trapped predominently by clays and to a lesser degree by fine silts, coarse silts and sands (Russel 1950), the maximum organic matter is to be expected in sediments with maximum clay. In the present study the highest percentage of organic matter ~~carbon~~ was noticed in stations 3 and 7 and the lowest in 2 and 6 The former two stations are the two stations with minimum coarse material and the latter with maximum coarse material.

Table 6 gives the percentage of organic matter ~~carbon~~ in different depths upto 6 cm., in the eight stations. This indicates a difference in the composition of each 2 cm. section of the sediment, but does not follow any definite pattern. This study has shown that there is a high percentage of clay in the first 2 cm. depth in most of the samples.

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Table 6 gives the percentage of organic matter ~~carbon~~ in

2 cm. sections of the sediment up to 6 cm. depth. This indicates that there is no appreciable difference in organic matter ~~carbon~~ with increasing depth up to 6 cm. However as Sanders (1960) pointed out there may be qualitative differences in the nature of the organic matter. According to Sanders the organic matter in the deeper layers of the sediments "being separated from the source of detritus both in time and space, may be refractory or "fossil" in nature and thus less utilisable as food source". Sanders could detect free small chain sugars only in the upper 2 cm. of the sediment and suggested that these sugars may be serving as a ready food source for deposit feeders.

CHAPTER -- VII

BOTTOM FAUNA

The history of benthos studies in Indian seas is rather recent. The first work in this direction was that of Samuel (1944), who described the animal communities of the level sea-bottom of the Madras coast. Other works on the subtidal bottom fauna of the Bay of Bengal are those of Ganapati and Lakshmana Rao (1959) and Sokolova and Pasternak (1964). The former work is a preliminary one, on some grab and dredge hauls made at widely separated stations, and the latter is on the deep sea benthos.

In the Arabian Sea, Kurian (1953) took a large number of dredge hauls and dealt with the occurrence of the bottom fauna in relation to the bottom deposits of the Travancore Coast, while Seshappa (1953) made quantitative studies using grab samples, in the inshore sea bottom of Malabar Coast. Recently Kurian (1967, 1969) made an extensive survey of bottom fauna along the South West Coast of India. Another observation on the bottom fauna is that of Neyman (1969) who studied the bottom fauna of the shelf region of the Arabian Sea. Sanders (1968) took bottom fauna samples along the east and west coasts of India and studied the species diversity. All the above works are restricted to macro-benthos and there is no information on the subtidal meio-benthos of the coastal waters of India.

Results

MACROFAUNA

Species composition and distribution

Polychaeta: Altogether twenty two species of Polychaeta belonging to nineteen genera were collected. Of these, six species can be considered as rare as they were present in only very small numbers in few samples. One of these species, *Sabellaria cementarium* from station 5, was a typical intertidal form and its presence in the samples could be accidental. This species builds fairly large reefs along the beach of Narakal most of which get dislodged from the beach during the beginning of the S.W. Monsoon. Six species of Polychaeta were distributed in all the stations and of these *Prionospio pinnata* was dominant in terms of number. In general most of the polychaetes showed a preference for stations within 10 m. depth and the maximum number were collected from stations 1, 2 and 6. Within this region the stations off Narakal (1 and 2) were considerably richer in polychaete fauna than the stations off Malipuram, (5 and 6). This feature can be clearly noticed in the distribution of species like *Cossura coasta*, *Euclymene insecta*, *E. watsoni*, *Diosoma orissae*, *Mesochaetopterus* sp., *Paraheteromastus teneus* and *Prionospio pinnata*. The distribution of the two maldanid polychaetes *E. insecta* and *E. watsoni* showed an interesting picture. The former species was collected from the profile off Narakal up to 14 m. depth and the latter up to 21 m. depth. But these species were collected only from 4 m. depth off Malipuram and were completely absent in all other stations. The total absence of these species from station 6, which is identical in depth and in the nature of the substratum to station 2 from where both the above species were collected in maximum numbers, is noteworthy.

The polychaete fauna as a whole did not show any seasonal variation. In the case of Cossura coasta and Prionospio pinnata a seasonal increase in number was noticed due to recruitment. The distribution of E. insecta and E. watsoni in stations 1 and 2 also showed changes during the period of study. At the beginning of the investigation both the species were common in station 1, but from the onset of the S.W. Monsoon in 1966 their numbers declined and they were practically absent in this station during the rest of the period. On the other hand both the species were insignificant in the fauna of station 2 during 1966, but from the 1967 premonsoon period onwards both started appearing in the samples from this station in significant numbers.

Crustacea:- Crustacean fauna was comparatively poor in terms of numbers of animals present in the grab samples. Only two groups; Amphipoda and Decapoda, were present in any significant numbers. Other groups of crustaceans were represented by one species of Mysidacea, two species of Cumacea, two species of Isopoda belonging to the family Arcturidae, one species of Tanaidacea, and one species of Stomatopoda. Among the amphipods Ampelisca cyclops was the most common species and constituted about 56% of the amphipod fauna. The decapod Hexapus (Labdophalus) saxpes was the other species of importance. All the specimens of this species were collected from stations 4, 7 and 8.

Mollusca:- A total of eighteen species of Mollusca were collected from the stations. A few young gastropods present in some of the samples were not identified. Of the eighteen species only two, Nucula sp. and Solariella biangulosa, were collected from all the stations and these two species accounted for a major proportion of the molluscs from all the stations. No adult Nucula sp. was collected from any of the stations during the period of study. All the specimens were newly settled juveniles between the size range of 1 and 2 mm. They appeared in large numbers in samples during certain months, especially between April and September. None of these specimens grew beyond a size of 2 mm. and eventually more or less completely disappeared from the samples during December and January. Solariella biangulosa although present in all the stations showed a preference for the four deeper stations. In general most of the molluscan species were more abundant in stations outside the 10 m. line. Among the stations within the 10 m. line only station 2 showed a slight increase in molluscan fauna. Stations 1, 5 and 6 were poorer in terms of number and species. Thus more than 76% of the total molluscs collected were from stations 3, 4, 7 and 8 and only less than 24% came from the remaining four stations. This preference to deeper stations was noticed in the distribution of all the important species. Only *Modiolus* sp. and *Barnaea* sp. were present in significant numbers in stations within 10 m. depth. The former was present in only a few samples and the latter only in one sample. Although collected only in one grab haul *Barnaea* sp. is an important constituent of the fauna of the subtidal region. The absence of this species in most of the grab hauls and its presence in large numbers (more than 8600/m^2.) in one indicate a patchy distribution.

Other groups:- Four species of Anthozoa, one of Nemertini, one of Sipunculoidea, one of Echiuroidea, two of Echinodermata and two of Pisces formed the rest of the fauna. Most of the anthozoans were collected from 8 and 14 m. depths off Narakal. Echiuroidea and Sipunculoidea were more common at 21 m. depth. The abundance of Sipunculoidea at this depth may be due to the availability of large numbers of dead shell which this species inhabits.

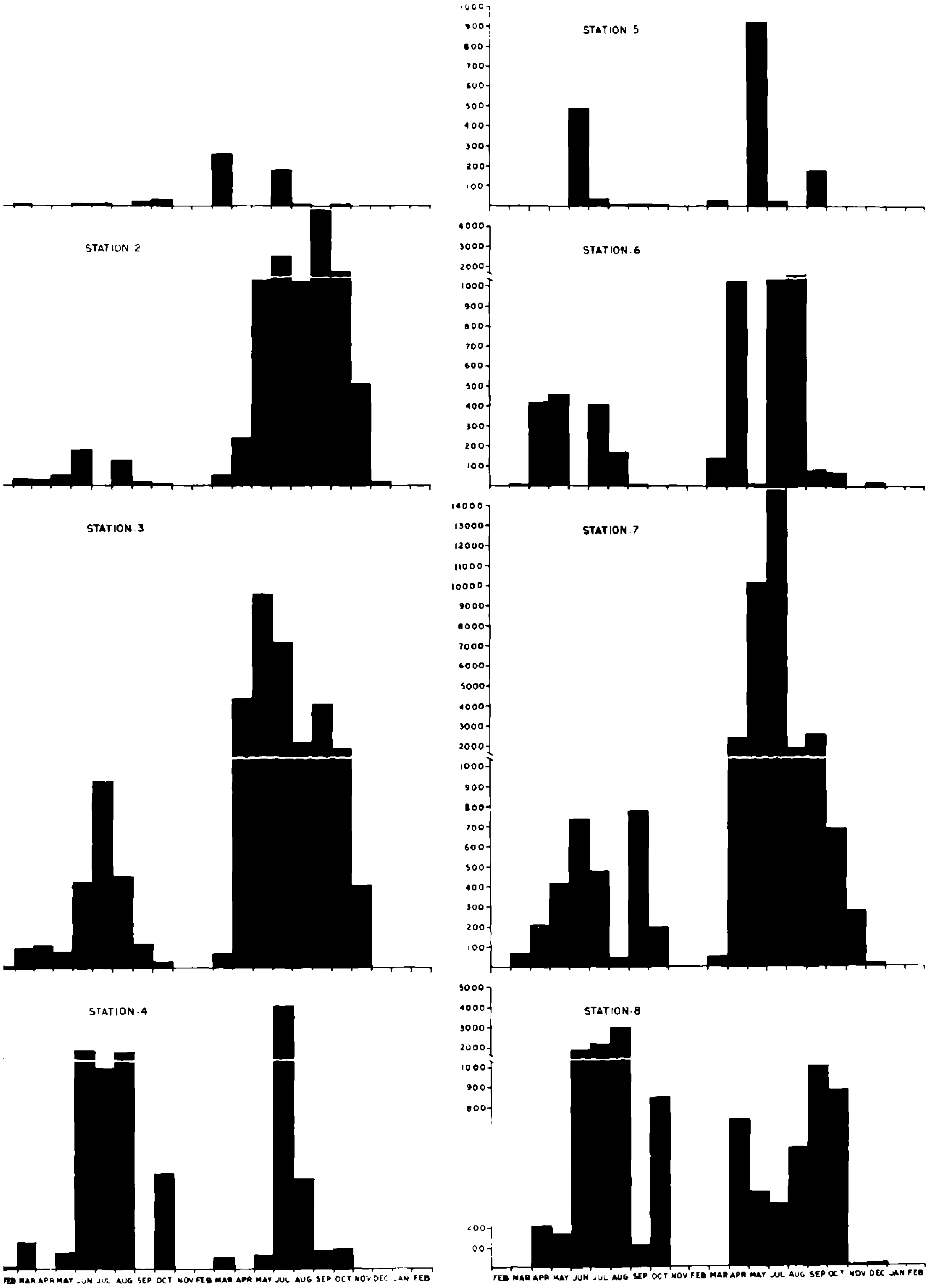
Larval settlement

One of the interesting aspects noted in the present study is the settlement of Nucula sp. (Fig. 9). Only juvenile specimens of 1 to 2 mm. size were collected from the region during the period of investigation. As the adult specimens were not available it was not possible to identify the specimens to species level. This species appears to breed throughout the year with a peak during April to October. Very few specimens were collected during November and the number was practically nil in the samples of December, January and February. The settlement of this species was poor in 1966 in comparison with 1967. In 1966 the maximum settlement was in the stations at 21 m. depth, and in 1967 14 m. depth. In both the years settlement was poor in stations at 8 m. depth, and especially low at 4 m. depth.

Regarding other species of molluscs, juvenile Arca inequavalvis was collected in the samples in significant numbers during December-January months. Specimens up to 2 mm. size was present in the samples till May. From the appearance of the young specimens in the samples, and from their size, A. tortosa also seem to have a breeding period similar to A. inequvalvis. Juveniles of no other species were present in significant numbers. Few juvenile specimens of Barnaea sp. were collected in October and that of Dentalium conspicum during March, May and September.

Only a few species of polychaetes were found to settle during the period of study. Prionospio pinnata settled in noticeable numbers during September-October.

Fig. 9. Settlement of Nucula Sp., in stations 1 to 8.


STATION 2
STATION 3
STATION 4
STATION 5
STATION 6
STATION 7
STATION 8
1000
900
800
700
600
500
400
300
200
100
4000
3000
2000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
FEB MAR APR MAY JUN JUL AUG SEP OCT NOV FEB MAR APR MAY JUL AUG SEP OCT NOV DEC JAN FEB
FEB MAR APR MAY JUN JUL AUG SEP OCT NOV FEB MAR APR MAY JUL AUG SEP OCT NOV DEC JAN FEB

From the presence of juveniles in the grab and core samples Paratreteromastus tenuis appear during March-April and Cossura coasta and Sternaspis scutata during December, January and February.

Number

The number of animals present in each sample taken from the eight stations is given in Tables 7 to 14.

The total number of macrofauna from individual samples showed considerable variation. Polychaetes and molluscs constituted the bulk of the fauna, and formed about 90 to 95% of the total in all the stations. The number of individuals ranged from 0 to 96/0.1 m^2. in station 5, to 3 to 1483/0.1 m^2. in station 7. A large percentage of the fauna in all the stations was composed of Nucula sp. and the number of individuals in different stations showed an increase from March-April onwards due to the settlement of this species. Barnea sp., C. coasta, E. insecta, E. watsoni, P. ninnata and S. biangulosa were the other species of importance and these species together with Nucula sp., constituted 75% or more of the fauna in all the stations.

If the total number of animals are taken into account, stations 3 and 7 recorded the maximum number of animals. In the four stations within 10 m. depth the fauna showed a decrease just before or during the S.W. Monsoon. This pattern was very evident in station 1. At the beginning of the study station 1 harboured a fairly rich fauna of polychaetes, but from May 1966 onwards the fauna showed a decline and never recovered. In station 2 the fauna was poor throughout 1966, but during 1967 it showed a marked enrichment. This change was mainly due to the appearance and disappearance of E. insecta and E. watsoni in these two stations. Compared to these two stations the stations 5 and 6 off Malipuram sustained a poorer fauna.

The four stations outside 10 m. depth did not show much seasonal variation except for the settlement of Nucula sp., but an increase in the fauna (excluding Nucula sp.) during the premonsoon period and a decrease during monsoon and early post monsoon, was noticed.

Weight

The biomass of the macrobenthos is given in Fig.10 and Tables 15-22.

The maximum biomass was recorded from stations 3 and 7 and the minimum from stations 5 and 6. There are two reasons for the increase in biomass in stations 3 and 7. First is the presence of large numbers of Nucula sp. in the samples from these stations. Secondly the contribution of individual specimens having more than 100 mg. was high in these two stations. This was especially due to the

Fig. 10. Dry weight of macrofauna (excluding Nucu
and animals weighting more than 100 mg.)
0.1 m^2 in stations 1 to 8 during 1966 to

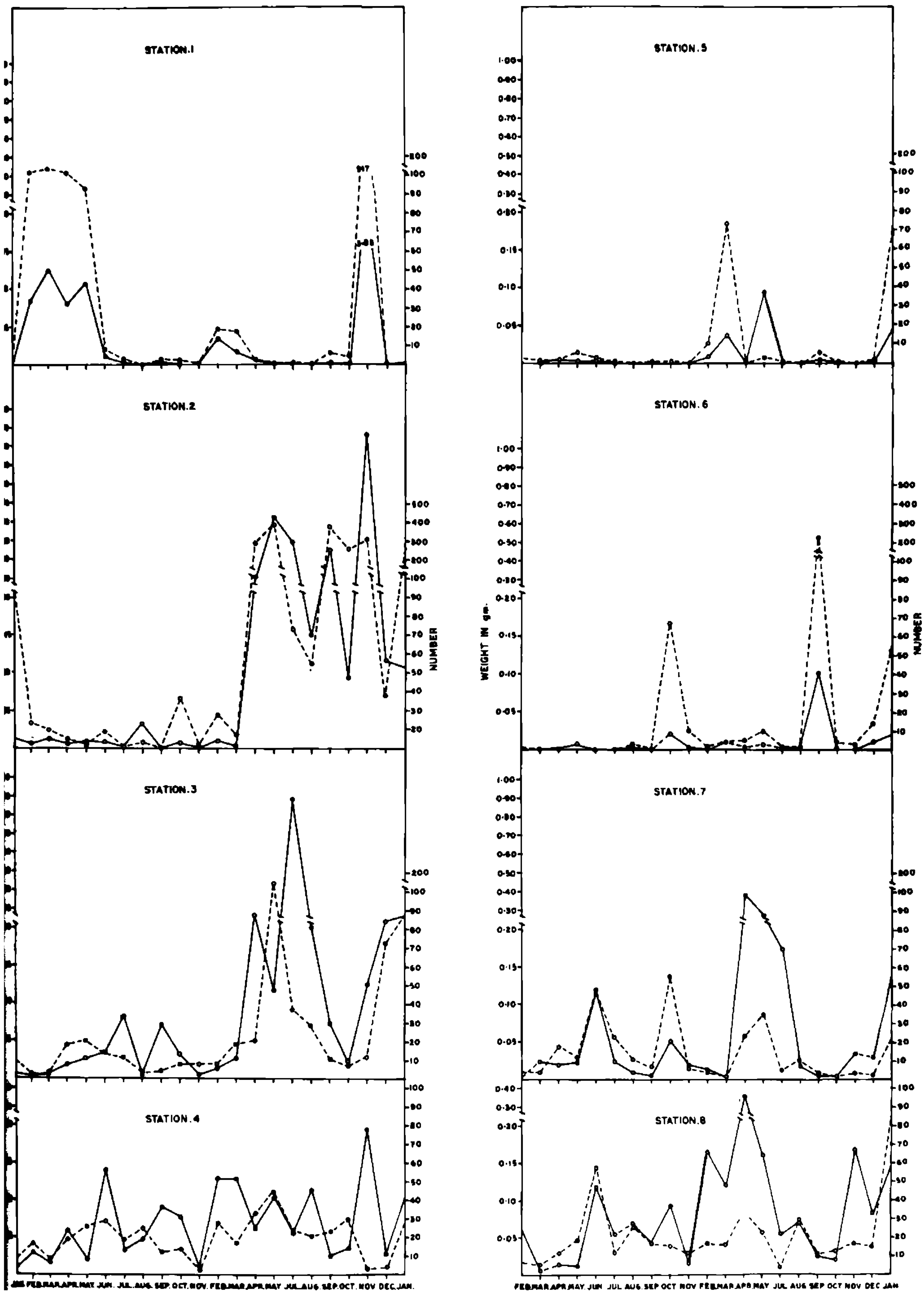

STATION.1
STATION.2
STATION.3
STATION.4
STATION.5
STATION.6
STATION.7
STATION.8
WEIGHT IN gm.
NUMBER
FEB.MAR.APR.MAY JUN JUL AUG SEP OCT NOV FEB.MAR.APR.MAY JUL AUG SEP OCT NOV DEC JAN

TABLE: 15

Biomass of the macrobenthos per 0.1 m^2 during 1966 to 1968 in Station 1

Month	Dry weight of Nucula sp.	Dry weight of animals weighting more than 100 mg.	Dry weight of other animals	Total dry weight	Total wet weight
January	0.0013	--	0.0017	0.0030	0.0800
February	--	--	0.0864	0.0864	0.4612
March	0.0009	--	0.1259	0.1268	1.0501
April	--	--	0.0806	0.0806	1.0037
May	--	0.2643	0.1081	0.3724	2.9730
June	0.0010	--	0.0104	0.0114	0.1306
July	0.0009	--	0.0036	0.0045	0.0212
August	--	--	--	--	--
September	0.0016	--	0.0039	0.0055	0.0529
October	0.0021	--	0.0009	0.0030	0.0188
November	--	--	--	--	--
February	--	--	0.0342	0.0342	0.1490
March	0.0182	--	0.0162	0.0344	0.1374
April	--	--	0.0061	0.0061	0.0149
May	--	--	0.0006	0.0006	0.0021
July	0.0240	--	0.0009	0.0249	0.0435
August	0.0014	--	--	0.0014	0.0025
September	--	--	0.0029	0.0029	0.0087
October	0.0014	--	0.0013	0.0027	0.0098
November	--	--	3.8326	3.8326	43.6320
December	--	--	--	--	--
January	--	--	0.0016	0.0016	0.0043
Total	0.0528	0.2643	4.3179	4.6350	49.7957

TABLE: 16

Biomass of the macrobenthos per 0.1 $m.^2$ during 1966 to 1968 in station 2.

Month	Dry weight of Nucula sp.	Dry weight of animals weighting more than 100 mg.	Dry weight of other animals	Total dry weight	Total wet weight
January	--	--	0.0146	0.0146	0.0891
February	--	--	0.0058	0.0058	0.0410
March	0.0016	--	0.0129	0.0145	0.0820
April	0.0025	0.4631	0.0062	0.4718	12.2837
May	0.0036	--	0.0095	0.0131	0.0763
June	0.0089	--	0.0078	0.0167	0.0759
July	--	--	0.0026	0.0026	0.0103
August	0.0117	--	0.0343	0.0460	0.3391
September	0.0026	--	--	0.0026	0.0049
October	0.0006	--	0.0081	0.0087	0.0579
November	--	--	0.0013	0.0013	0.0149
February	--	--	0.0098	0.0098	0.0282
March	0.0036	--	0.0045	0.0081	0.0375
April	0.0168	0.1032	0.3115	0.4315	4.6721
May	0.1008	--	0.6278	0.7286	6.1045
July	0.2241	--	0.4989	0.7230	3.7625
August	0.1080	--	0.1530	0.2610	1.3677
September	0.3447	--	0.4585	0.8032	5.3851
October	0.1457	--	0.0920	0.2377	0.9035
November	0.0459	--	1.0702	1.1161	8.4625
December	0.0016	--	0.1165	0.1181	1.5490
January	--	--	0.1077	0.1077	0.8366
Total	1.0227	0.5663	3.5535	5.1425	46.1843

TABLE: 17

Biomass of the macrobenthos in 0.1 $m.^2$ during 1966 to 1968 in station No. 3

Month	Dry weight of Nucula sp.	Dry weight of animals weighting more than 100 mg.	Dry weight of other animals	Total dry weight	Total wet weight
January	--	--	0.0060	0.0060	0.0416
February	0.0009	0.2511	0.0027	0.2547	11.7491
March	0.0061	--	0.0071	0.0132	0.0582
April	0.0079	--	0.0183	0.0262	0.1831
May	0.0056	--	0.0259	0.0315	0.3010
June	0.0344	--	0.0352	0.0696	0.3887
July	0.0837	--	0.0839	0.1676	0.4469
August	0.0251	--	0.0042	0.0293	0.1146
September	0.0096	0.5823	0.0723	0.6642	20.8091
October	0.0026	0.3974	0.0328	0.4328	17.8361
November	--	--	0.0055	0.0055	0.0646
February	--	0.2671	0.0120	0.2791	9.2550
March	0.0063	--	0.0272	0.0335	0.5364
April	0.3544	--	0.2726	0.6270	4.9375
May	0.5754	--	0.1172	0.6926	4.3378
July	0.5736	0.3791	0.8811	1.8338	15.2480
August	0.3472	--	0.2012	0.5484	1.4262
September	0.6619	--	0.0769	0.7388	1.4453
October	0.3624	0.1897	0.0236	0.5757	11.1134
November	0.0656	--	0.1242	0.1898	0.5204
December	--	0.2811	0.2410	0.5221	4.7761
January	--	--	0.2667	0.2667	0.9465
Total	3.1227	2.3478	2.5376	8.0081	106.5356

TABLE: 18

Biomass of the macrobenthos per 0.1 m.^{2} during 1966 to 1968 in station 4

Month	Dry weight of Nucula sp.	Dry weight of animals weighing more than 100 mg.	Dry weight of other animals	Total dry weight	Total wet weight
January	--	--	0.0092	0.0092	0.0685
February	0.0009	--	0.0301	0.0310	0.3516
March	0.0104	--	0.0162	0.0266	0.8214
April	--	--	0.0595	0.0595	0.7804
May	0.0072	--	0.0206	0.0278	0.4201
June	0.2232	--	0.1408	0.3640	1.4713
July	0.1226	--	0.0341	0.1567	0.6607
August	0.2576	--	0.0480	0.3056	0.8707
September	0.0034	--	0.0907	0.0941	0.5048
October	0.0582	0.1325	0.0798	0.2705	1.2436
November	--	--	0.0111	0.0111	0.1823
February	--	--	0.1282	0.1282	2.5692
March	0.0062	--	0.1287	0.1349	1.2734
April	--	--	0.0629	0.0629	1.1859
May	0.0081	--	0.1047	0.1128	1.6336
July	0.6490	--	0.0565	0.7055	1.8915
August	0.0720	--	0.1146	0.1866	1.3732
September	0.0121	--	0.0269	0.0390	0.3299
October	0.0118	--	0.0359	0.0477	0.3826
November	--	0.1439	0.1956	0.3395	7.1571
December	--	--	0.0275	0.0275	0.9147
January	--	--	0.1061	0.1061	1.7915
Total	1.4427	0.2764	1.5277	3.2468	27.8780

TABLE: 19

Biomass of the macrobenthos per 0.1 m.^{2} during 1966 to 1968 in station 5

Month	Dry weight of *Nucula* sp.	Dry weight of animals weighing more than 100 mg.	Dry weight of other anima.s	Total dry weight	Total wet weight
February	--	--	0.0009	0.0009	0.0041
March	--	--	0.0015	0.0015	0.0061
April	--	--	0.0056	0.0056	0.0623
May	--	--	0.0041	0.0041	0.0100
June	0.0412	--	0.0046	0.0458	0.2017
July	0.0046	--	0.0018	0.0064	0.0245
August	0.0015	--	--	0.0015	0.0027
September	0.0012	0.1667	0.0007	0.1686	1.0874
October	0.0012	--	0.0006	0.0018	0.0041
November	--	--	--	--	--
February	--	--	0.0084	0.0084	0.0705
March	0.0031	--	0.0375	0.0406	0.3870
April	--	--	--	--	--
May	0.1289	--	0.0940	0.2229	0.5016
July	0.0027	--	0.0009	0.0036	0.0074
August	--	--	--	--	--
September	0.0132	--	0.0053	0.0185	0.0387
October	--	--	0.0005	0.0005	0.0021
November	--	--	--	--	--
December	--	--	0.0017	0.0017	0.0037
January	--	--	0.0470	0.0470	0.3083
Total	0.1976	0.1667	0.2151	0.5794	2.7222

TABLE: 20

Biomass of the macrobenthos per 0.1 m.^{2} during 1966 to 1968 in station 6

Month	Dry weight of *Nucula* sp.	Dry weight of animals weighing more than 100 mg.	Dry weight of other anima.s	Total dry weight	Total wet weight
February	--	--	0.0015	0.0015	0.0069
March	0.0009	--	0.0018	0.0027	0.0206
April	0.0284	--	0.0024	0.0308	0.2613
May	0.0291	--	0.0084	0.0357	0.4207
June	--	--	--	--	--
July	0.0279	--	--	0.0279	0.1128
August	0.0102	--	0.0040	0.0142	0.0563
September	0.0008	--	0.0006	0.0014	0.0063
October	--	--	0.0208	0.0208	0.0622
November	--	--	0.0042	0.0042	0.0458
February	--	--	0.0012	0.0012	0.0039
March	0.0112	--	0.0117	0.0229	0.1053
April	0.0992	1.0271	0.0041	1.1304	3.8611
May	0.0009	--	0.0076	0.0085	0.0716
July	0.1463	--	0.0035	0.1498	0.5798
August	0.1672	0.1836	0.0031	0.3539	0.7828
September	0.0064	--	0.1012	0.1076	1.1880
October	0.0063	--	0.0030	0.0093	0.0561
November	--	--	0.0014	0.0014	0.0300
December	0.0018	--	0.0104	0.0122	0.0992
January	--	--	0.0209	0.0209	0.0763
Total	0.5366	1.2107	0.2118	1.9591	7.8470

TABLE: 21

Biomass of the macrofauna per 0.1 $m.^2$ during 1966 to 1968 in station 7.

Month	Dry weight of *Nucula* sp.	Dry weight of animals weighing more than 100 mg.	Dry weight of other animals	Total dry weight	Total wet weight
February	--	--	0.0022	0.0022	0.0089
March	0.0063	0.4169	0.0246	0.4478	21.7900
April	0.0126	--	0.0198	0.0324	0.2701
May	0.0290	--	0.0227	0.0517	0.1921
June	0.0697	--	0.1162	0.1859	1.2410
July	0.0423	--	0.0244	0.0667	0.3194
August	0.0041	--	0.0101	0.0142	0.1339
September	0.1063	--	0.0063	0.1126	0.2769
October	0.0220	--	0.0515	0.0735	0.3895
November	--	--	0.0198	0.0198	0.2216
February	--	--	0.0138	0.0138	0.1228
March	0.0028	--	0.0034	0.0062	0.0599
April	0.2151	--	0.3888	0.6039	5.2789
May	1.7306	--	0.2785	2.0091	11.8147
July	2.5169	--	0.1757	2.6926	6.6246
August	0.2940	--	0.0189	0.3129	1.0107
September	0.4419	--	0.0055	0.4474	1.6207
October	0.1273	0.3729	0.0045	0.5047	18.1632
November	0.0364	1.2347	0.0366	1.3077	19.1918
December	0.0027	--	0.0304	0.0331	0.4275
January	--	--	0.1433	0.1433	3.6316
Total	5.6600	2.0245	1.3970	9.0815	92.7768

TABLE: 22

Biomass of the macrofauna per 0.1 $m.^2$ during 1966 to 1968 in station 8.

Month	Dry weight of *Nucula* sp.	Dry weight of animals weighting more than 100 mg.	Dry weight of other animals	Total dry weight	Total wet weight
February	--	--	0.0591	0.0591	1.6521
March	--	--	0.0064	0.0064	0.0603
April	0.0147	--	0.0152	0.0299	0.2481
May	0.0136	--	0.0118	0.0254	0.2189
June	0.1728	--	0.1181	0.2909	0.7961
July	0.3018	--	0.0555	0.3573	0.9409
August	0.5342	--	0.0703	0.6045	1.7708
September	0.0192	--	0.0442	0.0634	0.7801
October	0.1105	--	0.0921	0.2026	0.8778
November	--	--	0.0168	0.0168	0.1799
February	--	--	0.1667	0.1667	3.4294
March	--	--	0.1218	0.1218	1.5754
April	0.0689	--	0.3570	0.4259	11.3410
May	0.0494	--	0.1610	0.2104	5.0576
July	0.0318	0.2904	0.0569	0.3791	2.1716
August	0.0691	--	0.0695	0.1386	1.0327
September	0.1482	--	0.0242	0.1724	0.4267
October	0.1744	--	0.0207	0.1951	0.5215
November	0.0019	--	0.1683	0.1702	1.7493
December	0.0037	--	0.0833	0.0870	1.2856
January	--	--	0.1460	0.1460	2.9885
Total	1.7142	0.2904	1.8649	3.8695	39.1043

presence of T. attenuata in the samples.

There was an increase in the biomass in all the stations during the pre-monsoon period. This increase was maintained in most of the stations till August-September due to the settlement of Nucula sp. If the weight of this species is excluded a decrease in biomass is noticed in the stations within 10 m. in the early half of the monsoon. A similar decrease is seen in stations outside 10 m. in late monsoon or early pre-monsoon.

MEIOFAUNA

Species composition and vertical distribution

Foraminifera:- This important group of meiobenthic fauna was studied with reference to animals retained in a 62 μ sieve. To exclude dead shells from the study, only specimens that had taken stain when treated with rose bengal are considered. With the exception of one sample from station 9, Foraminifera occurred in fair abundance in all the samples. Their contribution to the total fauna from different stations varied between 5.7% to 23.8%. In numerical abundance this group was surpassed only by nematodes. Foraminifera were more abundant in stations 2 and 6.

A number of species belonging to different genera are recorded from the South West Coast of India. (Sethulakshmi Amma 1958, Antony 1968). But in the present samples only a few species were found to be of importance from the point of view of their representation in the samples. Most important of these was Ammobaculites taylorensis Cushman and Waters. This species was especially rich in stations 2 and 6. Rotalia baccari Linnaeus was common in all the stations. Bolivina sp. was the dominant form in stations 4 and 8. In addition to these species, Roephax sp., Nonion sp., Quinqueloculina sp. and Discorbis sp. were present in most of the samples.

Foraminifera were distributed throughout the length of the core, with a maximum in the surface 2 cms. In most of the cores they were present in the 4-6 cms. depth.

Turbellaria:- Turbellarians were not present in the samples from stations 9 and 10. It was not possible to study this group in any detail. They were better represented in stations 5 to 8 than in 1 to 4. Maximum numbers of animals were collected from station 7 and minimum from station 4. Most of the turbellarians were found in the upper 2 cm. of the cores. They were present at 2-4 cms., and rarely collected from 4-6 cms. depth.

Nematoda:- By far the most important group in terms of number and species represented in the samples was Nematoda. They were present in all samples and constituted about 93% of the fauna collected from station 10. Nematodes formed only 57% of the fauna in station 5, but in all the other stations they accounted for more than 70% of the total fauna. As stations 1, 5, 9 and 10 were under the influence of the mud bank formation there was a rapid decline in the total fauna in these regions during the S.W. Monsoon. This decline was more conspicuous in nematode fauna as they were the dominant group. The nèmatode fauna was particularly rich in stations 3 and 7.

Correct identification of the species of this group was extremely difficult. It appeared that a number of species in the three regions studied were common, but the dominant species were not same. *Metachromadora* (*Bradylaimoides*) *benepapillata* Timm, was the dominant species in stàtions 1 to 8, with *Microlaimus* sp. next in importance. *Terschellingia longicaudata* De Man and *Pseudolella bengalensis* Timm, occurred in greater numbers in stations 9 and 10 respectively. In addition to the two species already mentioned a number of species of Chromadoroidea were present in all the stations. The important genera were *Chromodora*, *Sabatiera*, *Tricoma* and *Pterygonema*. The order Enoploidea was mainly represented by *Oxystomatina elongata* (Buetschli), *Oncholaimus* sp., *Oncholaimellus carlbergi* Allgen, and a few species (probably three) of *Halalaimus*. There were a large number of species of Axonolaimoidea and Monhysteroidea in the samples. Of these *Sphaerolaimus pacifica* Allgen was the common species in stations 1 to 8.

Nematodes were the most successful group to penetrate deep into the sediment. They were always present at a depth of 4-6 cms, but the maximum number in most of the samples was in the surface 2 cms.

Polychaeta:- Four species of Polychaeta were collected from the meiobenthos samples. They were identified as *Paraheteromastus teneus*, *Prionospio pinnata*, *Cossura coasta* and *Sternaspis scutata*. Of these the juveniles of the first two species were present during March-April and June-July samples respectively. *Cossura coasta* is a small species and present mainly in the December and January samples. Juvenile *sternaspis scutata* were collected during January and March.

The number of polychaetes present in the samples was always small, but they were collected from all stations, except 9 and 10. Their numbers were poor in samples taken during December and January. Relatively high numbers were present in samples taken during March, April, June and July. The maximum number of polychaetes were collected from stations 4 and 7.

Kinorhyncha:- These were found in all stations except 10. Two species of kinorhynchs were present in the samples, one of them of the genus *Echinoderella* and the other a homalorhagid. The former was most common, and this species resembled in most characters to *Echinoderella bengalensis*, Timm.

Most of the kinorhynchs were collected from the surface 2 cm. Only a small fraction of the total fauna was

<u>Lamellibranchiata</u>:- These were juvenile stages of the lamellibranchs. Their appearance in the meiobenthos samples depends on the breeding periods and they are therefore seasonal. Lamellibranchs appeared in the samples from December to July. Their maximum abundance was in April-May Months. They were absent in samples taken in September and October. Lamellibranchs were better represented in stations 1 to 8, and poor in stations 9 and 10. When compared with others, stations 2, 5 and 6 had lesser numbers of lamellibranchs per unit area. From March - April onwards macrobenthos samples from stations 1 to 8 contained large numbers of <u>Nucula</u> sp., and it may be correct to presume that most of the meiobenthic juvenile specimens were <u>Nucula</u> sp. In addition to this species it is possible that juveniles of <u>Arca inequvalvis</u>, <u>Macoma</u> sp. ~~gubernaculam~~ and <u>Mactra</u> ~~cunniata~~ lilacea were also present in the samples.

Most of these specimens were collected from the surface 2 cm. depth. They were also present in small numbers in 2 to 4 cm. depth. In only a few core samples were lamellibranchs present at 4 to 6 cm.

<u>Other groups</u>:- Cumacea, Isopoda, Amphipoda, Acarina and young Gastropoda were the other groups present in the samples. They were found only occasionally and even when present, were few in number. Crustacean nauplii were found in a few samples in good numbers and in one

sample from station 5, they were abundant. A few unidentified crustaceans were also present in the samples.

Number

The number of animals in the main taxonomic groups from all three regions are given in tables 23 to 32 and Fig. 11. When data from all the ten stations were considered the number of animals from individual samples ranged from 29 to 6687 / 10 cm^2. The range at the two stations at 4 m. depth off Narakal was 78 to 1455 / 10 cm^2. In stations at 8 m. depth it was 463 to 3446 / 10 cm^2. At 14 and 21 m. depth the corresponding values were 831 to 6687 / 10 cm^2. and 703 to 4800 / 10 cm^2. respectively. Only limited data are available from stations 9 and 10. In station 9, the number of animals present in individual samples ranged from 29 to 825 / 10 cm^2. and in station 10 between 71 and 1101 / 10 cm^2.

It is apparent from the tables that the fauna is poor in stations at 4 m. depth and fairly rich in all the other stations. The maximum abundance of fauna was noticed in stations 3 and 7. It is also evident from figure 10 that there is a decrease in the total number of animals in all the stations within 10 m. depth, after the month of ~~of~~ June. This decrease is not apparent in the September sample from station 5 because of the large number of crustacean nauplii present in the samples. In stations 1 and 2 the

Fig. 11. Number of meiofauna per 10 cm^2 in stations 1 to 10 during 1966-1967.

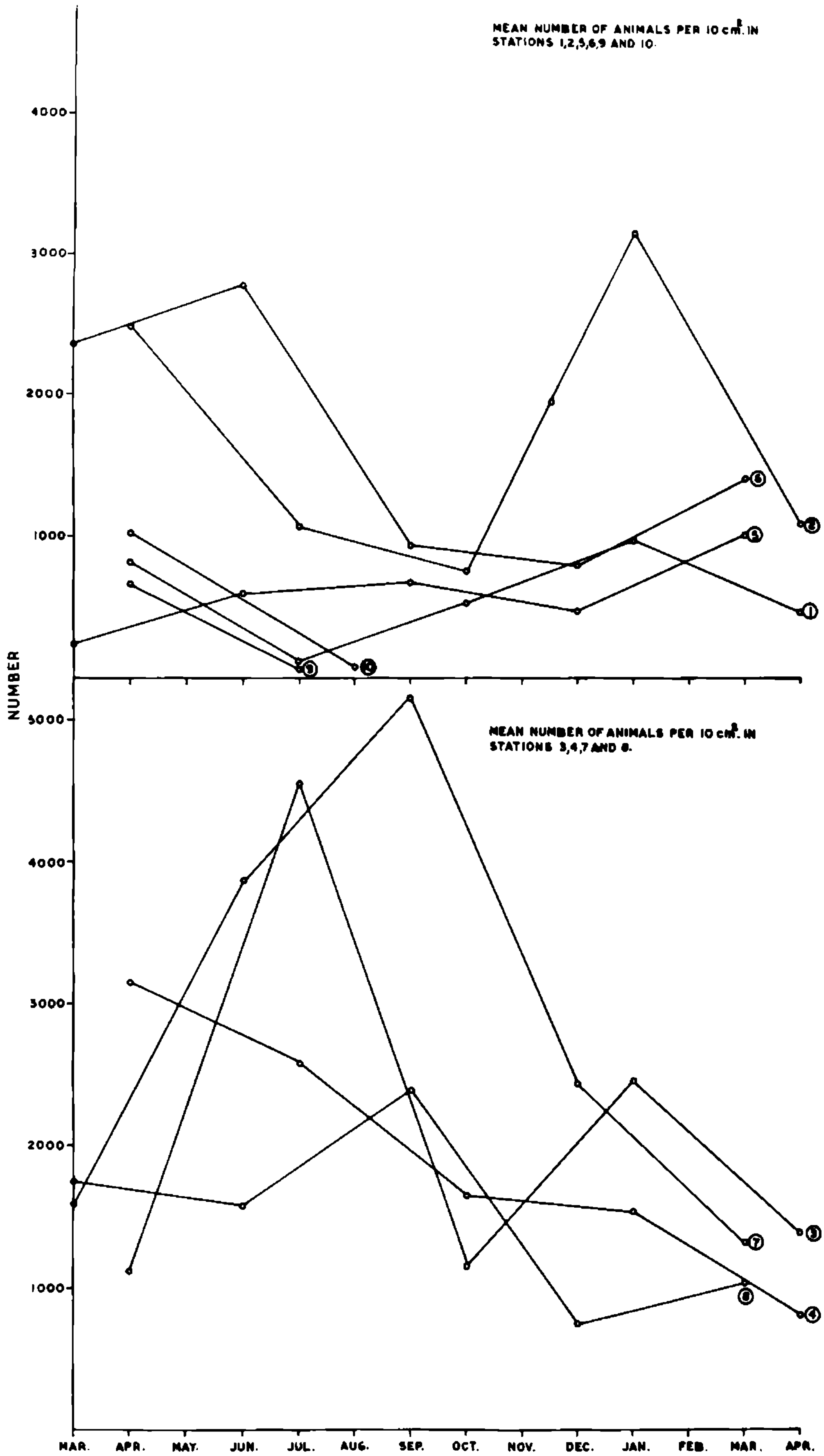

MEAN NUMBER OF ANIMALS PER 10 cm². IN STATIONS 1,2,5,6,9 AND 10.
MEAN NUMBER OF ANIMALS PER 10 cm². IN STATIONS 3,4,7 AND 8.
NUMBER
4000
3000
2000
1000
5000
4000
3000
2000
1000
MAR. APR. MAY. JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APR.

TABLE: 31

Station: 9

Number of meiofauna/10cm^2(in 6 cores)

Date of sampling	13--4--66			16--7--66			
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	Total
Foraminifera	102	42	74	32	10	--	260
Nematoda	587	764	376	57	70	29	1883
Kinorhyncha	--	--	3	--	--	--	3
Ostracoda	10	3	--	--	--	--	13
Copepoda	13	3	--	--	--	--	16
Other Groups	--	3	--	3	--	--	6
Total	712	815	453	92	80	29	2181

TABLE: 32

Station: 10

Number of meiofauna/10cm^2 (in 5 cores)

Date of sampling	4--4--67		12--8--67			
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	**Total**
Foraminifera	19	28	29	10	57	143
Nematoda	902	1061	42	67	35	2107
Ostracoda	--	3	--	--	--	3.
Copepoda	--	9	--	--	--	9
Other Groups	3	--	--	3	3	9
Total	924	1101	71	80	95	2271

July values are considerably poorer than those of April. Stations 5 and 6 recorded an increase from March to June. Between June and September there was a considerable decrease in the fauna at station 6. This decrease is seen in station 5 also if we exclude the number of crustacean nauplii present in the September sample, the occurrence of which should be considered as sporadic. A similar decline in the fauna was noticed in stations 9 and 10 also, where the samples collected during the S.W. Monsoon were considerably poorer than those collected during April.

Stations 3, 4 and 8, which are outside the 10 m. line, are comparatively richer than the near shore stations. Unlike the near shore stations there was no decline in the fauna in these stations during July or September. In fact a general increase in the number of the fauna was noticed in these stations during this period. Three out of these four stations recorded the maximum number of animals either in July or in September. The only exception to this was station 4 where the total number of animals per unit area showed a decreasing trend throughout the period of investigation. After this period in all these stations a marked decrease in the fauna is noticed during October and December.

Weight

The dry weight of the meiofauna is given in Fig.12 and tables 33 to 42.

Fig. 12. Weight of meiofauna in mg. per 10 cm^2 in stations 1 to 10 during 1966-1967.

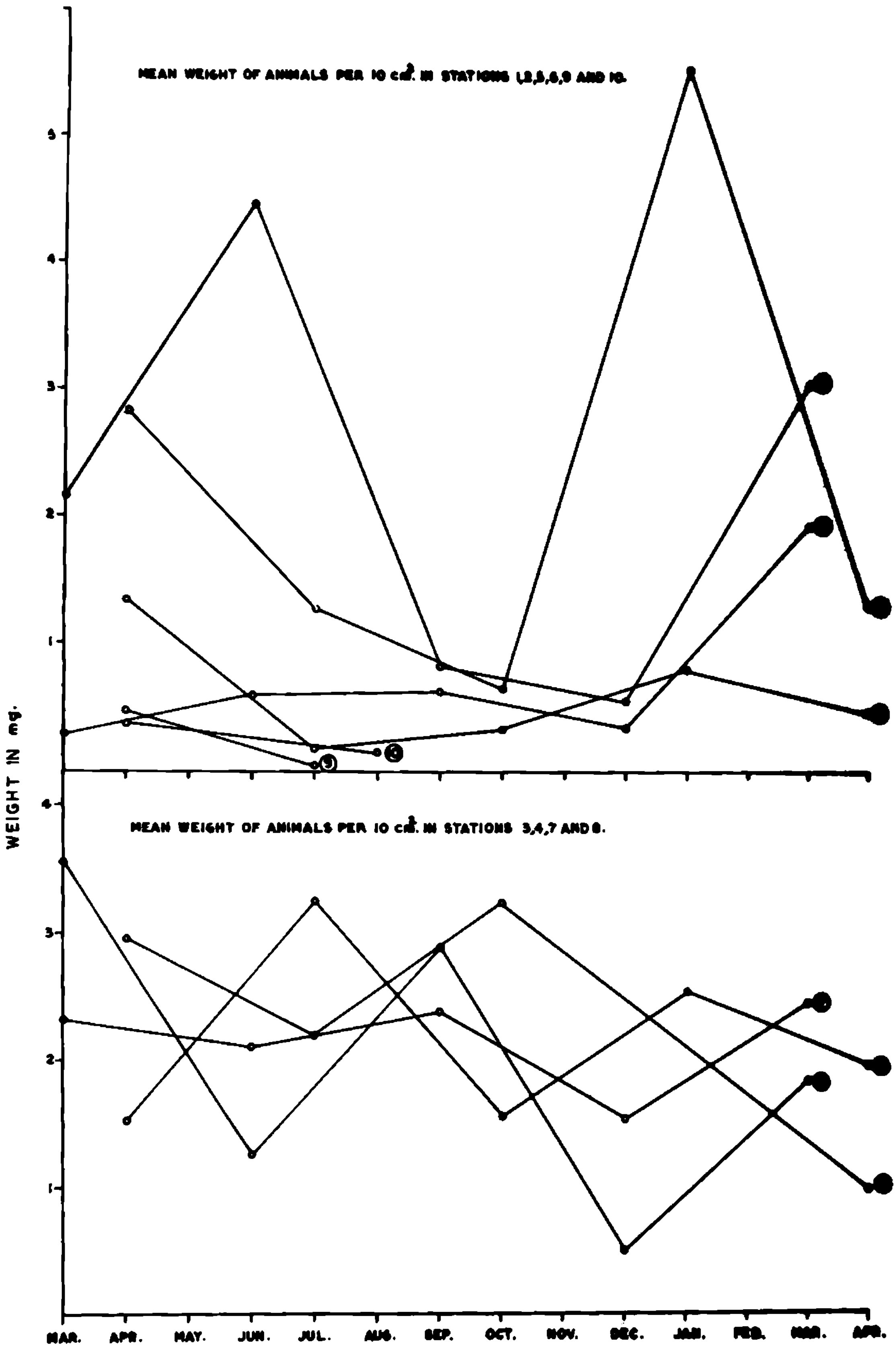

MEAN WEIGHT OF ANIMALS PER 10 cm². IN STATIONS 1,2,5,6,9 AND 10.
MEAN WEIGHT OF ANIMALS PER 10 cm². IN STATIONS 3,4,7 AND 8.
WEIGHT IN mg.
1
2
3
4
5
MAR. APR. MAY. JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APR.

TABLE: 33

Station: 1

Dry weight of meiofauna in mg./10cm^2(in 10 cores)

Date of sampling	19-4-66		29-7-66		20-10-66		30-1-67		24-4-67		Total
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	
Foraminifera	0.3528	0.2901	0.0352	0.0626	0.1490	0.1764	0.8036	0.1882	0.2979	0.2116	2.5674
Turbellaria	0.0624	--	--	--	0.0156	--	--	--	0.0312	0.0468	0.1560
Nematoda	0.1440	0.1163	0.0145	0.0254	0.1215	0.1659	0.3062	0.1250	0.1116	0.0966	1.2270
Polychaeta	0.0798	0.0399	--	0.1596	--	--	--	--	--	--	0.2793
Kinorhyncha	--	--	--	--	0.0130	0.0065	0.0065	--	--	--	0.0260
Ostracoda	0.1555	0.2592	--	--	--	--	--	--	0.0311	--	0.4458
Copepoda	0.1009	0.1218	--	0.0104	0.0104	0.0104	0.0104	0.0104	0.0052	--	0.2799
Other groups	0.4772	0.4916	0.0295	0.0295	--	--	0.0200	0.1218	0.0590	0.0884	1.3170
Total	1.3726	1.3189	0.0792	0.2875	0.3095	0.3592	1.1467	0.4454	0.5360	0.4434	6.2984

TABLE: 34

Station: 2

Dry weight of meiofauna in mg./10cm^2(in 10 cores)

Date of sampling	19-4-66		29-7-66		20-10-66		30-1-67		27-4-67		Total
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	
Foraminifera	1.2583	1.9562	0.8780	0.7252	0.7096	0.1373	3.7005	5.6213	0.3881	0.6625	16.0370
Turbellaria	0.2860	--	--	--	0.0156	--	--	--	--	--	0.3016
Nematoda	0.7119	0.4099	0.2787	0.2374	0.2448	0.1283	0.6782	0.4471	0.3573	0.1909	3.6845
Polychaeta	0.1596	0.0798	0.1732	0.0399	--	--	0.0399	0.0798	--	0.0798	0.6520
Kinorhyncha	0.0186	0.0186	0.0070	0.0035	--	--	--	0.0035	--	--	0.0512
Ostracoda	0.2696	0.1970	--	0.1659	--	0.0311	0.1659	0.1659	0.4563	0.2903	1.7420
Copepoda	0.1896	0.0939	0.0383	0.0226	0.0052	--	0.1566	0.0452	0.0452	0.0887	0.6853
Other groups	0.0010	--	--	--	--	0.0190	0.0190	--	0.0798	0.0295	0.1483
Total	2.8946	2.7554	1.3752	1.1945	0.9752	0.3157	4.7601	6.3628	1.3267	1.3417	23.3019

TABLE: 35

Station: 3

Dry weight of meiofauna in mg./10cm^2 (in 10 cores)

Date of sampling	19-4-66		29-7-66		20-10-66		30-1-66		27-4-66		Total
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	
Foraminifera	1.2426	0.9603	1.8777	1.7836	1.8031	0.4861	1.6347	1.1015	0.6272	1.2544	12.7712
Turbellaria	0.2652	0.0156	--	--	0.0156	--	0.0676	--	--	0.2028	0.5668
Nematoda	0.2259	0.1463	1.3307	0.9691	0.1404	0.3114	0.7633	0.2419	0.2304	0.2314	4.5908
Polychaeta	--	--	0.1729	--	0.0798	0.0399	0.1330	--	--	0.1729	0.5985
Kinorhyncha	0.0070	0.0151	0.0302	0.0035	0.0035	0.0116	0.0035	0.0186	--	0.0151	0.1081
Ostracoda	0.1037	0.0622	0.1037	0.0933	--	0.1659	0.0622	0.1970	0.2592	0.4977	1.5449
Copepoda	0.0052	0.0052	0.0661	0.487	0.0278	0.0226	0.2157	0.1166	0.2105	0.1288	0.8472
Other Groups	--	--	0.0190	--	--	--	0.1277	0.3535	0.0305	0.0589	0.5896
Total	1.8496	1.2047	3.6003	2.8982	2.0702	1.0375	3.0077	2.0291	1.3578	2.5620	21.6171

TABLE: 36

Station: 4

Dry weight of meiofauna in mg./10cm^2(in 10 cores)

Date of sampling	19-4-66		29-7-66		20-10-66		30-1-67		27-4-67		Total
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	
Foraminifera	2.0933	1.6425	0.9643	0.8271	4.5432	0.8545	1.6817	1.5053	0.2352	0.1842	14.5313
Turbellaria	--	0.0676	--	--	--	--	--	--	0.0156	--	0.0832
Nematoda	1.0276	0.2829	0.8173	0.4443	0.2165	0.2515	0.2735	0.2826	0.1593	0.2257	3.9812
Polychaeta	0.3458	0.0399	0.0399	--	0.2527	0.0399	--	--	0.2527	0.3458	1.3167
Kinorhyncha	0.0255	--	0.0302	0.0035	--	0.0151	--	--	0.0070	0.0070	0.0883
Ostracoda	0.1659	0.0622	0.4562	0.4252	0.1037	0.1348	0.1348	0.0622	0.0622	0.1037	1.7109
Copepoda	0.0957	0.0174	0.2175	0.1287	0.0174	0.0052	0.0104	0.0104	0.0452	0.0383	0.5862
Other Groups	--	0.0589	--	--	--	--	0.0590	0.0589	0.0504	0.2284	0.4556
Total	3.7538	2.1714	2.5254	1.8288	5.1335	1.3010	2.1594	1.9194	0.8276	1.1331	22.7534

TABLE: 37

<u>Station: 5</u>

Dry weight of meiofauna in mg./10cm^2 (in 10 cores)

Date of sampling	16-3-66		24-6-66		20-9-66		26-12-66		31-3-67		Total
Depth of core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	
Foraminifera	0.1882	0.1411	0.4508	0.4116	0.6899	0.4273	0.1764	0.1019	1.5955	1.1054	5.2881
Turbellaria	0.1092	0.0312	0.0468	0.0156	--	--	0.1352	0.0988	--	--	0.4368
Nematoda	0.0571	0.0253	0.1275	0.1004	0.0224	0.0310	0.0902	0.1032	0.1560	0.1737	0.8868
Polychaeta	--	--	--	--	--	--	0.1330	--	0.0798	0.0798	0.2926
Kinorhyncha	--	--	0.0070	0.0035	--	0.0035	0.0070	--	0.0406	0.0035	0.0651
Ostracoda	--	--	--	0.0311	--	0.0622	--	--	0.1970	0.3007	0.5910
Copepoda	0.0156	--	0.0052	0.0052	--	0.0052	0.0331	0.0052	0.0383	0.0939	0.2017
Other Groups	--	--	--	--	0.0100	0.0010	--	0.0731	--	0.0504	0.1345
Total	0.3701	0.1976	0.6373	0.5674	0.7223	0.5302	0-5749	0.3822	2.1072	1.8074	7.8966

TABLE: 38

Station: 6

Dry weight of meiofauna in mg./10cm^2 (in 10 cores)

Date of sampling	16-3-66		24-6-66		20-9-66		26-12-66		31-3-67		Total
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	
Foraminifera	0.3764	1.2270	5.7036	0.7880	0.7331	0.3253	0.2901	0.2509	1.2427	2.8381	13.7752
Turbellaria	0.1300	0.0676	0.1976	--	--	0.0156	--	--	0.0156	--	0.4264
Nematoda	0.6389	0.4665	0.5137	0.6601	0.1619	0.2640	0.2750	0.1101	0.2389	0.1669	3.4960
Polychaeta	0.0798	0.0798	--	0.2926	--	0.0798	--	--	0.0399	0.0798	0.6517
Kinorhyncha	--	0.0035	0.0035	0.0035	--	0.0035	--	--	0.0070	0.0070	0.0280
Ostracoda	0.2696	0.2592	0.4666	0.1348	0.0311	0.0311	0.0311	--	0.7985	0.3733	2.3953
Copepoda	0.1270	0.0905	0.0226	0.1827	0.0052	0.0052	0.0331	0.0452	0.2001	0.0887	0.8003
Other Groups	0.2794	0.2032	--	--	0.0010	--	--	0.0696	--	0.0380	0.5912
Total	1.9011	2.3973	6.9076	2.0617	0.9323	0.7245	0.6293	0.4758	2.5427	3.5918	22.1641

TABLE: 39

Station: 7

Dry weight of meiofauna in mg./10cm^2 (in 10 cores)

Date of sampling	16-3-66		24-6-66		20-9-66		26-12-66		31-3-67		
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	Total
Foraminifera	0.4548	0.9800	0.7879	0.2156	0.8780	0.3254	0.6782	0.2391	0.7761	1.2152	6.5503
Turbellaria	0.1508	0.3276	0.0988	--	0.0312	0.0156	--	--	0.0156	0.0156	0.6552
Nematoda	0.3699	0.1957	1.2313	0.6636	1.6025	0.7924	0.7950	0.2437	0.2140	0.2305	6.3386
Polychaeta	0.6783	0.0798	0.1729	0.2128	--	0.1197	0.0399	--	--	0.3458	1.6492
Kinorhyncha	0.0255	0.0302	0.0255	0.0592	0.0220	--	0.0186	--	0.0116	0.0557	0.2483
Ostrecoda	0.5289	0.1037	0.1348	0.3629	0.3629	0.1659	0.1970	0.0311	0.4979	0.8607	3.2457
Copepoda	0.2453	0.1444	0.0452	0.1723	0.2853	0.1496	0.3950	0.1496	0.0331	0.1113	1.7311
Other Groups	0.2246	0.0884	--	0.0295	0.0017	0.0017	0.2160	0.0589	0.2161	0.3038	1.1407
Total	2.6781	1.9498	2.4964	1.7194	3.1836	1.5703	2.3397	0.7224	1.7643	3.1386	21.5591

TABLE: 40

Station 8

Dry weight of meiofauna in mg./10cm^2 (in 10 cores).

Date of sampling	16-3-66		24-6-66		20-9-66		26-12-66		31-3-67		Total
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	
Foraminifera	2.2579	1.0898	0.2156	0.7762	0.8781	1.6464	0.2901	0.1646	0.7880	0.9760	9.0827
Turbellaria	0.2652	0.1976	--	0.0832	--	0.0520	--	--	--	0.0156	0.6136
Nematoda	0.3281	0.2168	0.3746	0.3884	0.5715	0.3765	0.1412	0.2034	0.1666	0.2331	3.0002
Polychaeta	0.0798	0.0798	0.0798	--	--	0.0399	0.0798	--	0.0798	0.0399	0.4788
Kinorhyncha	0.0626	0.441	--	0.0220	0.0186	0.0035	--	--	0.0035	0.0035	0.1578
Ostracoda	2.0843	0.1348	0.2281	0.1970	1.5243	0.5600	--	0.0311	0.0622	0.3318	5.1536
Copepoda	0.1165	0.0661	0.1009	0.0278	0.0435	0.0226	0.0557	0.0174	0.0052	0.0556	0.5113
Other Groups	0.0988	--	--	0.0209	--	0.0209	--	--	0.3143	0.5766	1.0315
Total	5.2932	1.8290	0.9990	1.5155	3.0360	2.7218	0.5668	0.4165	1.4196	2.2321	20.0295

TABLE: 41

Station: 9

Dry weight of meiofauna in mg./10cm^2 (in 6 cores)

Date of sampling	13--4--1966			16--7--1966			
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	0-6	Total
Foraminifera	0.3998	0.1640	0.2901	0.1254	0.0892	--	1.0191
Nematoda	0.1337	0.1874	0.0859	0.0111	0.0136	0.0057	0.4374
Kinorhyncha	--	--	0.0035	--	--	--	0.0035
Ostracoda	0.1037	0.0311	--	--	--	--	0.1348
Copepoda	0.0226	0.0052	--	--	--	--	0.0278
Total	0.6598	0.3883	0.3795	0.1365	0.0528	0.0057	1.6226

TABLE: 42

Station: 10

Dry weight of meiofauna in mg./10cm^2 (in 5 cores)

Date of sampling	4--4--1967			2--8--1972		
Depth of the core in cm.	0-6	0-6	0-6	0-6	0-6	Total
Foraminifera	0.0745	0.1098	0.1137	0.0392	0.2234	0.5606
Nematoda	0.2135	0.2688	0.0082	0.0139	0.0068	0.5111
Ostracoda	--	0.0311	--	--	--	0.0311
Copepoda	--	0.0157	--	--	--	0.0157
Other groups	--	--	--	--	--	0.0660
Total	0.3245	0.4253	0.1219	0.0531	0.2597	1.1845

The dry weight of the fauna from individual samples ranged from 0.0057 to 6.9076 mg./10 cm^2. Foraminifera, second in importance in terms of number, contributed the highest percentage of biomass in all the stations. Their contribution to the total biomass varied from 30.4% at station 7 to 68.81% at station 2. Although numerically abundant the nematodes contributed only 11.21 to 29.41% of the weight. Eventhough station 7 recorded the maximum number of animals, maximum dry weight was recorded from station 2. This was mainly due to the large percentage of foraminifera at this station. If foraminiferan weight is excluded from all the stations then station 7 records the maximum dry weight.

In all the stations within 10 m. there was a decrease in biomass during the period of monsoon. This decrease was very evident in stations 1 and 2 where the sampling had been done in July when the mud bank was active. In station 6 also the dry weight showed a marked decrease between June and September. No appreciable change in weight was noticed in station 5, but if the weight of foraminiferans is excluded this station also shows a decrease in biomass during this period. In stations 9 and 10 also the monsoon figures were poorer than pre-monsoon figures.

Stations outside the 10 m. line did not show any decrease in biomass during the monsoon. But this is followed by a decrease in weight and if foraminiferan weights are eliminated, all these stations recorded their minimum dry weight during October or December

DISCUSSION

Hydrography and bottom fauna

With the onset of S.W. Monsoon the hydrographic conditions of the waters off Cochin are subjected to rapid changes. Dissolved oxygen in the bottom water and sediment temperature decrease, and the former reaches near zero values in July-August. In the deeper stations the magnitude of these changes was high compared with the two shallower stations where the possibility of mixing is high. Of the three hydrographic parameters studied salinity did not appear to be of great significance to the bottom fauna except at stations 1 and 5.

Although the oxygen concentration in the bottom water drops and remains less than 0.5 ml/L. for long periods in all the stations (except stations 1 and 5) and anaerobic conditions are noticed in some stations, the effect of these changes on the macrobenthic infauna does not seem to be very great. There is a decrease in number and biomass in all the stations during S.W. Monsoon. This decrease in station 1 and 5 starts much earlier than the establishment of poorly oxygenated conditions and cannot be attributed to it. But in all the other stations where a decrease in the bottom fauna is noticed after July-August the poorly oxygenated condition of the bottom water during these months could be a major factor responsible. Although this decrease is noticeable, none of the species present in the area was completely eliminated. Adult specimens of most species were collected either during or after this period of very low oxygen values indicating their ability to survive anoxic periods. As pointed out by Hayes (1964) the ability to withstand anaerobic condition is of particular advantage to deep water and mud dwelling species where the oxygen tension of the environment may fall low for much of the time. Investigations on three species of _Nucula_ indicate that they can stand long periods of anaerobic conditions. Moore (1931) had shown that _N. tenuis_ can remain alive and active during 5 to 17 days of anaerobiosis. Trevallion (1965) studied the anaerobic respiration of _N. sulcata_ and _N. turgida_ and found that these species can stand 14 days of complete anerobiosis. It is likely that the species of this genus are highly adapted to withstand anaerobic conditions, and this may explain the settlement and survival of _Nucula_ sp. observed during the present study. The ability to stand anaerobic condition was also shown by number of other species of molluscs (Collip 1920, 1921, Mitchell 1912, Moore 1931). Karandeeva, (1959) investigated the anaerobic metabolism of _Modiola phaseolina_ and found that survival under anaerobic conditions varied inversely with the length of anaerobiosis and temperature. It was also observed that animals adapted better to gradually decreasing oxygen tension, than to a sudden drop.

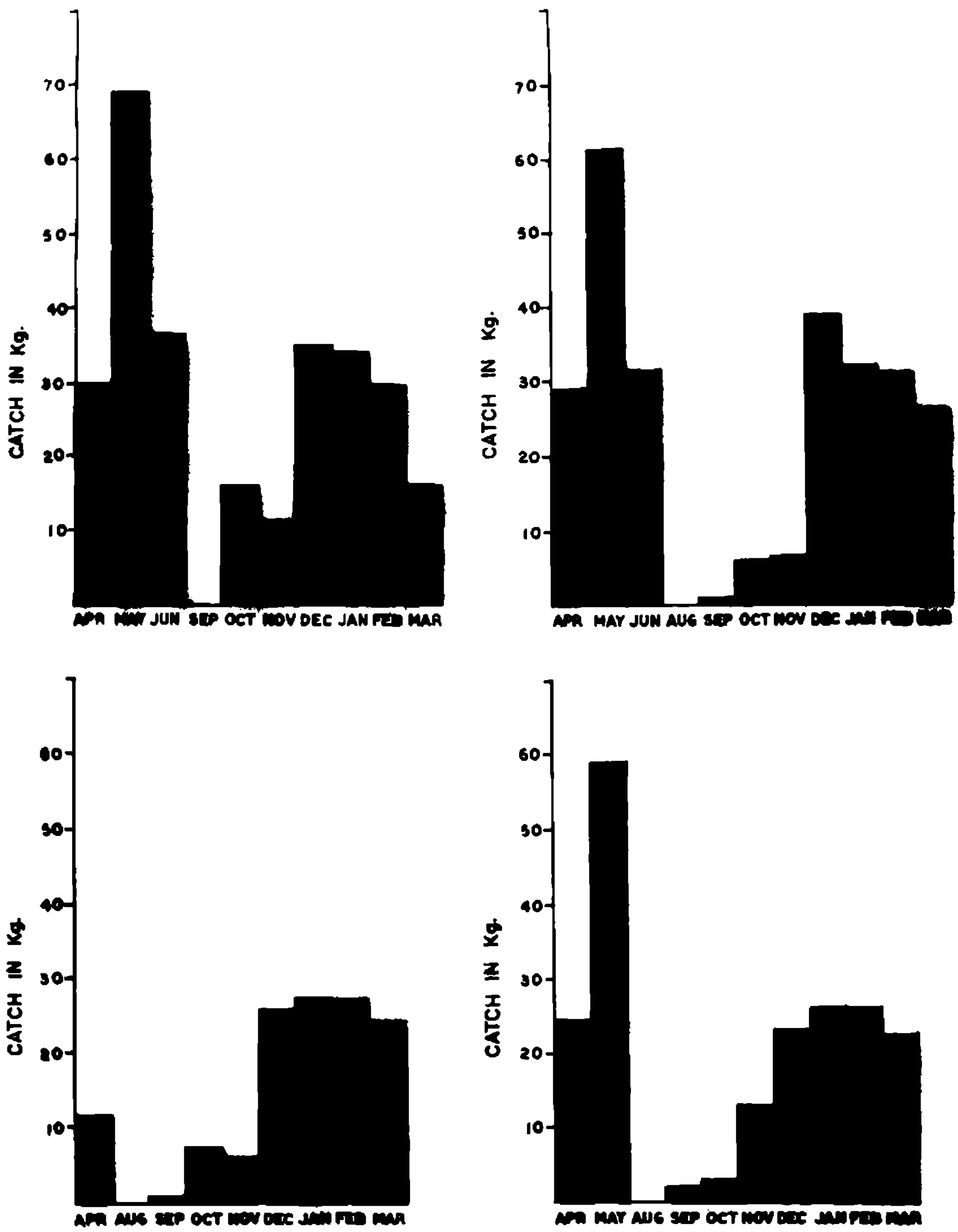
Many species of polychaetes were also found to withstand periods of anaerobic conditions for varying periods (Hecht 1932, Von Brant 1927, Jacubowa and Malm 1931, Packard 1905). Dales, (1958) working on the survival of anaerobic periods of *Arenicola marina* and *Owenia fusiformis* suggested that these species survive anaerobic conditions by suspending their normal activity. He did not find any utilization of glycogen in *O. fusiformis* during the period of anaerobiosis. Both Dales, (1958) and Trevallion, (1965) did not find any post anaerobic increase in oxygen consumption in the species they investigated. Observation of Dales on *A. marina* showed that there is no accumulation of lactate and pyruvate during the period of anaerobiosis, and suggested that glycogen breakdown leads to other acids. Von Brand *et. al.* (1950) and Mehlman and Von Brand (1951) found that resistance of certain planorbid snails to anoxia is associated with acetic acid as the main end product which rapidly diffuses out into the medium. The elimination of accumulation of toxic glycolytic end products may held the animal to maintain itself under anaerobic conditions as long as a steady supply of carbohydrate is available. Thus the benthic infauna off Cochin may be overcoming the periods of poor oxygen in the ambient medium by suspending their normal activity as suggested by Dales (1958), or by regulating the oxygen consumption so as to maintain a constant rate over a considerable range of oxygen levels or by regulating the total energy output by the compensating onset of an aerobic glycolysis disconnected from the aerobic cycle and by the disposal of its end products (Beadle 1961).

It is an acknowledged fact that tissues and whole animals survive a given low oxygen level better at low temperature. Lindeman (1942) recorded the survival of animals living anaerobically in or close to the bottom of a lake under winter ice. His experiments with several of these species had shown that a number of them could live anaerobically for a very long time at $0^{o}C$, though for a much shorter time at higher temperature. This evidently indicates the ecological significance of low temperature in the ambient medium of the infauna off Cochin when the dissolved oxygen in the bottom water is very low.

The decrease in oxygen tension and temperature of the bottom water did not appear to effect adversely the meiofauna population. Nematodes showed an increase in number in stations 7 and 8 between June and September suggesting that they are not adversely affected by the deteriorated oxygen concentration during July and August. Even active animals like copepods and ostracods showed tolerance to this low oxygen values.

The epifauna of the region avoid this unfavourable condition by moving away from the regions of low oxygen concentration. Banse (1959) had indicated that off Cochin de-oxygenation of near-bottom water results in the regular disappearance of demersal fishes and in unprofitable trawling. The most important epibenthic organisms in the region are penaeid prawns, belonging to the genus Penaeus, Metapenaeus and Parapenaeopsis. Six species belonging to these three genera constitute one of the most important fisheries of Cochin. The dredge and beam trawl hauls taken during S.W. Monsoon showed the absence of these prawns on these grounds. A clear picture of this situation can be seen in Fig. 13, which shows the catch per unit effort, during different months, by four boats belonging to the Indo-Norwegian Project, during 1967-1968. All these four boats operated off Cochin at a depth between 15 and 30 m. It can be seen that after June the trawling for prawns is highly unprofitable. This period of low or nil catch corresponds with the period of low oxygen in the bottom water. Another feature that is obvious from Fig.13 is the exceptionally good catch during May by all the three boats operating during this month, indicating the presence of a large population of prawns on the grounds. Banse (1968) suspects the possibility of fishes crowding inshore when the condition in the outer and middle shelf deteriorates. During 1967, by May the bottom water off Cochin showed a marked decline in oxygen concentration indicating upwelling. The oxygen concentration at 14 and 21 m. depth during this period was below 2 ml/L., and the concentration in the outer and middle shelf region would have been considerably lower. In this case the increased catch during May could have been due to

Fig. 13. Prawn catch per unit (hour) effort by four boats operated off Cochin at 15 fathom line during 1967-1968.


CATCH IN Kg.
70
60
50
40
30
20
10
APR JUN SEP OCT NOV DEC JAN FEB MAR
CATCH IN Kg.
70
60
50
40
30
20
10
APR MAY JUN AUG SEP OCT NOV
CATCH IN Kg.
60
50
40
30
20
10
APR AUG SEP OCT MAR
CATCH IN Kg.
60
50
40
30
20
10
APR MAY AUG SEP OCT DEC

crowding of prawns in the upper shelf region due to the deteriorated oxygen condition in the middle and lower shelf region. If we make the above assumption this will explain the reason for the large prawn fishery of the certain mud bank regions.

Among the three permanent mud banks the Alleppy mud bank supports a large prawn fishery during the S.W. Monsoon compared to that of Narakal and Calicut. All these prawns are caught by dug out canoes at a shallow depth within 10 m. If we consider that upwelling water, due to its low oxygen content, is likely to push the prawn shoals towards the shore as it creeps up along the shelf, the observations at Cochin show that it is only in the very shallow regions that these animals are likely to find the oxygen concentration needed to maintain life. The shallower regions along the coast are highly agitated during this period due to monsoon swells, but the mud bank regions remain calm during this period. Thus the prawn shoals may be aggregating in a region where there is enough oxygen supply and less agitation. If this is accepted then the remaining question is the scarcity of prawns in all the other mud banks compared to the Alleppy mud bank. As already stated in an earlier chapter all the mud banks other than the one at Alleppy are located close to the fresh water outlets to the sea, whereas no river outlet is close to the Alleppy mud bank region. The fresh water discharge is likely to dilute the surface water considerably in the other mud bank regions. This may bring about the dilution of bottom water in the shallow regions as observed off Cochin. Therefore, even if comparitively oxygenated calm water is available in all the other regions, prawns are likely to avoid them due to the unfavourable salinity conditions.

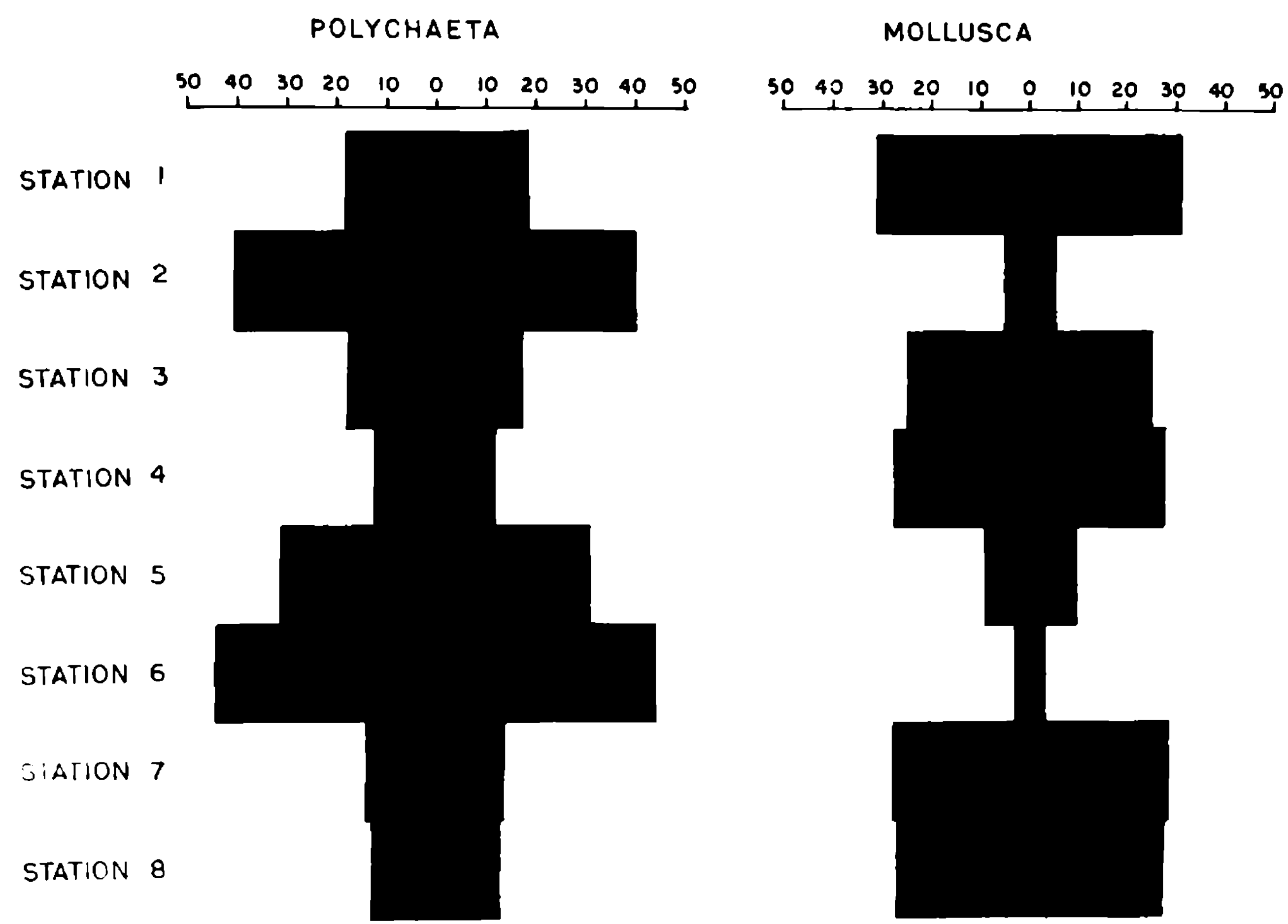
Substrate and bottom fauna

The investigations of Brett (1963), McNulty *et. al.* (1962) and Sanders (1956, 1958), showed a close relationship between the feeding habits of infauna and gross organic content and ~~mechanical~~ texture of the sediment. Sanders studies in Long Island Sound and Buzzards Bay have shown that small deposit feeders dominated numerically in mud. Although nothing can be said in definite terms about the feeding habits of all the species collected in the present study, there were very few known filter feeders or carnivores. If an assumption is made from the morphological features of the species, 90 to 95% of the fauna in all the stations, except in station 1, was composed of deposit or detritus feeders. In station 1, the one sample which brought up a large number of *Barnaea* sp., increased the percentage of filter feeders. It will be worthwhile to investigate the adaptations of this species to stand the highly turbid conditions prevailing during the active periods of the mud bank.

As far as the organic matter is concerned the area is rich. How much of this organic matter is readily utilizable by the bottom fauna is not known. Bader (1954) found that, up to a concentration of 3% organic matter in the sediment, infaunal bivalves increased in density, but beyond this level products of bacterial decomposition and decline in available oxygen became limiting and population density declined.

As preliminary sampling of the area showed little variation in the nature of the sediment, no detailed study of substrate preference by different species was undertaken. The distribution of polychaetes and molluscs in general showed that polychaetes prefer the region within the 10 m. line and molluscs outside the 10 m. line. Fig. 14 shows the percentage of molluscs and polychaetes in the total fauna (excluding *Nucula* sp.) from each station. This indicates a higher percentage of polychaetes in stations with a higher percentage of sand. The complete absence of *Euclimene insecta* and *E. watsoni* in station 6, where the percentage of sand is more or less similar to that in Station 2, suggests that too much weight should not be given to this correlation. Size of particles, the structure and contour of the surface of the substratum, the colour, luminosity and light refractive properties, presence of compounds of inorganic and organic nature, the presence of bacterio-algal film and the presence of colonies of their own species were all found to influence the settlement

Fig. 14. Percentage of total polychaetes and molluscs (excluding *Nucula* Sp.,) in stations 1 to 8.


POLYCHAETA
MOLLUSCA
50 40 30 20 10 0 10 20 30 40 50
50 40 30 20 10 0 10 20 30 40 50
STATION 1
STATION 2
STATION 3
STATION 4
STATION 5
STATION 6
STATION 7
STATION 8

and metamorphosis of pelagic larvae of benthic invertebrates (Kiseleva 1967). Under natural conditions it is difficult to assess the effect of any one of these factors in isolation. It is possible that the whole complex effects and controls the settlement of larvae and the completion of their metamorphosis on a favourable substratum.

Wilson (1952) observed that polychaete larvae when ready to settle will critically examine the substratum and postpone metamorphosis until they find one suitable for adult life. Wilson (1953 a, b, 1954) also observed that larvae which had already postponed their metamorphosis in their search for suitable substratum were less critical towards the substratum than younger ones. Accepting this observation Thorson (1966) suggested that in nature large number of larvae will eventually settle on a substratum which is not attractive to them. The species of Nucula are generally soft bottom dwellers and the apparent nature of the substratum may suggest that it is a favourable one. The complete failure of this species to survive in the area suggests that there is some factor (or factors) other than the apparent nature of the substratum that control the survival of this species. Heavy spatfall and the complete elimination of them from an area within a short period was also noticed by Muus (1966) who stated "that vast numbers of planktonic larvae will settle on a substratum where they do not belong".

As far as the meiofauna are concerned stations 3 and

7 were the richest in terms of number. Finer sediments appeared to harbour a greater number of meiofauna, especially nematodes. Wieser (1960) has suggested that nematodes are favoured in soft substratum because of their pump like feeding apparatus. In the present study the most numerous species in stations 1 to 8 was Metachromadora (Bradylaimoides) benipappilata, and from the nature of the buccal cavity this species appeared to be a carnivore. Muus (1967) attributed the relatively stable number of nematodes to the differential effect of predators on the surface dwelling and burrowing meiofauna.

Regarding other groups, foraminiferans were numerically high in station 2 and this group appeared to prefer slight admixture of sand in the substratum. Smidt (1951) and Tietjan (1966) observed that copepods prefer a coarse substratum over to a fine one. In the estuaries studied by Muus (1967) organic matter appeared to control the abundance of harpacticoids. Off Cochin maximum number of copepods were collected from a station with finer sediment (Station 7), and higher percentage of organic matter.

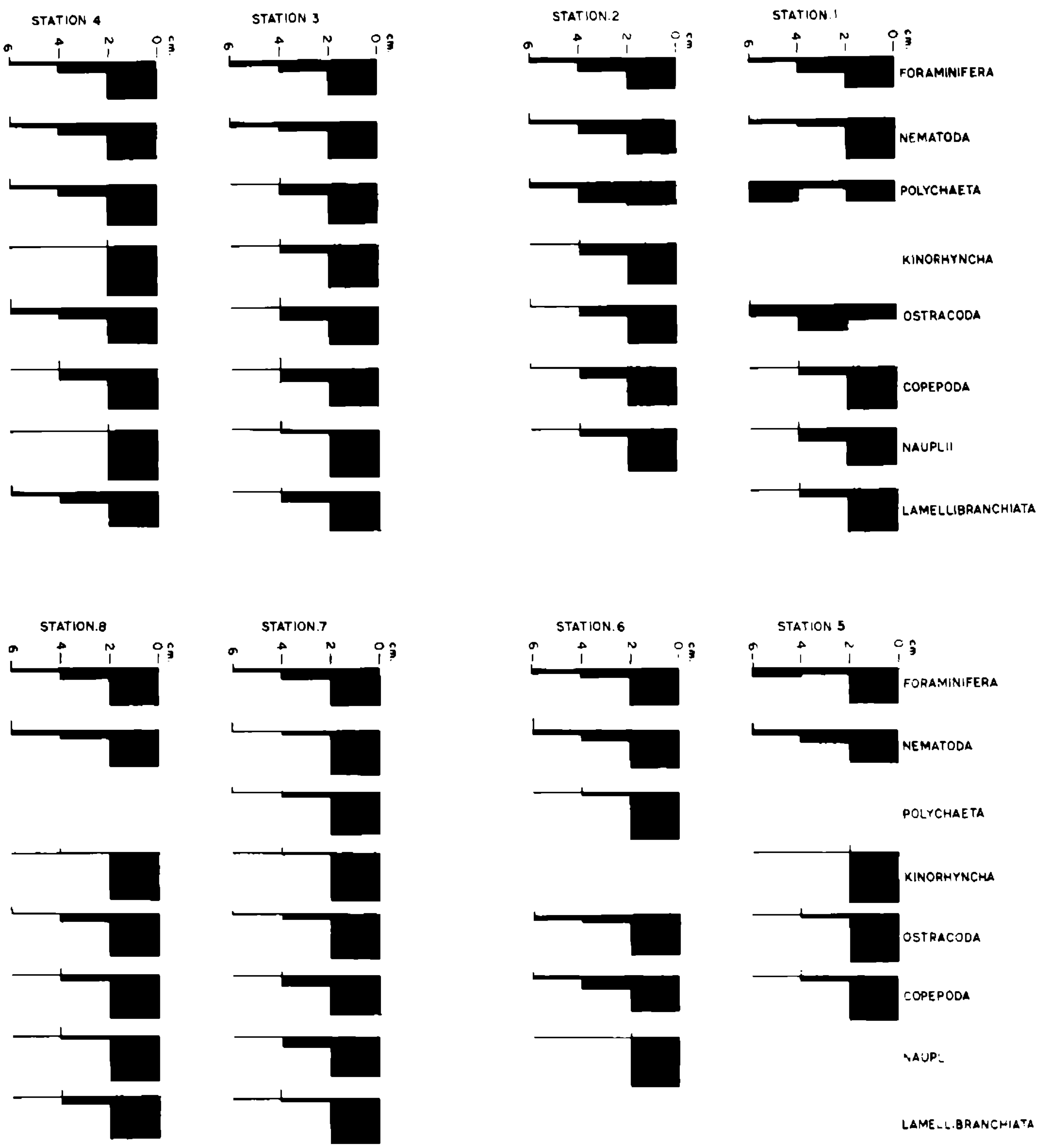
Vertical distribution of meiofauna

Altogether 68 core samples were taken to study the vertical distribution of the fauna. One possible error in the technique employed is that the animals caught at the periphery of the cores are likely to remain in situ when the core is pushed from below and may get entrapped in a deeper layer to which they do not belong. The magnitude of this error is not likely to be great as the total length of the core tube was only 10 cm.

The vertical distribution of some of the important groups in different stations are given in Fig. 15. It can be seen that most of the organisms are confined to the upper 4 cm. depth of the core. In eight stations where the vertical distribution was studied, between 66.5 and 88.5% of the total fauna was collected from surface 2 cm. Between 8.1 and 25.0% of the fauna was sampled from 2 to 4 cm. and only 3.4 and 12.3% from 4 to 6 cm.

In the present study two groups of animals were regularly found in the entire length of the core, and one of these, the nematodes, was always present in the deepest section of the core. The percentage of total nematodes collected from the top 2 cm. of different stations was 65.7 to 89.5%. The corresponding values for 2 to 4 and 4 to 6 cm. was 6.9 to 24.9% and 3.3 to 11.3%. Previous investigations on the vertical distribution of meiobenthos have shown that majority of the meiobenthic organisms are restricted in their distribution to the upper 1 to 2 cm, and only nematodes were found to penetrate to deeper layers (Bougis 1946, Mare 1942 and Moore 1931). Moore (1931) and McIntyre (1961) noticed a slightly deeper penetration of meiobenthos with an increase in depth.

Fig. 15. Vertical distribution of some of the important meiofaunal groups in stations 1 to 8.


STATION 4
STATION 3
STATION.2
STATION.1
6
4
2
0
cm
FORAMINIFERA
NEMATODA
POLYCHAETA
KINORHYNCHA
OSTRACODA
COPEPODA
NAUPLII
LAMELLIBRANCHIATA
STATION.8
STATION.7
STATION.6
STATION 5

The other group consistently found in the deeper layers are foraminiferans. Here too the bulk of the fauna was found in the top 2 cm. A marked oxygen gradient and a decrease in Eh with increase in depth of the sediment was noticed by Finchel and Jansson (1966). Therefore the presence of nematodes and foraminiferans regularly in the deeper layers of the sediment indicates the capacity of these groups to stand anoxic conditions. Nematodes have been found capable of standing anaerobic conditions for prolonged periods (Moore 1931, Wieser 1960, Wieser and Kanwisher 1961) and this may explain the regular occurrence of this group in deeper layers. The needle shaped body of this group of animals may be an advantage in this process.

The presence of foraminiferans in the deeper layers of sediment is not likely due to their own activity. This suggests the possibility that the sediments are reworked by some agency, trapping the animals in the deeper layers. So far foraminiferans are not reported in areas of near anoxic conditions. Their regular occurrence in the deeper layers of sediment tends to think that they are capable of surviving in such adverse conditions. However, this can be stated only with caution. The rose bengal stain imparts colour to all protoplasmic materials. Since the foraminiferan shells with secondary occupants also takes the stain, it is not possible to say, without further verification, that the foraminiferans in the deeper layers of sediment were alive at the time of sampling.

For all the other groups the top 4 cm. recorded the bulk of the fauna. Only ostracods and polychaetes were found in the deepest section of the core in significant numbers. Meiobenthic copepods are not very much specialised in their general structure. This and their limited ability to stand anoxic conditions (Moore 1931) may be limiting their movement to deeper layers of the sediment.

When the percentage of total fauna collected from different depths of the cores was taken from each station, the stations with a higher percentage of sand had shown a higher percentage of fauna in the deeper layers. Thus station 2 recorded 25.8% of its total fauna from 2 to 4 cm. depth, whereas in station 7 it was only 8.1%. The packing of the sediment was found to influence the vertical distribution of the meiofauna (Teal and Wieser 1966). It is possible that the greater admixture of sand in these sediments may make them less compact which is helpful for the migration of the animals to deeper regions. Thus as McIntyre, 1969 states "reduction of interstitial space and reduction of oxygen due to restricted water flow, as well as the concentration of food materials at the deposit surface" may be the main reasons for the concentration of the bulk of the fauna in the surface few cm.

Seasonal variation

seasonal variation in the number of macrofauna was noticed in stations 1 and 5 (Fig. 10 and tables 7 and 11). fairly rich fauna present in Station 1 during the beginning of 1966 completely disappeared after the mud bank formation. Again a slight increase in the number and bio-mass of the macrofauna noticed in the 1967 pre-monsoon period disappeared during the subsequent mud bank formation. The number of macrofauna in stations 5 was very poor during the entire period of 1966, but the pattern of distribution in 1967 was similar to that in station 1. Eventhough there was a general decrease in the number of macrofauna during the S.W. Monsoon in all the eight stations studied it was most evident at stations 1 and 5. Seshappa (1953) working off Calicut reported a "severe decline" in the shallow water macrobenthos during S.W. Monsoon. He also reported about the subsequent recolonisation during the post monsoon periods which was rather "slow and unsteady". Seshappa had attributed this decrease as due to the lowering of salinity in the inshore region during the active periods of S. W. Monsoon. Off Cochin the salinity of the bottom water re-corded low values at 4 m. depth during the active periods of the S.W. Monsoon. Added to this sudden change the appea-rance of "liquid mud" in stations 1 and 5 either burried the animals (if the mud was being transported to this region from some other place) or threw them out of their habitat (if the mud from the same region was disturbed). Thus the decrease in salinity and the loose nature of the sediment together might have contributed for the diminution of the fauna in the very shallow sub-tidal region off Cochin. The recolonisation of macrofauna in stations 1 and 5 was more or less similar to the pattern observed by Seshappa off Calicut.

It appears that meiobenthos was also subjected to the same fate of their larger counterparts, (Fig. 11) but their recolonisation seems to be rather quick, as fairly high values were obtained during December-January. The mean value of 813 animals/10cm^2. during April in Station 1 came down to 124/10cm^2. during July and recovered to 500/10cm^2. in October. Data are not available from stations 5 for July-August, but 257/10cm^2. in September (excluding nauplii) is clearly lower than 609/10cm^2. in June and 490/10cm^2. in December. The data from station 9 and 10 are for the premonsoon and monsoon periods and they show a monsoon decrease in the fauna in these stations. The mean values 660 and 1013/10cm^2. during April in both these stations came down to 67 and 82/10cm^2. respectively during the monsoon period. Eventhough a monsoon decrease of meiofauna was noticed in all the stations, a fairly high value in October from station 1 and moderately good numbers from station 5 during September indicate a quick recolonisation. A more detailed study at short intervals of sampling may be able to bring about the picture of recolonisation of meiobenthos in the shallow sub-tidal region along the Kerala coast.

Another interesting aspect noticed in the case of meiofauna was an increase in their numbers during July-September months in stations 3 and 7 and to some extent in station 8 (Fig. 11). In station 4 the number of meiofauna showed a continuous decrease during the entire period of study. The increase observed in the three stations mentioned above is mainly due to an increase in the number of nematodes in the samples. It is interesting to note that the increase in the number of meiofauna coincides with a decrease in oxygen content and a decrease in epibenthic organisms in these stations. The substratum in these stations was relatively stable during the period and the main adverse condition was the low oxygen concentration in the ambient water. It is possible that many of the meiobenthic forms especially nematodes which are capable of withstanding near anaerobic or anaerobic conditions increase their number when the predation upon them is less. The short generation period of at least some species of nematodes (Muus 1967) is in support of this argument. But this point can be stressed only after a detailed analysis of the species composition of nematodes and other groups of meiobenthos present in the different samples taken during the entire period of study.

Trophic relationships

The inshore region off Cochin does not support a rich fishery for bottom fishes, but it does maintain a rich prawn fishery between November and May. The feeding behaviour of demersal fishes and their dependence on the bottom fauna of the region is little known. It is possible that juvenile *Nucula*, prior to shell hardening may form an important food for fishes and prawns. Apart from this it is possible that because of their very hard shells the majority of benthic molluscs are not fed upon by these predators. This applies to most of the important species such as *A. inequvalvis*, *N. ischnis*, *S. biangulosa*, *T. attenuata* etc. Therefore, polychaetes are the only large group which are likely to make any important contribution to the fish food potential of the area. Seshappa (1953) working off Calicut correlated the *Prionospio pinnata* settlement and the subsequent abundance of food to the inshore migration of *Cynoglossus semifasciatus* Day. The settlement of *P. pinnata*, off Cochin during both the years of observation was comparatively insignificant to that off Calicut.

The average standing crop of the macrobenthos of the area is 2.12 g/m^2, This includes the weight of *Nucula* sp. (The mean weight of *Nucula* sp. in the area is about 0.80 g/m^2., which includes the shell weight) also. Even if we consider the weight of *Nucula* sp., with the weight of the permanent component of the macrofauna of the region, the amount of standing crop is very low. Most species of the macrobenthos of the region live for a period of one year and if we accept Sanders' (1956) suggestion of a production of about twice the standing crop for these animals we get an annual production of 4.24 g dry weight/$m.^2$/year.

Regarding meiofauna the mean standing crop of the area is 1.82 g/m.^{2}. This includes the weight of Foraminifera (mainly arenacious) and temporary meiofauna. If we exclude these two groups the average standing crop of the permanent meiofauna of the area will be 0.686 g/m^2. Muus (1967) found that most of the harpacticoids and nematodes produce 5-15 generations (this could be more in the tropical region) per year. McIntyre (1964) considering the short generation time of most of the meiobenthic groups suggested a factor of ten to calculate the production from the standing crop. If this factor is applied to the present study the average annual production of the meiofauna will be about 6.86 g. dry weight/m^2./year, for the inshore areas off Cochin.

Neyman (1969) while studying the distribution of bottom fauna in the west Indian Ocean shelf found a direct correlation in the distribution of benthos to the phosphates in the surface layers. No such correlation was apparent in the present study. Phosphate values from the region suggest that enough of this nutrient is available for phytoplankton production during most of the year. Thus it is likely that phosphate is not acting in any significant way as a limiting factor in the phytoplankton production and thus may not have any direct influence on the bottom fauna.

Shah (personal communication) using C_{14} technique estimated a production of 600 to 900 mg. C/m^2./day off

Cochin, during the period from December to April 1965, with a maximum in May of about 2000 mg. C/m^2./day. The period from December to April does not include the period of phytoplankton bloom off Cochin. Thus if we take the former figures which does not include the period of peak production we get an estimate of 219 to 328 g C/m^2./year.

If the total annual production of bottom fauna is 11.1 g. dry weight/m^2./year or 5.55 g C/m^2./year an ecological efficiency of 10% (Slobodkin 1962) would call for a demand of about 55.5 g C/m^2./year for this production. Considering the relative shallowness of the area a good proportion of the surface water production is likely to be available for the bottom fauna. To this should be added the bacterial production on the bottom. This picture indicates an adequate supply of carbon for benthic production.

The available information suggests that at least some of the meiofaunal groups are actively fed upon by predators like fishes and prawns. As far as Cochin is concerned it is possible that a part of the meiofaunal production is utilized by non selective deposit feeders (Thorson 1966), but the bulk of it should be available for bottom feeding fishes and crustaceans. The little information we have suggests that harpacticoids and ostracods are consumed to a great degree by these predators (Darnell 1961, Muus 1967). Gerlach and Schrage (1969) showed, experimentally that Crangon crangon can survive for long periods feeding only on nematodes.

They could not find any growth in the shrimps during the period of study and attributed it to limited food supply. The observation on the gut contents, and the efficiency shown by the experimental animals in hunting nematodes in the interspacial system of the sand suggest that free living nematodes are a regular component of the food of these shrimps.

As far as the present observations are concerned all the above informations suggests the importance of meiofauna. For most of the predators it may be expedient to feed upon the macrofauna. The limited biomass of the utilizable macrofauna suggests that off Cochin meiofauna may be playing an important role as food for commercially important prawns.

SUMMARY

An investigation on the meiobenthos and macrobenthos of a mud bank on the South West Coast of India was carried out during 1966-1968, based on collections of bottom deposits, bottom fauna and hydrographical data from 8 stations in two profiles off Narakal. Meiobenthos samples taken from two other mud bank regions (Alleppy and Calicut) were also utilized for comparative study.

The formation of the mud bank at definite localities along the South West Coast of India is a strange phenomenon for the region and an attempt has been made to bring together all the informations available and discuss the different aspects of the problem.

A study of the hydrographical conditions of the region showed that there was marked seasonal variation in the temperature and dissolved oxygen at the bottom, the minimum being observed during the South West Monsoon. (Temperature 4 m: 30.8°C. to 24.75°C.; 21 m: 28.8°C. to 22.0°C; Dissolved oxygen 4 m: 5.85 to 1.02 ml/L.; 21 m.: 4.23 to 0.15 ml/L.)

Annual variation of bottom salinity was not considerable except at near shore stations (4 m.) where it recorded values as low as 20.7 $^{o}/_{oo}$ during South West Monsoon.

A study of the inorganic phosphorus in the bottom water at the stations showed that the high values (5.39 to 8.02 μg.

at./L.) occured during July and August and the low values (0.07 to 0.14 /ug. at./L.) between October and January. The intensity of total phosphorus followed the same trend as in inorganic phosphorus but high values were observed during February and March.

Bottom sediment in the region was mostly silty clay. Within the 10 m. line the sediment showed seasonal variation in their sand, silt, clay percentage, the clay fraction being more prominent at 4 m. depth during the active period of the mud bank, while at 8 m. depth there was a decrease in the finer fraction of the sediment during the above period. The sediment between 10 m. and 21 m. depth was relatively stable throughout the year.

The organic matter in the sediment varied from 1.97% to 3.57%, the maximum being in the stations with high percentage of clay.

Macrofauna was constituted mainly by deposit and detritus feeders. Polychaetes and molluscs formed the bulk of the fauna in all the stations (about 90 to 95%). Polychaetes were more numerous within the 10 m. line and molluscs in the deeper stations. Heavy spat fall of <u>Nucula</u> sp. was observed in the region during March to October but they failed to survive.

Meiofauna consisted mainly of nematodes, foraminiferans Harpacticoid copepods and ostracods. Maximum number of meiofauna was noticed in fine sediment.

Studies on the vertical distribution showed that about 66.5% to 88.5% of the meiofauna occured in the first 2 cm. of the deposit.

It is suggested that very low oxygen content of the bottom for long periods might be one of the factors that limit the abundance of the macrofauna (infauna) in the region. However no mass mortality of infauna has been noticed during the periods of low oxygen concentration, which might be due to the capability of some of these organisms to survive such adverse conditions. The epifauna of the region appears to migrate to shallower regions during this period.

The upwelling and resulting low oxygen concentration in the bottom water in the deep shelf region of the S.W. Coast of India is suggested as one of the reasons for the crowding of prawns in the inshore regions before the beginning of the S.W. Monsoon. With the onset of the Monsoon the low oxygen water creeps into the inshore regions also, resulting in the movement of the prawns further inshore to the very shallow regions where oxygen concentration is comparatively high. This may be an explanation for the large prawn fishery in certain mud bank regions during the S. W. Monsoon.

Meiofauna and Macrofauna (infauna) showed a decrease in intensity in the 4 m. depth, which might be due to the unconsolidated nature of the sediment. An increase in the meiofauna was observed outside 10 m. depth during the S.W. Monsoon where the deposit is more stable and predators are less during the period.

Biomass of the macrofauna suggest that they make only a small contribution towards the food of bottom feeding fishes and other forms. High values of meiobenthic biomass show that meiofauna may be important as the food of bottom feeding forms especially for prawns which form an important fishery in the S.W. Coast of India.

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