

# Ecology of Benthic Production During Southwest Monsoon in an Estuarine Complex of Goa

ARUN H. PARULEKAR

*Arabian Sea Islands Project, Indian National Science Academy (INSA)*

S. N. DWIVEDI

*Biological Oceanography Division, National Institute of Oceanography,  
Panaji (Goa)*

The paper discusses the role of environmental factors in benthic production during southwest monsoon period, (June-September) in the Mandovi-Combarjua Canal Zuari estuarine complex of Goa.

This estuarine complex has five different types of substrata, supporting distinct animal populations, and thus exhibiting an animal-sediment relationship. The system has three well marked environments in Mandovi, Combarjua Canal and Zuari, respectively. Though, these water masses are interconnected, ecologically they represent different ecosystems. Variations in environmental factors, like temperature, pH, salinity and dissolved oxygen clearly demonstrate this differentiation.

The environmental factors, in turn, influence faunal elements of the bottom resulting in qualitative and quantitative differences. The benthic biomass production is highest in Mandovi followed by Combarjua Canal and the production is least in the Zuari. The differences also appear to be influenced by the quantity of influx of fresh water.

Diurnal changes in environmental factors, due to tidal oscillations in relation to benthic biomass production, are also discussed.

## Introduction

The Estuarine system in Goa region comprising of the Mandovi and Zuari rivers and the inter-communicating Combarjua Canal is being investigated at the National Institute of Oceanography in view of its importance as a potential resource for prawns and clams. Earlier investigations have shown that both these estuaries are very productive, (Dehadrai : 1970, a and b). These estuaries constitute a complex ecological system with strong interactions of biotic and abiotic factors. The rivers Mandovi and Zuari originating in the Western Ghat region traverse a distance of about 115 kilometres before emptying into the Arabian Sea. The two river mouths are separated by a distance of about 5 kilometres. The Combarjua Canal meets Mandovi at a distance of about 11 kms from the river mouth and the river Zuari at a distance of about 9.0 kilometres. The catchment areas of the river systems receive heavy Southwest monsoon rains between June and September and the total rainfall is of the order of three thousand millimetres. Considering the size of the rivers and the annual precipitation, it is seen that these two rivers receive a considerable quantity of fresh water. However, fairly high

---

*R. Natarajan (ed.), Recent Researches in Estuarine Biology, pp. 21-30.*

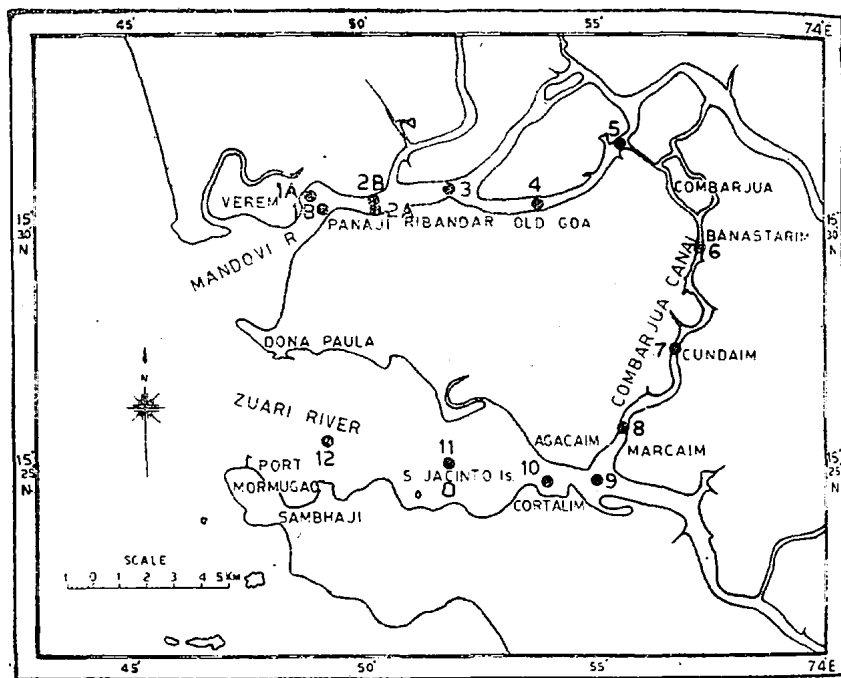
©Hindustan Publishing Corporation (I), Delhi (India)

tidal range brings about the mixing of fresh and sea water in the estuaries leading to complex environmental conditions.

As part of the studies of the living resources of these estuaries, investigations have been undertaken on the benthos of this estuarine system and the present paper is the first of the series dealing with this aspect.

### Material and methods

The investigations were carried out at 12 stations almost equidistant from one another (Fig. 1) and the samplings were done at intervals of two weeks.



ECOLOGY OF MANDOVI AND ZUARI ESTUARINE COMPLEX

Fig. 1

The stations in the region of Mandovi opening were sub-sampled, as in this part the river is sufficiently wide and also sufficiently deep on the banks. The gear used was a modified van Veen's Grab, giving a substrate coverage of 0.4 sq. m. and penetration depth of 10 cms. The samples were washed through 0.5 mm size mesh sieve which retains most of the macro-benthos and a small part of meiobenthic forms.

The environmental parameters studied are depth, substratum, temperature, pH, salinity and dissolved oxygen. The benthic biomass and population count per unit area were evaluated and interrelationships with environmental parameters worked out. Diurnal changes in the benthic population, in

relation to environmental factors, were studied for three selected sections, each representing a distinct section of this complex.

**Results and discussion**

From the study of the environmental parameters, given in Tables 1 and 2, it is seen that the depth varies from 2.5—13 metres in this estuarine complex,

TABLE 1

Environmental Factor	Total Range	SECTIONAL RANGE		
		Mandovi	Combarjua Canal	Zuari
Depths (in mts).	2.5 — 13.0	2.5 — 13.0	3.0 — 6.0	3.0 — 6.5
Temperature (°C)	23.5 — 30.4	23.5 — 28.8	25.4 — 30.4	25.0 — 29.0
pH	7.1 — 9.9	7.1 — 9.4	7.2 — 9.3	7.2 — 9.9
Salinity (‰)	0.12 — 32.90	0.12 — 32.72	0.12 — 20.75	0.27 — 32.90
Dissolved Oxygen (ml/L)	0.90 — 8.55	0.90 — 7.76	3.64 — 5.93	1.36 — 5.35

Biological Factor	Total Range	SECTIONAL RANGE		
		Mandovi	Combarjua Canal	Zuari
Biomass (gms/m <sup>2</sup> )	0.12 — 667.50	0.12 — 459.35	0.27 — 62.70	0.15 — 196.75
Population Count (nos/m <sup>3</sup> )	3 — 590	3 — 538	3 — 236	3 — 501

with a maximum range in Mandovi section. The Zuari and the Combarjua Canal sections are comparatively shallower regions having a maximum depth of 6.5 metres.

The bottom temperatures are seen to exhibit a wide range of fluctuations (23.5—30.4°C) with sectional differences of 4—5°C. It is observed that the region of river opening coincides with higher temperatures, probably due to the mixing of warm neritic waters. The lowering of temperature is maximum in July, when the rainfall is intensive. Intrusion of cold upwelled neritic waters in this estuarian system has been reported recently by Sankaranarayanan and Jayaraman (1972).

Among the environmental factors, under study, the salinity was highly variable. The Tables No. 1 and 2 show that at one time or other in all the three sections the salinity becomes very low and almost fresh water condition is reached. Again the amount of fresh water drainage coupled with varying tidal phases reverses back the ecosystem either to brackish or marine state.

TABLE 2 — VARIATION IN ENVIRONMENTAL FACTORS AND BENTHIC PRODUCTION DURING SOUTHWEST MONSOON (STATION-WISE)

Section	St. No.	Depth (mts)	Temperature (°C)	pH	Salinity (0/100)	Dissolved Oxygen (ml/L)	Biomass (gms/m <sup>2</sup> )	Populat. count (nos/m <sup>2</sup> )
M	1a	4-11	23.5-28.1	8.3-9.4	1.49-32.56	1.36-5.20	0.22-6.00	5-20
A	1b	5-6	24.0-28.8	8.4-9.4	4.18-32.72	0.90-4.66	0.25-39.68	3-57
N	2a	2.5-6	25.5-27.5	7.3-9.4	0.27-27.00	2.49-4.95	0.067-19.841	17-88
D	2b	5.5-13	25.0-27.65	7.3-9.0	0.27-32.39	1.36-7.76	0.15-156.27	5-90
O	3	4.5-7	24.95-27.7	7.3-8.9	0.12-23.24	2.49-4.96	0.78-495.35	12-505
V	4	5.0-7	25.65-29.1	7.1-9.3	0.12-6.64	4.84-8.55	0.25-28.27	3-538
I	5	4-5	25.5-28.5	7.2-9.2	0.12-0.45	3.97-6.50	0.12-2.55	5-82
COMBAR-	6	4.5-6	25.4-30.4	7.3-8.9	0.21-5.72	4.36-5.93	1.469-62.700	13-236
JUA	7	3-5	25.9-29.5	7.2-9.2	0.12-5.63	4.07-5.59	0.27-10.40	3-20
CANAL	8	4-5.5	26.1-29.4	7.2-9.	0.30-20.75	3.64-5.08	0.47-50.25	7-18
Z	9	5-6.5	26.2-29.0	7.2-9.9	0.27-16.67	3.39-5.24	0.25-196.75	10-157
U	10	5-6.5	26.2-28.7	7.6-9.6	1.23-24.49	1.48-5.08	0.15-110.20	3-118
A	11	3-5	25.9-28.5	7.8-9.6	3.53-22.18	1.36-4.79	0.50-1.25	3-501
RI	12	3.5-5.5	2.50-28.5	7.9-9.6	5.63-32.90	1.36-5.35	0.029-2.809	3-61

TABLE 3

Type of Substratum	Stations	Benthic Infauna and Epifauna	Overall Biomass (gms/m <sup>2</sup> )	Overall Populat. count (nos/m <sup>2</sup> )	No. of observa. (n)	Mean $\pm$ standard Error* (Population count)
Hard - rocky or bouldered	1 (a) and 7	Cirripeds, bryozoans, oysters, mussels, hydroids isopods and amphipods	2.4	11	12	11.0 $\pm$ 3.7
Sandy Mud (70-80%) (30-20%)	1 (b)	Polychaeta sedentaria and Mysids	9.7	19	6	19.3 $\pm$ 4.1
Sandy	3, 4, 5 and 12	Pelecypoda and Polychaeta errantia	46.2	114	27	65.0 $\pm$ 48.4
Muddy Sand (70-80%) (30-20%)	6 and 8	Decapods and Polychaeta errantia	26.5	20	16	19.6 $\pm$ 1.4
Silty	2 (a), 2 (b), 9, 10 and 11	Polychaeta sedentaria, amphipods, alpheids, gobid fishes and planktonic forms	23.0	50	38	49.8 $\pm$ 4.4

\* (Standard error calculated at 95% security level—Mayer *et al.* ; 1969).

Such variations in salinity values (0.12—32.90‰) severely affect the benthic fauna. A comparative study of salinity values, section-wise and station-wise (Tables 1 and 2) indicates that the Combarjua Canal along with adjacent water mass, undergoes a smaller range of variations (0.12—20.75‰) whereas the salinity scour is maximum in the region of river opening (1.49—32.90‰).

The variations in the dissolved oxygen content (Tables 1 and 2) give an indication to the pattern of mixing of freshwater with saline water. It is observed that the region of confluence along with Combarjua section coincides with high values of dissolved oxygen (3.64—5.93 ml/l) whereas in Mandovi, the values exhibit a wide range of fluctuations (0.90—8.85 ml/l). The variability is due to the predominance of freshwater and its local impact on the ecosystem. It is also seen that there is the usual inverse relationship between salinity and dissolved oxygen.

The substratum, amongst all the physical environmental factors, has the greatest influence on the benthic populations. The role and importance of the nature of substratum in the estuarine environment has been discussed in some detail by Vanucci (1969). As shown in Table 3, the substratum in this estuarine complex comprises of 5 distinct categories. Each category is characterised by the quality and quantity of its epi- and infauna. A reference to Table 3, also reveals that higher biomass values are associated with sandy substratum followed by silty bottom and the minimum in hard substrate. Desai and Krishnankutty (1967) have made similar observations for the benthos in Cochin backwaters. The population at stations having sandy and silty bottom are found to be dominated by relatively bigger-sized animals, such as pelecypods and polychaete sedentaria. In sandy substrate, the pelecypods abound whereas the tubicolous reef-building polychaetes are important faunal elements in silty substrate. The molluscs and the polychaetea sedentaria are the major animal communities encountered in this study and they play an important part in the benthic production in different sections of this estuarine system.

The observations on the benthic biomass, in the environment as a whole and individual stations (Tables 1 and 2), give a diversified picture of the distribution of benthic fauna. A review of Tables 1 and 2, reveals that region of confluence of two different water masses coincide with the zone of low production. Accordingly, stations 1a, 1b, 2a, 2b, 5, 11 and 12 (see Fig. 1) fall under this category. It is in this part of the estuarine complex that most of the environmental parameters have a wide range of variations (Table 2) thus giving rise to perhaps a most unstable ecosystem and consequently low benthic production. An overall evaluation of benthic biomass values suggests that the production of standing crop is steady in Combarjua Canal where the variations in environmental parameters are of smaller magnitude. Between Mandovi and Zuari where vagaries in environmental parameters are of comparable magnitude, it is the favourable substratum that

accounts for high benthic standing crop in Mandovi. Qasim *et al.* (1972) observed that in an estuarine environment where changes in salinity are very large, maximum abundance of many organisms occurs at exceptionally low salinities.

The population count per unit area is directly linked with the biomass values for all the stations except station 11. Here, despite low biomass values, the population count range is quite extensive. It was observed that, at this particular station, the planktonic forms, viz. chaetognaths, lucifers and copepods, dominated over the usual infaunal organisms. The abundance of planktonic forms is attributable to strong tidal currents prevailing in this part of Zuari.

The observations on diurnal changes in environmental factors and benthic biomass, as shown in Fig. 2, indicate that the temperature values vary within a modest range of 2°C, whereas the salinity values exhibit large range of 17‰. Comparatively, the dissolved oxygen shows a low value of 1.6 ml/l. Accordingly, the biomass values exhibit differences in different sections, with Mandovi recording maximum and Zuari accounting for minimum fluctuations.

### Summary

1. Of the physical environmental factors that affect the distribution of benthic fauna, the most significant seem to be salinity and the nature of substratum.
2. Sediment-animal population relationship clearly indicates that a particular animal assemblage flourishes only in a certain kind of substratum where favourable conditions prevail. In this estuarine complex, it is the sandy substratum that supports high production where mean average value of 46.2 g/m<sup>2</sup> has been recorded.
3. The wide fluctuations in the environmental factors, and especially in the salinity values (0.12—32.90‰), clearly indicate that in spite of the heavy freshwater drainage, it is the strong tidal influence that balances the environment.
4. When compared with Mandovi or Zuari, the Combarjua Canal appears to be a more stable ecosystem, as evidenced by lesser degree of fluctuations in the environmental parameters and high rate of benthic production.
5. Mandovi and Zuari undergo a similar trend of fluctuations, both seasonal and diurnal, but it is the availability of favourable substratum, and secondly, the predominance of euryhaline faunal assemblages, that account for a comparatively high rate of benthic production in Mandovi.
6. The river mouths coincide with the zone of low benthic production. It is in this section that mixing of sea and fresh water is at its maximum and the ecosystem is unstable.

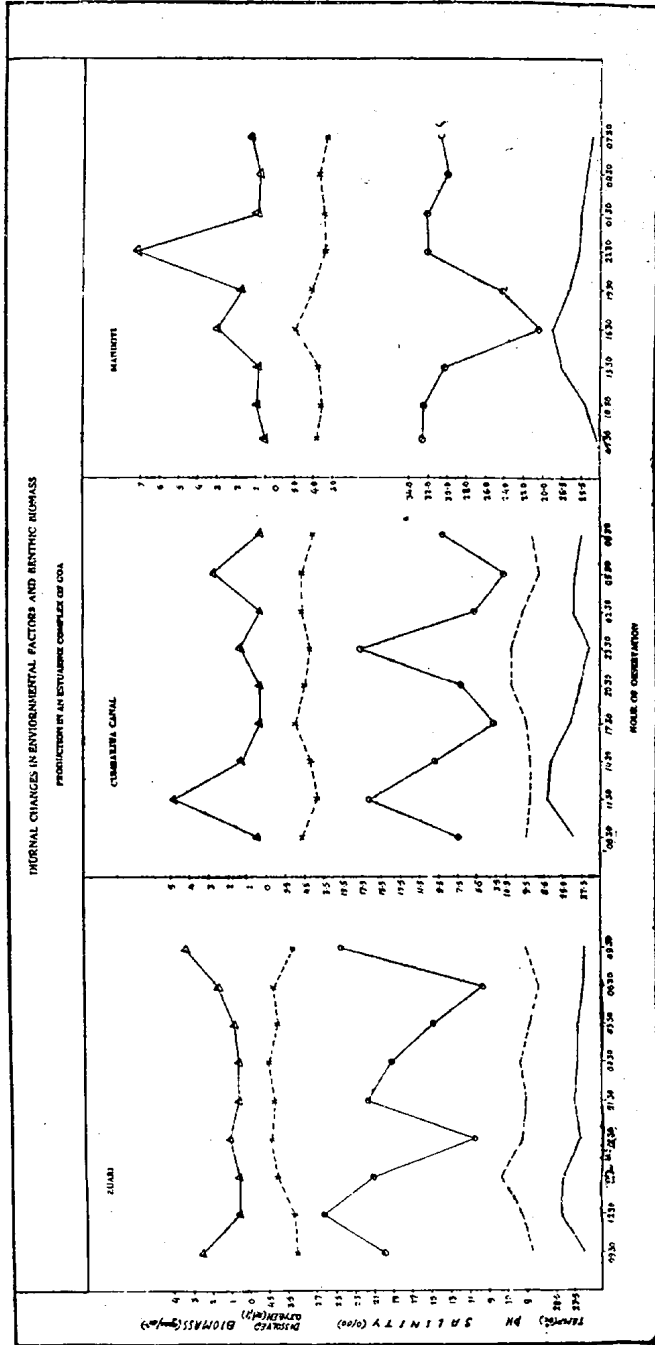


Fig. 2



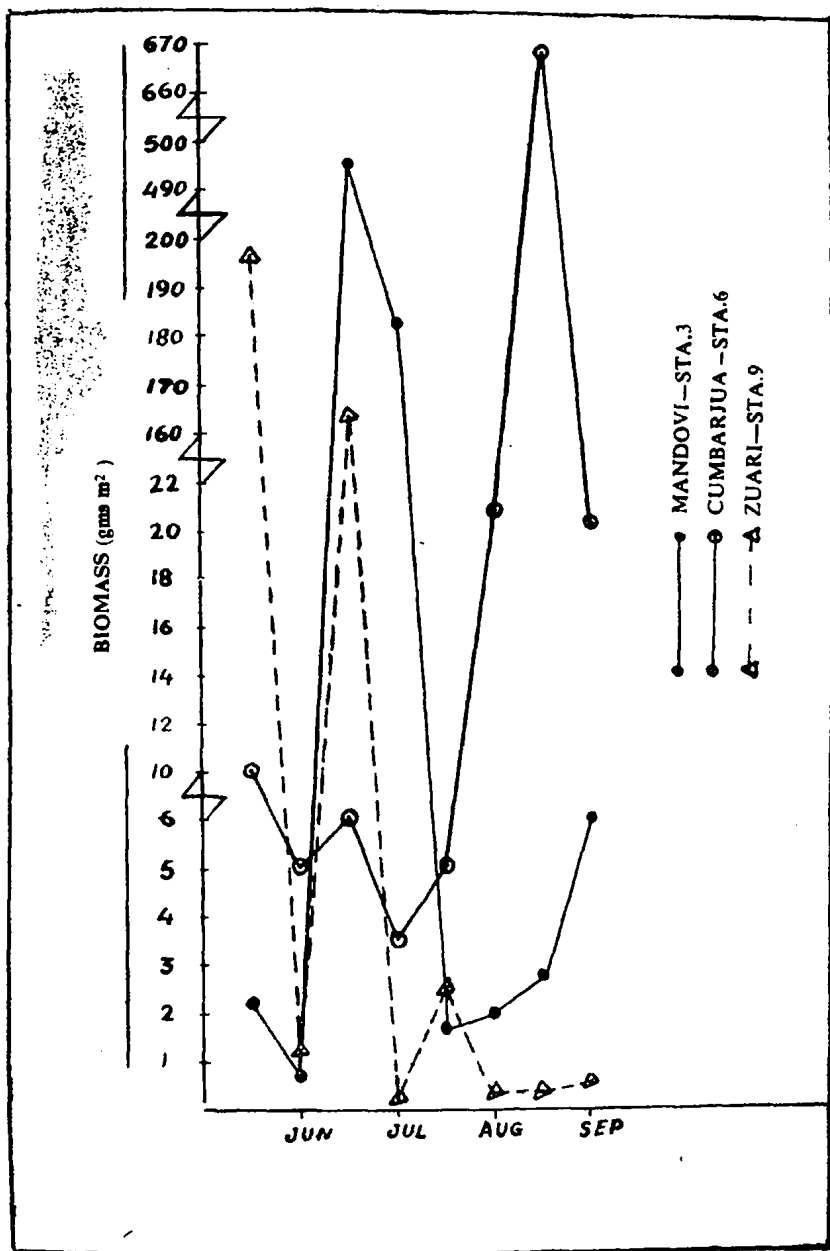


Fig. 3

7. Thus, this estuarine complex, though formed of physically interconnected watermasses, is not homogeneous ecologically. Accordingly, there exist three different ecosystems which are to a greater extent, independent of each other.

The authors record their grateful thanks to Dr. N. K. Panikkar, Director, National Institute of Oceanography and Project Leader, Arabian Sea Islands Project, for the facilities and keen interest in this research work. Thanks are also due to our colleagues for help in the field and in the laboratory.

#### REFERENCES

- DEHADRAI, P. V., (1970a), Observations on certain environmental features at the Dona Paula Point in Marmagoa Bay, Goa, *Proc. Ind. Acad. Sci.*, 72(2) B : 56-7.
- . (1970b), Changes in the environmental features of the Zuari and Mandovi estuaries in relation to tides, *Ibid.*, 72(2) B : 68-80.
- DESAI, B. N. and KRISHNANKUTTY, M., (1967), A comparison of the marine and estuarine benthic fauna of the nearshore regions of the Arabian sea, *Symposium on Indian Ocean. Bull. Natl. Inst. Sci. India*, 1969, 38 (II), 677-83.
- MAYR, ERNST, (1969), *Principles of Systematic Zoology*, McGraw-Hill Inc., New York.
- QASIM, S. Z., BHATTATHIRI, P.M.A. and DEVASSY, V. P., 1972, The influence of salinity on the rate of photosynthesis and abundance of some tropical phytoplankton, *Mar. Biol.*, 12(3) : 200-206.
- SANKARANARAYANAN, V. N. and JAYARAMAN, R., (1972), Intrusion of upwelled waters in Mandovi and Zuari Estuaries, *Curr. Sci.*, 41(6) : 204-206.
- VANUCCI, M., (1969), *What is Known About Production Potential of Coastal Lagoons*, In: *Coastal Lagoons* : Symposium Ed. A.A. Castanares, publ. Univ. Nacional Autonoma De Mexico.