

CONTRIBUTION OF PHYTOPLANKTON PHOTOSYNTHESIS TO A MANGROVE ECOSYSTEM

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ABSTRACT

Primary production in a fringing mangrove ecosystem was measured using two techniques. The first estimated gross oxygen production and community metabolism based on the diel difference in dissolved oxygen concentrations. The second estimated carbon assimilation in the water column. The difference between the two results has been taken as the contribution of benthic microalgae and bacterial chemo- and photosynthesis to primary production in the environment.

There is no apparent causal relationship between phytoplankton biomass and either benthic animal populations or edible fish catch in the area. Phytoplankton activity appears to be of marginal importance in this environment.

Detritus contribution of mangrove leaves to the water column and sediment of this region is considerable. If smaller tidal estuaries such as the Galjibag are bunded, they will prove very useful for the aquaculture of deposit feeders.

INTRODUCTION

A variety of techniques have been used to assess aquatic primary production in mangrove ecosystem (Teixeira, Tundisi and Santoro Yeaza, 1969; Krishnamurty, Sundararaj and Santhenam, 1975) and fairly high values for such production have been reported. The estimation of the oxygen metabolism of a community (Odum, 1956) has the advantage that it takes cognizance of benthic algal primary producers in the system. In a plankton dominated environment, Odum and Hoskin (1958) have found that gross production calculated from free dissolved oxygen is comparable to results from simultaneous measurements using the conventional light and dark bottle technique. Untawale, Balasubramanian and Wafar (1977) have concluded that although the two sets of data are not directly comparable, an assessment of the community metabolism of oxygen is more useful in determining the ecology of a mangrove aquatic system than the measurement of CO_2 assimilation into particulate matter alone.

However, bacterial photosynthetic and chemosynthetic fixation of CO_2 cannot be assessed using oxygen-based techniques and it is likely that bacterial biomass is an important component in detritus-rich ecosystems like the mangroves.

Furthermore, studies on particulate fixation underestimate total CO_2 assimilation to the extent that extracellular production occurs. It has been earlier reported (Pant, Balasubramanian, Rajegopal, Wafar and Vijayaraghavan, 1977) that upto 60% of recent photosynthate may be lost by algae in tropical environments due to the excretion of metabolites. Thus the measurement of total CO_2 assimilation, *i.e.*,

particulate plus extracellular production may give a more realistic estimate of primary production in the water column.

Description of area

The area chosen for the study was the Galjibag estuary, Mashe, South Goa. This tidal estuary widens into a backwater a little upstream of its mouth (Fig. 1). The stream has a bund about 3 km from its mouth to provide freshwater to nearby fields. The influence of the sea, therefore, penetrates 3 km inland and in the area of sampling the conditions were more marine than estuarine. Three species of mangroves, namely *Rhizophora mucronata*, *R. apiculata* and *Avicennia officinalis* line the banks of the estuary almost upto the bund. Although the water column is influenced by the mangrove community, the water surface is fairly open. There are no seaweed communities in the area. The total surface area of the creek from the mouth to the bund is about 4.3 km². The average depth of the area is 1.5 m. The maximum tidal range in the area was 1 m during the three diurnal measurements.

Earlier investigations (Table II) show that the main phytoplankton pulse in these waters occurs in February followed by a decline in biomass in the pre-monsoon month of May. Minimum phytoplankton biomass values, however, were found in August which is also the period of low salinity. Generally, the dominant organisms are diatoms although flagellates are also present.

Thus a series of experiments was conducted to estimate the importance of the contribution of phytoplankton and benthic algal communities to production in a mangrove ecosystem in relation to benthic animal populations and fish production in the area.

MATERIAL AND METHODS

Three diurnal measurements were made at stations in the open backwaters of the Galjibag estuary in May and August 1975 and February 1976. During the course

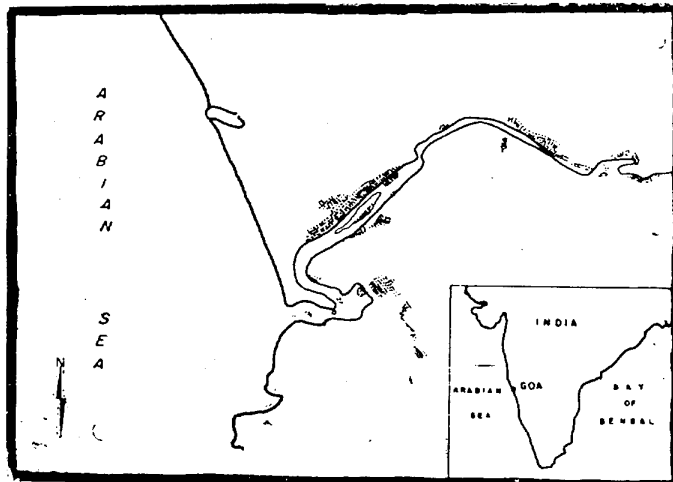


Fig. 1. The Galjibag creek. Mangrove area is stippled.

of each 30-hour diurnal, oxygen, salinity and alkalinity were estimated titrimetrically (Strickland and Parsons, 1968) every two hours. All estimations were made in triplicate. Community oxygen metabolism was calculated according to Owens (1974).

Particulate fixation and extracellular production were estimated on samples taken every 4 hours. After inoculation with $4 \mu\text{Ci NaH}^{14}\text{CO}_3$, the samples were incubated *in situ* for 6 hours. These estimations were done in duplicate. Further analysis was done using standard methods given elsewhere (Pant, Balasubramanian, Rajagopal-Wafar and Vijayaraghavan, 1977). Results are presented as production per day.

Phytoplankton cell counts were taken from duplicate water samples collected every 4 hours. Cell counts were made on settled aliquots.

Sub-surface water samples collected in sterile glass tubes were inoculated into 125 ml each of medium A and B (Table I) in aliquots of 0.1, 0.5 and 1 ml for bacterial investigations. The cultures were incubated at room temperature in the dark on a mechanical shaker. Stepwise dilutions with modified Winogradsky medium (Rodina, 1972) were made on repeated subculturing. Artificial seawater was used for all dilutions (Table I). The bacterial culture was maintained in a liquid medium at a pH of 8, under aerobic conditions, with a bicarbonate concentration of 0.5 g l^{-1} .

Growth of stage I and II nitrifiers was checked by the appearance of colour on the addition of appropriate reagents (Rodina, 1972) with visual comparison between cultures and controls. Both appearance of the product and disappearance of the substrate were estimated. Microscopic examination confirmed the presence of gram negative bacteria although the species have not been identified.

Bacterial CO_2 fixation was estimated using standard radioactive procedures except that all incubations were in the dark for 3 hours.

Samples were filtered for particulate oxidizable organic carbon every 4 hours on pre-fired GF/C filters. Chlorophyll *a* and particulate organic carbon were determined spectrophotometrically. The filtered water samples were analysed for $\text{PO}_4\text{-P}$, $\text{NO}_3\text{-N}$, $\text{NO}_2\text{-N}$ and pH by standard methods (Strickland and Parsons, 1968).

Table 1. Media for bacterial growth studies. Modified Winogradsky medium was made with artificial sea water. Samples kept in the dark, under aerobic conditions, at room temperature.

Salt	Winogradsky NH_4 medium A (grams per litre)	Winogradsky NO_2 medium B (grams per litre)	Arti- ficial seawater	Salt	Winogradsky NH_4 medium A (grams per litre)	Winogradsky NO_2 medium B (grams per litre)	Arti- ficial seawater
NaCl	—	—	29.518	$(\text{NH}_4)_2\text{SO}_4$	2.0	—	—
MgCl_2	—	—	2.447	K_2HPO_4	1.0	0.5	—
MgSO_4	—	—	3.305	$\text{MgSO}_4 \cdot 2\text{H}_2\text{O}$	trace	0.3	—
CaCl_2	—	—	1.141	$\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$	trace	0.4	—
KCl	—	—	0.725	NaNO_2	—	1.0	—
Na_2CO_3	2.0	2.0	2.0	Distilled water	—	—	1000.0 ml
NaBr	—	—	0.083	Artificial seawater	1000 ml	1000 ml	—
					pH adjusted to 8.0		

Benthos was sampled with a quadrant of 0.1 m² area to depth of 15 cm. Samples were collected every three hours in triplicate over a period of 24 hours. Sediment was analysed following the procedure by Parulekar and Dwivedi (1974).

Fish landing data have been taken from the published report of the Directorate of Fisheries, Goa.

RESULTS

The results for the three diurnal studies are more conveniently discussed as a series starting in February and ending in August on the basis of the data collected earlier and given in Table II. Experiments in May 1976 (Table III) show that phytoplankton biomass was lower in this month than in February 1976, thus maintaining the trend of previous years.

Diurnal variations in salinity, temperature, PO₄-P and NO₃-N data are given in Table II. Nutrient values were lowest in August and highest in May. Salinity and temperature did not vary markedly from the corresponding monthly averages of previous years. There was no significant correlation for any of the 4 variables with either ebb or flood of the tide.

Phytoplankton pulses in this locality were mainly composed of either diatoms or flagellates (Table III). In February 1974, for example, the bloom was composed principally of *Navicula* sp. whereas in the following month the principal component was a cryptophycean, *Cryptochrysis* sp. A computation of Heip's Evenness Index (Heip, 1974) for February 1976 (Table III) on the other hand, shows that although cell counts are high, no single species dominated the environment. *Navicula* spp., *Nitzschia* spp. and several flagellate species were found in the samples. The variation of phytoplankton cell counts over the diurnal or tidal cycles was not statistically significant.

Table II. Seasonal data from the Galjibag environment in the years 1973-74. Values are averaged from fortnightly observations.

Month/year of sampling	Temperature °C	O ₂ ml/l	Salinity ‰	PO ₄ -P µg-at	NO ₃ -N per litre	Cell counts m ⁻²
Oct. 1973	29.5	3.7	20.0	0.3	0.3	3.6 × 10 ⁷
Nov. 1973	29.2	3.7	—	1.5	1.1	5.0 × 10 ⁷
Dec. 1973	28.3	5.0	34.0	0.53	1.1	6.5 × 10 ⁷
Jan. 1974	27.0	5.1	33.0	—	—	1.0 × 10 ⁷
Feb. 1974	28.0	4.0	33.0	0.7	1.05	8.1 × 10 ⁹
Mar. 1974	30.3	4.6	34.0	0.6	0.2	4.0 × 10 ⁸
May 1974	30.0	2.0	35.5	—	—	2.4 × 10 ⁷
July 1974	27.0	4.6	4.0	—	—	1.1 × 10 ⁷
Aug. 1974	27.0	5.3	2.0	—	—	0.31 × 10 ⁵
Sept. 1974	26.0	5.4	5.0	—	—	1.5 × 10 ⁸
Oct. 1974	27.0	5.6	21.0	—	—	3.0 × 10 ⁸
*Feb. 1976	26.6 ± 1.4	—	31.0	1.7	1.2	—
*May 1975	28.5 ± 1.5	—	35.0	1.3	1.6	—
*Aug. 1975	26.7 ± 0.7	—	4.0	0.8	2.5	—

* Present series

Fig. 2 and Table III present data for the community oxygen budget in February and May. Gross oxygen production was $2.06 \text{ g m}^{-2} \text{ day}^{-1}$ in February and $0.8 \text{ g m}^{-2} \text{ day}^{-1}$ in May. In August water was supersaturated with oxygen over the entire 30-hour period and it was not possible to estimate community metabolism. Hence results are not discussed further.

Estimates of total carbon dioxide assimilation (Table III) in the water column show that production in February is high with a value of $1.64 \text{ gC m}^{-2} \text{ day}^{-1}$ and low in August, $0.21 \text{ gC m}^{-2} \text{ day}^{-1}$. Extracellular production shows a marked increase in August concomitant with decreased carbon assimilation in this month. Fig. 3 presents data showing diel variations in carbon dioxide assimilation and extracellular production in February 1976. These variations are typical of the data obtained in all the three diurnals although values in May and August are lower (Table III).

Bacterial CO_2 assimilation data on stage I and II nitrifiers in laboratory cultures are given in Table IV. Particulate fixation in these cultures was quite high, as is expected, and there was no extracellular production.

Benthic animal population data are given in Table V. The null hypothesis that there is no significant difference in the total biomass of the benthic community between the 3 diurnals was tested by analysis of variance and the hypothesis was accepted. The average total biomass of the benthic animal population was 29.07 g m^{-2} wet weight. The dominant species was the detritophagus *Cerithidia fluviatilis* on the basis of both biomass and number of organisms. Polychaetes were consistently present although never in very high numbers.

DISCUSSION

Gross photosynthetic production of oxygen in this community was much lower than an earlier reported value of $7.06 \text{ g m}^{-2} \text{ day}^{-1}$ in the Pichavaram mangroves (Krishnamurty, Sundararaj and Santhanam 1975). However, the value of $2.06 \text{ g m}^{-2} \text{ day}^{-1}$ in February (Table III) is comparable to a production between 2 to $3 \text{ g m}^{-2} \text{ day}^{-1}$ reported for the Cundapoor swamps by Untawale, Balasubramanian and Wafar (1977) at the same time of year.

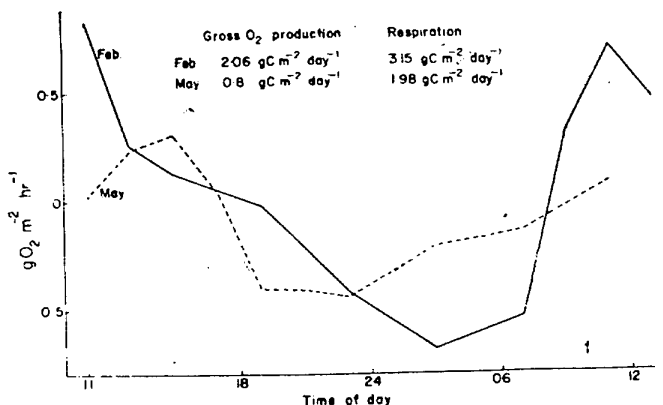


Fig. 2. Community oxygen budget in February and May.

The maxima in oxygen production during each diurnal coincided with the flood tide both in February and May (Fig. 2). These maxima are probably due to benthic microalgal organisms which photosynthesize at low tide and enrich the oxygen concentration of the flood waters. Untawale (unpublished) has identified *Pleurosigma* sp., *Gyrosigama* sp. and several species *Navicula* in the intertidal mud of the Galjibag river, and a tide-related vertical migration and consequent photosynthesis by benthic microalgae has been shown earlier by Palmer and Round (1965).

The maxima in both high gross production in the community and particulate carbon dioxide assimilation can be correlated to the peak in phytoplankton populations in February 1976 (Table III). Low particulate fixation in August is probably due to limiting light intensities and high turbidity during this monsoon month.

Diel variations in carbon dioxide fixation (Fig. 3) correlate with the amount of light available for the photosynthesizing organisms. There is no apparent tidal effect superimposed on the basic diel pattern. This is not surprising as neither phytoplankton populations nor nutrient values show a significant variation with the tide.

Extracellular production (Fig. 3) was generally higher when particulate fixation was high during the day. When expressed as a percent of total CO_2 fixed, extracellular production per day (Table III) was higher in May (20%) than in either of the other two months (February 7% and August 9%). The higher value in May was probably due to the effect of high light intensity and higher water temperature (Table II) on phytoplankton photosynthesis at this time of year.

In the Cundapoor swamps, Untawale, Balasubramanian and Wafar (1977) found a difference of more than $1 \text{ g m}^{-2} \text{ day}^{-1}$ between gross oxygen production and particulate carbon fixation. At the same time of year, in the Galjibag area, the difference in total carbon dioxide assimilation and gross production was about $0.4 \text{ g m}^{-2} \text{ day}^{-1}$ (February, Table III) and extracellular production appears to be one of the factors contributing to a better agreement between the two estimates of primary productivity. However, since the two estimates of productivity do not necessarily measure the activity of similar organisms in the ecosystem, this agreement between the results may be coincidental.

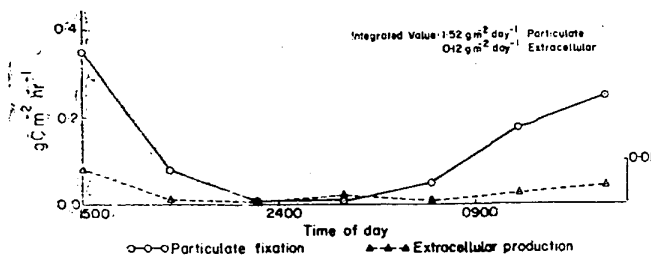


Fig. 3. Light bottle particulate fixation and extracellular production for February 1976. Light bottle values have not been corrected for dark uptake. Dark uptake of CO_2 (not shown in Figure) is $0.11 \text{ g C m}^{-2} \text{ day}^{-1}$.

The presence of chemosynthetic CO_2 assimilating bacteria (Table IV) in the water column suggests that particulate fixation is partly a consequence of bacterial organisms in this environment.

Although the actual contribution of these organisms to this ecosystem is yet to be determined, dark uptake of CO_2 which at 17% of light particulate uptake is highest in May (Table III), could be a consequence of chemoautotrophic bacterial activity. Dark uptake was lowest in February (7% of light uptake) when phytoplankton counts are maximum in the water column. In the Cundapoor swamps (Untawale, Balasubramanian and Wafar, 1977) dark uptake was about 28% of light particulate fixation.

Production to biomass ratios calculated on the basis of CO_2 uptake and phytoplankton cell counts show a significantly larger production per cell in May in the water column (Table III). This is inspite of the lower total particulate fixation in this month as compared to the February values. However, total bacterial counts are higher in the month of May in environments similar to Galjibag (Matondkar, Mahtani and Mavinkurve, 1978) and it is possible that the high ratios of particulate fixation per cell at this time are misleading to the extent that both bacterial chemosynthesis and photosynthesis occur in the water column.

In addition to chemoautotrophic organisms in the water, several forms of purple sulphur, non-sulphur and green photosynthetic bacteria have been isolated from sediment samples of mangrove environments (Aguiar and D'Souza, 1978). It appears, therefore, that results from the two estimates of primary productivity in this environment measure the activity of phytoplankton plus bacteria in the water column on the one hand and phytoplankton plus benthic microalgae in the community on the other.

P/R ratios calculated on the basis of gross oxygen production and community respiration (Table III), which would necessarily refer only to plant photosynthesis in this environment, were 0.65 in February and 0.42 in May. The ratio was less than 1 even when phytoplankton biomass and, presumably, activity was at its peak in February. Since there is no growth of macroscopic seaweeds during any part of the year in this region, it is likely that the community is 'heterotrophic' (Odum, 1956) throughout the year. This suggests that algae, both planktonic and benthic, form a minor subset of the aquatic part of the Galjibag mangrove ecosystem.

The average value for chl *a* from samples taken during the February 1976 diurnal study is 2.1 mgm^{-3} . Using a ratio of 1:50: : chl *a*: phytoplankton organic carbon (Strickland, 1960) the average carbon equivalent weight of phytoplankton was about 100 mgC m^{-3} a time high standing stock of these organisms. In comparison to this,

Table IV. Chemoautotrophic uptake of $^{14}\text{CO}_2$ by bacteria in the dark. There was no extracellular production. Details of media used are given in Table I.

Sample	Particulate fixation $\text{gC m}^{-3}\text{hr}^{-1}$
NH_4-NO_2	1.5
NH_4-NO_2	1.5
NO_2-NO_3	1.1
NO_2-NO_3	0.4

Table III Primary productivity and related data. The Evenness Index (E.I.) has been calculated according to Heip (1974). Selected earlier data has been included for easier comparison with the present series. Oxygen production and respiration have been converted into the carbon equivalent weights.

Month/year of sampling	Cell counts per m ²	Primary production gC m ⁻² day ⁻¹				Respiration	Production/Biomass C cell ⁻¹ day ⁻¹ 14CO ₂ uptake	Particulate organic carbon m ⁻³	Evenness Index and dominant organisms
		Particulate	Extra-cellular	Dark	Gross oxygen				
Jan. 1974	1.0 × 10 ⁷	0.35	—	—	—	—	35.0	—	0.82; none
Feb. 1974	8.1 × 10 ⁹	1.54	—	—	—	—	0.19	—	0.16; <i>Navicula</i> spp.
Mar. 1974	4.0 × 10 ⁸	0.87	—	—	—	—	2.2	—	0.03; <i>Flagellates</i> > 10μ
Feb. 1975	5.6 × 10 ⁸	—	—	—	—	—	—	—	0.5; none
*Feb. 1976	11.1 × 10 ⁹	1.52	0.12	0.11	2.06	3.15	0.14	1.5	0.5; none
*May 1975	1.4 × 10 ⁷	0.4	0.1	0.07	0.8	1.98	35.7	1.0	0.8; none
*Aug. 1975	3.8 × 10 ⁸	0.19	0.02	0.02	—	—	0.55	2.9	0.89; none
May 1976	1.0 × 10 ⁷	0.25	—	—	—	—	25.0	—	0.52; none

*Present study

Table V. Wet weights of benthic animal population. Dominant species was *Cerithidia fluviatilis* in all the samples.

Time/month of sampling	1100	1500	1900	2300	0300	0700	1100	Average ± standard deviations	Dominant organism and percent composition
May 1976	0.35	22.82	12.80	11.76	32.42	26.78	0.01	15.28 ± 12	<i>C. fluviatilis</i> 97.1%
Feb. 1975	2.07	13.70	0.31	46.93	129.62	1.45	1.72	27.97 ± 47	" 88.05%
Aug. 1975	23.02	32.78	1.62	9.77	23.63	0.32	0.77	13.13 ± 13	" 94.2%

Source of variation	df	MSS	Variance ratio
Months	2	450.34	0.681
Time of day	6	1299.94	1.965
Error	12	661.41	—

particulate oxidizable carbon in the water column varied from 1.5 to 3 gC m⁻³ in the 3 diurnals (Table III). It would not be surprising, therefore, if phytoplankton *per se* contributed marginally to the system in terms of utilizable biomass.

Benthic animal populations (Table V) in this heterotrophic community show no significant differences between the months. The average value for total wet weight is 29.06 g m⁻². Besides the detritivorous *Cerithidia fluviatilis*, which is the dominant organism, *Maya* spp. and *Uca annulepes* are also consistently present in the samples. The edible oyster, *Crassostrea cucullata*, is found in the area although in small numbers. There is no statistically significant correlation between phytoplankton biomass and benthic animals and a causal relationship between them is unlikely.

Estimates of leaf fall rates show that about 40g of leaf material is added per square metre every 24 hours in this region (Untawale, unpublished). The wooded area lining the Galjibag creek (Fig. 1) is about 0.195 km². Thus approximately 2.8 metric tonnes of leaf material is added to the water every year. In addition to this, terrigenous sources also contribute to organic and inorganic detritus in the environment.

On an areawise basis, the 4.4 metric tonnes of edible fish catch landed in this region in the year 1974 (Goa Fisheries Department statistics) represents about 3.28×10^2 gC m⁻² year⁻¹. Assuming an ecological efficiency of 10% (Slobodkin, 1962) it is quite clear that production at the primary trophic level is insufficient to support even the herbivore level. Most of the edible catch found in this locality, such as *Mugil cephalus*, *Sillago sihama*, *Etroplus suratensis*, *Gerressetifer* and *Plotossus* sp. are tertiary or deposit feeders. Therefore, detritus, and bacteria associated with it, probably provide the most important nutritional source to detritivorous species.

Although more experimental studies are necessary to draw definitive conclusions, areas such as the Galjibag estuary are potentially useful for the culture of deposit feeders. Bunding of such estuaries would decrease the loss of detritus from these systems to the sea. Proper management could result in good and sustainable yields of cultured stock in the locality.

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REFERENCES

- Aguiar, A. and J. D'Souza, 1978. Studies on photosynthetic bacteria: II. Studies on chlorophyll and growth in *Chlorobion limicola* and *C. thiosulphatophilum*. *Manasagar-Bulletin of the National Institute of Oceanography*, 11: 29-34.
- Heip, C. 1974. A new index measuring evenness. *Journal of Marine Biological Association*, U.K., 54: 555-557.
- Krishnamurty, K., V. Sundararaj and R. Santhanam, 1975. Aspects of an Indian Mangrove. In: *Proceedings of the International Symposium on Biology and Management of Mangroves*, edited by G. Walsh, S. Snedekar and H. Teas, 1: 88-95.
- Matondkar, S G P., S Mahtani and S. Mavinkurve, 1978. Seasonal variations in bacterial and fungal counts in mangrove swamps. In: *19th Annual Meeting of Association of Microbiologists of India*, Baroda (Abstract only).

- Odum, H. T., 1956. Primary production in flowing waters. *Limnology Oceanography*, **1**: 102-117.
- Odum, H.T. and C.M. Hoskin, 1958. Comparative studies on the metabolism of marine waters. *Publication Institute Marine Science University, Texas*, **5**: 16-46.
- Owens, M., 1974. Methods for measuring production in running waters. In: *Primary Production in Aquatic Environment*, edited by R.A. Vollenweider, *IBP Handbook* (IIInd edition) **12**: 111-118.
- Palmer, I.D. and F.E. Round, 1965. Persistent vertical migration rhythms in benthic microflora: I. The effect of light and temperature on the rhythmic behaviour of *Euglena obtusa*. *Journal of Marine Biological Association, U.K.*, **45**: 567.
- Pant, A., T. Balasubramanian, M.D. Rajagopal, M.V.M. Wafar and Sumitra Vijayaraghavan, 1977. Contribution of extra-cellular production by nannoplankton to $^{14}\text{CO}_2$ fixation in a tropical estuary. *Indian Journal of Marine Sciences*, **6**: 147-150.
- Parulekar, A.H. and S.N. Dwivedi, 1974. Benthic studies in Goa estuaries: I. Standing crop and faunal composition in relation to bottom salinity distribution and substratum characteristics in the estuary of Mandovi river. *Indian Journal of Marine Science*, **3**: 41-45.
- Rodina, A. G., 1972. *Methods in Aquatic Microbiology*. Translated, edited and revised by R. R. Colwell and M. S. Zarubruhi, Univ. Park Press, Baltimore, 461 pp.
- Slobodkin, L.B., 1962. *Growth and Regulation of Animal Populations*. N.Y. Holt Reinhart Winston, 184 pp.
- Strickland, J.D.H., 1960. Measuring the production of marine phytoplankton. *Bulletin Fisheries Research Board of Canada*, **122**: 172 pp.
- Strickland, J.D.H. and T.R. Parsons, 1968. *A Practical Handbook of Seawater Analysis*. *Bulletin Fisheries Research Board of Canada*, **167**: 311 pp.
- Teixeira, C., J. Tundisi and Santoro Yeaza, 1969. Plankton studies in a mangrove environment: VI. Primary production, zooplankton standing stock and some environmental factors. *International Revue gesamtender Hydrobiologia*, **54**: 289-301.
- Untawale, A.G., T. Balasubramanian and M.V.M. Wafar, 1977. Structure and production in a detritus rich estuarine mangrove swamp. *Mahasagar-Bulletin of the National Institute of Oceanography*, **10**: 173-177.