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By
E. G. SILAS AND P. PARAMESWARAN PILLAI

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DYNAMICS OF ZOOPLANKTON IN A TROPICAL ESTUARY (COCHIN BACKWATER), WITH A REVIEW ON THE PLANKTON FAUNA OF THE ENVIRONMENT

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Central Marine Fisheries Research Institute, Cochin - 682018

ABSTRACT

Although the extent of the influence of the widely fluctuating environmental factors on the abundance of specific zooplankton groups in Cochin Backwater has been reported by several authors, a compendious picture of the dynamics of zooplankters in this tropical estuarine area is wanting. The environmental factors fluctuate in accordance with the monsoon cycle which makes the year divisible into distinct periods. The amplitude of seasonal and diel changes in the physico-chemical features, especially salinity, is extremely impressive and these produce highly unstable conditions in the estuary which induce variations in the nature and heterogeneity of different zooplankton taxa. The phytoplankton production does not seem to have a definite seasonal rhythm, but the reported values of primary production establishes it as a highly productive ecosystem.

The present communication deals comprehensively with the zooplankton fauna of the Cochin Backwater. Among the various groups, copepods, decapod larvae, cladocerans and cirrepede larvae constitute the predominent component of zooplankton. Most of the constituent groups evince fortuitous distribution, showing seasonal fluctuations in abundance in quality and quantity which can be related to the pattern of variations in the hydrobiological characteristics of the environment. The greater number of zooplankters belong to the inshore populations, some to the freshwater envrionment, and a few endemic. It is also observed that the plankton population in the Cochin Backwater is rich and varied during the pre-monsoon period, when the salinity is comparatively high in this area.

The composition and periodicity in the abundance of zooplankters in the Cochin Backwater suggest that the food potential of zooplankton for plankton feeding fishes and fish larvae is high.

INTRODUCTION

During the last few years various aspects related to the physico-chemical and biological features of the Cochin Backwater, a tropical estuary

have been reported by several authors. The characteristics of different zooplankton groups and the physico-chemical and biological processes which may be responsible for their seasonal variations were discussed in these reports. Bio-ecological investigations extending over four years (1968 - 1972) carried out during the present study and a perusal of the literature reveal that the amplitude of seasonal and diel changes in the physico-chemical features of the Cochin Backwater is considerable and these produce highly unstable conditions in the estuary, which in turn is reflected in the composition and diversity of the zooplankton taxa.

The pioneering attempt of making a qualitative and quantitative study of the plankton of this area was by George (1958) who enumerated the more common groups and brought to light the relationship existing between the seasonal changes of the zooplankton population and some of the environmental factors. More recently, a few reports were published depicting the amplitude of seasonal and spatial changes of zooplankton of the Vembanad Lake and connected backwaters (Nair and Tranter, 1972; Menon *et al.*, 1972; Haridas *et al.*, 1973). Variations in the relative proportions of specific groups such as copepods, chaetognaths, hydromedusae, siphonophores, decapod larvae and cladocerans have also been studied by various authors (Wellershaus, 1969, 1970; Abraham, 1970 a, b; Pillai, 1970; Pillai, 1972; Pillai *et al.* 1973; Nair 1972; Srinivasan, 1972; Santhakumari and Vannucci, 1972; Rengarajan, MS; Mohammed and Rao, 1972; Pillai and Pillai, MS). Despite the present knowledge of the various zooplankton taxa, accumulated through these reports, a compendious picture of the different aspects of the dynamics of zooplankters in this area is wanting. In the ensuing report a critical review of our present knowledge on the zooplankton fauna of the Cochin Backwater has been made and the different aspects of their dynamics discussed. In addition, the diversity of the zooplankton fauna is briefly examined in the light of the hydro-biological features and their influence on the maintenance of the plankton population in the estuary evaluated. The potential value of zooplankton as food of the larval and adult plankton feeding fishes in the backwaters is also briefly discussed.

Environment

The Cochin Backwater (09°58′N. 76°28′E.) is a shallow semi-enclosed body of water of the tropical zone with the characteristics of a tropical estuary. Topography and related features of the environment have been discussed in some of the earlier publications (Qasim and Reddy, 1967; Sankaranarayanan and Qasim, 1969; Wyatt and Qasim, 1973). A narrow gut, about 450 m. wide forms its main connection with the Arabian Sea, and this region is subjected to regular tidal influence. It is a catchment basin for several rivers such as

Periyar, Pamba and Muvattupuzha which empty either into the Vembanad Lake or into the Cochin Backwater which extends in the form of shallow brackishwater lagoons. Except at Cochin, these backwaters are essentially shallow with a mean depth of about 3.5 m. Along the main channel near Cochin Harbour, the depth is 10-14 m which is maintained for navigational purposes. The inflow of freshwater, particularly during the monsoon months is considerably high and the influx of this large scale freshwater runoff extends far beyond the harbour mouth during this period. The continual discharge of the freshwater and the inflow of seawater into the estuary bring about dynamic conditions which make the backwater extremely interesting and ecologically an intriguing environment.

The atmospheric temperature is maximum in April-May and minimum in July-August. The annual rainfall in this area is about 3.2m which shows considerable fluctuations. More than 75% of the rainfall is recorded during the south west monsoon period which occurs during late May or in June to September. The rainy season also extends from late October to early December, which is the period of North-east monsoon. The rate of flushing and the total discharge of water through the Cochin Channel have been discussed by Waytt and Qasim (1973). Maximum solar radiation reaches the surface from December to March and minimum from June to September. Wellershaus (1974) studied the stability characteristics of the Cochin Backwater and according to him it was very high at the end of the monsoon season when the increased freshwater supply supports the stratification of the backwater into two layers. As the freshwater influx gets reduced, the stability also decreased. From February onwards, the stablity was very low indicating a situation of vertically homogeneously mixed estuary.

Tides in the Cochin Backwater are of mixed, semidiurnal type, and two successive high and low waters appears each day, with substantial differences in range and time (Fig. 1a). The reversal of the tidal current at the surface lags behind the tidal height by about two hours. A General picture of the outgoing and incoming tides in the backwaters has been presented earlier (Qasim and Gopinathan, 1969). However, the maximum frequency of the tide was observed during different years in the amplitude of 0.8 to 0.9 m and lowest frequency in the range 1.1 m (Josanto, 1971).

HHYDROGRAPHIC FEATURES

The hydrography of the Cochin Backwater has been studied by several workers. The information available includes seasonal distribution of temperature and salinity, patterns of distribution of dissolved oxygen, pH, alkalinity and nutrients (Balakrishnan, 1957; Ramamirtham and Jayaraman,

1963; George and Kartha, 1963; Qasim and Reddy, 1967; Cherian, 1967; Sankaranarayanan and Qasim, 1969; Qasim *et al.*, 1969; Josanto, 1971; Haridas *et al.*, 1973; Wellershaus, 1974 and Sreedharan and Salih, 1974).

Temperature:

Seasonal changes in temperature are not pronounced in the estuary although the surface water shows extreme values than the bottom water. These rarely exceed 4 - 5°C and generally fall within a range of 27° - 32°C. Due to the warm weather and maximum solar radiation during the summer months the temperature remains uniform throughout the water column and maximum values are recorded during this period. Thermal stratification is absent during the summer months. But during the monsoon months, from May onwards a sharp thermal gradient develops in the estuary with a maximum difference of about 5°C at the surface and bottom. Concurrent with the freshwater discharge during the monsoon months, there is an incursion of cold saline water from the Arabian Sea into the deeper layers of the Cochin Backwater, as recognised by Ramamirtham and Jayaraman (1963). The rapid change of temperature at the bottom during the monsoon period is traceable to this phenomenon. At the surface a secondary rise in temperature was observed during the North East Monsoon period.

Salinity,

Wide ranges in the salinity values have been observed at the surface than in the bottom water. Like temperature, during summer months, salinity shows a vertical homogeneity. With the onset of monsoon rains, the surface water is considerably diluted and a clearly defined halocline develops with very low saline water or freshwater at the surface and seawater at the bottom. This condition is maintained until November - December, when homogenous conditions are restored.

The cold high saline water present at the bottom during the monsoon months is traceable to the upwelled water of the Arabian Sea. The salinity stratification is more pronounced near the estuarine mouth whereas in the shallow areas little mixing takes place and the salinity gradient is not well marked.

Dissolved Oxygen:

At the surface the dissolved oxygen values are subjected to little fluctuation and normally range between 3.5 to 6.2 ml/l. At deeper layers, a rapid lowering of the values were noticed during the monsoon months, and as low as 1-2 ml oxygen/l were observed. The possible mechanism which gives

rise to such a pronounced gradient in oxygen values at the surface and bottom may be the persistance of the upwelled bottom water in the estuary during the monsoon months. The gradient disappears when the mixing of the surface and bottom waters takes place and typically marine features are restored.

pH:

pH of the surface water shows considerable fluctuations. Maximum values were recorded from October to March and minimum both at surface and bottom was observed during August to October.

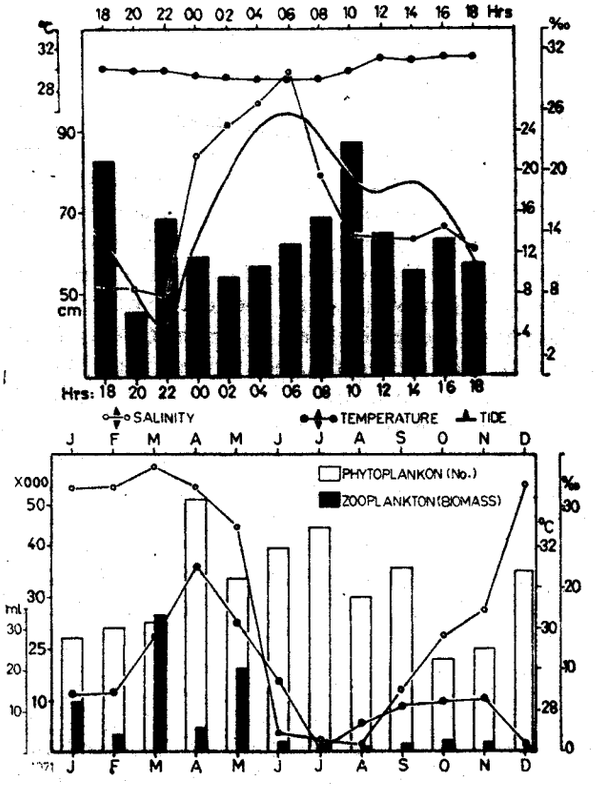

Fig. 1. a. Diel variations of tide, temperature, salinity and zooplankton biomass in the Cochin Backwater during November 1969. b. Distribution of temperature, salinity, phytoplankton (cell numbers) and zooplankton (biomass) in the Cochin Backwater during the period January to December, 1971.

Alkalinity:

A pronounced fall was observed during the monsoon months and the values show increasing trend during the post-monsoon period. Alkalinity values in the summer months indicate little variation.

Nutrients:

Nutrient distribution in the Cochin Backwater shows a marked rhythm, mainly due to the local precipitation and river runoff. Its concentration remains homogenous throughout the water column during the period when the estuarine system remains predominantly marine. During the monsoon period high concentrations were recorded. After a sharp decline, another peak of nutrient enrichment in the backwaters occur during October - December period.

Wellershaus (1974) commented that the Cochin Backwater is alternatively characterised by two estuarine types, (i) during the pre-monsoon period and the beginning of the monsoon, it is vertically homogenous with varying salinity conditions, and (ii) at the end of the monsoon and during the post-monsoon period it is stratified and is continuously supplied with freshwater at the surface and seawater at the bottom. However, it is evident from the foregoing discussion that the cycle of events leading to the fluctuations in the physico-chemical factors in the Cochin Backwater is fairly regular and the year can arbitrarily be divided into three seasons of four months each : (i) a pre-monsoon season (Jan. - April) of stable hydrographic parameters showing typical marine conditions; (ii) a monsoon season (May to Sept.) associated with pronounced changes in the environmental features, and (iii) a period of recovery during the post monsoon season (Oct. - December) when the marine components being to develop in the estuarine system.

Biological Features

Phytoplankton production:

Primary production values reported from Cochin Backwater by Qasim *et al.* (1969) shows a daily gross production of 0.5 to 1.5 gC/m^2; daily net production of 0.35 to 0.88 gC/m^2 and 24 hour net production of 0.12-0.58 gC/m^2. These values clearly indicate that the area is a highly productive ecosystem. Detailed *in situ* and experimental ecological studies on the various aspects of phytoplankton production in relation to salinity, light and nutrients, and production in relation to the flushing rate were conducted earlier (Qasim and Reddy, 1967; Qasim *et al.*, 1969; *et al.*, 1972, Qasim, 1973 and Wyatt and Qasim, 1973). The seasonal abundance of phytoplankters of

the Cochin Backwaters has been reported by Gopinathan (1974). Altogether 88 species of diatoms, 27 species of dinoflagellates, 2 species of silicoflagellates, and three species of blue-green algae have been reported from this area. Throughout the year, diatoms formed the major component of the phytoplankters; dinoflagellates, silicoflagellates and Cyanophyceae were very few. However, the abundance of species such as *Skeletonema costatum*, *Prorocentrum micans*, *Katanymus spiralis* and *Oscillatoria* sp. were also observed towards the end of pre-monsoon period in Cochin Backwater, which contribute substantially to the standing crop of phytoplankters. The first peak of phytoplankton abundauce (Fig. 1b) was recorded during the early momsoon period which coincide with high nutrient concentration in the eastuary. A secondary peak noticed during the post-monsoon months is mainly contributed by dinoflagellates and it shows concurrence with the increased nutrient enrichment and relative stability during this period.

Zooplankton biomass:

Generally, estuarine zooplankton is volumetrically abundant but limited in species composition. A general picture of the seasonal variation in zooplankton biomass of this area can be summarised thus: it is relatively high during the pre-monsoon period and low during the monsoon months with relatively minor secondary peak during the post-monsoon season. During the pre-monsoon period the entire water column shows stable and uniform hydrographic conditions and the estuary becomes virtually an extension of the adjoining sea with high salinity and temperature values. Heavy rainfall during the monsoon months has significant effect on the zooplankton distribution of this area since the dominant species constituting the bulk of the zooplankton are marine in origin. Consequent to the heavy rainfall and the resultant large influx of freshwater to the estuarine system, many marine organisms migrate from the environment. Following the monsoonal decline the marine components gradually get established in the estuarine system during the post-monsoon season with the invasion of seawater from the bottom zone towards the surface. A gradual rise in salinity was noted during this period. This was reflected in the biomass distribution of the zooplankton also. However, it was observed that the adults of different zooplankton taxa constitute a major share of the pre-monsoon zooplankton biomass, whereas the larvae of benthos and nekton along with the larvae and adults of different zooplankton groups contribute major proportion of the post-monsoon biomass of the zooplankton.

Zooplankton Composition

Published papers on zooplankton do not contain many qualitative listing of the zooplankton fauna of the Cochin Backwater and hence the

different taxa of zooplankton so far recorded from this area are briefly reviewed and ascribed under holoplankters and meroplankters.

HOLOPLANKTERS

Hydromedusae:

Our knowledge of the taxonomy and distribution of the hydromedusae of the Cochin Backwater is mainly based on the studies by Vannucci *et al.* (1970), Santhakumari (1970), Santhakumari and Vannucci (1972), Nair and Tranter (1972) and Menon *et al.* (1972). Altogether, thirtytwo species of hydromedusae are reported from this area as follows: *Obelia spp., Phialidium brunescens, P. hemisphericum, P. rangiroae, Blackfordia virginica, Eucheilota menoni, E. ceyloninsis, Eutima commensalis, E. hartlaubi, E. Brownei, Ectopleura* sp., *Halocordyle disticha, Cytaeis tetrastyle, Bougainvilla fulva, Pandea rubra, Aequorea aequorea, A. cornica, A. macrodactyla, Aglaura hemistoma, Aglantha elata, Liriope tetraphylla, Geryona proboscidalis, Cunina peregrina, Solmundella bitentaculata, Podocoryne carnea, Eutima neucaledonia, E. japonica, zanclea costata, Tiaropsidium japonicum, Phialucium carolinae* and *P. taeniogonia.* They are common and abundant in the estuary during the pre-monsoon period and during the post-monsoon period they are apparently absent except near the mouth of the estuary (Fig. 2). *Eutima commensalis* has been reported by Santhakumari (1970) as endemic to Cochin Backwater.

Scyphomedusae:

Achrometes sp. has been reported by Nair and Tranter (1972) as common during the pre-monsoon months in the estuary.

Ctenophores:

George (1958) recorded *Pleurobrachia globosa* as a common component of the zooplankton during January to April. Subsequently, Nair and Tranter (1972) recorded few ctenophores in the lower half of the estuary during the post-monsoon period, and their maximum has been reported to be during the pre-monsoon and post-monsoon periods.

Siphonophores:

Rengarajan (1974) studied the species composition of siphonophores and stated that high salinity plays an important role in the influx of these organisms into the Cochin Backwater. According to him, they were present in the estuary during the pre-monsoon and post-monsoon periods except during January in the year 1971. Their primary peak coincided with the

February–March period. Secondary peak was in December (Post-monsoon period) (Fig. 3a). *Lensia subtiloides*, *L. hotspur*, *Muggiaea delsmani*, *Diphyes chamissonis* and *Eudoxoides mitra* are the species of siphonophores recorded from this area.

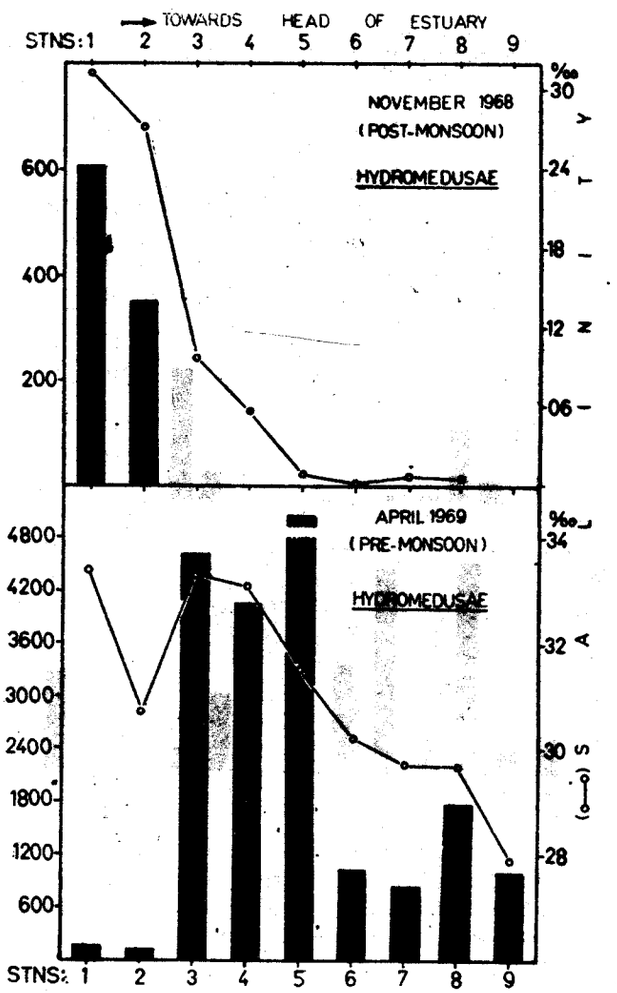

Fig. 2. Distribution of hydromedusae in relation to salinity in the Cochin Backwater during the post-monsoon (1968) and pre-monsoon (1969) periods.

Polychaetes:

George (1958) recorded "one or two" species of pelagic polychaetes belonging to the family Nereidae from the Cochin Backwater during all the months and their maximum was recorded during October.

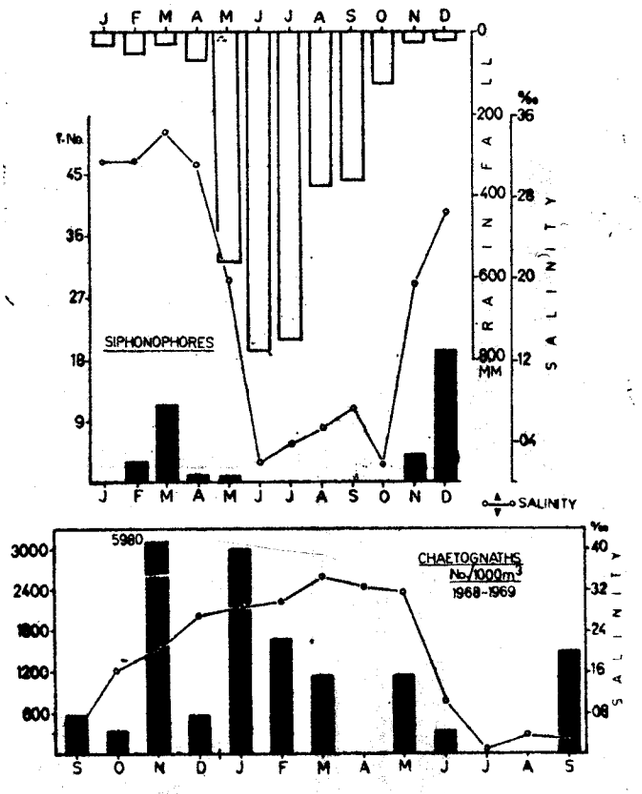

Fig. 3. *a*. Distribution of siphonophores in relation to salinity and rain fall in the Cochin Backwater during January to December, 1971; and *b*. Distribution of chaetognaths in relation to salinity in the Cochin Backwater during the period September, 1968 to September, 1969.

Cladocerans:

Evadne tergestina and *Penilia avirostris* are the two species recorded from the Cochin Backwater. Recently, their abundance, seasonal distribution and temperature-salinity relationship have been investigated by Pillai and

Pillai (1973). They were numerically high during the post-monsoon months of September, October and November. *E. tergestina* was present more or less throughout the year whereas *P. avirostris* evinced restricted distribution.

Copepods:

Both in number and species, copepods constitute the most predominent component of the zooplankton in the Cochin Backwater throughout the year. Our present knowledge on the taxonomy and distribution of this group in this estuarine area around Cochin are due to the works by Sewell (1919), George (1958), Wellershaus (1969, 1970, 1974), Abraham (1970, a, b), Tranter and Abraham (1971), Pillai (1970), Pillai (1972), Pillai *et. al.* (1973), Pillai and Pillai (1973) and Pillai (MS). Nair and Tranter (1972) and Menon *et. al.* (1972) presented a general picture of the distribution of the copepod component of the zooplankton in the Cochih Backwater and connected estuarine waters. A total of thirtythree species of calanoid copepods have been recorded from this area by Pillai *et al.*, 1973 as follows: *Acartia spinicauda, A. centrura, A. erythraea, A. plumosa, A. bilobata, Acartiella gravelyi, A. keralensis, Centropages trispinosus, C. alcockii, C. furcatus, C. orsinii, C. tenuiremis, Pseudodiaptomus mertoni, P. serricaudatus, P. annandalei, P. jonesi, P. aurivillii, P. tollingerae, P. binghami malayalus, Diaptomus mirabilipes, D. cinctus, Labidocera pectinata, L. kroyeri, L. pavo, L. minuta, Temora turbinata, T. discudata, Candacia bradyi, Paracalanus-crassirostris, Eucalanus subcrassus, Acrocalanus similis, Tortanus gracilis* and *Isias cochinensis.*

In addition, eleven species of cyclopoid copepods were also found to occur in the Cocin Backwater during the present study: *Oithona plumifera, O. rigida, O. hebes, O. brevicornis, O. nana, O. occulata, Corycaeus andrewsi, C. dubius, Oncaea venusta, O. media* and *O. conifera.* Two maxima are apparent during the course of an year, a major peak of copepods during the pre-monsoon period and a minor one during the post-monsoon months (Fig. 4 a). The pattern of distribution of the larval copepods shows that they are usually abundant in the Cochin Backwater during November to April period.

Ostracods:

Cypridina dentata was met with near the mouth of the estuary during the high salinity period. However, George (1958) recorded "maximum numbers" of ostracods during September-October and according to him "one species of ostracod has been noted to occur in quite small numbers mostly in the months of low salinity, the maximum having been observed in September and December".

Mysids:

Mesodopsis orientalis and *Mesodopsis* sp. were reported by George (1958) from this area. According to him *M. orientalis* was present in maximum numbers during September to October and scarce during January to March.

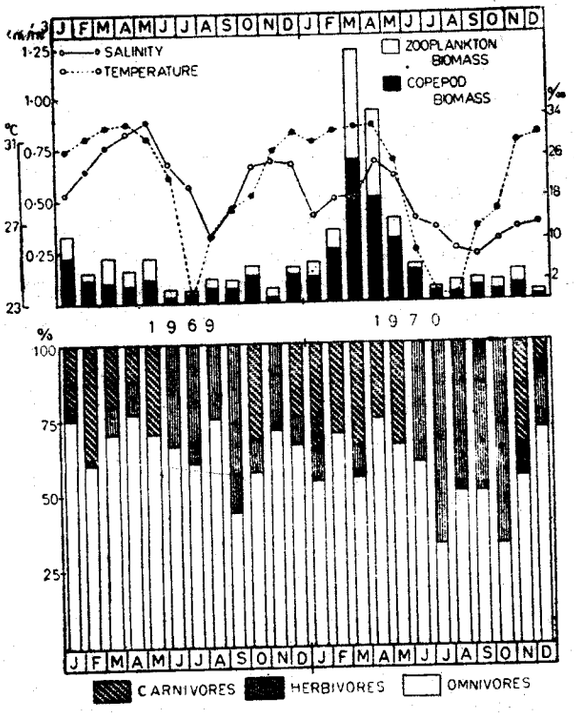

Fig. 4. *a.* Seasonal variation in the total quantity of zooplankton in the Cochin Backwater in relation to temperature and salinity during 1969 and 1970. Shaded portion indicate the contribution of copepods in the total zooplankton biomass, and *b.* Percentage composition of three different categories of copepods (carnivores, herbivores and omnivores) in the monthly zooplankton samples collected during 1960 and 1970.

Cumaceans:

Paradyastylis culicoides and *Eucoma* sp. were recorded from the estuarine waters by George (1958) during July to February with a period of maximum in September.

Tanaidaceans:

Apseudes gymnophobia and *Apseudes* sp. have been reported from Cochin Backwater during July to March (George, 1958). They were maximum during August to November.

Isopods:

Spheroma sp. has been recorded by George (1958) from this area during post-monsoon months of September to December.

Amphipods:

George (1958) and Nair and Tranter (1972) reported on the amphipods of the Cochin Backwater. The following species are recorded from this area: *Corphium triaenonyx, Photis longicaudata, Perioculoides longimanus, Eriopisa chilkaensis, Grandidierella* sp. and *Hyperia* sp. Gammarid amphipods were found in the estuarine waters during the pre- and post-monsoon periods.

Adult decapods:

The following species were recorded from the Cochin Backwater (George, 1958; Rao, 1971; Mohammed and Rao, 1972; Achuthankutty and George, 1973): *Lucifer hanseni, Ogyrides striaticauda, Periclimenes indicus, Palaemon rudis, Acetes indicus, A. japonicus, A. cochinensis, A. erythraeus* and *A. sibogalis*. George (1958) reported that *Lucifer hanseni* with its larvae were present in the estuary during November to July and their maximum was recorded during December and January.

Chaetognaths:

Five species of chaetognaths *viz., Sagitta inflatta, S. bedoti, S. pulchra, S. robusta* and *Krohnitta pacifica* are known to occur in this area. These species have been reported to evince different patterns of occurrence and abundance in the Cochin Backwater (Nair, 1972; Srinivasan, 1972) (Fig. 3b).

Pelagic tunicates:

Doliolum sp. has been recorded by Pillai and Pillai (1973) in the plankton collected during November.

MEROPLANKTERS

LARVAE OF BENTHIC INVERTEBRATES:

Polychaete larvae:

Nair and Tranter (1972) and Menon *et al.* (1972) recorded larval polychaetes during pre-monsoon and post-monsoon periods. Their abundance was observed during pre-monsoon months in the estuarine area.

Cirrepede larvae:

George (1958) and Menon *et al.* (1972) recorded the larvae of *Balanus amphitrites* during all seasons except the monsoon months. Their maximum was during January and February.

Bryozoan larvae:

Menon and Nair (1971) studied the larval settlement of bryozoans in the Cochin Backwater and reported that bryozoan larvae were present during all seasons and were common during the low salinity period.

Decapod larvae:

(i) *Post-larvae of penaeids*: such as those belonging to *Metapenaeus dobsoni*, *M. affinis*, *M. monoceros* and *P. indicus* were reported by George (1958) and Mohammed and Rao (1972) from the Cochin Backwater. Larvae of *M. dobsoni* and *M. monoceros* showed peaks during June, August, October and December; those of *M. affinis* during June, July, October and December while *P. indicus* showed larval peaks during February, April, November and December.

(ii) *Caridean larvae*: belonging to *Periclimenes* sp. and *Palaemon* sp. were recorded by George (1958) from Cochin Backwater during August to February.

(iii) *Brachyuran zoea*: were present during December to May and their maximum number was found during December to February. Nair and Tranter (1972) and Menon *et al.* (1972) reported the distribution of brachyuran zoea in the plankton as "more or less throughout the year". Wellershaus (1972) reported on the larval development of an unknown 'brachyuran crab' from the Cochin Backwater.

Stomatopod larvae:

George (1958) recorded *Alima* larvae during the pre-monsoon period from the estuarine waters.

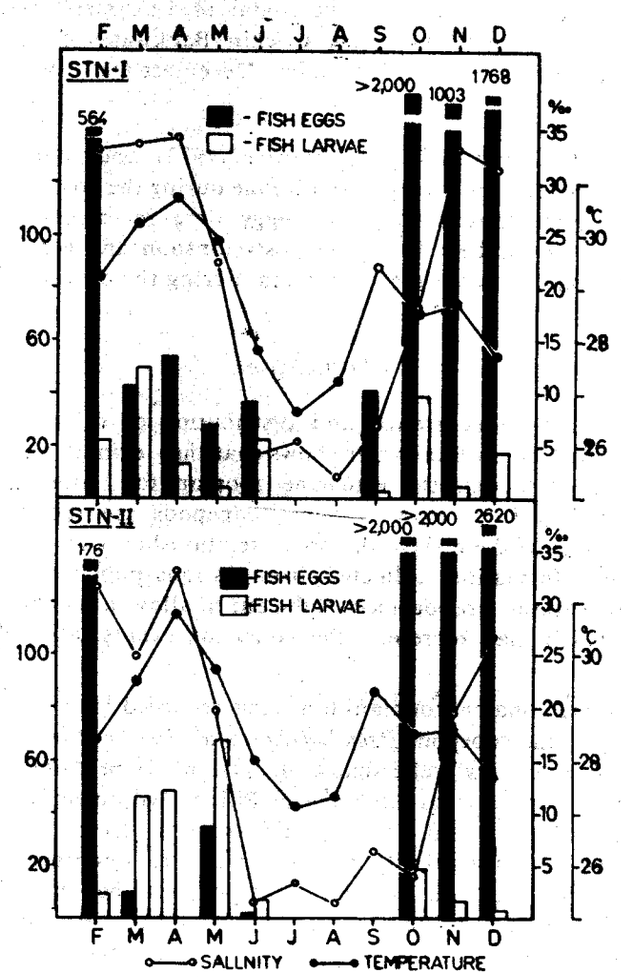

Fig. 5. Distribution of fish eggs and fish larvae in relation to temperature and salinity at two stations in the Cochin Backwater during February to December, 1971 (Station I: Bar mouth; Station II: Ernakulam Channel).

Molluscan larvae:

(i) *Gastropod larvae*: belonging to *Thias* sp. and *Neretina* sp. have been recorded during both pre-monsoon and post-monsoon periods (George, 1958; Nair and Tranter, 1972) and their maximum was recorded during the post-monsoon period.

Table 1. *General pattern of the occurrence and abundance of various zooplankton groups in the Cochin Backwater during different seasons*

Group	Seasons		
Holoplankters:	*Pre-monsoon*	*Monsoon*	*Post-monsoon*
1. Hydromedusae	x	AA	R
2. Scyphomedusae	x	A	A
3. Siphonophores	x	AA	xx
4. Ctenophores	x	A	R
5. Polychaetous annelids	x	R	x
6. Cladocerans	x	R	xx
7. Copepods	xx	x	xx
8. Ostracods	R	A	A
9. Adult Decapods	x	A	R
10. Decapod larvae:			
Penaeids	xx	R	xx
Carideans	x	AA	x
Brachyuran zoea	xx	AA	R
11. Mysids	R	R	xx
12. Cumaceans	R	AA	xx
13. Tanaidaceans	R	R	xx
14. Isopods	R	A	A
15. Amphipods	R	AA	xx
16. Sergestids	x	R	xx
17. Chaetognaths	x	AA	xx
18. Appendicularians	x	A	R
19. Fish eggs	x	R	xx
20. Fish larvae	x	R	xx
Meroplankters:			
21. Polychaete larvae	x	AA	x
22. Oligochaete larvae	A	x	x
23. Cirreped larvae	x	AA	x
24. Gastropod larvae	R	A	R
25. Lamellibranch larvae	R	R	xx

xx = abundant; x = common; R = Rare;
AA = Apparently absent; A = Absent.

(iii) Groups showing allochthonous distribution pattern which are unable to propagate and have limited survival potential. Species showing fortuitous distribution belong to this group.

Based on the biocoenoses three different 'types' of water are traceable during the course of an year. However, with reference to the different zooplankton taxa it should be noted that there are differences in the estuarine penetration even among species belonging to the same genus and hence the problem of distribution with reference to salinity must be approached at the species level. Available information in this line from the Cochin Backwater is confined to: the succession and coexistence of copepod species (Tranter and Abraham, 1971; Pillai, 1972); correlation between copepod species diversity, biomass distribution and salinity (Pillai *et al.*, 1973; Wellershaus, 1974); occurrence and abundance of hydromedusae, bryozoan larvae and cladocerans in relation to salinity (Santhakumari and Vannucci, 1972; Menon and Nair, 1971; Pillai and Pillai, 1973) and the general aspects of zooplankton distribution along salinity gradients in the Lake System (Nair and Tranter, 1972; Haridas *et al.*, 1973). It is apparent from these studies that the normal salinity range for a particular species may vary considerably and salinity plays a major role in balancing the inter-specific competition. Detailed and critical information on this kind of problem is yet to be acquired.

The maintenance of local populations in the Cochin Backwater and the rate of intrusion by coastal marine forms seems to be dependent mainly on the flushing rate, circulation patterns and other biological features such as predation. The vertical homogeneity of hydrological factors met with during the pre-monsoon period provide excellent condition for the zooplankton populations to establish and propagate in the backwaters. The high rate of freshwater runoff may possibly flush out many such forms from the environment. In a system where salinity is completely reversed during the seasonal cycle, this must be the main factor which governs the adaptation of the life cycle of the organisms to the changing hydrographic patterns. Several groups of planktonic organisms such as copepods are represented by typical brackishwater, marine and freshwater forms and the latter two categories evince fortuitous distribution in the estuary. Oligohaline forms can propagate in the less saline water but the marine components should alleviate the problem either by adapting a benthic mode of life by limiting their distribution to the tongue of cold, high saline upwelled water of the Arabian Sea found in the bottom layer of the Cochin Backwater during the monsoon period or they should physically disperse themselves to the nearby inshore waters. The line of adaptation selected by the planktonic forms to tide over such constraints is obscure but it is apparent that practically no marine species are found to occur in the upper stratum of the water in the shallow estuarine area during the monsoon months.

It is of interest to note the mechanism by which intermonsoon water is repopulated by the marine species. Vannucci and Shanthakumari (1971) identified three levels of adaptations which they consider to be important for the maintenance of hydromedusae population in the estuary *viz.*, (1) production of sessile resting stages in the life cycle of plankton species which will produce the following vagile stages; (2) production of resting stages such as eggs which will repopulate the area, and (3) the euryhaline forms will be carried out to the sea and brought back after the monsoon. According to them, stenohaline species with high salinity requirements are not found inside the backwater system at any time. The post-larval stages of several species of *Penaeus* and *Metapenaeus* have been reported to enter the estuary by taking advantage of the flood water during the dry season (October to May) and they settle to the bottom before the tide reverses. This behavioural pattern is another adaptation to the strong water currents (Wyatt and Qasim, 1973). A more plausible method of adaptation is that most of the planktonic species make use of the inward flowing bottom current to prevent themselves being washed out.

Predation is another significant factor that control the population density of zooplankters in the Cochin Backwater. The faunistic composition (Table 1) reveals that during the pre-monsoon period the dominant taxa were hydromedusae, siphonophores, copepods, decapod larvae, chaetognaths, ctenophores and fish larvae. During monsoon months only those taxa evincing considerable tolerance and adaptation to low values of hydrographic parameters would succeed in colonising the backwaters. During the post monsoon months the major taxa present were copepods, polychaete larvae, cladocerans, siphonophores, chaetognaths, decapod larvae and during this period an abundance of fish eggs and larvae were observed. Thus, it is evident that the cycles of maxima of carnivorous forms such as medusae, chaetognaths and ctenophores are closely geared with the abundance of meroplankters and other holoplankers in the estuary.

It is apparent that the diversity of zooplankton fauna cannot be discussed in generalised terms. Hence the discussion presented here is limited to some particular types which constitute the dominent component of zooplankton population.

Three factors were taken into consideration for discussion on the diversity of zooplankton fauna in the Cochin Backwater. They are (i) salinity, (ii) temperatnre and (iii) availability of food. The diversity of copepod popuiation in the Cochin Backwater has been studied by Pillai *et al.* (1973). Accarding to them a definite correlation exists between the seasonal variation of temperature and salinity and the total abundance of different species of

copepods. Food supply seldom acts as a limiting factor in the estuary and does not seem to govern the seasonal distribution and abundance of copepods. When considering these factors in relation to zooplankton diversity, it is evident that salinity acts in a different way affecting the nature and type of fauna and *not* on the biomass of zooplankters as a whole. Investigations carried out earlier on the influence of these factors show that the biomass-salinity correlation coefficient values are not significant, which indicate that freshwater organisms also contribute to the total biomass of zooplankton in the estuary. Significant correlations were found between biomass and temperature. The highly significant relationship between temperature and salinity, as given by these authors clearly indicates that the changes in one are associated with the other and these two factors together explain a great deal of variation in the zooplankton composition in the estuary. According to Wellershaus (1974) a linear correlation does not exist between the abundance of zooplankters and salinity but a double-logarithmic correlation was found between zooplankton abundance and salinity at 1 m. depth (value of $r = 0.7246$ at 1% significance level).

As reported earlier, production of phytoplankton is high during the monsoon and post-monsoon months, and throughout the year the phyto-plankton production far exceeds the consumption by the zooplankton (Qasim, 1970). The fauna is constituted by various trophic groups *viz.*, herbivores, carnivores and omnivores and it is noteworthy that their composition varies drastically during the course of an year. In copepods it has been established that omnivores dominate in the plankton collections practically during all the months; herbivores appear during the monsoon and post-monsoon months and carnivores were largely confined to the post - and pre-monsoon periods (Fig. 4b). Even the herbivorous zooplankton does not seem to be efficient in the utilisation of the plant food. This may be due to the fact that the abundant taxa are inefficient feeders and their dominance presumably depends upon wide tolerance to salinity, temperature and various other features.

The faunal composition shows that the secondary peak of zooplankton during the post-monsoon months is largely constituted by the larval forms of benthic invertebrates, eggs and larvae of different species of fishes and holo-plankters such as copepods and cladocerans. The high diversity of the fauna which is noticeable during the pre-monsoon months sees to be derived partly from the post-monsoon peak of these populations and partly induced by the re-establishment of favourable hydrographic conditions prevailing in the estuary during this period. Although no decisive conclusions could be drawn out on the factors that determine the diversity and seasonal characteristics of zooplankters in the Cochin Backwater, it is apparent that a combination of hydrographic parameters and other biological features induce diversity of the fauna in the estuary.

The necessity of the estuarine phase in the life cycle of the commercially important prawns has been discussed by Mohammed and Rao (1972). With the exception of *Parapenaeopsis stylifera*, the larvae and juveniles of all other commercially important species of prawns of this area are represented in the estuary. The causative factors for such immigration of larvae into the Cochin Backwater have been ascribed to the congenial hydrobiological conditions prevailing in the estuary. According to them, in Cochin Backwater availability of food especially phytoplankters and detritus for the larvae and the conditions which offer them refuge from predators help them to maintain themselves in the estuary. Emigration of the juvenile prawns to the sea is induced by their breeding instinct than by the flushing out by the flood waters during the monsoon period. The period of stay of different species vary from a minimum of four months (*Metapenaeus affinis*) to a maximum of ten months (*M. monoceros*) with a growth rate of 6.72 mm (*M. monoceros*) to 13.3 mm (*Penaeus indicus*) per month (Mohammed and Rao, 1972).

Cochin Backwater is a typical nursery ground for a variety of fishes, which in the larval and juvenile stages are voraceous plankton feeders. Fish eggs and larvae were abundant in this area during the post-monsoon period (Fig. 5) and early pre-monsoon months indicative of active breeding of fishes. Zooplankton standing crop also evince rapid increasing trend during this period. The head of the Cochin Barmouth area support a rich fishery constituted by many commercially important fishes such as *Lates calcarifer*, *Chanos chanos*, *Mugil* spp., *Etroplus suratensis*, *Thrissocles* spp., *Anchoviella* spp. and *Eleutheronema tetradactylum*. In the upper reaches of the estuary, species such as *Mugil* spp., *Caranx* spp., *Tylosurus strongylurus*, *Hemiramphus cantori* and *Scatophagus argus* contribute towards the fishery. It has also been reported that the maximum fishery occurs during the inter-monsoon months of October to April. The closely geared cycles of the abundance of different groups of zooplankters and plankton eating food fishes and their larvae probably suggest that the food potential of zooplankton is high, depending on the degree of selectivity and orientation to the plankton distribution patterns by the fishes.

Despite the conclusions which have been drawn on the characteristics of the zooplankton dynamics in the Cochin Backwater, this review presents only an introduction to a number of problems concerning the zooplankton fauna and their ecology. Annual variations in the reproductive potential and cycles, factors controlling their seasonal variation, influence of hydro-biological features on the growth rates and population density are some of the problems remaining open for further investigation.

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