Special Lecture

ECOLOGY OF BENTHOS IN A TROPICAL ESTUARY

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Studies on the benthos of the Cochin backwaters—a typical, tropical, positive estuary—are based on seasonal collections from 30 stations in 10 profiles during 1966–1968.

The hydrographical features play an important part in the sedimentation and distribution of fauna at the different stations.

Salinity and grade composition of the sediment have the maximum influence on the distribution and abundance of fauna ; fine sand with silt harbours the maximum number of macrofauna.

The polychaetes are present in large numbers at all the stations and during all the seasons in spite of the wide changes in salinity.

The meiofauna are more numerous in the finer sediments and their abundance is not affected by the tidal changes.

The benthic biomass is high near the barmouth, mostly constituted by bivalves and polychaetes.

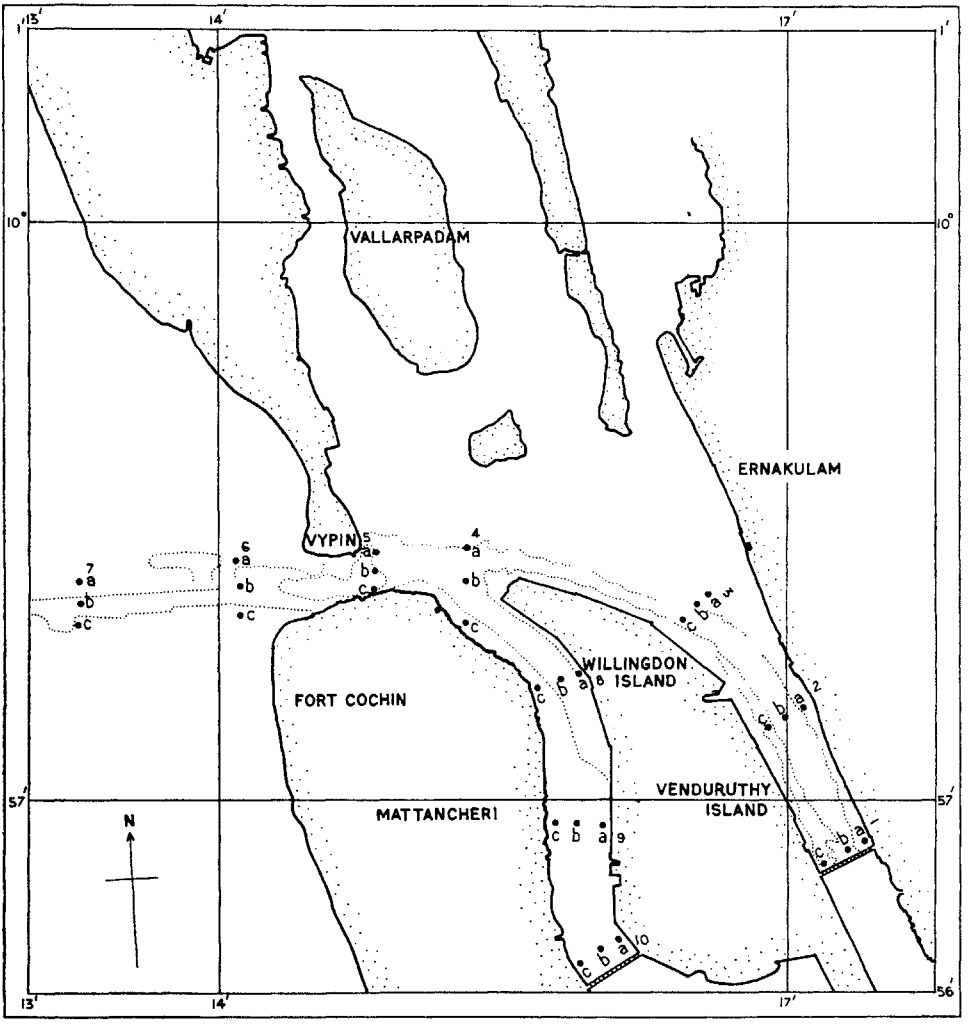
INTRODUCTION

The term 'Estuary' has been applied primarily to the lower tidal reaches of a river. According to Pritchard (1967), "an estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea-water is measurably diluted with fresh water derived from land drainage". When the inflow of fresh water in a separated basin develops a stable body of brackish water, it may be considered as a lagoon. If the mixing of fresh and marine waters is not stable, but shows periodic changes, the basin may be termed as an estuary. Estuaries are of importance as they play a prominent part in the transportation, production of food and waste disposal. Owing to high biological productivity, important fisheries may exist in estuaries and inshore waters. Detailed knowledge about the circulation and sedimentation in estuaries is essential for the maintenance of harbours and also for improving fisheries potential.

The distribution of animals in estuaries is based on a complex of periodically changing parameters that limit colonization to a restricted number of organisms, with a wide range of ecological adaptations. Whereas the plankton community moves with the water masses, benthos is subjected to variations in hydrographical features. The bottom communities in the estuary must survive extreme hydrographical changes, sometimes in a period of one tide.

The main physical problems to be investigated in an estuary are the water movements, the mixing processes and the distribution of salinity which results from their combined action. The distribution of temperature is of secondary importance in an estuary, especially in the tropics. The estuarine environment also depends upon the morphometric features, the degree of enclosure and the shape of the basin which affect the circulation.

Both the coasts of India abound in estuaries of various diamensions. Those on the west coast are comparatively small and here I am dealing with an estuary on the west coast. The 'Vembanad Lake' is a typical 'positive estuary' situated very near and parallel to the west coast of India between latitudes 9° 30′ and 9° 58′ (*see* Map). It covers an area of *ca.* 500 sq. km and opens into the sea at Cochin through a barmouth *ca.* 450 m wide. Three major rivers empty into the lake and as a result during the monsoon floods, fresh water bathes the whole area. But during the summer months water of low salinity occurs even at the head of the estuary 50 km away from the barmouth. The lake is comparatively shallow having an average depth of 2–3 m. But there are a few places with 6 to 9 m depth and in the centre of the barmouth 16 m depth has been recorded. The greatest width



Map of Cochin port showing the 30 stations investigated.

of the lake is only 16 km. Much silting occurs during the monsoon and the shipping channels in the harbour area are kept at 11 m depth by constant dredging. The lake is known for its prawn fisheries and high productivity (Quasim and Reddy 1969). A detailed study of the benthos and hydrography of the lake has been undertaken by working at 154 stations distributed in the lake. The observations given here are mainly based on the investigation of benthos, bottom deposits and hydrographical features carried out at 30 stations in the 'lower reachers' and 'mouth' of the estuary (Cochin harbour area) during 1966-1968.

Methods

There are different methods for the collection of benthos, and paper by Holmes (1964) reviews the efficiency of various instruments used. No single instrument is found suitable for collecting all types of benthos from all grounds.

Though the early investigations of benthos were directed only towards the discovery of species and enumerating them, during the beginning of the present century, interest in the benthos became more ecological with particular reference to benthos as a source of fish food. Quantitative studies were initiated by Petersen and Boysen (1911) who used a grab of 0.1 sq. m for bringing up the sample. This instrument though modified by later workers (Smith and McIntyre 1954) remains the basic and standard tool for quantitative collection of benthos from soft grounds. As the weight of the instrument alone helps penetration of the bottom, satisfactory collections are obtained only from muddy grounds. On hard packed sand, full penetration is not possible by the weight of the instrument alone. The Smith and McIntyre grab has been successfully used in the Scottish and Danish waters for collection of benthos from sandy grounds also, as the spring loaded mechanism is helpful in driving the instrument into the deposit. Van-Veen grab which is very similar to Petersen grab may be used advantageously in a variety of grounds. These are particularly suitable for the collection of undisturbed samples from mixed grounds. Similarly, Muus (1964) trap is found to be very suitable for the collection of fauna from the surface of the deposit. Though the grabs are suitable for collection of epifauna, for some of the infauna which are more deeply seated, heavier instruments or those instruments which are capable of deeper penetration have to be used.

For the collection of larger organisms and to have a comprehensive idea of the distribution of fauna of a ground it is always necessary to use dredges and trawls. The Naturalist's dredge and Beam trawl may be advantageously used for such studies. Various other types of instruments are also described by Barnes (1959).

Regarding the divsion of benthos, there are different opinions. The early workers (Mortensen 1925; Remane 1933) divided 'benthos' into microbenthos and macrobenthos considering the size. Mare (1942) coined the term meiobenthos to distinguish the organisms of intermediate size. The microbenthos include bacteria, diatoms and most protozoans, and are usually separated by bacteriological techniques. The macrobenthos constitute organisms which are separated by sieves of 2–0.5 mm (according to different authors). It is desirable that the lower limit for macrobenthos

is fixed as 0.5, though separation of fauna from coarse sandy deposit would be rather difficult at this range. Again, in meiobenthos, organisms that pass through 0.5 or 1.0 mm sieve and having a lower limit of 0.04 or 0.06 mm are included (McIntyre 1969). Though the above limits are only arbitrary, it is desirable that the upper limit for meiobenthos is fixed as those passing through 0.5 mm sieve and lower limit as those which are retained in 0.04 mm sieve. As the meiofauna constitute mainly nematodes, harpacticoids, ostracods and a group of very small organisms including larval forms of macrofauna, it is essential that the collections are made with great care. As the upper few centimetres of the deposits contain most of the meiofauna, undisturbed samples using grabs, corers and other special instruments like Muus trap have to be obtained.

For the study of the ecology of benthos, it is always necessary to collect a sample of the bottom deposit and also the data on temperature, salinity and flow of water very near the bottom. The deposits may be collected using the same instruments used for collection of benthos. While the hydrographical data may be obtained by Nansen bottle fitted with reversing thermometers. As the Nansen bottle will collect water sample only from $\frac{1}{2}$ m or 1 m above the substratum, special bottom samplers may be used for collecting samples of water from very near the substratum. The interstitial water may be collected by pressing the bottom samples. The deposits collected are usually analysed for grain size, organic content and nutrients which have a direct bearing on the distribution of benthos. The fauna collected is separated from the deposit by passing the collection through a series of sieves and expressed as wet weight or number occurring in 1 sq. m.

Hydrography

The temperature of the surface water is always dependent on air temperature, and round the year in the locality it varies only from 27–32°C. But the bottom temperature varies according to the depth of the station and also the circulation of water. At the 30 stations studied in the Port of Cochin area the difference of bottom temperature is 10°C (21–30°C). But the seasonal difference of bottom temperature at a particular station varies only from 2–4°C and so temperature is not an important factor affecting the distribution of fauna in the Cochin backwaters.

The tides in the estuary under reference are semi-diurnal with a maximum range of about 1 m and the salinity changes are considerable. During the pre-monsoon and post-monsoon months, high saline water of 32.5–34.5°/$_{oo}$ occupies all the stations and the difference between the salinity of water at the surface and bottom is only within 1°/$_{oo}$. But during the monsoon (May–September/October) the variation in salinity is very high (0.39–34.25°/$_{oo}$), the highest figure occurring in the barmouth near the bottom. About 70 per cent of the 320–375 cm of rain in the area falls during May/June–September/October months and so during this season there is strong flow of fresh water and the salinity of water at all the stations is very much reduced. But during the high tide, sea-water creeps into the estuary and this is visible near the barmouth extending up to about $1\frac{1}{2}$ km to the lower reaches of the estuary, thus forming the 'salt wedge type' estuary described by Bowden (1957). During this period the difference in salinity from the top to the bottom may be as much as 33°/$_{oo}$.

Though in the shallow regions salinity at the bottom changes very much owing to tides and run off from rivers, the variation in the deeper regions especially in the shipping channels is not considerable and high saline water of 17–34°/$_{oo}$ is always trapped there. Again in shallow regions the vertical mixing due to tidal currents of increasing amplitude extends throughout the depth, mixing the fresh water downwards and the more saline water upwards and the salinity profile shows a continuous increase from surface to bottom.

The salinity of interstitial water in the mud a few millimetres below the bottom can be almost constant, while the salinity of the overlying water varies back and forth through a tidal range of perhaps 10–15°/$_{oo}$. The amount of inflow of fresh water and the rate of exchange with coastal waters regulate the salinity of an estuary. The fresh water usually enriches the estuary owing to the organic as well as inorganic input of nutrients.

As regards dissolved oxygen there is always supersaturation at the surface and owing to the shallow nature of the estuary and mixing of water, it seldom goes below 2.5 ml/l even at the bottom and so the fauna in the Cochin backwaters is not affected by the distribution of dissolved oxygen. However, Ramamrithan and Jayaraman (1963) observed oxygen less than 1.0 ml/l during late monsoon and post-monsoon seasons till the middle of October in the sea outside the barmouth. This is accounted as due to the presence of upwelled water from the continental shelf finding its way into the backwaters.

The blooming of dinoflagellates (*Noctiluca* sp.) was also was observed in 1959 causing oxygen depletion down to the bottom in the Cochin backwaters. But these are only temporary and of short duration and as such do not affect the distribution of benthos.

Turbidity of water may also indirectly influence the fauna in an estuary. During monsoons the flood waters bring down much alluvium and a major part of it settles down in the estuary. This causes turbidity in water and consequently affects production.

Sediments

Sedimentation in the Cochin backwaters is peculiar. The rivers carrying a great amount of suspended particles are the main source of sedimentation which finally results in burrying of the shipping channels which are being dredged every year for keeping a depth of 11 m. Some tracer studies conducted in the estuary have shown that a portion of the mud dredged and deposited in the sea on the southern side of the barmouth about 4 km away from the shore gets back into the estuary within a week.

In the Cochin backwaters there is a wide range of substratum types. There is coarse sand and clay near the barmouth, sandy mud in the upper reaches, muddy sand at the junction of two channels and fine sand and silt in the shallow regions. The nature of the deposit has a close relation to the current system in the estuary and also on the distribution of fauna. While the barmouth with mostly sandy bed harbours the bivalve *Meretrix ovum* the muddy or clayey sand away from the barmouth, where the current is not prominent shows *Modiolus* sp. and *Diapatra neapolitana* in large

numbers. Again, in silt and clay the gobioid fishes, nemertines and nematodes occur in large numbers.

BENTHOS

The estuarine environment has many variants. It permits the maintenance of a population peculiar to the varying conditions. The fauna of an estuary is derived partly from the river and partly from the sea, and it is possible to separate the different faunestic components by their salinity tolerance.

In shallow estuaries the bottom fauna competes directly with zooplankton for food. The surface of the bottom mud may be greenish with lot of phytoplankton and the bottom filter feeders and detritus feeders will have a ready source of living material.

The dominant groups of macrofauna represented are polychaetes, amphipods, isopods, bivalves, gastropods, sea-anemones, prawns, gobioid fishes and brittle starts. The polychaetes constitute the major group throught the year at all the stations, which shows that they are able to withstand wide ranges in salinity and bottom substratum and have established as a part of the estuarine fauna. However, it is more abundant in the pre-monsoon months. Regarding the amphipods and isopods they are more abundant in the late monsoon period and are present in the upper reaches of the estuarine system also. *Meretrix* is abundant in the mouth of the estuary throughout the year. *Modiolus* sp. occurs in the muddy and fine sand and mud deposit in the pre-monsoon and beginning of the monsoon. When the salinity lowers considerably, most of them die. Sea anemones and brittle stars occur at all the stations during the pre-monsoon months and they continue to be present till the rains are intense, but absent in the monsoon and immediately afterwards, which shows that they are incursions from the marine habitat. Gobioid fishes occur round the year. Young prawns and prawn larvae are present throuhgout the year at all the stations, more numerous immediately after the onset of the monsoons, distributed at all types of grounds, but more intense in a deposit of fine sand and clay and very rare in sand.

Regarding the total intensity of fauna, the maximum number occurs immediately after the onset of the monsoon during June. A second maximum occurs during the pre-monsoon period which is mainly caused by sea anemones and brittle stars which are definitely marine in habitat.

As regards the distribution of fauna at the different stations, polychaetes and especially *Diapatra* occurs abundantly near the barmouth and at stations having a deposit of fine sand and clay.

The meiofauna is constituted mainly by nematodes, copepods, ostracods, foraminifera and small bivalves. All except foraminifera are abundant at the stations away from the barmouth in silt and clay deposit. Foraminifera are more numerous near the barmouth at a fine sandy bottom. The changes in salinity of the overlying water is not found to affect most of the meiofauna as well as the infauna in the clayey deposit, evidently as the interstitial water does not loose the salinity even for long periods, as already mentioned.

Desai and Krishnankutty (1967) also observe that the two stations near the barmouth they studied contained more bottom fauna than those stations in the

interior part of the estuary, and that higher salinity, favourable substratum and rich supply of nutrients are the causes for the abundance of bottom fauna. The stations 5*b* and 4*b* coincide with the stations 1 and 2 of Desai and Krishnankutty. However, the fauna in the present collection seems to be more intense than that observed by Desai and Krishnankutty. This may perhaps be due to the different methods used in the collection of material.

The maximum numbers of macrofauna occur at station 4*a* (4m) (35,000/m^2) constituted mostly by amphipods and at 6c (3m) (36,770/m^2) constituted mainly by *Modiolus* sp. The former station is situated at about 1 km. inside the estuary and the latter at about 1 km. outside the barmouth. Both stations are undisturbed, shallow places with the same type of depsit constituted by fine sand and silt. This supports the view that the largest population occurs in sediments of mean diameter ranging from 0.12 to 0.14 mm. It also agrees with the observation of Thorson (1959) that the higher densities of benthic organisms are found in shallow water with ample water renewal and surrounded by a region of higher precipitation.

The average numbers of specimens at a station in the Cochin backwaters is 1470/m^2. The biomass of benthos* normally varies from 50 to 150 g/m^2. But at stations where there are large numbers of bivalves (*Meretrix* sp. and *Modiolus* sp.) and Polychaetes (*Diapatra*), the biomass shows a Figure as high as 688 g/m^2.

Animals extending from the open sea into the estuary are abundant only in lower parts of the estuary and the penetration of infauna into upper reaches is probably as a result of less variability of salinity whithin the sediments. Salinity is concerned as a major factor in limiting the distribution of estuarine organisms. As sea-water becomes more dilute up the estuary, species drop out in part. In the 'middle reaches' and 'upper reaches' (Melbourne 1967) of the estuary the fauna is different. Though polychaetes, isopods and amphipods are present in these regions also, their intensity is less and the bivalve mollusc *Villorita* sp. appears in place of *Meretrix* in the less saline regions.

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*Live weight (wet weight) excluding the shells of molluscs and tubes of polychaetes.

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