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ECOLOGY OF THE CYCLOPOID COPEPODS FROM THE COCHIN BACKWATER

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ABSTRACT

The ecological investigations on the cyclopoid copepods, wherein various trends in the occurrence and seasonal abundance in Cochin Backwater, an estuarine system, have been studied. The material is based on regular weekly zooplankton samples collected from two fixed stations during January, 1970 to December, 1971. The various trends in the occurrence and abundance of 28 species of planktonic cyclopoid copepods belonging to 5 genera and 4 families are dealt with. The effect of salinity and temperature on their distribution is also elucidated.

INTRODUCTION

COPEPODS especially cyclopoids form an important constituent of the plankton and play a significant role in the estuarine ecosystem. Cyclopoid copepods with their larvae constitute the food of many fish larvae and plankton eating food fishes, and hence their fluctuation in abundance have a direct bearing on the local fisheries. Many commercially important food fishes, most of which are found in good numbers, constitute the fishery in Cochin Backwater especially at the head of the estuarine system around Cochin. Several species of cyclopod copepods which have been recorded only from neritic and oceanic waters were encountered in brackish waters showing their euryhaline nature. During the Southwest monsoon season and soon after, salinity goes low in the estuary and its visinity and this is similar to the prevailing condition in the estuarine head. Thus, the organisms inhabiting such a coastal estuarine system at certain periods of the year are able to withstand drastic changes. Another possible factor is the great increase in the available food supply that is found in the region of such estuaries.

Earlier works on this group of copepods in Indian estuaries is confined to the description of species or records of their occurrence in different areas. George (1958) made an attempt at quantitative study of the planktonic copepods of Cochin Backwater mentioning of only *Oithona* sp. and its occurrence. Wallershaus (1969, 1970) gave a detailed treatment of the taxonomy of some of the copepods of the estuarine system chiefly calanoids found around Cochin. Thompson and Easterson (1977) studied the dynamics of cyclopoid copepod population in Cochin Backwaters. In this account the various trends in the occurrence and abundance of 28 species of planktonic cyclopoid copepods are dealt with. The effect of salinity and temperature on their distribution is also elucidated.

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Material and Methods

The material for the present study is based on regular zooplankton samples collected from two fixed stations (Fig. 1) for two years from January, 1970 to December, 1971. Tows were made for 10 minutes (5 minutes subsurface and 5 minutes along the surface)

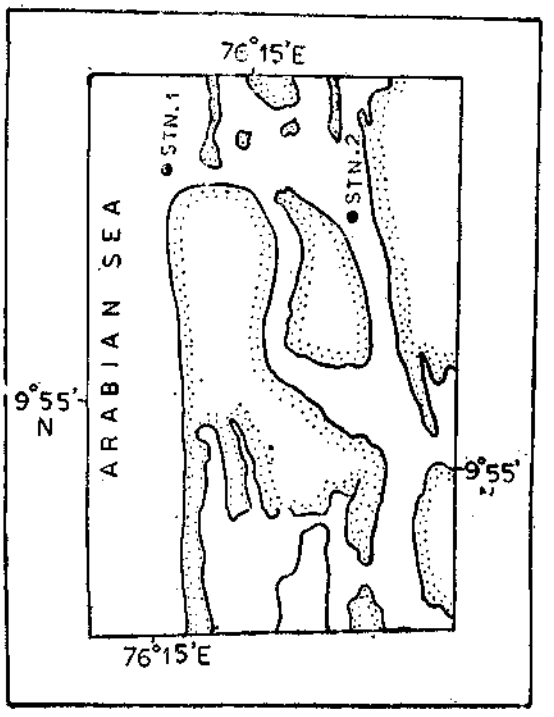

Fig. 1. Part of the Cochin Backwater showing the stations from where material was collected for ecological study.

and the speed of the boat in each tow was kept at 1-1.5 knots. The conical net used had a diameter of 0.5 m with nylon gauze of 0.33 mm mesh size. The volume of the water filtered was determined by 'TSK-487' flow meter. The samples were preserved in 5% formalin. Along with each plankton collection, measurements of temperature and salinity were also made from the same station.

By the displacement method the total quantity of zooplankton was studied volumetrically. Through a close meshed gauze attached to the bottom of a cylindrical tube, the samples were strained and was allowed to drain off on paper towelling, after which a known volume of 5% formaldehyde was added to it. The total volume of the sample was estimated since the values obtained thus was so small. Since the volume of plankton was less in most of the samples, for the enumeration of cyclopoid copepods, entire samples were examined. The number of each species of cyclopoid copepod present in the samples was tabulated.

Total estimate for 1000 m^3 of water filtered have been calculated and monthly averages are plotted for the same period. In studying the numerical abundance and correlations, standard statistical methods were used.

Environment

The northern portion of the Vembanad Lake is called the Cochin Backwater (09° 58'N, 76°15'E) and it is a typical estuary and includes part of a long chain of canals. The ecosystem of the area is influenced by the sea and fresh water of which, the influence of the latter being considerable during the monsoon period. It has a perennial connection with the Arabian Sea, which form the main entrance to Cochin Harbour. This region is subjected to regular tidal influence and the tides of this area are of semi diurnal nature whose maximum range is about 1 m. There also exists a similar connection with the Arabian Sea at Azhicode, about 25 km north of Cochin which also has a bearing on the hydrography of the Vembanad Lake. Variation of annual temperature at Cochin being 28°-34°C and average annual rainfall based on data from 1967-1972 is

about 1080 mm, of which about 75% occurs during the Southwest Monsoon (June — September).

Environmental features

The topography and hydrography of the Cochin Backwater has been reported by a number of recent workers (George, 1958; George and Kartha, 1963; Ramamirtham and Jayaraman, 1963; Cheriyan, 1967; Qasim *et al.*, 1969; Qasim and Gopinathan, 1969; Sankaranarayanan and Qasim, 1969; Josanto, 1971; Gopinathan and Qasim, 1971; Menon *et al.*, 1971; Gopinathan, 1972; Wellershaus, 1972; Sumitra *et al.*, 1972; Pillai *et al.*, 1973; Pillai and Pillai, 1973; Qasim *et al.*, 1974; Madhupratap and Haridas, 1975; Nair *et al.*, 1975; Joseph and Pillai, 1975). There seems to be three distinct periods in any year noticing the trend in salinity of this area (1) a period of low salinity — June to September; (2) a period of gradual rise in salinity — October to January; and (3) when the surface salinity of Cochin Backwater is comparable to that of the adjacent inshore waters — February to May.

Temperature remains uniform throughout the water column and records its higher values due to warm weather and solar radiation during the period January to April. A gradual fall in temperature at the surface and a rapid lowering at the bottom were noticed with the onset of monsoon during July and thence onto August which is mainly due to the intrusion of cold water into the estuary (Ramamirtham and Jayaraman, 1963; Sankaranarayanan and Qasim, 1969). The thermal gradient which usually develops by June lasts till September-October. During November-December, the temperature records a fall and this usually coincides with the onset of Northeast monsoon.

Various seasonal environmental features of the Cochin Backwater have been reviewed by Sankaranarayanan and Qasim (1969). Little change in dissolved oxygen is noticed in surface layers, but at deeper layers during the monsoon months, very low oxygen values were recorded, and when the marine condition begin to occur, this gradient disappears. During the monsoon months, pH values are low. A pronounced fall in alkalinity is seen during monsoon months and also recovery of values were observed during the same period. From January to May, the nutrient concentration is homogeneous, but high concentrations are recorded during the monsoon months with gradient zone in different depths. Solar radiation and its penetration in the Cochin Backwater have been studied by Qasim *et al.*, (1968) and according to them the maximum solar radiation reaches the surface during December to March and the minimum from June to September, 250-500 g cal/cm^2/day being the range of radiation intensity.

Physical Features

Salinity

The mean monthly variation of surface salinity during the period of observation are shown in Fig. 2 a. The yearly cycle of variations was more or less similar in 1970 and 1971. A decreasing trend in surface salinity was noticed from higher values in March-April and a sharp fall at the onset of Southwest monsoon in June. From June to August, this decline was continued, after which period, a steady increase till December was recorded. A slight decline was noted during December January and after that until March-April, the values evinced an increasing trend.

Temperature

Observations in the variations on monthly mean values of surface temperature at stations are shown in Fig. 2 b. The annual cycle of variations was observed to be more or less similar in 1970 and 1971. The maximum value were recorded during April and minimum value during September, 1970. A steady increase in temperature from March to April

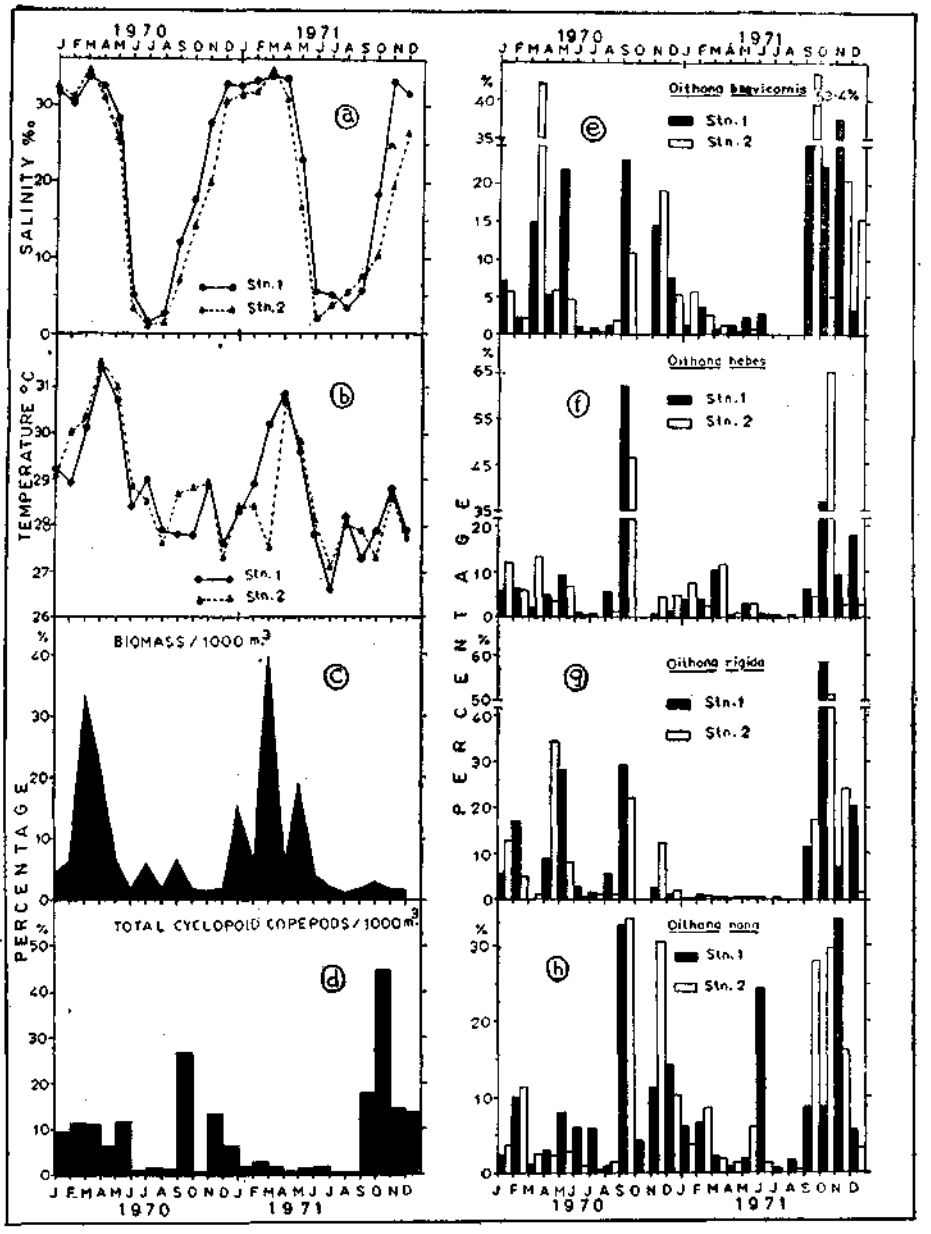

Fig. 2 a. Fluctuation in salinity from January, 1970 to December, 1971, b. Fluctuation in temperature, c. Monthly fluctuation of zooplankton biomass, d. Monthly fluctuation in composition of total cyclopoid copepods. Relative percentage by counts of cyclopoid copepods in the Cochin Backwater, e. *Oithona brevicornis*, f. *O. hebes*, g. *O. rigida* and h. *O. nana*.

was noticed and registered a peak in April and a fall in May. Till August its downward trend was continued after which during October in 1970, a gradual increase was noted, followed by a gradual decline during the following months. A rapid increase in surface temperature was observed from January onwards.

Biological Features

The variation in the distribution of the mean monthly displacement volumes of zooplankton from January, 1970 to December, 1971 are shown in Fig. 2 c. During January to May, usually the plankton volumes were relatively high and during June to August, they were low. In the September to November period, a secondary maximum was noticed. In 1970 and 1971, the yearly cycle of variations was more or less similar, but from year to year the period of maxima showed slight variations. As previously noted, during June to August, the rainfall was maximum and this has a significant effect on the distribution of zooplankton of this area, since the dominant species constituting the bulk of the zooplankton are marine in origin. Many marine organisms migrate from the environment consequent to the heavy rain and the resultant large influx of fresh water into the estuarine system.

From January to April (peak in March) the mean monthly data of zooplankton biomass shows high values and low values during August, 1970. A secondary peak was observed in July. During the Northeast monsoon period (October-December), a downward trend in the values was noted. Although low values were met with in April, 1971, the seasonal trend in increase was maintained. Thus the zooplankton abundance showed more or less a similar pattern of variation from year to year despite changes in the seasonal abundance of the cyclopoid copepod in the plankton.

Total cyclopoid copepod population

A total of 28 species of cyclopoid copepods were identified and the data presented here pertains to the species which occur in the estuary.

Two maxima were apparent during the period, a minor peak during the pre-monsoon period and a major one during the post-monsoon months (Fig. 2 d). Aside from the first maxima noted either during the months of March, April or May of any year, it was seen that greater number of species of cyclopoid copepods were present in the estuary during October to March when the temperature and salinity values were higher. A drastic diminution of the stock was noted from April onwards with least numbers occurring during the monsoon months. Following the monsoonal minimum noted, the average monthly catches increased from August onwards and registered a major peak during September in 1970, and October in 1971. A gradual decline in population was noted in October, 1970 and November in 1971.

During this period, other planktonic organisms such as fish eggs, fish larvae, chaetognaths, hydromedusae, ctenophores and lucifers were abundant in the estuary, of these the fish larvae and chaetognaths are known to feed extensively on cyclopoid copepods especially copepodites. The presence of fish eggs in abundance in the plankton samples during May indicates that fishes were spawning at that time in the estuary, the postlarvae and juveniles of which could have made serious inroads on the existing stock of copepods. Studies on the seasonal occurrence of the carnivorous forms carried out by George, 1958 ; Vannucci *et al.*, 1970 ; Santhakumari and Vannucci, 1971 ; Srinivasan, 1971 ; Nair, 1971 ; Menon *et al.*, 1971 reveal that their abundance in the plankton coincide with that of cyclopoid copepods in the Cochin Backwater.

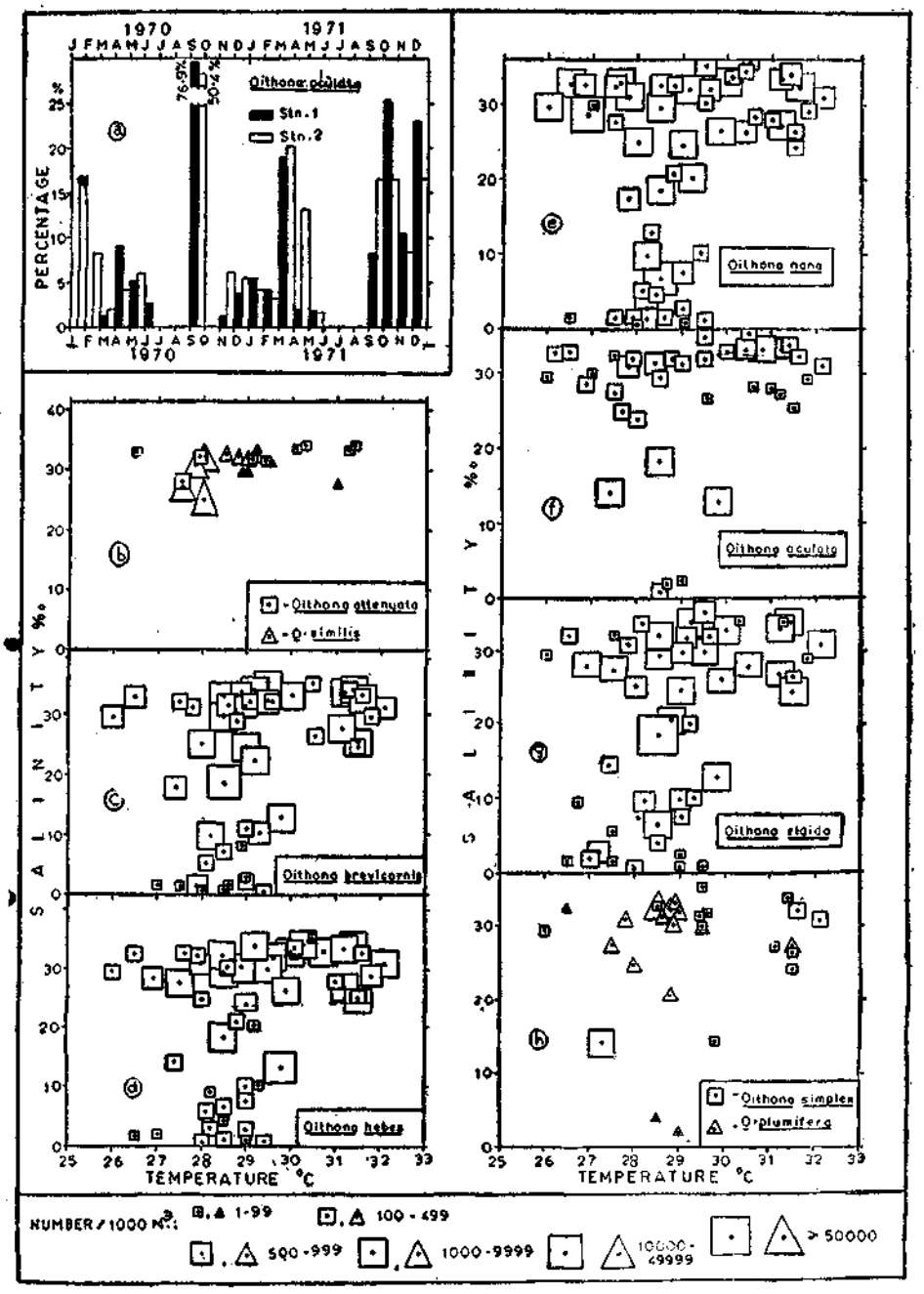

Fig. 3 a. Relative percentages by counts of cyclopoid copepod *Oithona oculata*. T-S-P diagrams and species abundance of b. *Oithona attenuata* and *O. similis*, c. *O. brevicornis*, d. *O. hebes*, e. *O. nana*, f. *O. oculata*, g. *O. rigida* and h. *O. simplex* and *O. plumifera*.

All these above observations suggest that these carnivorous forms occur in the plankton in good numbers when there is also an increase in the cyclopoid copepod population in the estuary and diminish soon after when the cyclopoid copepod decrease in their numbers. No study has been carried out on the feeding behaviour and the propensities of these predators, but it is felt that a good proportion of cyclopoid copepods as nauplii, copepodites and adults form food for other zooplankters. Moreover the occurrence of these predatory forms in the Cochin Backwater in large numbers indicates a very high secondary production in the estuary.

Distribution of Adult Cyclopoid Copepods

During the post-monsoon months in 1970 and 1971, the adult population of copepods represented by cyclopoid species were highest. Almost all the species recorded decline in number to varying degrees by the end of May or June, although certain typical brackish-water species such as *Oithona hebes*, *O. brevicornis*, *O. rigida* and *O. nana* continued to be present in good numbers. In several species, during the end of pre-monsoon months (May-early June), decline was constant and in the beginning of October-November period, a reversal in trend was noted. A unimodal pattern of distribution was noticed when the adults of all the species were taken together, although it was found that several of them showed more than one peak and the peak was not synchronised in these species when different species were studied separately. One of the peak periods observed of majority of copepod species corresponds with the period September-April, which is the season of population abundance in the estuary.

Occurrence and Seasonal Distributions

The species-wise analyses of the numerically more abundant species are dealt with below.

Oithona brevicornis Giesbrecht (Fig. 2 e)

This is one of the common species present in the plankton in abundance during pre-monsoon months and to a lesser extent during monsoon and post-monsoon months during 1970, but the case was reversed during 1971. During 1970, it was numerous during March to May, September and November and was absent in October. In 1971, a minor peak was seen in February and numerically abundant during September-December. From the pattern of distribution it was evident that it occurs in the plankton throughout the year, but in more numbers during high saline and warm waters of the pre-monsoon and post-monsoon months.

Oithona hebes Giesbrecht (Fig. 2 f)

This species was present in the plankton in abundance during the pre-monsoon and to a higher extent during post-monsoon months during 1970 and 1971. During 1970, it was numerous during January to May, August and September and in 1971 during January to March and September to December. The major peak in 1970 was observed during September and in 1971 during October. From the pattern of distribution it is evident that this species prefers the warm and high saline waters of the pre-monsoon and post-monsoon months.

Oithona rigida Giesbrecht (Fig. 2 g)

This is a common species present in the plankton in good numbers during the pre-monsoon and to a higher extent during the post-monsoon months. During 1970, it was numerous during January, April, May, September and November and in 1971, it was more abundant during the period September to December. In 1970, its peak period was observed in April, after which dwindled in numbers, but a secondary peak was seen in

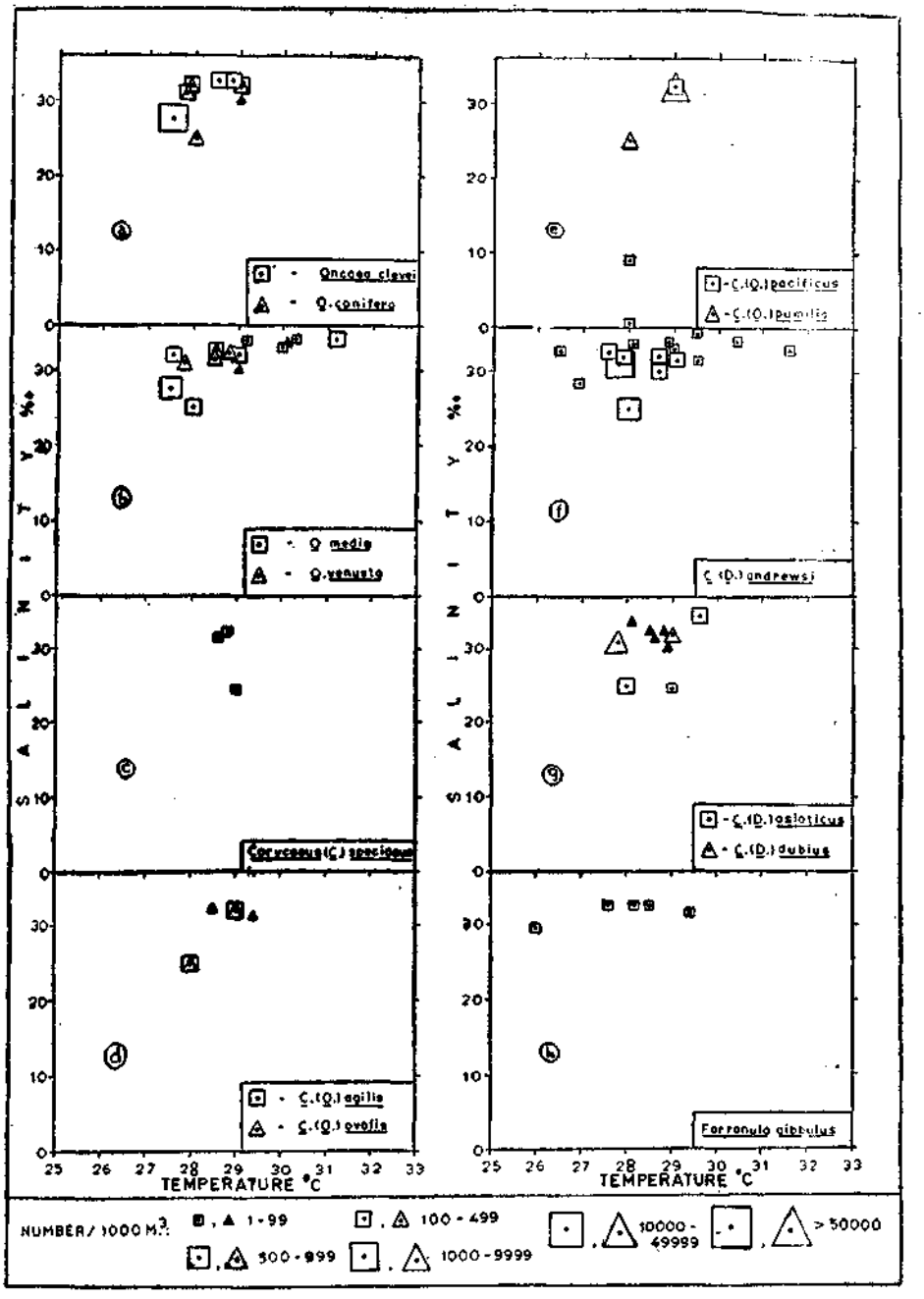

Fig. 4. T-S-P diagrams and species abundance of a. *Oncaea clevei* and *O. conifera*, b. *O. media* and *O. venusta*, c. *Corycaeus* (*Corycaeus*) *speciosus*, d. *C.* (*Onychocorycaeus*) *agilis* and *C.* (*O.*) *ovalis*, e. *C.* (*O.*) *pacificus* and *C.* (*O.*) *pumilis*, f. *C.* (*Ditrichocorycaeus*) *andrewsi*, g. *C.* (*D.*) *asiaticus* and *C.* (*D.*) *dubius* and h. *Farranula gibbulus*.

TABLE 1. *Species-wise average monthly occurrence of cyclopoid copepods (No/1000 m³)*

Species (1)	Year (2)	Stn. (3)	J (4)	F (5)	M (6)	A (7)	M (8)	J (9)	J (10)	A (11)	S (12)	O (13)	N (14)	D (15)
Oithona attenuata	A	1	235	—	47	47	—	—	—	—	—	—	—	—
		2	47	—	47	47	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	470
		2	—	—	—	—	—	—	—	—	—	—	—	470
O. plumifera ..	A	1	423	—	47	—	—	—	—	—	—	—	235	—
		2	454	—	—	—	188	—	—	—	—	—	—	47
	B	1	—	—	—	—	—	—	—	—	—	—	—	235
		2	—	—	—	—	—	—	—	—	—	—	—	235
O. similis ..	A	1	188	—	—	—	—	—	—	—	—	—	—	—
		2	188	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	1,410	6,932
		2	—	—	—	—	47	—	—	—	—	—	—	1,175
O. simplex ..	A	1	47	—	—	—	159	—	—	—	—	—	71	94
		2	71	—	—	47	—	—	—	—	—	—	—	94
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	47	—	—	—	—	—	—	—	—	—
Oncaea clevei ..	A	1	188	—	—	—	—	—	—	—	—	—	—	—
		2	235	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	470	470
		2	—	—	—	—	—	—	—	—	—	—	—	1,880
O. conifera ..	A	1	47	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	470	—	470	235
		2	—	—	—	—	—	—	—	—	—	—	—	235
O. media ..	A	1	188	—	—	47	—	—	—	—	—	—	—	—
		2	117	—	—	94	—	—	—	—	—	—	—	—
	B	1	—	47	—	—	—	—	—	—	—	—	470	235
		2	—	—	—	—	—	—	—	—	—	—	—	1,175

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
O. mediterranea ..	A	1	—	—	—	—	—	—	—	—	47	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
O. venusta ..	A	1	94	—	47	—	—	—	—	—	—	—	235	—
		2	141	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
Corycaeus (Corycaeus)	A	1	—	—	—	—	—	—	—	—	—	—	—	—
crassiusculus		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	235
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (C.) speciosus	A	1	47	—	—	—	47	—	—	—	—	—	47	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (Ditrichocorycaeus)	A	1	—	—	—	—	—	—	—	—	—	—	—	—
affinis		2	47	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (D.) andrewsi ..	A	1	59	—	—	—	47	—	—	—	—	—	—	94
		2	94	—	94	47	—	—	—	—	—	—	—	—
	B	1	—	47	—	—	—	—	—	—	—	—	470	1,410
		2	—	70	47	—	—	—	—	—	—	—	—	940
C. (D.) asiaticus ..	A	1	—	—	—	—	47	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	47	—	—	—	—	—	—	—	—	235

TABLE 1 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
C. (D.) dahli ..	A	1	—	—	—	—	94	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (D.) dubius ..	A	1	94	—	—	—	—	—	—	—	—	—	47	—
		2	70	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	47	—	—	—	47	—	—	—	—	470	940
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (D.) subtilis ..	A	1	71	—	47	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (Onychocorycaeus) agilis	A	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	470	—
		2	—	—	—	—	—	—	—	—	—	—	—	235
C. (O.) ovalis ..	A	1	47	—	—	—	—	—	—	—	—	—	—	—
		2	47	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	470	—
		2	—	—	—	—	—	—	—	—	—	—	—	235
C. (O.) pacificus ..	A	1	47	—	—	—	—	—	—	—	47	—	—	—
		2	—	—	—	—	—	—	—	—	94	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	1,410	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (O.) pumilis ..	A	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	1,410	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
Farranula gibbulus	A	1	47	—	—	—	—	—	—	—	—	—	—	—
		2	47	—	—	—	—	—	—	—	—	—	—	47
	B	1	47	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
Sapphirina nigromaculata	A	1	—	—	—	—	—	—	—	—	—	—	—	47
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—

A = 1970; B = 1971

September. During 1971. the secondary peak was in October.

Oithona nana Giesbrecht (Fig. 2 h)

This is one of the common species present in the plankton and found in abundance during the pre-monsoon months and to a higher extent during post-monsoon months. A major peak was observed during October, 1970 and 1971. The maximum number of this species were seen during September to December during both the years.

Oithona oculata Farran (Fig. 3 a)

This species is present in the plankton samples during the pre-monsoon and post-monsoon months. The major peak was observed during September 1970 and 1971. It was absent in the plankton during July, August and October in 1970 and during June to August in 1971. It was present in the plankton samples in good numbers during September to December.

Several other species appear only occasionally and details about their seasonal cycles and relative abundance are given in Table 1 for a period of two years for the two stations.

Seasonal Fluctuations

George (1958), Tranter and Abraham (1971), Pillai *et al.*, (1973) and Madhupratap *et al.*, (1975) have attempted studies on the seasonal cycle of different group of copepods through the course of a year from the Cochin Backwater. Similar investigations carried out from the inshore waters along the west coast of India revealed that the peak period of occurrence was during January to February along Trivandrum coast (Menon, 1945); during October to December at Calicut (George, 1953; Subrahmanyan, 1959; Mukundan, 1971) and during March to April and October to November in the inshore waters off Bombay (Pillai, 1968). From all these studies it is evident that the copepod density along the western coastal waters of India is higher during October to March. The characteristics of the inshore coastal waters exert profound influence on the seasonal rhythm as it is evident in the pattern of occurrence and distribution of the copepod in the Cochin Backwater.

Many species of pelagic cyclopoid copepods exhibit distinct seasonal periodicity as it is evident in the monthly distribution of species.

Table 2. *Maximum abundance recorded for 5 species of cyclopoid copepods in the Cochin Backwater during January 1970 to December 1971 for the two stations*

Species	Stn.	January 1970 to December 1970	January 1971 to December 1971
Oithona brevicornis	1	September	November
	2	March	September
Oithona nana	1	September	November
	2	September	October
Oithona hebes	1	September	October
	2	September	October
Oithona oculata	1	September	October
	2	September	March
Oithona rigida	1	September	October
	2	September	October

The following categories of ecological subdivisions can be made out in the Cochin Backwater based on the pattern of distribution and seasonal occurrence.

(i) Species which occur either throughout the year or for most part of the year: *e.g. Oithona brevicornis, O. hebes, O. nana, O. rigida, O. oculata.*

(ii) Species which occur only during certain months of the year apparently influenced by higher salinity: *e.g. Oithona plumifera, O. simplex, O. attenuata, Corycaeus (Ditrichocorycaeus) andrewsi*, etc.

(iii) Species which are very rare and occur sporadically in small numbers in Cochin

Backwater, the distribution of some of which may be considered fortuitous : *e.g. Oithona similis, Oncaea venusta, O. media, O. conifera, O. clevei, Corycaeus (Onychocorycaeus) pacificus, C. (O.) Ovalis, C. (O.) agilis, C. (O.) pumilis, C. (Ditrichocorycaeus) asiaticus, C. (D.) dubius, C. (D.) affinis, Farranula gibbulus.*

Role of Temperature and Salinity on the Distribution

In the estuary, environmental changes are of prime importance because of their action directly upon the physiological processes of the organisms, especially upon the rate of metabolism reproductive cycle and longivity which have a direct bearing on their relative abundance. Not merely species, but many genera and even higher systematic categories are confined entirely, or nearly so to a particular watermass. The relationship of a particular species with T-S can be utilised as a character which determines the range and tolerance of that species when it occurs at a particular environment and is also an useful instrument for understanding the ecology of the species. There are hardly any references from the Indian Seas on the effect of environmental changes on the abundance of a given species of planktonic cyclopoid copepods.

The monthly fluctuation in composition of the total cyclopoid copepod in the Cochin Backwater during the two year period January 1970 to December 1971 are shown in relation to T-S diagram (Fig. 2). In Fig. 3 b-h and 4 a-h, the occurrence and abundance of the following species namely *Oithona similis, O. attenuata, O. brevicornis, O. nana, O. oculata, O. rigida, O. simplex, O. plumifera, Oncaea clevei, O. conifera, O. media, O. venusta, Corycaeus (Corycaeus) speciosus, C. (Onychocorycaeus) agilis, C. (O.) ovalis, C. (O.) pacificus, C. (O.) pumilis, C. (Ditrichocorycaeus) andrewsi, C. (D.) asiaticus, C. (D.) dubius,* and *Farranula gibbulus* in the temperature and salinity ranges are also drawn.

Distribution of species

Distribution pattern of 23 species of calanoid copepods that were recorded from Cochin Backwater during 1968-1969 has been briefly discussed by Pillai (1971) and the range of salinity within which each species occurs, and came to the conclusion that particularly the marine forms in the estuary have restricted distribution.

28 species of cyclopoid copepods have been studied in the present observation. Based on the observed salinity values and the range of salinity within which each species occur, the species are divided into two groups as follows :

Group A : *Species which generally occur in salinity less than* 25‰.

Oithona brevicornis, O. hebes, O. rigida, O. plumifera, O. nana, O. oculata, Corycaeus (Onychocorycaeus) pacificus.

Group B : *Species which occurs in salinity above* 25‰.

Oithona similis, O. simplex O. attenuata, Oncaea venusta, O. media, O. clevei, O. conifera, O. mediterranea, Corycaeus (Corycaeus) speciosus, C. (C.) crassiusculus, C. (Ditrichocorycaeus) subtilis, C. (D.) affinis, C. (D.) andrewsi, C. (D.) dubius, C. (D.) dahli, C. (D.) asiaticus, C. (Onychocorycaeus) ovalis, C. (O.) agilis, C. (O.) pumilis, Farranula gibbulus, Sapphirina nigromaculata.

The following species namely *Oithona similis, Oncaea venusta, Corycaeus (Corycaeus) crassiusculus, C. (Ditrichocorycaeus) subtilis, C. (D.) affinis, C. (D.) dubius,* and *Sapphirina nigromaculata* which are categorised under Group B, have limited distribution in the estuary during the pre-monsoon months when the salinity in the estuary is in par with that of nearshore waters.

Discussion

The Cochin Backwater receives run off from the Southwest monsoon between June and August and also some rain from the Northeast monsoon from October to December. The discharge from the rivers during the monsoon period reduces the salinity of the backwater system considerably. Thus for six months of the year, the environment is subjected to drastic changes due to the influx of fresh water. The estuarine area for the remaining six months (December to May) is relatively stable with regard to temperature and salinity, particularly near the mouth of the estuary from where the collections were made for the present study. During the hot pre-monsoon period, evaporation and reduced flow of fresh water results in an increased salinity of the whole system. Based on the hydrographical condition of the Cochin Backwater, three seasons can be recognised in any year as indicated earlier. Thus fluctuating hydrological conditions influence the ecosystem resulting in the seasonal and biological cycles of cyclopoid copepods.

This study tends to show that of all the physico-chemical factors, salinity is pivotal in controlling the occurrence and abundance of cyclopoid copepods in the Cochin Backwater. Owing to the perennial connection with the sea, there is a regular ingress and egress of marine plankters to the backwater, caused in part by the tidal flow. This was evident, for most of the species studied, the maximum abundance was met with during the pre-monsoon months, when the estuary was less turbulant and the hydrographical parameters were comparable to the inshore waters.

The mixo-euryhaline population tend to re-establish themselves in the estuary after the monsoon as evidenced by a general reversal from limnophilous condition to the monsoon period. With steady high tidal influence and watermass movements, pockets of high saline water persist in the lower layers in the estuary. On the distribution of surface salinity, Ramamirtham and Jayaraman (1963) remarked that with high salinity at the bottom and almost freshwater at the surface, there is a very sharp gradient of salinity resulting from the stratification, during the monsoon months. Studies on the salinity changes in the Cochin Backwater corresponding to tidal variation were studied by Qasim and Gopinathan (1969) and they opined that during the monsoon period large quantities of freshwater enter the estuary, resulting in very low saline waters at the surface and a denser layer of saline water at the bottom. Moreover differences induced by tides are well pronounced at the surface and bottom during this season and the mixing gets prevented with the result that brackishwater at the surface remains more or less undisturbed. Since zooplankton collections were not made from the bottom layers, the effect of this layer on the distribution of cyclopoid copepods could not be ascertained. There is reason to believe that since some species do not completely disappear, it can be migrating to this higher saline bottom waters or present in the pockets of high saline waters.

The tidal action is quite conspicuous throughout the year in the Cochin Backwater. During the post-monsoon months, the maximum tidal ranges were about 1 m. The entire water column gets well mixed during this period and the salinity of the backwater increases at the flow and decreases at the ebb. During this period along with the tidal current, several marine species of the cyclopoid copepod population also enter the estuarine system. This is evident from the nature of the cyclopoid copepod population of the backwater. Several of the species present are marine forms that have been recorded from the coastal waters of this region and some species have a very wide distribution and are found in tropical waters in almost all the world oceans. The marked fluctuation in abundance of the various

typically marine forms is easily explained when linked up with the widely varying salinity of the estuarine waters. It is also observed that such species propagate in the estuary (e.g. *Oithona simplex, O. attenuata, Corycaeus* (*Ditrichocorycaeus*) *andrewsi, Oncaea clevei, C.* (*Onychocorycaeus*) *agilis* from the end of post-monsoon period to throughout the pre-monsoon period, but are uncommon during the low salinity regime.

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