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DISTRIBUTION OF CHAETOGNATHS ALONG THE SALINITY GRADIENT IN THE COCHIN BACKWATER, AN ESTUARY CONNECTED TO THE ARABIAN SEA*

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ABSTRACT

A study was made of the chaetognaths of the Cochin Backwater. *Krohnitta pacifica* Aida, *Sagitta bedoti* Béraneck, *Sagitta enflata* Grassi and *S. oceania* Gray were the species found in the collections. *S. bedoti* was the dominant chaetognath. *S. oceania* is recorded for the first time from Indian waters.

Representatives of different sizes of *S. bedoti* belonging to two maturity cycles were encountered in a few samples. This phenomenon of recurring maturity stages in *S. bedoti* is observed for the first time and this may ensure sufficient reproductive potential to maintain the population in an estuarine habitat. Occurrence of *S. enflata* in great abundance at barmouth during the postmonsoon period is associated with the incursion of oceanic water into the area.

Salinity plays a major part in controlling the distribution of chaetognaths in this estuary. They penetrated to the southernmost part of the estuary during the premonsoon period when a uniform high salinity prevailed throughout the system. In the postmonsoon period the chaetognath population synchromically followed the steep gradient in salinity along the estuary and became restricted to its seaward end. It is suggested that during the monsoon period they are removed from the area and fresh recruits from the sea are brought back to the system along with the incoming waters of the postmonsoon period.

INTRODUCTION

PRELIMINARY observations on the seasonal fluctuations of environmental conditions and of chaetognaths in the Cochin Backwater (Vijayalakshmi, 1971) indicate that salinity is probably the principal factor controlling the distribution of chaetognaths in the area. This prompted further studies on the aspect. An ideal environment for such an investigation was found in the extensive stretches of shallow water lagoons connecting the main part of the Vembanad Lake with the Arabian Sea. Salinity in the estuary during the monsoon and postmonsoon season is almost nil, but during the premonsoon, marine conditions prevail. The varying salinity conditions were expected to take place along a considerable extent towards the head of the estuary and hence resultant changes in the chaetognath population along with the salinity gradient was studied. Surveys were conducted with a view to find out the seasonal changes in the faunal composition of the local waters.

The area of investigation, namely the Cochin Backwater is an open estuary with a perennial connection with the Arabian Sea. The hydrographical conditions prevailing in the area have been studied by previous workers (Ramamirtham and Jayaraman, 1960, 1963 ; Qasim and Gopinathan, 1969 ; Vijayalakshmi, 1971 and others).

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Material and Methods

Two series of samples were taken between the barmouth at Cochin and Alleppey (Fig. 1) towards the head of the estuary, a distance of about sixty kilometres from barmouth. One was in November 1968 and the other in April 1969. During both the cruises, samples were taken at nine stations, working towards the head of the estuary by day and towards the mouth by night (Nair and Tranter, 1971). The stations are shown in Fig. 1.

All the samples were taken from surface hauls of 2-5 minutes duration using a HT net (Tranter *et al.*, 1972). The net has a mouth area of 0.25 m² and a mesh width

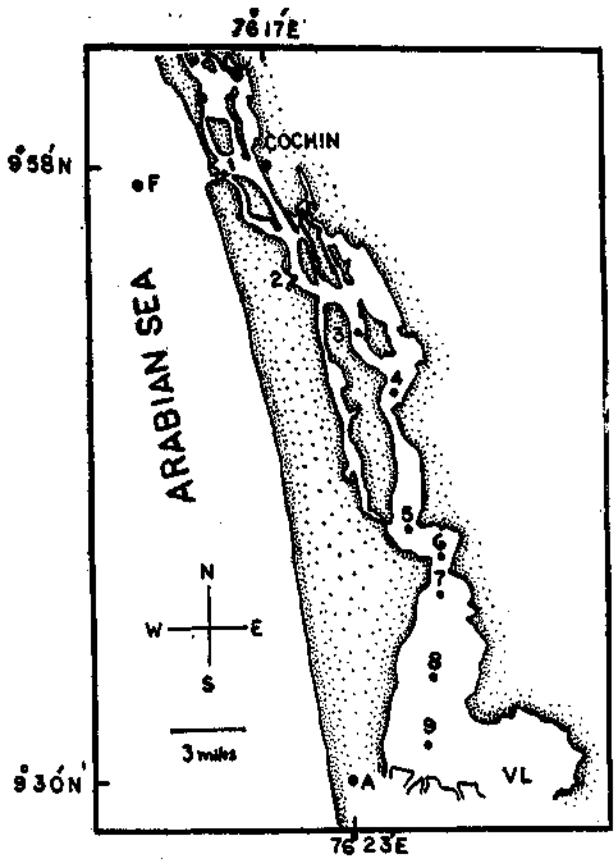

Fig. 1. Map of the Cochin Backwater and Vembanad Lake showing the location of the stations. (A—Alleppey; F—Fairway Buoy; and VL—Vembanad Lake).

of 0.2 mm. The samples were preserved in 5% formalin buffered with 1% hexamethylene tetramine. Chaetognaths from these collections were separated and identified. The figures given here refer to the calculated number of specimens per 100 cubic metres of water filtered which is here taken as the measure of density of the population.

Salinity was measured at each station using an Induction Salinometer and temperature of the surface water was also recorded.

OBSERVATIONS

Salinity values are shown in Figs. 2, 3 and 4. The estuary showed a steep gradient of surface salinities during the postmonsoon period (November) with a maximum value at the barmouth and very low towards the head of the estuary (28.6‰ to 0.2‰). During the premonsoon period (April) higher salinity prevailed throughout the estuary with a lowering towards the head (33.5‰ to 25.3‰).

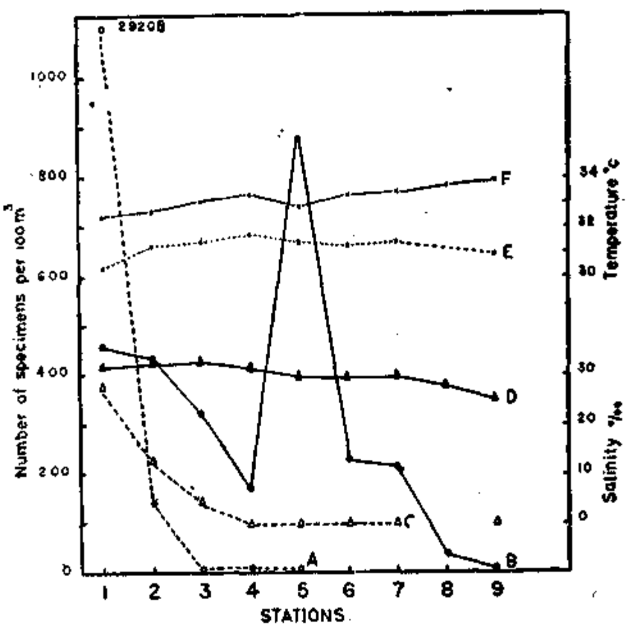

Fig. 2. Distribution of chaetognaths during the postmonsoon and premonsoon periods along with salinity and temperature data. A. Chaetognatha (Postmonsoon), B. Chaetognatha (Premonsoon), C. Salinity (Postmonsoon), D. Salinity (Premonsoon), E. Temperature (Postmonsoon) and F. Temperature (Premonsoon).

Compared to the wide salinity range, temperature variations were not pronounced. During the postmonsoon it varied from 30.3-31.7°C and in the premonsoon period it ranged from 32.4-33.9°C.

Fig. 2 shows the average representation of chaetognaths along with temperature and salinity values for the nine stations worked during the postmonsoon and premonsoon periods. The postmonsoon collections showed high concentrations of chaetognaths at station 1 (29208/100m^3) and a sudden decline in numerical abundance was observed at station 2 followed by extreme low value towards the central part of the area, and complete absence in stations 6 to 9. In the premonsoon, chaetognaths were abundant and they were present in all the samples, the maximum abundance was noticed at station 5 (878/100m^3) located at a distance of about 26 km from station 1. During the postmonsoon period total (average) number of chaetognaths in the whole area of investigation was 29367 and that found in the premonsoon period was 2748 for the same amount of water filtered. Thus the total abundance of chaetognaths was found to be ten times more during the postmonsoon period than the premonsoon period. In the postmonsoon period chaetognaths were concentrated at the barmouth, where the population density was about sixty-four times more than that at the same place in the premonsoon period. The area of the barmouth seems to be the boundary between backwaters and coastal waters and thus an enriched area.

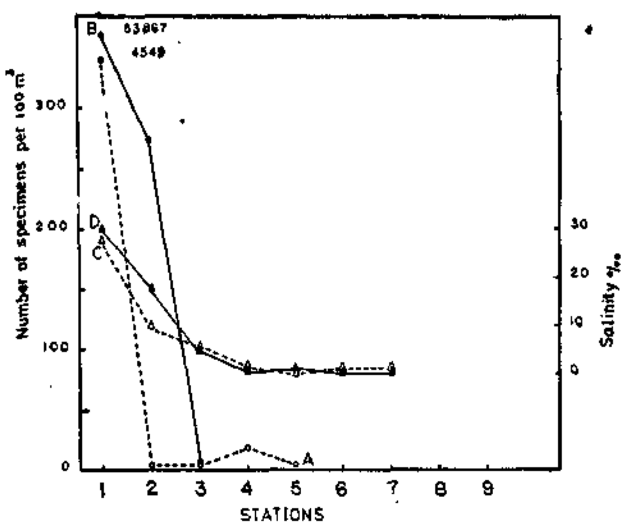

Fig. 3. Distribution of chaetognaths during the postmonsoon period. A. Chaetognatha (day), B. Chaetognatha (night), C. Salinity (day) and D. Salinity (night).

Distribution of chaetognaths during the day and night for the postmonsoon period is shown in Fig. 3 and for that of the premonsoon period in Fig. 4. The day-night differences in salinity are also shown in these figures. These data show that in the postmonsoon period there was marked difference between the day and night samples for chaetognaths at the stations 1 and 2 where the night haul was richer in total numbers. This was probably due to the incoming water as shown by the presence of higher salinity water during the night. At station 3 the values are about the same for both salinity and number. The situation was reversed at station 4 and a few chaetognaths were found during day when salinity was slightly higher, while they were absent in the night samples. During the premonsoon the day and night samples showed remarkable variation in numerical representation of chaetognaths. Salinity was practically the same at the time of day and night sampling. However, population density was found to be much greater in the night samples. At station 9, where salinity was as low as 25‰ chaetognaths were very rare. The day hauls had a maximum of 145/100m^3 at station 1, while the night hauls had a peak of 1721/100 m^3 at station 5.

Four species belonging to two genera *Krohnitta* Ritter Zahony and *Sagitta* Quay and Gaimard were present in these collections. The species were *K. pacifica* Aida, *S. bedoti* Béraneck, *S. enflata* Grassi and *S. oceania* Gray. Of these *S. bedoti* and *S. oceania* were the common species found in the samples. In Fig. 5 is shown the abundance of these two species along with the day-night variation for the premonsoon period.

K. pacifica Aida

This species was recorded only at station 1 (186/100 m^3) in the night sample taken during the November cruise.

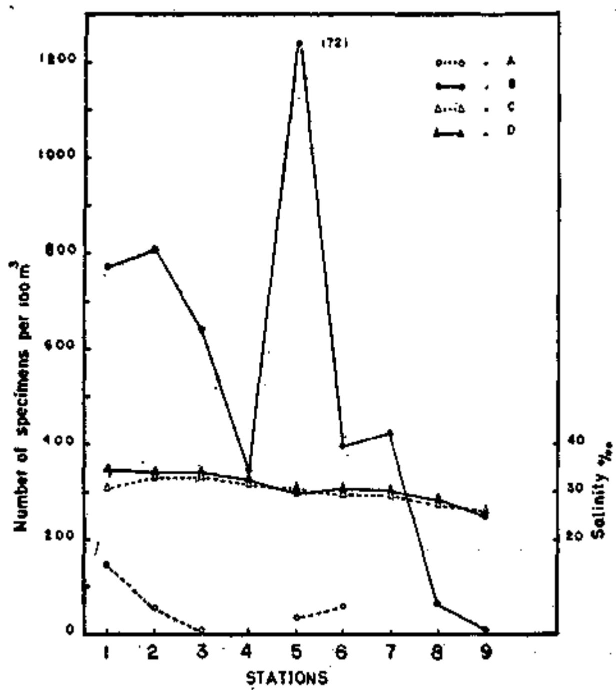

Fig. 4. Distribution of chaetognaths during the premonsoon period. A. Chaetognatha (day), B. Chaetognatha (night), C. Salinity (day) and D. Salinity (night).

S. bedoti Béraneck

S. bedoti was the dominant species in the backwater. In the postmonsoon it was present only at stations 1 and 2, the maximum number being 1527/100 m^3 at barmouth. In the premonsoon month high density populations of chaetognaths in the night collections were partly due to swarms of this species and the maximum abundance was at station 2 (806/100 m^3).

During the analyses of the samples it was observed that the representatives of different sizes belonging to two maturity cycles occur in the same sample. The principal characteristics of the species for the two maturity cycles are shown in Table 1. These two types of specimens differ only in total length and extent of the ovaries. In the smaller specimens which represent the first cycle of maturity the ovary reached upto the middle of the anterior fin. In the second cycle they become longer and the ovaries extend upto the middle of the ventral ganglion. This phenomenon of recurring maturity stage in *S. bedoti* is observed for the first time.

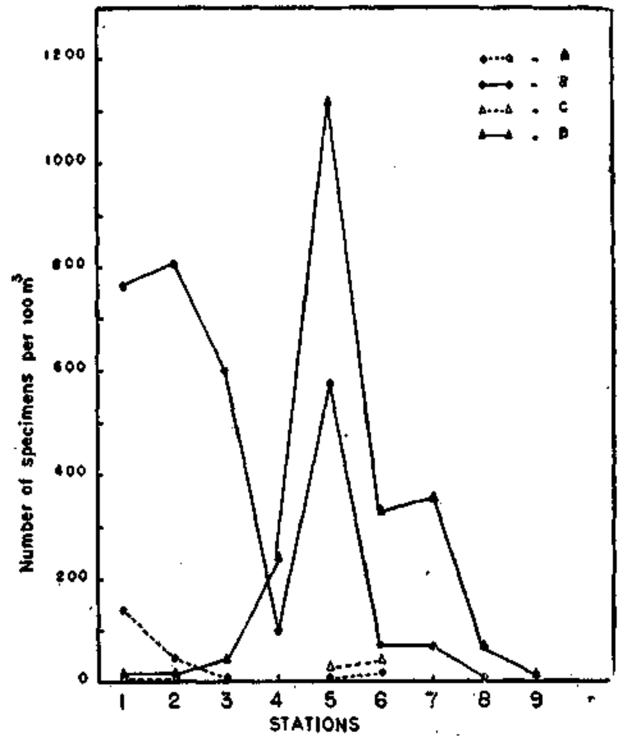

Fig. 5. Distribution of *S. bedoti* and *S. oceania* during the premonsoon period. A. *S. bedoti* (day), B. *S. bedoti* (night), C. *S. oceania* (day) and D. *S. oceania* (night).

Specimens belonging to the second cycle of maturity were encountered only in a few night collections. In the November cruise they were found only at the barmouth (41/100 m³). In the premonsoon period they were recorded from station 1, 2 and 3. The numerical values were 229, 273 and 134/100 m³ respectively.

S. enflata Grassi

This species is not very common in the estuary. However, swarms of *S. enflata* (52154/100 m³) were obtained in the night samples taken at the barmouth during the November cruise. In this cruise *S. enflata* was represented in the samples upto the middle part of the estuary whereas in the month of April they occurred only in one sample taken from station 5.

TABLE 1. *Principal characteristics of* S. bedoti *for the two maturity cycles*

Characteristics	First Cycle	Second Cycle
Total length (mm)	7.9-8.5	10.4-14.7
Tail (% of the total length)	24-25.3	21-24.5
Head	Small with a conspicuous neck	Similar to the first cycle.
Collarette	Short and not thick	Similar to the first cycle.
Anterior fin	Longer and narrower than the posterior fin reaching up to level of middle of ventral ganglion, inner part rayless, most anterior part narrow.	Similar to the first cycle.
Posterior fin	Triangular, reaching close to anterior fin and touching seminal vesicles; more of the posterior fin on the trunk segment.	Similar to the first cycle.
Tail fin	Large and triangular	Similar to the first cycle.
Ovary	Reach up to the middle of the anterior fin; ova round.	Reach up to the middle of the ventral ganglion; ova round.
	Length—27.8-32.6% of the total length; width—0.2 mm.	Length—43-53.3% of the total length; width—0.3 mm.
Seminal vesicles	Oval opening by lateral slit; touching both posterior and tail fin.	Similar to first cycle.
Hooks	6-7	6-7
Anterior teeth	4-5	5-6
Posterior teeth	11-13	11-15

S. oceania Gray

In the postmonsoon collections it was present only at station 3. *S. oceania* was very common in the premonsoon period and numerical representation of the species was more towards the head of the estuary and they dominated in stations 4-9 (Fig. 5). The maximum population density was at station 5 (1116/100 m^3).

This species is recorded now for the first time from Indian waters. The specimens from the present collection attains sexual maturity at a length of 4.4 to 4.8 mm similar to those reported from Pacific (Tokioka, 1959). The recorded length is 7.9 mm from the Palao lagoon (reported as *S. lacunae*) by Tokioka (1942) and it attains 6.5 mm in South China Sea and Gulf of Thailand (Alvariño, 1967). Alvariño has described the presence of spaces in between the ova. But this feature is not to be seen in the present material nor in the specimens described by Tokioka.

The above account of the distribution of chaetognaths shows that during the premonsoon period they penetrate even to the upper reaches of the estuary consequent on the presence of high salinity water in the area. In the postmonsoon period the chaetognath population synchronically follows the decreasing steep gradient in salinity along the estuary.

Discussion

The present investigation confirms the fact that salinity plays a major part in controlling the distribution of chaetognaths in the Cochin Backwaters (Vijayalakshmi, 1971). The incidence and abundance of chaetognaths in this estuary seem to be indicative of the salinity of the water.

Occurrence of *S. bedoti* during the postmonsoon period at station 2 suggests that this species can tolerate salinities as low as 17.5‰. Presence of *S. bedoti* in night samples during November collections at station 2 and the absence of the species in the day samples of the same station coinciding with the lowered salinity value do not seem to be of much significance, and the absence of the species except at stations 1 and 2 during the postmonsoon period can clearly be correlated with the very low salinity of the environment. During the premonsoon period, *S. bedoti* was encountered in all the stations except station number 9. However, in this area *S. bedoti* was most abundant in the 29.6-34.4‰ range of salinity. This species was found to be most abundant in the neritic waters off Visakhapatnam at a range of 31-33‰ (Rao and Ganapati, 1958). The optimum range of salinity seems to be almost similar in the east and west coasts.

Ramamirtham and Jayaraman (1960) studied the hydrographical features of the continental shelf waters of Cochin and considered October-February as the period of sinking. During this period the entire water over the shelf is highly saline because of the deep waters that were previously brought in by upwelling during the southwest monsoon season. By November the fresh water influx practically ceases. Investigations by these authors (1963) in the backwaters around Willingdon Island show that highly saline waters from the sea intrude into the estuary during the period November to May. Thus swarms of *S. enflata* and other oceanic forms may be found at the barmouth during the postmonsoon period (November) and may penetrate into the system with the shelf waters. The distribution of chaetognaths in the Cochin Backwater (Vijayalakshmi, 1971) also shows maximum density population of the species after the monsoon at Fairway Buoy, about 4.8 km from barmouth.

S. oceania was relatively more abundant in the 29.6-32.2‰ range of salinity. *S. oceania* is considered to be a neritic chaetognath (Alvariño, 1965).

The distribution of *S. oceania* during the premonsoon period indicates that they were restricted to a limited area in the estuary. They were present in very few numbers in the samples taken from stations 1 and 2. During the year 1968 fortnightly collections were taken from two stations, one at Fairway Buoy farther north of barmouth (station 1 of the present collection) and the other at Aroor (station 2 of the present collection). *S. oceania* was not represented in these samples (Vijayalakshmi, 1971). It seems that *S. oceania* is not a common species of the backwaters. There is no permanent chaetognath population in this estuarine habitat. During the monsoon period they are carried out to the sea and there they may probably die off. The survivors or fresh recruits from the sea may be brought back to the estuary along with the incoming waters of the postmonsoon period and species with neritic tendencies seem to dominate the estuarine habitat. This suggests that the chaetognath fauna present in the estuary is dependent on the faunal composition of the incoming waters of the postmonsoon period. This may probably be the reason for the occurrence of *S. oceania* in the present samples—a chance occurrence at the time of repopulation.

The two forms of *S. bedoti* encountered in the present collections may indicate separate phases of sexual maturity in the life span of the species. They were found to co-exist in the same sample. This phenomenon of apparent multiplicity of maturity cycles in *S. bedoti* is recorded for the first time and appears to be similar to the different cycles of maturity described for *S. enflata* by Alvariño (1967), Furnestin and Balança (1968) and others. Thomson (1947) considers this size difference as a variability in brood length. Owre (1960) commented that several species in addition to *S. enflata* reproduce more than once. According to Alvariño (1967) the different maturity cycles ' might indicate the presence of different populations in which maturity was reached at various length-sizes. This would also suggest that the source of those populations was different either latitudinally, longitudinally or bathyally '. However, the presence of these two size groups of *S. bedoti* in the present collection suggests that they undergo consecutive cycles of maturity during which they continue to increase in length. As is evident from Table 1, the two groups differ only in total length and extent of ovaries. This indicates the presence of a single population. Perhaps in the backwaters, *S. bedoti* reaches a second maturity cycle due to lack of competition. This may be advantageous to the species by ensuring sufficient reproductive potential to maintain population *S. enflata* which undergoes three or four cycles of maturity is usually dominant and successful in the competition with other chaetognaths and other carnivores.

Tokioka (1942) has reported on the morphological differences among specimens that he identified as *S. bedoti* from the Japanese waters and from the waters surrounding the Palao Islands. The specimens from the Palao regions were smaller (upto 11 mm), with longer tail segment, collarette inconspicuous, anterior fins beginning at the middle of the ventral ganglion, ovary short and area of eye pigment roundish and larger than in the usual type. Japanese specimens were longer (upto 30 mm) with conspicuous collarette, anterior fins beginning in front of the middle of the ventral ganglion and eye pigment in crescent shape. He considers the smaller forms as *S. bedoti f. minor* and the larger forms as *f. typica*. Alvariño (1967) while reporting on the chaetognaths from the Naga Expedition disputed the occurrence of *S. bedoti f. typica* from Japanese waters and considers it to be *S. nagae* Alvariño. However, the form under consideration does not show any morphological differences pointed out by Tokioka and hence they cannot be considered as a different species or form.

The occurrence of *K. pacifica* in the Cochin Backwater is associated with the incursion of oceanic waters (Vijayalakshmi, 1971). The incidence of this species at barmouth during the postmonsoon period indicates the presence of oceanic waters.

In the premonsoon series chaetognaths showed the maximum concentration in the night hours and at stations 1 and 2 in the postmonsoon collections. A perusal of the tidal data during the time of collection indicates that there was no tidal effect and therefore conditions were comparable in day and night. Even though the estuarine area is very shallow (1-5 metres) this remarkable difference in numerical representation of chaetognaths at stations 1 and 2 during the postmonsoon period and in all the night samples during the premonsoon period may be due to diurnal vertical migration. Perhaps this may also be due to avoidance of samplers during the day as suggested by earlier authors (Clutter and Anraku, 1968).

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