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Seasonal Variations in Secondary Production of the Mandovi-Zuari Estuarine System of Goa

R A SELVAKUMAR, VIJAYALAKSHMI R NAIR & M MADHUPRATAP
National Institute of Oceanography, Dona Paula, Goa 403 004

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Mean rates of secondary production in the Mandovi, Zuari and Cumbarjua canal were 16.9, 35.9 and 32.4 mg C/m^2/day respectively. The general hydrographic conditions of the Zuari were responsible for the higher secondary production. In general, the saline period was more productive (24.9 mg dry wt/m^3/day) compared to the low saline period (11 mg dry wt/m^3/day). The average secondary production in the estuarine system was 21.4 mg dry wt/m^3/day or 1078 tonnes carbon/yr. The coefficient of energy transfer from primary to secondary level was 6.6%. Theoretical estimate of fish biomass in this estuarine system was 1007 tonnes/yr.

The Mandovi and Zuari rivers and the interconnecting Cumbarjua canal form the major estuarine system of Goa. Earlier reports indicate that the primary[1] and benthic[2] productions in the estuary are quite high. Studies on zooplankton from this area[3-7] are limited to the abundance and diversity of different groups. In this communication, an estimate of secondary production of the Mandovi-Zuari system is presented. From the yield ratio of carbon production in the area, a theoretical estimate of fish biomass is also made.

The Mandovi and Zuari rivers open into the Arabian Sea and the Cumbarjua canal connects them at a distance of about 15 and 12 km respectively from the mouths. The width of the Mandovi and Zuari rivers at the mouth region is 3.2 and 4.9 km respectively. The average depth at the midstream of Mandovi is 7 m and that of Zuari 8.5 m. The average rainfall of Goa is about 3000 mm, the major part being contributed by the southwest monsoon during June-September. A large number of tributaries are connected to the Mandovi and consequently the estuary receives a lot more fresh water than the Zuari. The tides in the estuaries are of semi diurnal type with a tidal range of about 2.5 m. Compared to the drastic variations in salinity, fluctuations in temperature and dissolved oxygen are considered unimportant to affect the secondary production of this estuarine system.

Materials and Methods

Fortnightly observations were made from June 1971 to May 1972 at 12 stations in the estuarine system (Fig. 1). The distance from st 1 to st 12 is about 43 km. Most of the collections were made during the high tide. Zooplankton was collected in surface tows lasting 5 min using a HT net (mouth area 0.25 m^2 and mesh size 0.3 mm) with a flow meter attached. Surface water samples were collected for determining salinity. Dry weight of samples was determined after removing larger organisms. A factor of 33.1% of dry weight estimated as the organic carbon content of estuarine zooplankton[8] was used to compute the secondary production in terms of carbon. Although collections were made fortnightly it was assumed that this represented the secondary production for the period to convert it to daily production[9].

Depending on the salinity regime in this estuarine habitat, mid-June to mid-September was considered as the low saline period and mid-September to mid-June as the saline period. Rates of secondary production were estimated separately for saline and low saline periods and also for different regions in the system.

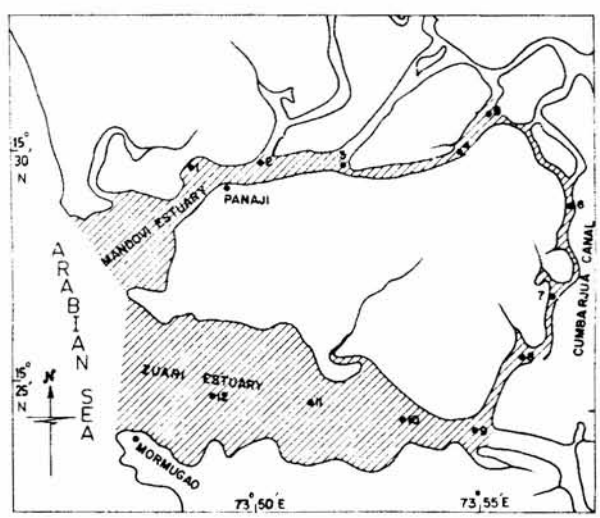

Fig. 1—Location of stations [Secondary production was estimated for the hatched area]

Results and Discussion

Salinity—The estuary becomes seawater dominated during the summer months (April/May) resulting in high salinity ($>35^{o}/_{oo}$ except at sts 4 and 5) whereas it becomes freshwater dominated during the monsoon (Fig. 2). A salinity gradient along the longitudinal axis decreasing from mouth to the head of the estuaries occurred even during the high saline period. With the onset of southwest monsoon in mid-June, salinity gets reduced drastically ($<0.35^{o}/_{oo}$) in the interior stations (3-8). At stations located towards the mouths salinity values were slightly higher during the monsoon period owing to their proximity to the sea, the lowest values observed in July from Mandovi and Zuari were $0.93^{o}/_{oo}$ and $4.27^{o}/_{oo}$ respectively. In general, the Zuari estuary showed relatively higher salinity than the Mandovi estuary, probably because of the greater tidal influence, larger opening at the mouth and lesser riverine discharge. It was reported[10] that due to the influence of Zuari estuary, salinity value in the Cumbarjua canal was higher than the interior parts of Mandovi during high saline period and the present study also confirms this observation.

Zooplankton production—The changes in the hydrographical conditions of this estuarine system directly influenced the zooplankton abundance. Zooplankton biomass was low in the estuarine system during the low saline period. High salinity period sustained relatively higher amount of zooplankton. Seasonal variations in the secondary production of the Mandovi-Zuari-Cumbarjua estuarine system are given in Tables 1 and 2. Mean production in the Mandovi was estimated as 12.8 mg dry wt/m^3/day. Stations located near the mouth of Mandovi had higher zooplankton biomass during the low saline period than the interior stations (Table 1). However, during the saline period the interior stations sustained higher production probably because these areas provide a stabler environment compared to turbulent conditions prevailing near the mouth.

The Cumbarjua canal had a production rate comparable to that of the Mandovi during the low saline period. During the saline season, the average production from this area was 29.4 mg dry wt/m^3/day, the highest for the estuarine system. Mean zooplankton production in the canal was 23.3 mg dry wt/m^3/day.

The Zuari estuary sustained a higher yearly mean production rate compared to the Mandovi and Cumbarjua canal (Table 2; Fig. 3). Average zooplankton biomass at different stations indicated that higher values were confined to sts 9-12 due to general conditions of higher salinity prevailing in this estuary. Thus, the Zuari showed highest production (Table 1) for the low saline period compared to the other regions.

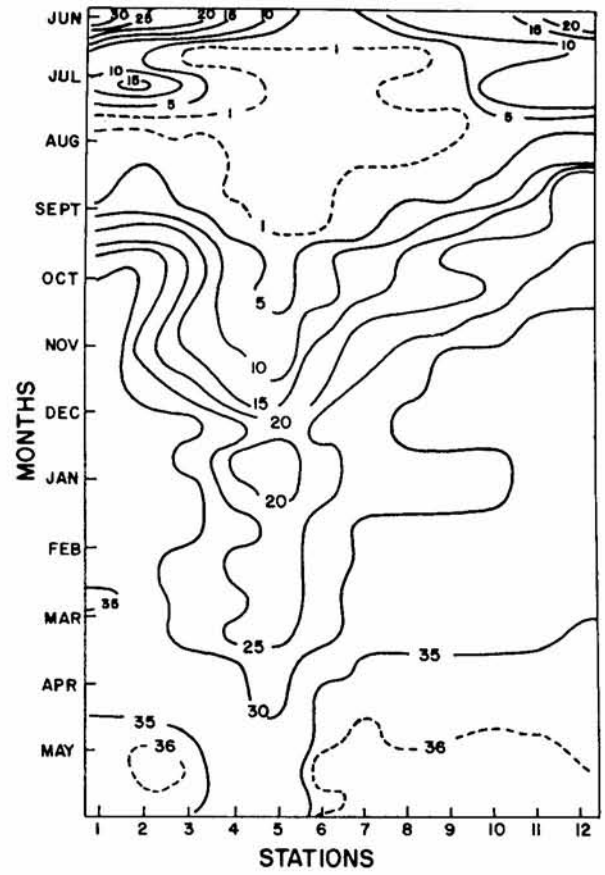

Fig. 2—Distribution of salinity ($^{o}/_{oo}$) in the surface waters of Mandovi-Zuari estuarine system during June 1971 to May 1972

Table 1—Secondary Production (mg dry wt/m^3/day) at Different Locations during Low Saline and Saline Periods

Region	Low saline	Saline
Mouth of Mandovi (sts 1 & 2)	5.8	13.5
Interior part of Mandovi (sts 3, 4 & 5)	3.3	24.2
Mouth of Zuari (sts 11 & 12)	14.6	29.7
Interior part of Zuari (sts 9 & 10)	11.3	24.5

Table 2—Secondary Production (mg dry wt/m^3/day) in the Mandovi-Zuari Estuarine System during Low Saline and Saline periods

Period	Region			
	Mandovi	Cumbarjua canal	Zuari	Entire system
Low saline	5.3	5.3	14	11
Saline	15.3	29.4	28.8	24.9
Whole year	12.8	23.3	25.1	21.4

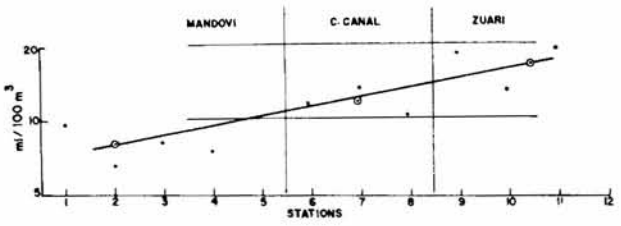

Fig. 3—Average values of zooplankton displacement volume (ml/100 m^3) obtained from different stations in the Mandovi-Zuari estuarine system during June 1971 to May 1972

Further, the difference in production between lower and upper reaches during the saline as well as low saline periods was not very pronounced.

Biomass obtained from the entire system over the seasons ranged from 0.3 to 158 mg dry wt/m^3. The average production in the estuarine system (Fig. 1) with an approximate area of 92 km^2 was 21.4 mg dry wt/m^3/day which is less than the figure (31.8 mg dry wt/m^3/day) reported[9] for Cochin backwaters. The mean column production of zooplankton, computed from the column depths of stations, for Mandovi, Zuari and Cumbarjua canal were 16.9, 35.9 and 32.4 mg C/m^2/day, respectively. The average rate of secondary production for the entire system was 29.6 mg C/m^2/day. These values fell within the ranges estimated earlier[1] for zooplankton production in the system.

Production at different trophic levels—The estimated production at different trophic levels for the entire estuarine system is presented in Table 3. The total primary production in the system was estimated as 16388 tonnes carbon from a mean net production rate of 485.97 mg C/m^2/day[11]. The yearly secondary production was estimated to be 1078 tonnes carbon. The tertiary production of plankton eating fishes was averaged from 1% of primary production and 10% of secondary production and raising the figures by a factor of 7.41 given by Vinogradov[12] to obtain the wet weight of fish. The theoretical estimate of fish yield was 1007 tonnes per year.

The coefficient for energy transfer from primary to secondary level in the system was 6.6% (Table 3). The transfer coefficient of 2.7% for Cochin backwaters[9] would become 7.4% if the carbon content for zooplankton was raised to 33.1% of dry weight used in the present study and this fairly agrees with the coefficient obtained. This also compares well with the average consumption rate of phytoplankton by zooplankton (7%), given by Qasim[13] for the Mandovi-Zuari estuarine complex.

Table 3—Production at Different Trophic Levels in the Mandovi-Zuari Estuarine System

Area (km^2)	92.14
Primary production (tonnes carbon/yr)	16388
Secondary production (tonnes dry wt/yr)	3257
Secondary production (tonnes carbon/yr)	1078
Transfer coefficient (%)	6.6
Tertiary production (based on primary production)	1215
Tertiary production (based on secondary production)	799
Mean tertiary production	1007

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