

Some problems related to the food chain in a tropical estuary

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ABSTRACT. An annual cycle of gross and net primary production was determined for the Cochin Backwater (a tropical estuary) along with phytoplankton and zooplankton crops. It then appeared that the bloom of phytoplankton and growth of zooplankton were somewhat out of phase. Throughout the year the phytoplankton production far exceeded the rate of consumption by the zooplankton herbivores.

If it is assumed that most of the organic material which is produced in an ecosystem is likely to be consumed by the animal communities, then there is every possibility that the production of large quantities of surplus food may lead to several "alternate pathways" in the food chain of the estuary. Some of these have been shown and discussed. The precise nutritive requirement, however, of any species or group is not yet known.

INTRODUCTION

The backwaters of Kerala (India) include a chain of shallow, brackish water lagoons and swamps of the tropical zone. These are hundreds of miles long and are located along lat. $9^{\circ}58'N$ and long. $76^{\circ}15'E$. The northern part of the backwaters, adjacent to Cochin Harbour, is called the "Cochin Backwater". It has a permanent connection with the Arabian Sea which forms the main entrance to the Cochin Harbour. This region is subjected to regular tidal influence and has all the characteristics of a typical estuary.

In recent years the Cochin Backwater has been a centre of intensive studies on the hydrography and primary productivity. The following account of the food chain formed part of a more detailed investigation carried out recently on the organic production of this estuary (Qasim *et al.*, 1969).

METHODS

Fig. 1 shows the stations in the estuary from where sub-surface tows of

phytoplankton (with no. 25 net) and zooplankton (with no. 3 net) were made throughout the year. Measurements of primary production were carried out at station 2 by using oxygen and ^{14}C methods. All experiments dealing with the rate of photosynthesis were conducted *in situ* throughout the year, at different depths of the euphotic zone, which was predetermined from the compensation depth as 1% of incident illumination.

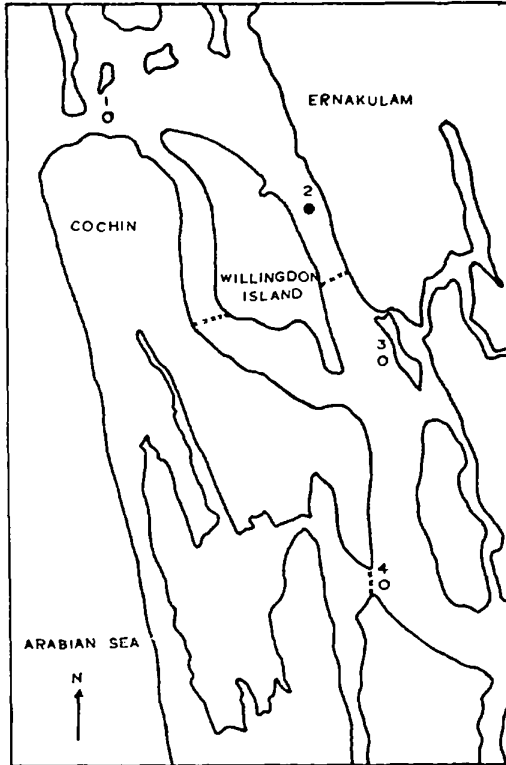


Fig. 1. Map showing a portion of the Cochin Backwater and the stations from where data on phytoplankton and zooplankton crops were obtained. Closed circle indicates station 2 where measurements on primary production were made.

The phytoplankton crop was estimated by taking settled volume and the zooplankton crop by taking displacement volume of the total organisms in relation to the volume of water filtered by the nets. Other parts of the same programme included studies on the microbial flora, fish and benthos.

Gross production was estimated by the oxygen method while the ^{14}C assimilation was taken as the net production. The average value of respiration from the oxygen decrease in the dark bottle during light-dark bottle experiments was taken as the respiratory loss which probably gave rise to the

difference between gross and net production. This was done on the assumption that the rate of respiration occurring in the dark is the same as that during the corresponding periods of light in conjunction with photosynthesis. A further assumption that the rate of respiration remains constant throughout day and night made it possible to estimate the 24 hr (daily) net-production, after subtracting the respiratory loss occurring during the night from the daytime production. This 24 hr net production was taken to be the potential source of organic matter which is transferred to the next trophic level and has been mentioned here as the basic food.

RESULTS AND DISCUSSION

Seasonal changes in the column production (gross and net) have been shown in Fig. 2, together with the average respiration for the euphotic zone. As can

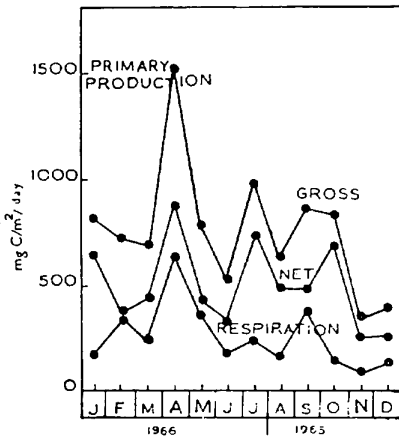


Fig. 2. Annual cycle of gross and net primary production in the Cochin Backwater together with the seasonal changes in community respiration. The values of production and respiration refer to euphotic zone.

be seen from the figure, although the annual cycle of primary production forms three small peaks, the fluctuations hardly exceed twofold. It can thus be concluded that primary production in the backwater goes on at a uniform level, with little seasonal increase, throughout the year.

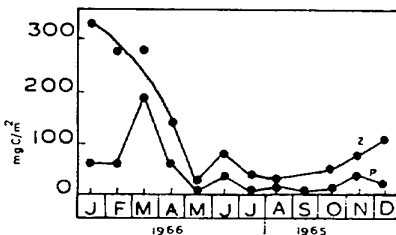


Fig. 3. Relation between phytoplankton (P) and zooplankton (Z) taken from parallel hauls on the same day.

Using the conversion factor, 96 mg C for each ml of zooplankton by displacement (Cushing *et al.*, 1958) and 1.4 mg C for each ml of settled phytoplankton (Sverdrup *et al.*, 1942) the zooplankton and phytoplankton crops have been shown in Fig. 3 in terms of their carbon equivalents. It is clear

from the figure that maximum zooplankton in the estuary occurred during Jan.-April (pre-monsoon months) when the salinity in the backwater is high. During this period the estuary becomes virtually an arm of the adjoining sea. From May, with the onset of monsoon rains, the salinity in the estuary begins to fall and during the following months (June-Sept.), typically brackish water occupies the entire euphotic zone. These changes in the salinity are accompanied by a marked increase in the turbidity of water throughout the monsoon months. The zooplankton crop during the monsoon months remains at a low level and does not show any appreciable change until December.

The ratio of gross photosynthesis to the carbon content of phytoplankton has been shown in Fig. 4 as production coefficient (Riley *et al.*, 1949), from which it can be seen that the range in the ratio is very large (3.7-119). This indicates that the phytoplankton crop sampled by the plankton-net included only a small fraction of the total carbon assimilation (1-28%), as measured by the rate of photosynthesis. During the period when the ratio was large (monsoon and post-monsoon months), the crop was mainly dominated by such "small forms" (nanoplankton) which were not retained by the net; and similarly the low ratio obtained from November to March signifies that the net sampled nearly one-quarter of the standing crop consisting mainly of larger marine diatoms and dinoflagellates. Fig. 4 also includes the ratios

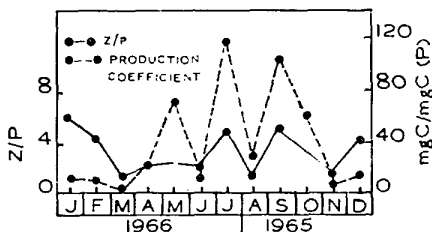


Fig. 4. Relation between zooplankton: phytoplankton (Z/P) and production coefficient (photosynthesis: carbon content of phytoplankton).

of zooplankton to phytoplankton (Z/P). It can be seen from the figure that the seasonal fluctuations in Z/P fall in accordance with a similar increase and decrease in the production coefficient. This indicates that the type of phytoplankton bloom in the estuary is so adjusted that, with the seasonal changes in the zooplankton composition, it provides the specific food requirement of the herbivores.

Taking the daily metabolic requirement of tropical zooplankton in terms of carbon as 12% of its dry weight (Menzel and Ryther, 1961), the seasonal changes in the rate of consumption of the basic food have been given in Fig. 5, along with gross and net primary production. The rate of consumption works out as 10% of the production by plants during the monsoon months, 20% during the post-monsoon months and 40% during the pre-monsoon months.

The estimated gross production in the estuary ranges from 270-295 g C/m²/year (average = 280 g C/m²) while the net production, for days only, is 180-200 g C/m²/year (average = 195 g C/m²). The average daily net production (24 hr) is approximately 124 g C/m²/year. The estimated annual con-

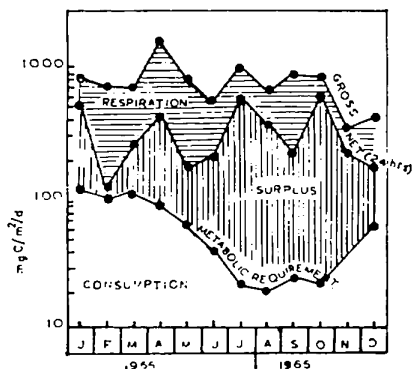


Fig. 5. Relation between metabolic requirement of zooplankton and gross and net primary production. The lower portion shows the approximate consumption of primary production by zooplankton herbivores; the middle portion shows the approximate surplus of basic food and the upper portion indicates the average respiration (24 hrs.).

sorption by the zooplankton herbivores is only about 30 g C/m^2 . This indicates that there is a large surplus of basic food in the estuary. A general lack of zooplankton herbivores seems to be the main factor responsible for such an inefficient utilization of the primary production, which in turn may be due to changing environmental features of the estuary. From the general composition of the zooplankton crop, however, there seems no evidence to suggest that the herbivore population is kept at a minimum because of the presence of a large number of carnivorous forms.

The "apparent wastefulness" of the primary production, however, may not remain so well marked, if we consider that the unconsumed material may perhaps be used more efficiently by the other members of the estuarine ecosystem. This raises the possibility of several "alternate pathways" in the food chain. One such pathway may be directly linked with the herbivorous fishes (mullets) which are always present in the estuary in appreciable numbers. Another direct link from the basic food may be with the omnivorous prawn and shrimp populations through detritus, as the backwater is well known for its rich crustacean fishery (see Fig. 6). Finally, a substantial portion of the basic food which keeps sinking to the bottom may be utilized directly by the sedentary animal communities. The small depth of the euphotic zone greatly increases the rate of loss from this zone and thus prevents an excessive outburst of the phytoplankton bloom at any one time of the year. The unconsumed food which, on reaching the bottom becomes a part of the sediment, may be chemically and biologically altered, but remains in the system to take part in the cycle of events.

In a typically marine environment it has been suggested that nearly 80% of the primary production is consumed by the zooplankton herbivores, while the remaining 20% goes to the demersal animal communities (Steele, 1965). In the oceanic environment of the Sargasso Sea off Bermuda, the utilization of the basic food by the zooplankton herbivores is even more efficient and works out nearly 100% (Menzel and Ryther, 1961). These figures seem certainly true of such environments where the primary production is spread over a large column of water and has to travel a long distance, even below the

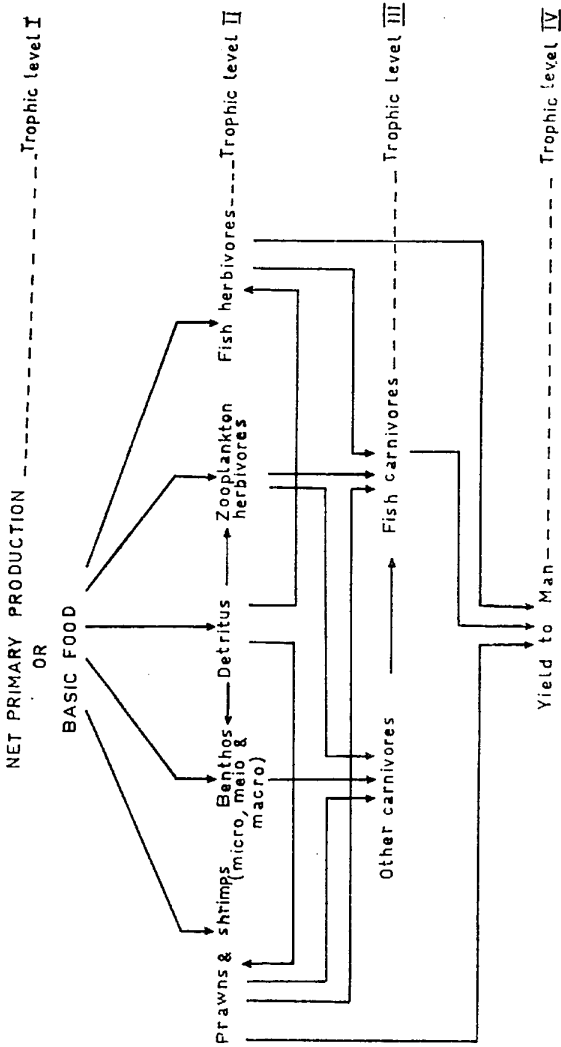


Fig. 6. Generalized representation of a food web in the Cochin Backwater.

cuphotic zone, before it decays and gets chemically altered. Thus its chances of being grazed are invariably high. In a shallow estuary an increase in the benthic herbivorous forms thus compensates for the lack of zooplankton, and probably makes the system just as efficient. It is therefore less surprising to find the primary production in the estuary far exceeding the rate of consumption by the zooplankton herbivores.

Based on the above discussion, a diagrammatic and rather simplified representation of the food chain in the estuary is given in Fig. 6. The web has been constructed according to the generalized scheme enunciated by Steele (1965). It is not intended to give any final answer to the problems of food chains in the estuary, but to give an overall picture of the transmission of food to different trophic levels, I-IV. The representation, though to a large extent arbitrary, indicates some possible links within each trophic level and from one to the next higher trophic level. The several links within the same trophic level, as shown in Fig. 6, recall Steele's (1965) hypothesis of a greater "ecological cannibalism" which leads to competition and a decrease in the amount of food transmitted to the next higher trophic level. Such a situation is to be expected in a tropical estuary where, to start with, a fairly uniform rate of production is maintained throughout the year, which probably induces a large assemblage of herbivorous feeders.

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