

# CONTRIBUTION OF ZOOPLANKTON IN THE FOOD CHAINS OF SOME WARM WATER ENVIRONMENTS

S. Z. QASIM

*National Institute of Oceanography, Dona Paula - 403 004, Goa, India*

In the food chains of open ocean, the role of zooplankton becomes very important both as consumers of phytoplankton and as contributors to the next higher trophic level. The total zooplankton biomass in the Indian Ocean is approximately  $5.19 \times 10^8$  tonnes/year and secondary production amounts to  $69 \times 10^6$  tonnes of carbon/year. Major energy pathways in the open ocean are : phytoplankton  $\rightarrow$  zooplankton  $\rightarrow$  fish.

Regularity and irregularity in the production cycles of the environments largely determine the trophic relationships. In cold water environments of higher latitudes, seasonal peak in primary production is phased with a large biomass of zooplankton herbivores which grow at the expense of primary producers. The peak in zooplankton production is followed by the abundance of primary carnivores and fish which graze heavily on zooplankton. Thus, in the temperate region, the sequence of events occurs with such marked regularity that one trophic level can easily be equated with the other.

In specialized warm water environments of the tropics, such as turbid estuaries, coral reefs, atolls and mangroves, the contribution of zooplankton is not as important as in the open ocean. Irregularity in the production rates is the characteristic feature of these warm water environments in which the rate of primary production generally far exceeds the rate of consumption by zooplankton. These environments lead to branched food chains associated with a large production of detritus. The lack of zooplankton is thus compensated by decomposing material or detritus on which many forms of life become largely dependent. The warm water environments are very flexible in their food relationships and have a flow of energy in various directions. In these branched food chains detritus remains the main source of energy practically throughout the year.

## INTRODUCTION

Ecologically and collectively, zooplankton form the largest group of animals and their total production in the sea, as we know today, is only next to phytoplankton. During the International Indian Ocean Expedition (IIOE), the study of zooplankton formed one of the major investigations, and for this purpose, the Indian Ocean Biological Centre (IOBC) was established at Cochin, initially as a sorting centre, and subsequently, as a repository of zooplankton collections from the Indian Ocean. The sorting centre developed considerable expertise in the study of zooplankton, and today IOBC, which is a part of the Regional Centre of National Institute of Oceanography, holds the largest collection of sorted and unsorted zooplankton from the Indian Ocean. It also has a number of well known specialists in different groups of zooplankton. From the studies conducted

by the staff of IOBC, 10 atlases, several handbooks and many papers were published on the distribution, systematics and ecology of zooplankton.

This symposium on warm water zooplankton offers a good opportunity to discuss some of the results on zooplankton collected during the IIOE, and also the significance of zooplankton in other types of warm water environments of the tropics.

In this communication, the importance of zooplankton in four different types of environments has been summarized. These are: 1) open ocean, 2) tropical estuaries, 3) coral reefs and atolls and 4) mangroves.

#### OPEN OCEAN

Fig. 1 gives the distribution of zooplankton biomass in the Indian Ocean based on day and night samples. The data have been taken from the biomass atlas (IOBC, 1968a and b). The number of zooplankton samples analysed for Fig. 1 was 1622. It is clear from Fig. 1 that the highest biomass values ranging between 25-50 ml/m<sup>2</sup> occur between Lat. 10°-25°N and Long. 50°-65°E in the areas close to Saudi Arabia, Somalia and the northern Arabian Sea. High biomass values are also found along the southwest and southeast coasts of India and in the area adjoining Sri Lanka up to the equator. Moderately high values of biomass, ranging between 15-20 ml/m<sup>2</sup>, are found in the northern Bay of Bengal. In the rest of the Indian Ocean, the values range between 5-10 ml/m<sup>2</sup>. For the entire Indian Ocean up to Lat. 40°S shown in Fig. 1, the total zooplankton biomass amounts to approximately  $5.19 \times 10^6$  tonnes/year (Prasad *et al.*, 1970).

Secondary production from zooplankton biomass can be calculated by multiplying the average value of each 5° square with a factor 0.065 (Cushing, 1971) and by determining the generation time of zooplankton in relation to temperature. The relationship  $D = 71.72 t^{-1.22}$  given by Cushing (1973) was used, where D is the copepodid generation in days and t is the temperature in °C.

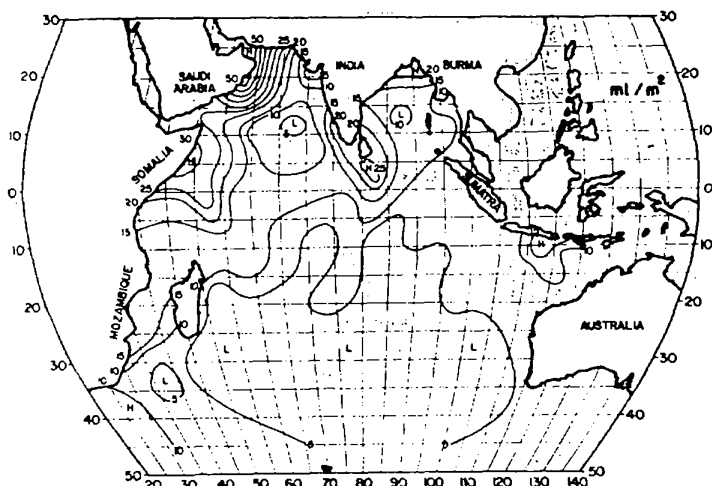


Fig. 1. Distribution of zooplankton biomass in the Indian Ocean based on day and night samples of the whole year

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The annual temperature for every 5° square was taken from the Oceanographic Atlas of IIOE (Wyrтки, 1971). Thus, the annual secondary production was estimated, after calculating the generation time and by multiplying the zooplankton values in gC/m<sup>2</sup> with 365/n, where n is generation time in days.

Secondary production in the Indian Ocean computed by Qasim (1977) from the zooplankton biomass has been shown in Fig. 2. High secondary production ranging between 15-20 mgC/m<sup>2</sup>/day and between 10-15 mgC/m<sup>2</sup>/day are largely confined to coasts of Saudi Arabia and Somalia. The next range of 5-10 mg C/m<sup>2</sup>/day is found in the entire Bay of Bengal, southwest coast of India and Western Indian Ocean covering almost the entire eastern region of the African continent. Another prominent area with 5 to 10 mg C/m<sup>2</sup>/day gets demarcated south of Java and extends up to Australia. The rest of the Indian Ocean has secondary production less than 5 mg C/m<sup>2</sup>/day (Fig. 2). The total secondary production for the entire Indian Ocean is of the order of 69.27 × 10<sup>6</sup> tonnes of carbon/year. From primary and secondary production rates, tertiary production or the exploitable yield (fish etc.) for the Indian Ocean has been estimated as 15 and 17 million tonnes respectively (Qasim, 1977).

Thus, in all types of open ocean, zooplankton occupies a central position in the food chain and its trophic significance can be determined in two ways: firstly, as consumers and secondly as contributors to the next higher trophic level. It is, therefore, evident that in the open ocean, the pathways of major sources of energy would be:

Phytoplankton → zooplankton → fish

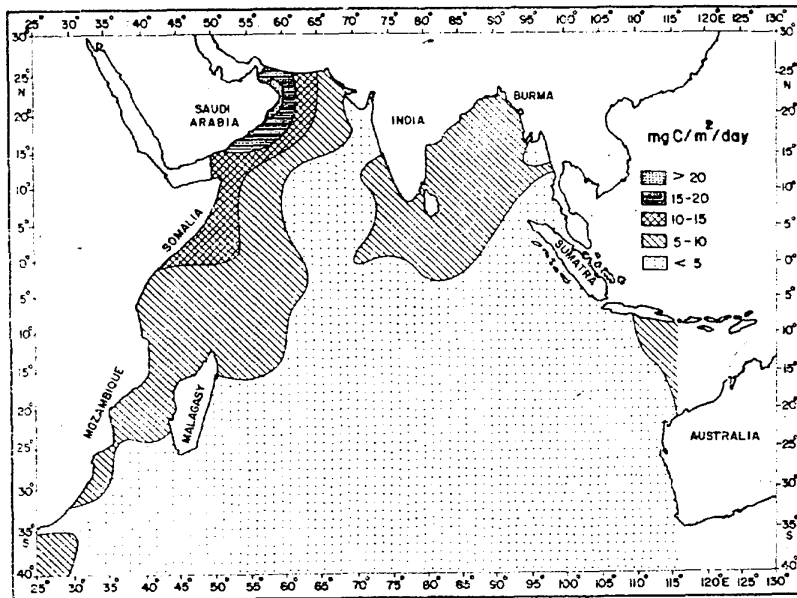


Fig. 2. Secondary production in the Indian Ocean determined from zooplankton biomass

Additional sources of energy could possibly be detritus and bacteria, but the total contribution of these in the open ocean is not yet fully known.

#### REGULARITY VERSUS IRREGULARITY

Trophic relationship between phytoplankton, zooplankton and fish in the open ocean could either be regular or irregular. In the former case, the seasonal cycle of all the three trophic levels is geared to an annual rhythm. Fig. 3 shows such a regular cycle diagrammatically. In this cycle, as can be seen from the figure, maximum phytoplankton production is confined to about 3 months in summer (June, July and August), when it is intense. Such a seasonal rhythm can be expected to occur in higher latitudes, where, for the rest of the year, because of low temperature, primary production remains low. The peak in primary production is followed by maximum zooplankton (secondary production) for about 4 months (July-September) and a greater intensity of fish (tertiary production) for about 5 months (May to September). Secondary production is almost entirely dependent upon primary, and the tertiary production on secondary (Fig. 3). Under the secondary production, we include both zooplankton and forage fish which have a short food chain and are largely dependent on phytoplankton. The other category of secondary producers include filter-feeding benthic community. Tertiary producers will thus subsist on different categories of secondary producers at the second trophic level.

Fig. 4 shows another regular seasonal cycle. In such a cycle, the peaks of all the three categories are broader, which would indicate that the cycle is well spread out and maximum production lasts 5 to 6 months during spring and summer. This type of regular cycle occurs in middle latitudes (temperate regions), where favourable conditions of temperature prevail over a longer period (Fig. 4).

In contrast to the two cycles noted above, we have the irregular cycle shown in Fig. 5 in which primary production goes on at a moderate level practically throughout the year with brief pulses of bloom occurring almost at any time during the year. In the Arabian Sea, blooms of diatoms and flagellates are more commonly seen during the SW monsoon (Sankaranarayanan and Qasim, 1969) and that of the blue-green alga *Trichodesmium* in March and April (Qasim,

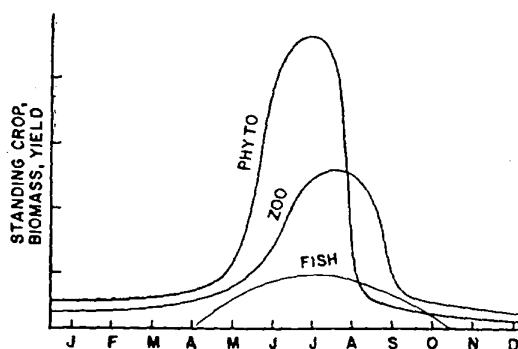


Fig. 3. A generalized representation of regular seasonal cycles of primary, secondary and tertiary production rates found in higher latitudes

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1970a). The zooplankton production also follows an irregular rhythm and is not strictly phased with the maximum phytoplankton production (Fig. 5). Similarly, fish abundance occurs practically throughout the year except for 2-3 months during the monsoon when fishing gets suspended because of unfavourable weather conditions. The irregular cycles are the characteristic features of the tropics.

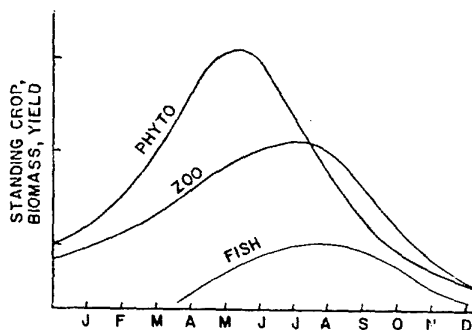


Fig. 4. A generalized representation of regular seasonal cycles of production found in temperate regions

The salient points of regular and irregular cycles, therefore, indicate that:

- a) Regularity in the production rates leads to a greater dependence of one trophic level on the other.
- b) Regularity leads to transfer of food from one trophic level to the other very efficiently *i. e.*, much of the production gets periodically consumed leading to little surplus.
- c) Irregularity leads to less efficient consumption of food so that surplus food is available in the environment to be consumed throughout the year.

Qasim (1955) correlated the regularity and irregularity in the food production with the seasons of breeding and hatching of larvae in marine animals. He pointed out that breeding in animals is so adjusted that planktrophic larvae must occur during a period when there is maximum food in the environment. Regularity in the food production thus leads to seasonal breeding whereas irregularity is marked with continuous (non-seasonal) breeding practically throughout the year.

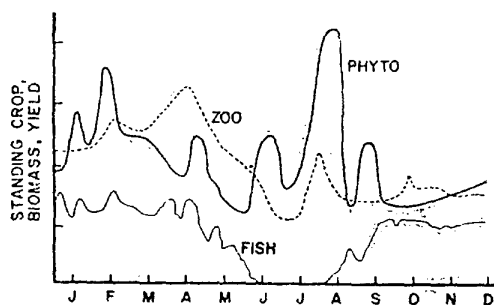


Fig. 5. A generalized representation of irregular seasonal cycles of primary, secondary and tertiary production rates found in warm water environments of the tropics

## TROPICAL ESTUARIES

### COCHIN BACKWATERS

It has been shown earlier that in the Cochin Backwaters, seasonal changes in zooplankton production have little correlation with the cycle of primary production (Qasim *et al.*, 1969; Qasim, 1970b). The rate of consumption of primary production estimated from the metabolic requirement which is taken as 12% of zooplankton dry weight (Menzel and Ryther, 1961), was found to be approximately 10% of primary production during the monsoon months, 20% during the post-monsoon months and 46% during the pre-monsoon months (Qasim *et al.*, 1969). The large surplus of unconsumed primary production gives rise to several alternate pathways in the food chain (Qasim, 1970b). The high turbidity in the estuary, with euphotic zone ranging between 2-6 metres (Qasim *et al.*, 1968), increases the fall-out of primary production which keeps sinking to the bottom as detritus. The rate of sedimentation of detritus during the year ranges from 67 to 1013 g/m<sup>2</sup>/day (Qasim and Sankaranarayanan, 1972). The composition of detritus, although highly variable in the estuary, consists of dead material of plants and animals. The caloric content of detritus ranges from 250-400 cal/g dry wt (Qasim and Sankaranarayanan, 1972). Energy budget of the shrimp *Metapenaeus monoceros* using detritus as food was worked out earlier and gross and net efficiencies were 21.6% and 24.1% respectively (Qasim and Easterson, 1974). The riverine discharge and massive land runoff increase the detrital load of the estuary considerably.

### MANDOVI-ZUARI ESTUARINE COMPLEX

This estuarine complex has two estuaries namely Mandovi and Zuari which are interconnected by a natural canal called Cumbarjua Canal. In this estuarine complex also, the seasonal zooplankton production was totally out of phase with the cycle of primary production. In the Mandovi estuary, the rate of consumption of primary production by zooplankton during the year ranged from 0.60 to 15.39% (average 6.71%). In the Zuari estuary, the rate of consumption ranged from 1.77 to 43.36% (average 10.24%) whereas in the Cumbarjua Canal, the range was from 0.79 to 2.33% (average 1.22%). The average rate of consumption by zooplankton in the entire estuarine complex was about 7% of the total phytoplankton production. Thus, there is enough surplus energy left at the primary trophic level to be passed on to several different pathways (Bhattathiri *et al.*, 1976). In general, this estuarine complex, in its trophic relationship, behaves very similar to that of Cochin Backwaters.

From the account of the two estuaries presented above, it is clear that in tropical estuaries, fish and crustaceans largely become dependent upon detritus as their food, and even the most carnivorous species of fish and prawns readily consume detritus (Darnell, 1961). In the estuarine Chilka Lake, many fishes, which normally have different food preferences, have been found to consume detritus (Rajan, 1968).

### CORAL REEFS AND ATOLLS

Coral reefs and atolls are specialized warm water environments from the tropics. These are characterized by high primary production and complexity of food web. In these environments also, the trophic significance of zooplankton is not as high as it was originally thought. High primary production in coral reefs is largely derived from benthic sources such as algal mats, seagrass beds and corals. Phytoplankton production in the vicinity of atolls has been found to be low (Qasim *et al.*, 1972). Thus, the low phytoplankton production generally leads

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to small zooplankton biomass. In certain seasons, when zooplankton become quite abundant, the source of their food supply seems to be organic aggregates of detrital origin (Johannes, 1967; Qasim and Sankaranarayanan, 1970).

A direct comparison between phytoplankton and zooplankton production is possible from Kavaratti and Agathi atolls from where concurrent data on both the trophic levels have been collected (Qasim *et al.*, 1972; Wafar, 1977). In Kavaratti atoll, phytoplankton production ranged from 16.68 to 17.16 mgC/m<sup>3</sup>/day and the zooplankton biomass was from 2.0 to 5.7 mg wet wt /m<sup>3</sup> in November and December (Qasim *et al.*, 1972). In another season, phytoplankton production in Kavaratti atoll was 22.68 mgC/m<sup>3</sup>/ day, whereas zooplankton biomass was 40 mg wet wt/m<sup>3</sup> (Wafar 1977). In Agathi atoll, phytoplankton production was 27.4 mgC/m<sup>3</sup>/day and the zooplankton biomass 39 mg wet wt/m<sup>3</sup> (Wafar, 1977).

Quantitative evaluation of zooplankton as a source of food to fishes and corals was done by Talbot (1965), Johannes *et al.* (1970) and Johannes (1974). While analysing the fish fauna of Tutia reef (Tanzania), Talbot (1965) has shown that the plankton feeders constitute only 1% of the total fishes. Others are either herbivorous, carnivorous or coral feeders. Similarly, after a detailed study, Johannes (1974) concluded that only 5.4% of the total energy requirement of corals is met by the available zooplankton found in the vicinity of the reef. Consequently, much of the energy appears to be contributed by symbiotic zooxanthellae to the corals (Wafar and Qasim, 1975).

### MANGROVES

Mangroves are also specialized warm water environments of the tropical zone. The mangrove plants grow in sheltered areas of the coast and at the river mouths and estuaries. Their luxuriant growth may extend up to a considerable distance from the sea where tidal action is very little and the substratum becomes soft and swampy. These swamps are often studded with aerial roots of mangroves or pneumatophores.

Recent studies on primary production conducted by some of the colleagues of the present author in NIO and, Dr. A. Pant in particular (unpublished), have indicated that because of highly turbid conditions prevailing in these swamps, phytoplankton production is very limited. The algal crop generally consists of a few species and their appearance in succession is a notable feature. Photosynthetic bacteria predominate the environment and these are capable of fixing carbon dioxide just like the phytoplankton organisms, but they do not release oxygen. This leads to large differences in the results obtained from <sup>14</sup>C uptake and oxygen measurements.

Zooplankton organisms are very few in the mangrove swamps and contribute an insignificant proportion to the food chain. However, fish, crustaceans and molluscs, living in the mangroves, largely feed on detritus which is derived from various sources including the foliage of mangrove plants.

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