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Production at Different Trophic Levels in the Estuarine System of Goa

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Primary production in the estuaries of Goa has been measured during the monsoon period. This estuarine system sustains a high production having a maximum average production of 316 mgC $m^{-2}d^{-1}$ in Cumbarjua canal followed by Zuari (249) and Mandovi (247). The chlorophyll concentration is also maximum in the canal. In Zuari only, the production increases linearly with the increase in chlorophyll *a*. Assimilation number varies at different places and depths. Relation between nutrients and production is poor. The 'transfer coefficient' varies from 1·7 to 39·9% and decreases with increase in production. With these data, the average tertiary production in terms of wet weight is 19 mg $m^{-2}d^{-1}$, a very close estimate with the corresponding figure of the Indian Ocean.

VARIOUS types of investigations were carried out in the Mandovi-Zuari estuarine system of Goa[1,2]. An earlier estimate on organic production in these estuaries was from the surface waters at a single station[3]. In this investigation, therefore, while emphasis was laid on characterization of the estuarine waters on the basis of their photosynthetic production of organic carbon, an attempt is made to compute the 'transfer coefficient' to the next trophic level and also to estimate the fishery potential which this system could possibly support.

Materials and Methods

Positions of sampling stations are shown in Fig. 1. Fortnightly observations made at these stations were confined only to the monsoon period (June-September) of 1972. Samples from 4 depths were collected for estimating the photosynthetic production, chlorophyll, phytoplankton, salinity and nutrients. Since there was little difference in the salinities and the nutrients with depth these were considered and discussed for 2 depths only, viz. surface and compensation depth. However, primary production and chl. *a* were computed for the column of euphotic zone and presented. For photosynthetic production, ^{14}C technique was used with *in situ* incubation from midday to sunset. Radioactivity was determined in a G. M. counter, the efficiency of which was obtained by comparing with that of a liquid scintillation system. The counts were corrected for dark uptake and then the column production was calculated. Standard methods were used for estimating other parameters mentioned above. Values thus obtained were averaged monthwise and zonewise.

Results

Mandovi estuary — Changes in production along with the environmental features are shown in Fig. 2. The maximum production which was 540 mgC $m^{-2}d^{-1}$ in June (Fig. 2a) declined to 56 during July and increased thereafter. The column chl. *a* (Fig 2b) followed similar trend and ranged between 1·6 and 12·7 mg m^{-2}. Surface phytoplankton (Fig. 2c) varied between 0·37 and 0·015 million cells/litre. As could be seen from Fig. 2d there was little difference between the salinities at the surface and subsurface (compensation depth) waters. Concentrations of both the nutrients — phosphate and nitrate — did not show much difference between surface and subsurface (Fig. 2e). The compensation depth never exceeded 3·1 m and the lower limit was, however, 1·5 m only (Fig. 2f).

Correlation coefficient between carbon assimilation and chl. *a* was only 0·54. Assimilation numbers calculated for the 4 depths, i.e. 100% illumination (surface), 50%, 30% and 1% varied from 2·7 to 11·4; 0·8 to 20; 0·6 to 8·4 and from 0·2 to 5·4 respectively. The correlation between nitrate and production (−0·29) and between phosphate and production (−0·12) was less. N: P ratios by atoms ranged from 0·4:1 to 21:1.

Zuari estuary — Different parameters studied are shown in Fig. 3 (a-f). Here the production

Fig. 1 — Location of sampling stations

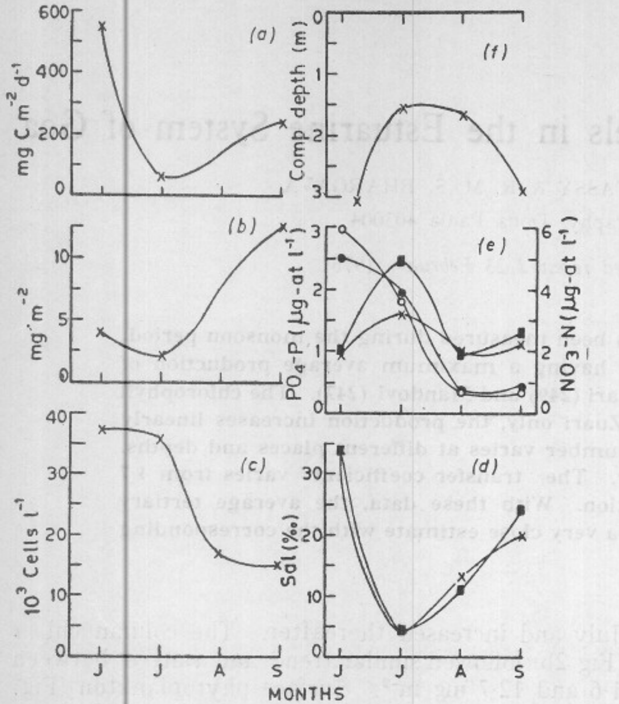

Fig. 2 — Monthly changes in different parameters in Mandovi estuary [a, primary production; b, column chl. *a*; c, phytoplankton cell counts at surface; d, salinity at surface (×) and at compensation depth (■); e, nutrients: PO_4-P-surface (×) and comp. depth (■), NO_3-N-surface (○) and comp. depth (●); and f, compensation depth]

ranged from 108 to 502 mgC $m^{-2}d^{-1}$ (Fig. 3a). The chl. *a* with a variation of 1·9 to 12·4 mg m^{-2} (Fig. 3b) followed the trend in phytoplankton variation, which ranged between 0·39 and 0·004 million cells/litre (Fig. 3c).

The salinities of surface and subsurface waters did not differ much in June and July but the difference increased in August and September (Fig. 3d). Nitrate concentrations at the 2 depths decreased with reduction in salinity in contrast to phosphate concentration which was highest when salinity was minimum. The values of phosphates and nitrates are shown in Fig. 3e. Compensation depth varied from 1·1 to 2·7 m (Fig. 3f) and was minimum when salinity was lowest.

Correlation between production and the corresponding chl. *a* concentration was 0·7. The range of assimilation number (mg C/mg chl. *a*/hr) for, different per cent illuminations was: 3·2 to 17·2, 1 to 5·8, 0·9 to 5·9 and 0·5 to 8·8 respectively for 100, 50, 30 and 1%.

When the production was compared with the nutrients (NO_3-N and PO_4-P) a very low correlation coefficient (−0·065 and −0·02 respectively) was found in both the cases, showing that production is almost independent of nutrients in monsoon. N: P ratios varied from 0·1:1 to 39:1.

Cumbarjua canal — This narrow canal interconnects the Mandovi and Zuari estuaries. Fig. 4 (a-f) shows the variations in the environmental parameters and associated changes in primary production. The production ranged between 175 and 440 mgC $m^{-2}d^{-1}$ (Fig. 4a). Chl. *a* values followed the trend of production during only first 3

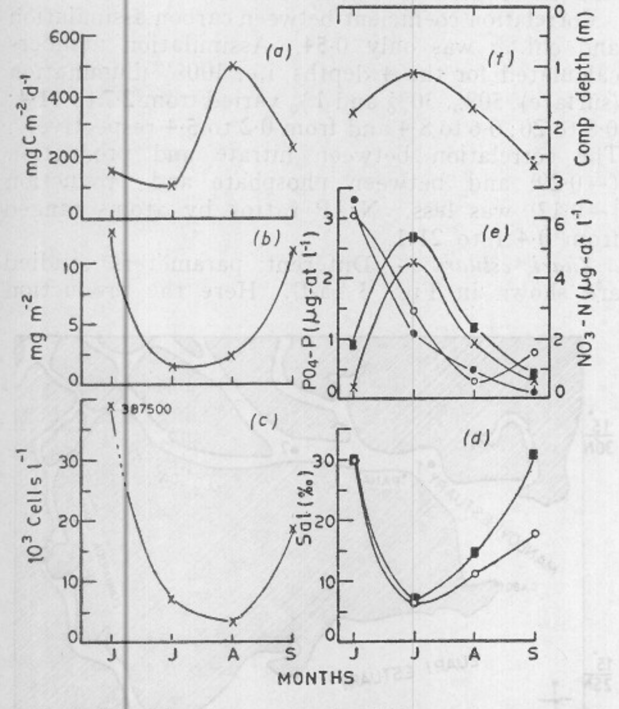

Fig. 3 — Monthly changes in the different parameters in Zuari estuary: a, primary production; b, column chl. *a*; c, phytoplankton cell counts at surface; d, salinity at surface (○) and at compensation depth (■); e, nutrients: PO_4-P-surface (×) and comp. depth (■), NO_3-N-surface (○) and comp. depth (●); and f, compensation depth]

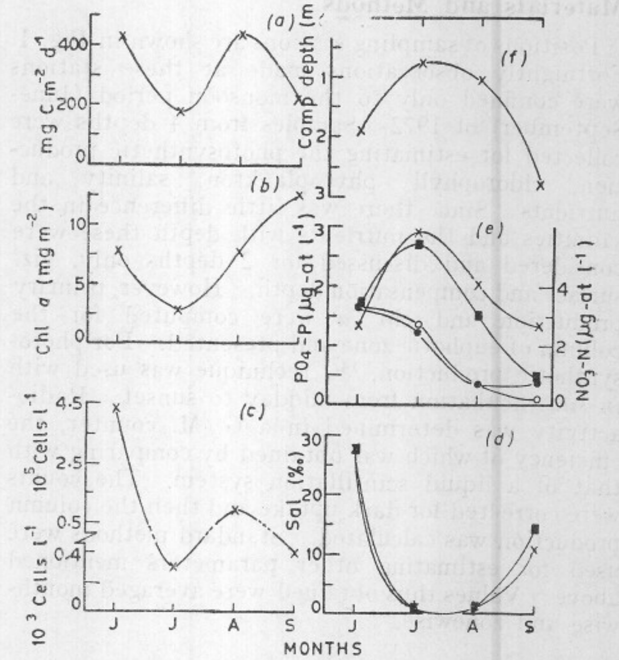

Fig. 4 — Monthly changes in the different parameters in Cumbarjua canal: a, primary production; b, column chl. *a*; c, phytoplankton cell counts at surface; d, salinity at surface (×) and at compensation depth (■); e, nutrients: PO_4-P-surface (×) and comp. depth (■), NO_3-N-surface (○) and comp. depth (●); and f, compensation depth]

months (June to August). It ranged from 2·2 to 12·6 mg m^{-2} during this period (Fig. 4b). Phytoplankton abundance which ranged between 0·43 and 0·04 million cells l^{-1} (Fig. 4c) corresponded with production values. Salinity was lower than that of the 2 other estuaries and the difference between surface and subsurface salinities was negligible (Fig. 4d). Nitrate decreased with lowering of salinity but the trend was reversed in August and September (Fig. 4e). Compensation depth varied from 0·75 to 2·75 m (Fig. 4f) and was found to follow the salinity trend.

Correlation between chl. *a* and production was poor ($r = 0{\cdot}48$). Assimilation number varied considerably at different depths; it varied from 1·8 to 23·2 at surface (100% illumination); 2·6 to 7·5 at 50%; 1·4 to 7·6 at 30% and from 0·23 to 5 at 1% illumination depth.

The correlation between nutrient and production was very poor (0·39 and 0·44 for N and P respectively) but positive. N:P ratios varied between 0·2:1 and 4·5:1.

Discussion

The foregoing results indicated that the 3 sectors of the estuarine system sustain a high production. The maximum average production during the period of study was in Cumbarjua canal (316 mgC $m^{-2}d^{-1}$) followed by Zuari (249) and Mandovi (247). Qasim *et al.*[4] found still higher values of production (515 mgC $m^{-2}d^{-1}$) in the Cochin backwater during monsoon period. These authors attributed high production due to low salinity when the photosynthesis would be maximum and also to the euryhaline nature of the phytoplankton crop prevailing at that time. This reason seems to be applicable for the high production rate in the Cumbarjua canal where the salinity always remains lower than that of the Mandovi and Zuari estuaries. The surface primary production of these estuaries, reported earlier by Dehadrai and Bhargava[3], was much lower than that observed in the present study but the trend was similar. Again when chl. *a* concentration was compared, Cumbarjua canal showed the highest concentration of 7·72 mg m^{-2} while the Mandovi and Zuari exhibited 6·97 and 6·47 mg m^{-2} respectively. These values were more or less in agreement with the trends in production. However, the variations in chl. *a* were much more in Mandovi-Zuari estuarine system than in the Cochin backwater[5] where the surface chl. *a* varied between 2·96 and 7·34 mg m^{-3}. Bhargava and Dwivedi[6] also found maximum values of chl. *a* in the Cumbarjua canal.

A considerable variation in the abundance of phytoplankton was noticed from place to place (Table 1) and the concentration was more in this estuarine complex than in the Coch in backwater[7] where during monsoon it varied from 0·022 to 0·062 million cells/litre.

TABLE 1 — ABUNDANCE OF PHYTOPLANKTON (CELLS/LITRE) AT SURFACE

Region	June	July	August	September
Mandovi	371000	35700	16700	14900
Zuari	387500	7200	3600	18600
C. canal	430000	3000	89400	4000

From depthwise changes in salinity, it is clear that unlike in Cochin backwater, the euphotic zone of Mandovi and Zuari estuaries is well mixed. Salinity was always higher in the Zuari as compared to Mandovi. The distribution of nutrients was influenced by land run off and behaved differently from that in the Cochin backwater. The phosphate values tend to increase with the lowering of salinity while nitrate decrease → a feature, quite different from that of the Cochin backwater. The phosphate concentration was generally higher in Cumbarjua canal but not the nitrate. Correlation coefficient between either of the nutrients (N and P) and production was very low indicating that instantaneous concentration of nutrients is not as important as regeneration rate to affect production. N:P ratios by atoms were found to be highly variable and were never close to the normal ratio of 16:1. Highest ratios (39:1) were found for Zuari followed by Mandovi (21:1) and Cumbarjua canal (4·5:1). In Cochin backwater, this ratio was still higher (99:1)[8].

Penetration of solar radiation as measured by Secchi disc was limited to a narrow zone in this system. The compensation depth never exceeded 3·1 m in any of the places during the observation period. This is very much comparable with that of the Cochin backwater where during monsoon, it varied from 2 to 5 m (ref. 9).

Carbon assimilation to chl. *a* ratio varied with the depth of sampling as well as from place to place. At all the stations the highest assimilation number occurred either at the surface or at the depth having 50% of the incident solar radiation. Considerable variation in assimilation number could probably be attributed to the photosynthetically inactive chlorophyll.

Trophic relationship — Slobodkin[10] defined ecological efficiency as the ratio of yield in one trophic level to the next trophic level. The ratio of production will be an estimate of ecological efficiency only if the yield is a constant fraction of production. Therefore, the ratio of production or transfer coefficient, as Cushing[11] calls it, has been computed. It varied from 1·7 to 39·9%. Unusually high values were rejected. For the entire Indian Ocean the values ranged between 2 and 34%[11]. A plot of transfer coefficient against primary production (Fig. 5) shows that the former decreased with increasing production. The daily ration of zooplankton being equivalent to 1/20th of the body carbon[12,13], their metabolic requirement will be 0·1 to 2·6% of the primary production in Mandovi. In Zuari and Cumbarjua canal, this varied between 0·3 and 7·2% and 0·1 and 0·4% respectively. These values are much less than the values (46-71% of primary production) reported for the Indian Ocean along meridian 110°E[14]. Obviously, there is enough surplus energy at the primary level to be passed on to various channels.

Secondary production — The secondary production has been estimated from the primary production (as 10%) and the zooplankton biomass (volume)

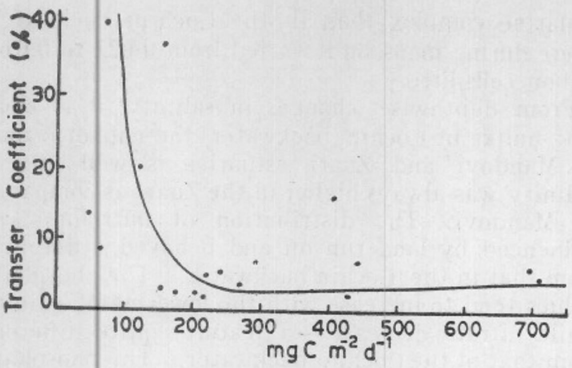

Fig. 5 — Transfer coefficient as a function of production in the estuarine system of Goa

reported by Goswami and Singbal[15]. Since the euphotic zone is well mixed as stated earlier, it can be assumed that zooplankton is uniformly distributed. The column biomass thus calculated was converted into gC by a factor of 0·065 (ref. 16). The generation time was then computed as suggested by Marshall and Orr[17]. Finally, from the biomass and the generation time, the production (mgC $m^{-2}d^{-1}$) was estimated. Its ranges are as below:

	From primary production	From zooplankton biomass
Mandovi	5·9-54·9	3·6-65·9
Zuari	10·8-50·7	5·4-71·0
C. canal	17·6-43·9	5·0-29·5

The secondary production values obtained as mentioned above are comparable between themselves and also with the average production (41 mgC $m^{-2}d^{-1}$) for the entire Indian Ocean during the south-west monsoon[11].

Tertiary production — From the data discussed above, it is possible to estimate the fish yield. The tertiary production was calculated as 1% of the primary production and as 10% of secondary production (both in terms of gC m^{-2}) and then averaged. These values of carbon were then converted into wet weight of fish by using a factor 7·47 (ref. 18). The average tertiary production (wet weight) in this estuarine system during the monsoon thus works out to be 19 mg m^{-2} d^{-1}, an estimate, very close to the average tertiary production for the Indian Ocean (22 mg $m^{-2}d^{-1}$) during the south-west monsoon[11]. However, as these estimates are made assuming that all the energy is passing through the successive food chains, any deviation from this will alter the average yield at the tertiary level.

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