

Benthic Studies in Goa Estuaries*: Part I—Standing Crop & Faunal Composition in Relation to Bottom Salinity Distribution & Substratum Characteristics in the Estuary of Mandovi River

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Benthic standing crop and faunal composition in relation to salinity intrusion and sediment types have been investigated in the estuary of Mandovi river, during December 1971 to January 1972. The estuary has a steep, salinity gradient with a variation of 31.7‰ over a distance of 35.4 km. The tidal action is weak and freshwater dominance is clearly seen. Bottom salinity values demonstrate the existence of 4 different salinity zones. Substratum types, as determined by visual examination and median grain-size analysis, show the existence of four sediment zones which are comparable with salinity zones, in longitudinal expanse. The results demonstrate the influence of salinity and substratum on the benthic production and distribution of fauna. The present investigation forms baseline study for assessment and management of benthic resources.

MANDOVI river, rising in Parwa ghat of Sahyadri hills, is the most important of the rivers in Goa. The river follows a south-westerly course of 61.6 km, before joining the Arabian Sea, through Aguada Bay near Panaji. The Mandovi along its course has a number of islands, narrow bends, shallow depths and openings of tributaries and canals (Fig. 1). Amongst the canals, the Cumarbarja canal connecting the estuaries of Mandovi and Zuari, plays an important role in the water movement in the Mandovi¹.

Materials and Methods

The present investigation was undertaken from December 1971 to January 1972, when the freshwater discharge in the Mandovi river is very little¹. All observations were carried out during high tide to follow the extent of salinity intrusion, and while sampling in the upper reaches of the estuary, the time lag between predicted and actual tide time, was duly accounted for.

Twenty-five sections, almost equidistant, were fixed for sampling of 36 km, of the estuary. Depending on the width of each section, 1 to 7 sampling points were fixed. In all 73 stations were operated (Fig. 1). At each station, temperature, salinity, dissolved oxygen, nutrients and substratum were recorded, but only the role of salinity and substratum, is discussed here.

Benthic samples, in duplicate, obtained by a 0.04 m² Van Veen grab were sieved through 0.5 mm mesh, and hence the results mainly pertain to macrobenthic organisms. The standing crop is represented by dry weight, obtained by the same procedure as described earlier².

Results and Discussion

Bottom salinity distribution—Salinity distribution resulting from the cumulative effect of water

movements induced by freshwater run-off, tidal amplitude and the mixing processes, is very important in an estuarine environment. Depending upon the degree of mixing, an estuary may vary from a well-mixed type to a stratified type^{3,4}. The mixed type of estuary exhibits lateral as well as longitudinal variations in salinity distribution.

The lateral variations, generally caused by 'coriolis' force⁵, are well pronounced. In relatively narrow estuaries, where the direction of water movement is symmetrical about the longitudinal axis, the coriolis effect is not very pronounced⁶. Mandovi has a narrow river bed and shallow depths (Fig. 1), which results in a small ratio of width to depth, and consequently, insignificant lateral variations⁷.

The longitudinal distribution generally varies with a decreasing trend in salinity in the upstream direction, and is due to the tendency for the salt water to be driven out of the estuaries by the water movements towards the mouth⁷.

It is seen that from the mouth up to 4 km upstream, the values are above 32‰. In the next 2 km, a sudden fall of 6‰ is observed. Thereafter, the values go on gradually increasing up to 12 km and the total rise is 2.5‰. This gradual rise is due to the water movements through the Cumarbarja canal¹. In the next 1 km, there is a sharp decrease of 10‰. The decreasing trend continues for another 15 km, till the value recorded is 15‰. The decrease, to a certain extent is stalled by a 2‰ rise in the next 3 km. This rise is followed by a gradual decrease of 1‰ within next 4 km. Thus up to a distance of 22 km, from the mouth, the fall in salinity is 16‰. Thereafter, the values go on decreasing rapidly, till the lowest value (1.85‰) is recorded at 35.4 km, upstream. The longitudinal fall, for a distance of 35.4 km, therefore, is 31.7‰.

For a distance of 35 km, in the Vembanad Lake (Kerala), the reported fall in bottom salinity has been 10‰ (ref. 7). In a 116 km stretch of Hoogly river, India, a 20‰ decrease has been observed⁸, whereas Pritchard⁹ has recorded a 20‰ decline for

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84 km in Delaware estuary. Therefore, the bottom salinity gradient in the estuary of Mandovi is much steeper than reported for other estuarine environments.

The trend in longitudinal salinity distribution, as observed in the present investigation indicates the existence of 4 distinct salinity regimes or zones in a 35.4 km stretch of Mandovi estuary, and each of the zone is characterized by the following features:

Zone	Range value	Extent in km
Eubaline	32 and above	4
Polyhaline	18-30	9
Mesohaline	5-18	15
Oligohaline	0.5-5	7.4

The above-mentioned salinity zones are largely agreeable with the 'Venus' system^{9,10}. The Vellar estuary, on the east coast of India, has also been demarcated into four distinct zones¹¹.

Substratum—The substratum acts as an important abiotic factor in the benthic environment, by

its mere physical conditions¹². As elsewhere, a definite animal-sediment relationship in Goa estuaries has already been reported¹³.

As seen from Fig. 2, the estuary of Mandovi river is characterized into 7 different types of bottom deposits, possessing varying median grain-size component. Further, an attempt has also been made (Fig. 3A-D) to classify the different sediment zones, by using the sand, silt and clay percentage distribution¹⁴. Fig. 3A shows the sediment distribution in three components in the mouth region. Large variations, in percentage composition of different ingredients, reflect on the characteristic feature of tidal influence. Fig. 3B is dominated by clayey sand with the limited diversification to sand and sand-silt-clay component. The next zone (Fig. 3C) shows the dominance of silt-clay fraction, with more inclination towards sediments of freshwater origin. Fig. 3D, representing the uppermost reaches of Mandovi estuary, shows characteristic sandy distribution. The four broad-based sediment zones (Fig. 3A-D) in their extent within the estuary

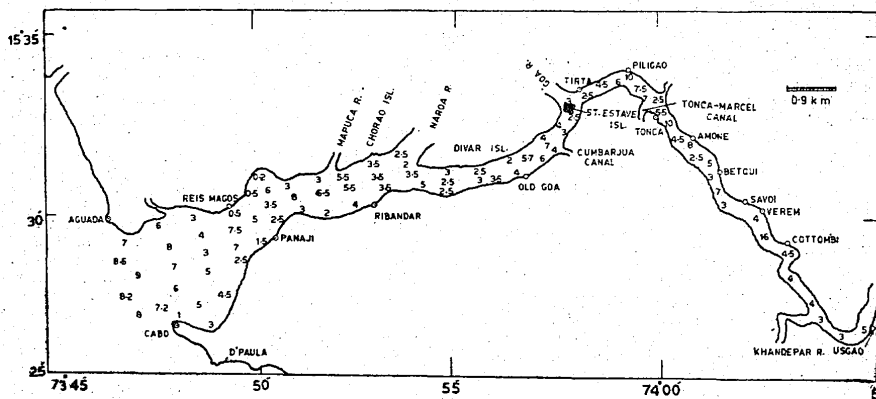


Fig. 1 — Estuary of Mandovi river showing depth (in metres) at different stations

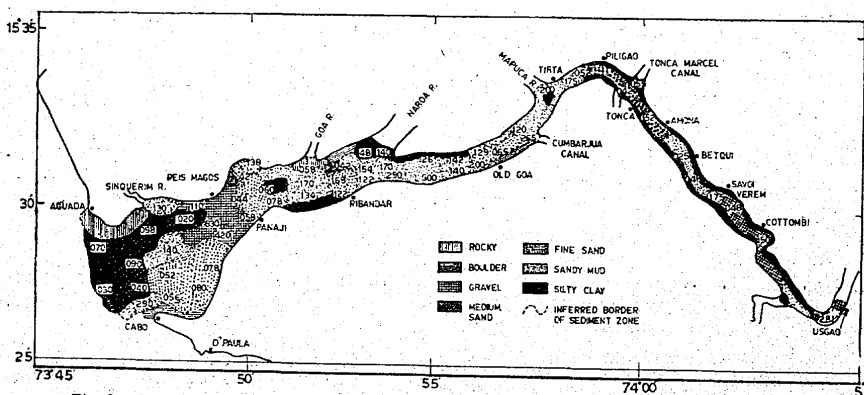


Fig. 2 — Substrate characteristics and median grain-size distribution in the estuary of Mandovi river

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(Fig. 2) are comparable with the already demarcated salinity zones.

Standing crop — The benthic standing crop, as seen from Fig. 4, varies between 0.075 and 301.3 g/m², for the entire stretch of 35.4 km of the estuary of Mandovi river.

The first 4 km, characterized by the isohaline of 33 and sandy-silty sand substratum (Fig. 5) show wide fluctuations in biomass values (Fig. 4). This region, where the biomass on an average, is less than 1.5 g/m², except on some part of the right bank, where due to rich mussel beds, the standing crop goes up to 301 g/m², is otherwise a zone of low benthic production. However, the mean standing crop is 18.5 g/m².

The next zone, lying between the isohalines of 29 and 19 respectively (Fig. 4) and characterized by

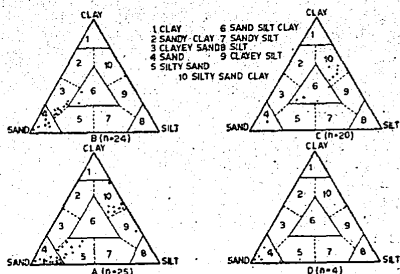


Fig. 3 — Triangle diagrams representing sediment zones in the estuary of Mandovi river

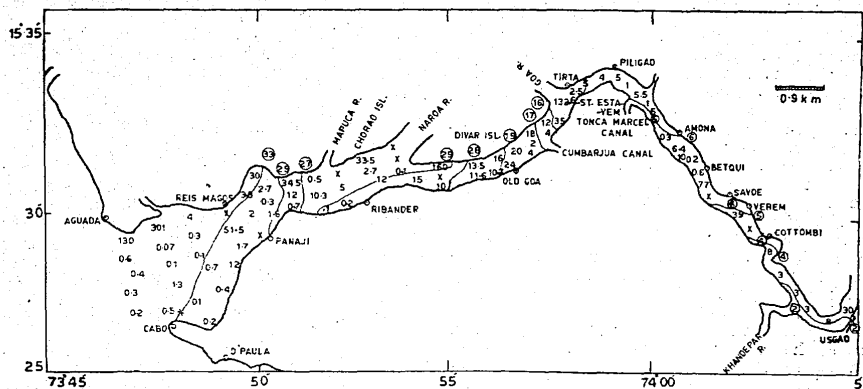


Fig. 4 — Benthic biomass distribution (numbers without circle) in relation to isohalines (numbers with circle) in the estuary of Mandovi river

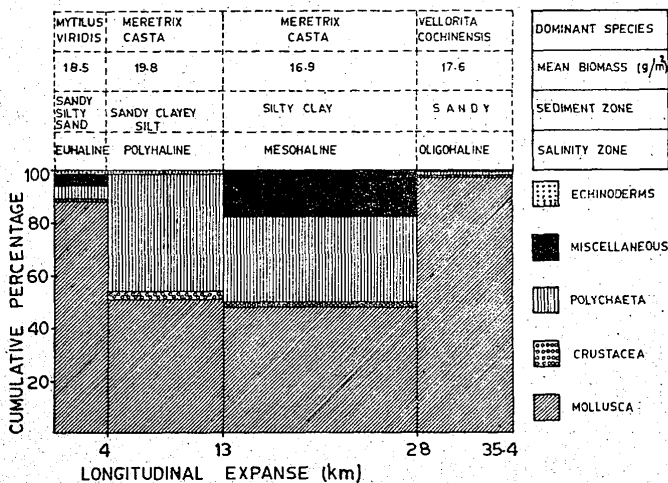


Fig. 5 — Faunal composition and dominant species in relation to salinity, sediment and mean biomass in different zones of the estuary of Mandovi river

sandy-clayey silt substratum (Fig. 5), has a biomass range of 0.1-160 and mean value of 19.8 g/m². This zone shows almost an even pattern of biomass distribution. Another notable feature is the observed low biomass in the regions of confluence of Goa and Naroa river respectively with Mandovi (Fig. 4).

The mesohaline zone, having dominant silty-clay substratum, shows (Fig. 5) a moderately high benthic standing crop (0.3-132 g/m²) with a mean value of 16.9 g/m². The variations, within stations, though of lower magnitude, are balanced by relatively high biomass values in the region of confluence of Cumbarjua canal and Goa river respectively with Mandovi (Fig. 4). Das *et al.*¹ have observed "a net salinity influx from Zuari side to Mandovi side of the canal and to the upper reaches of the Mandovi river". This movement of Zuari waters proves conducive for the benthic production in this zone.

The last zone with salinity values less than 5‰ and with predominantly sandy substratum (Fig. 5) shows a smaller range (0.2-77.5) of biomass values but a moderately high mean value of 17.6 g/m².

Population count and faunal composition — The macro-benthic population, as assessed from numerical counts, shows wide fluctuations (Fig. 5) in different zones. The population density is highest (2533/m²) in the euhaline zone, followed by oligohaline and the lowest (504/m²) in mesohaline.

The estuarine fauna is, generally, formed of marine, brackish water, freshwater and migratory component¹⁶, and the faunal composition is determined by several mutually independent parameters, having a limited influence on the number of species¹².

As seen from Fig. 5, out of the four demarcated zones, the first two, viz. euhaline and polyhaline, have the maximum number of faunal group representation. This finding, while reflecting on the salinity tolerance of individual faunal groups, especially echinoderms (Fig. 5), also supports the findings of earlier workers^{12,16,17} about the impoverished state of mesohaline fauna.

Another interesting feature is the observed numerical superiority of the molluscan faunal elements. In predominantly sandy bottom, the molluscs, especially bivalves, outnumber other faunal groups by more than 10 times, whereas, in other regions, they account for almost 50%. Similar dominance of molluscs has also been observed in Cochin backwaters¹⁸. Based on numerical abundance and also on high dry weight, any benthic faunal assemblage is characterized¹⁹ by a dominant species, ultimately around which a 'bottom community' is raised²⁰. In the Mandovi estuary, the commercially important clam, *Meretrix casta*, mainly due to its euryhaline and euroecious abilities²¹, forms an extensive animal community, whereas the other bivalves, *Mytilus viridis* and *Velloria cochiniensis*, dominate the zones of highest and lowest salinities respectively (Fig. 5).

The other important faunal group, namely annelids, are mainly represented by polychaetes, and in the distribution exhibit limitations in relation to both the abiotic factors considered here. While they are present in varying abundance in all the four zones, the highest (45%) is attained in polyhaline and the next best (31%) in mesohaline. Both these zones have almost similar substratum with dominance of silty-clay to clayey-silt component

(Fig. 5) and thus the substratum is more effective in limiting the distribution of polychaetes in Mandovi estuary.

The crustaceans (Fig. 5) though represented in all the zones, with maximum abundance in euhaline zone, exhibit a preference for regions of higher salinities. Being epifaunal and, therefore, 'detriophages' in trophic structure²², they do not have much substratum specificity²³.

The distribution of echinoderms, in Mandovi, is limited to the zones of higher salinities (<18‰). The 'miscellaneous' faunal group comprising of hydroids, actinarians, planarians, nematods, polychaetes, echinuroidea, gobioida and some zooplanktonic organisms like medusae, arrow-worms and various larval stages, occur rather in insignificant numbers in all the zones. The occurrence of zooplankton in estuarine benthic fauna, though strange, has been reported^{13,24}.

A résumé of the present investigation brings out the vital role of salinity and substratum in the distribution of benthic organisms, but it is rather difficult to single out either of them as an 'ecological master factor'²⁵.

A review of relevant literature indicates that the salinity is only one of the several master factors which through their interplay determine the benthic faunal distribution in the estuaries. In an environment like Mandovi estuary, where the observed distance between isohalines (Fig. 4) is only a few hundred metres, the possibility that one or more environmental factors, apart from salinity, are limiting the local distribution is very great.

In this context the role of substratum is also not absolute. As seen from the preceding sections, the substratum, while acting as a master factor for polychaetes, is not equally effective in limiting the distribution of *Meretrix casta* in Mandovi estuary.

It is possible that for some faunal groups, other physical factors, than discussed in the present investigation, may act as limiting factors. As such, when compared to other environmental factors, the role of substratum in benthic life cannot be viewed independently of the other factors²⁶.

The biomass, discussed here, is an index of the standing crop of benthos²⁷. It provides basic data for distribution of bottom fauna, in relation to salinity and substratum, for a stretch of 35.4 km of the estuary of Mandovi river, and also enables in the assessment of benthic resources.

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