OBSERVATIONS ON THE CHAETOGNATHA OF THE WATERS AROUND MANDAPAM

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Introduction

Different species of organisms belonging to diverse groups like diatoms, medusae, pteropods, chaetognaths and tunicates that occur in the plankton are known to be indicators of the water-masses and changing hydrological conditions and of those, chaetognaths have been successfully used in many regions during recent times. Further, the chaetognaths take their place in the food cycle of the sea as predators, competitors and prey in relation to the other constituents of the marine animal community and hence the importance of their study cannot be overemphasised.

Ever since the classical work of Russell (1935 and 1939) on the chaetognaths of the English Channel and the North Sea and their use as indicators of the movements of water masses in that region, the study of chaetognaths has assumed considerable importance. Special mention may be made to the works of Tokioka (1940), Clarke *et al.* (1943), Thomson (1947), Pierce (1953), Bieri (1959), Heydorn (1959) and Sund (1959) outside India.

Though our knowledge of the systematics and distribution of the Chaetognatha of the Indian waters is by no means extensive, there have been useful contributions by workers from different parts of the country. John (1933 and 1937) gave an account of the systematics and distribution of *Sagitta* from the Madras coast. Lele and Gae (1936) recorded three species of *Sagitta* from the Bombay Harbour. Subramaniyam (1937) critically reviewed John's work and in 1940 recorded *S. bedoti* Beraneck from the same collections. Varadarajan and Chacko (1943) and Chacko (1950) worked on the arrow-worms of Krusadai and recorded *Spadella cephaloptera* and *Krohnitta pacifica* for the first time from Indian waters. George (1952) gave a detailed account of the systematics of the Chaetognatha of the Indian coastal waters and the seasonal distribution of the different species along the Malabar coast in relation to the prevailing hydrographical conditions. Ganapati and Rao (1954), Rao (1958 *a* and *b*) and Rao and Ganapati (1958) made investigations on the systematics and distribution of the Chaetognatha

off Visakhapatnam coast and discussed their value as indicators off that coast.

The present paper gives an account of the seasonal changes in the abundance of chaetognaths of Mandapam waters with a comparison of their occurrence in the Gulf of Mannar and Palk Bay. An attempt is made to correlate the seasonal fluctuations of the different species with the changes in the salinity and temperature of the surface waters and other environmental factors.

Mandapam lies at 9° 16′ N and 79° 08′ E on a small strip of land lying east-west with Palk Bay to the north and the Gulf of Mannar to the south.

Material and Methods

Material for the present study was derived from weekly plankton collections from Palk Bay and the Gulf of Mannar during the period January 1955 to December 1958. A total of 332 samples, 182 from the Gulf of Mannar and 150 from Palk Bay have been examined. The collections were made by 15 minute surface hauls by a 50 cm. diameter net of organdy cloth (*ca* 36 strands per cm.) towed from a motor launch between 06·00 and 07·00 hours. The samples were made up to 250 c.c. and preserved in 5% formalin (40% formalin was poured into the sample till the whole sample reached a strength of about 5%). This method of preservation always gave satisfactory results. From each of the samples a subsample of 5 c.c. was pipetted out with the help of a Stempel's pipette and the chaetognaths from these fractioned samples were picked, identified and recorded. In the majority of the cases staining of the specimens was not necessary for identification. In difficult cases staining was done as suggested by George (1952) to facilitate correct identification.

The data on temperature and salinity were obtained from the records maintained by the Central Marine Fisheries Research Institute, Mandapam Camp.

Hydrographical Conditions

Salinity values are available for the years 1955, 1956 and 1958. The salinity of the surface waters in both the Gulf of Mannar and Palk Bay shows a similar pattern of variation with steady increase from low values in January to June-July. They remain more or less steady till about September-October with the highest values in September. Thereafter a sharp decline is noticed and by December very low values are again obtained. Jayaraman (1954)

observed that, " High values for salinity are observed in the period, May to October, while low values are to be found between November and April. It may be noted that the earlier months of these two periods coincide with the two monsoons, south-west and north-east. Thus it is seen that salinity is high during the months of the south-west monsoon and low during those of the north-east monsoon". The present data are also in conformity with the above remark.

Temperature data are available for all the four years 1955 to 1958 from the Gulf of Mannar. But unfortunately they are not available from Palk Bay. The general characteristics of the surface temperatures of sea-water at Mandapam were discussed by Prasad (1957) based on five years' data from the Gulf of Mannar. The present values also exhibit a similar trend.

OBSERVATIONS

List of Species Recorded

The waters around Mandapam are rich in Chaetognatha. The following species have been recognised from the plankton of the Gulf of Mannar and Palk Bay:—

Genus *Sagitta* Quoy and Gaimard, 1827 :

1. *Sagitta enflata* Grassi, 1881;
2. *S. neglecta* Aida, 1897;
3. *S. bedoti* Beraneck, 1895;
4. *S. robusta* Doncaster, 1903;
5. *S. tenuis* Conant, 1896;
6. *S. pulchra* Doncaster, 1903;
7. *S. hispida* Conant, 1895.

Genus *Krohnitta* Ritter-Zahony, 1911:

8. *Krohnitta pacifica* Aida, 1897;
9. *K. subtilis* Grassi, 1883.

Genus *Spadella* Langerhans, 1880 :

10. *Spadella cephaloptera* Busch, 1851.

Of the three genera occurring in the Mandapam waters *Sagitta* is by far the most common. *Krohnitta* occurs in comparatively fewer numbers. *Spadella* which is known to be a benthic form is extremely rare and only four

specimens were observed in the samples from Palk Bay during the whole period of study. Varadarajan and Chacko (1943) recorded a total of six species, *viz.*, *S. enflata*, *S. tenuis*, *S. robusta*, *S. neglecta*, *K. pacifica* and *Sp. cephaloptera* from Krusadai. Subsequently, George (1952) identified *S. bedoti*, *S. pulchra* and *Pterosagitta draco* from the Gulf of Mannar. The last-named species, however, was not observed during the present study. The record of *K. subtilis* is the first for this area.

Small numbers of very young ones were encountered in the samples and their identification was difficult due to their smallness of size. These, together with certain doubtful specimens, formed only a very negligible percentage of the total number of specimens examined and as such are not taken into consideration.

Chaetognaths occur in the plankton of the Gulf of Mannar and Palk Bay all through the year but show qualitative and quantitative fluctuations during the different months of the year (*see* Figs. 1 and 2). In Palk Bay the peak occurrence is during July-September. Two minor peaks are observed during February-April and October to December. In the Gulf of Mannar, however, they are at their maximum during the period January-March. Their occurrence does not show any regular sequence during the second half of the year as observed by Prasad (1954). But generally a minor peak is observed during November-December. In 1958 this peak was more prominent than the peak in January. Besides, one or two peaks of lesser magnitude may be observed in the intervening months.

Though the species composing the chaetognath fauna of the two areas under study are the same, excepting *Spadella cephaloptera*, which was found only in Palk Bay, the inter- and intra-specific fluctuations are different and the individual species have their own maxima and minima during the different seasons of the year, at the two stations studied. Quantitatively the Gulf of Mannar is richer in chaetognaths than Palk Bay. In the former area January to March, August and November to December are rich months while, April, September and October are the poorest months. In the latter area the second half of the year, in general, is comparatively richer than the first. July-September are the richest months. During the rest of the year they are few in number, May being the poorest month.

A comparison of the seasonal fluctuation of the individual species in the two areas studied brings out some interesting differences in the behaviour of the species concerned. Of the nine planktonic species only six, namely *Sagitta enflata*, *S. bedoti*, *S. neglecta*, *S. robusta*, *S. tenuis* and *Krohnitta pacifica* occurred in sufficiently good numbers over the period of study and their

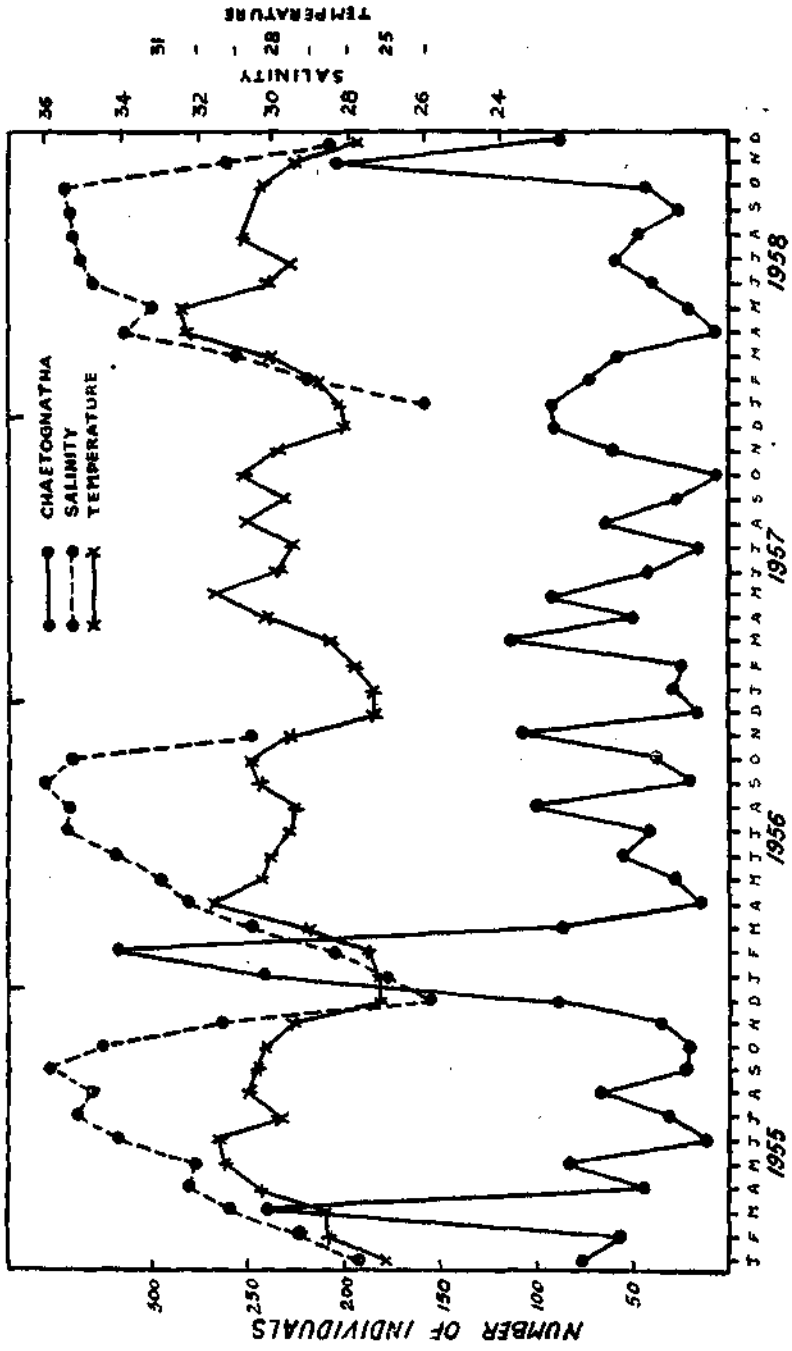

FIG. 1. The distribution of total Chaetognatha in the Gulf of Mannar.

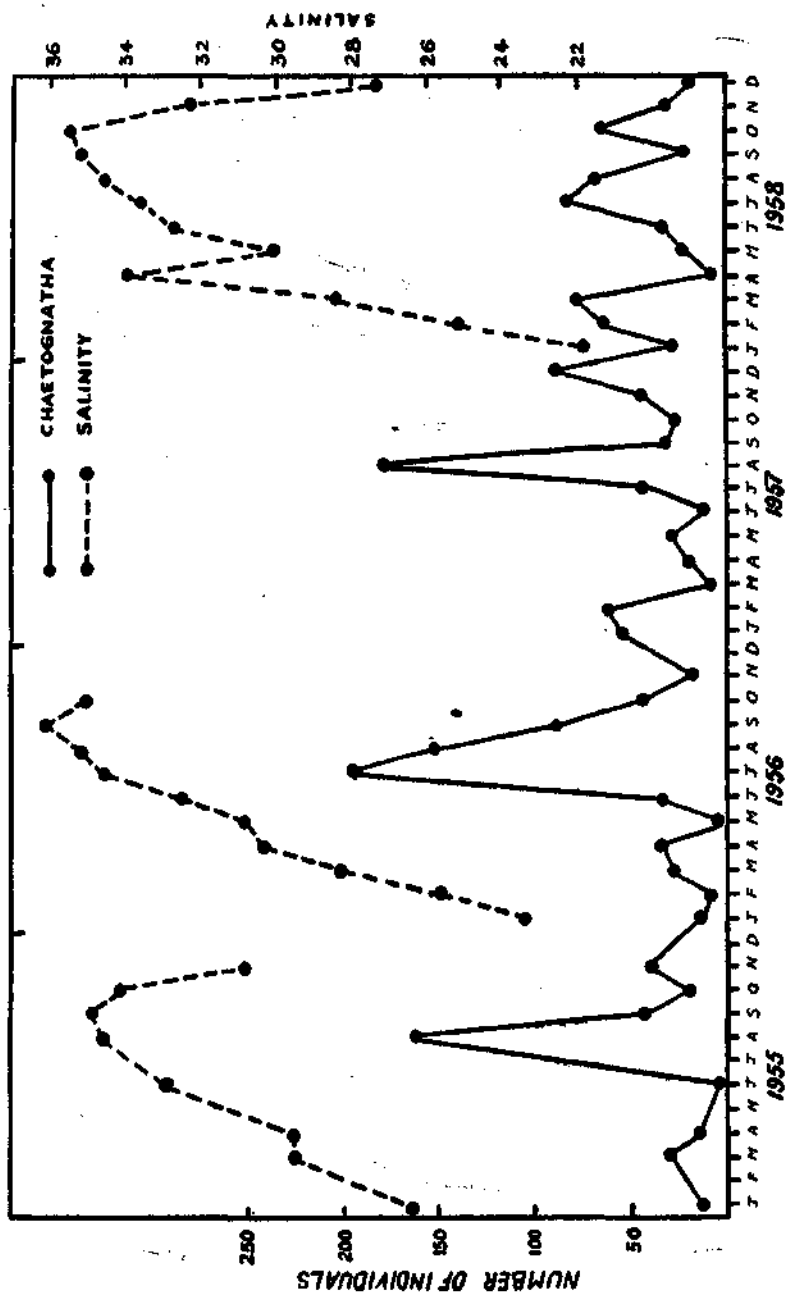

FIG. 2. The distribution of total Chaetognatha in Palk Bay.

seasonal fluctuations are compared. Figures 1 and 2 represent the seasonal abundance of Chaetognatha in Palk Bay and the Gulf of Mannar for a period of four years (1955–58). Figures 2–6 give the seasonal fluctuation of the six species from both the areas during the period of study. The numbers on the ordinate indicate the total counts for an aliquot of 5 c.c. from the standardised samples. The salinity and temperature for the corresponding period have also been plotted against the data in the first four figures. The remaining three species, *S. pulchra*, *S. hispida* and *K. subtilis* occurred only very rarely and as such they are not considered for a comparative study.

Sagitta enflata (Figs. 3 and 4).—This is a cosmopolitan species which can be easily recognised. It is the most common and numerically the most abundant species in the Gulf of Mannar occurring all through the year in varying numbers. There are no well-defined maxima and minima though it may be said in general that they are more abundant during the November-March period which falls in the low salinity, low temperature period of the year. However, two peaks of considerable magnitude are always observed one during February-March and the other during November-December. One or two more peaks of lesser intensity are observed during the remaining months. In 1957, however, there was a distinct decrease in numbers during November-December. In general, during the second half of that year, the population was comparatively at a lower level. The numerical strength of the *enflata* population in the Gulf of Mannar may be judged by the fact that as many as 656 individuals were present in a subsample of 5 c.c. during November 1958.

In Palk Bay, *S. enflata*, numerically, is only second in importance, *S. neglecta* being the most abundant species. Large numbers of this species are found invariably in the latter part of the year during August-September and sometimes also in November-December. A distinct minor peak was observed during February 1958 only, during which year it was relatively more abundant than in the preceding three years. It is interesting to note that the major peak of this species in Palk Bay falls in the high salinity period unlike in the Gulf of Mannar where the maximum numbers occur in the low salinity, low temperature months.

Sagitta neglecta (Figs. 3 and 4).—In the Gulf of Mannar it occurs during a greater part of the year being numerically, fourth in importance. The occurrence of this species here appears to be a little erratic. However, there is an apparent tendency for this species to occur in the plankton in good numbers during January-March when the salinity and temperature are low. In 1957 considerable numbers were obtained during April-May, August

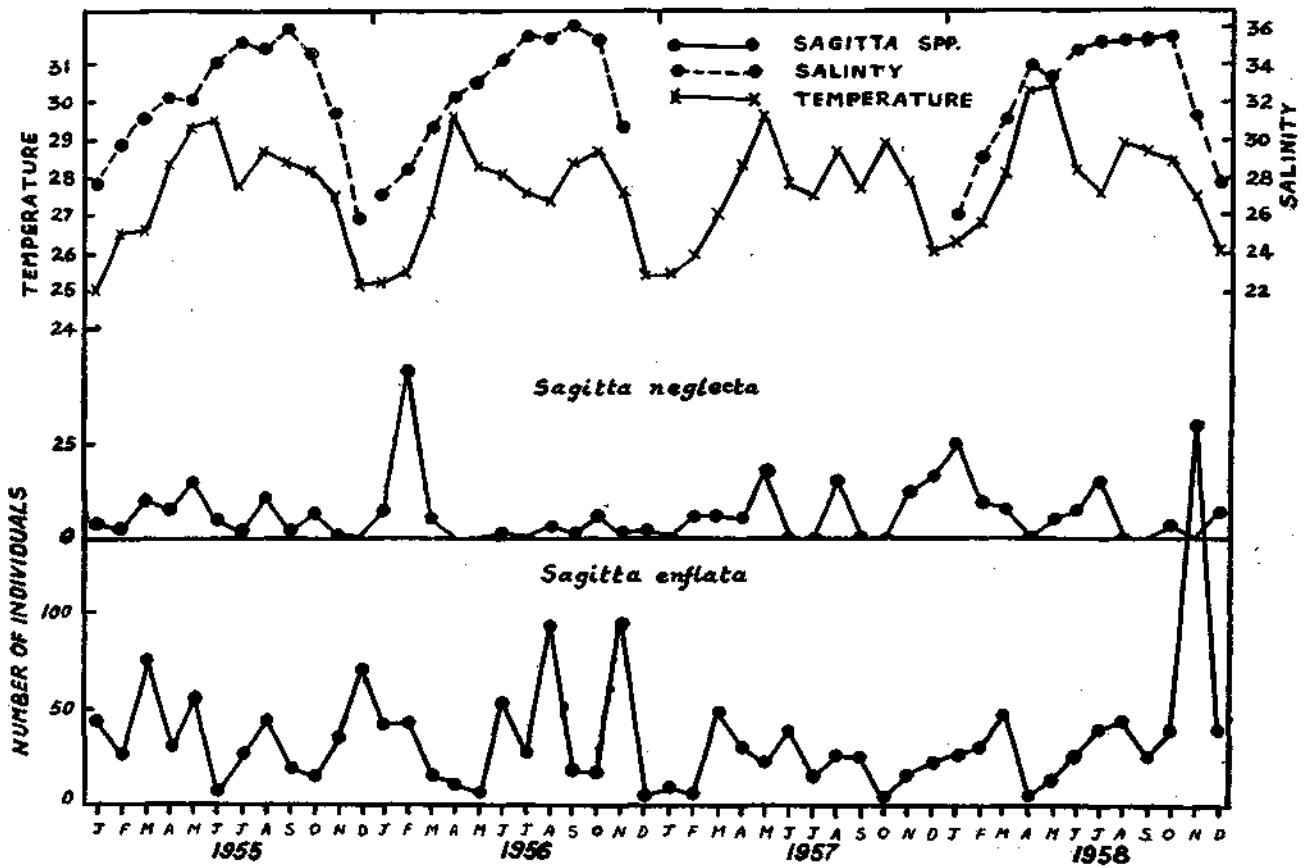

FIG. 3. The distribution and fluctuation of *Sagitta enflata* and *S. neglecta* in the Gulf of Mannar.

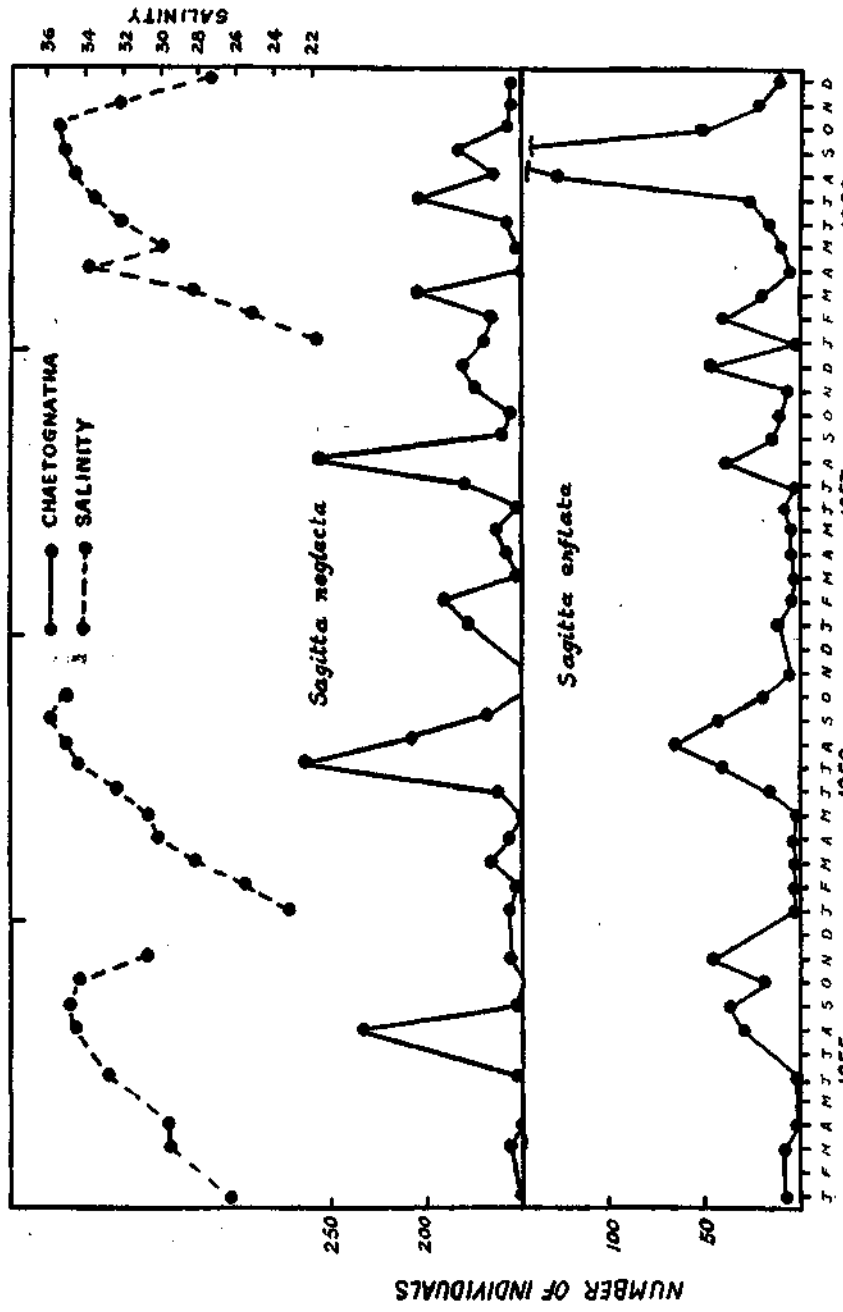

FIG. 4. The distribution and fluctuation of *Sagitta enflata* and *S. neglecta* in Palk Bay.

and November-December. As already stated, *S. neglecta* is the most abundant species in Palk Bay. It occurs in the plankton all through the year with a clearly demarcated maximum in the July-September period. At other times they are observed in lesser quantities showing irregular rises and falls. In 1958 there was an unusual increase of *S. neglecta* during March and April. It is of interest here, to note that the peak of occurrence of this species always coincides with the high salinity months just as in the case of *S. enflata* in this area.

Sagitta bedoti (Figs. 5 and 6).—This species is common in the Gulf of Mannar particularly during January-March when the salinity and temperature are low. During the rest of the months there is a decimation in their numbers (with occasional pulses) and sometimes it may even be entirely absent. In 1956 the *bedoti* population was at a very high level. It should be noted in this instance that the juveniles were predominant in the samples. In 1955 also they were fairly abundant though not as much as in 1956. In Palk Bay this species occurs sporadically in much smaller numbers and may even be absent for fairly long periods during the year. In 1957, for instance, they were totally unrepresented in the plankton from the middle of March to the middle of October.

Sagitta robusta (Figs. 5 and 6).—This is one of the important species occurring in the waters of Mandapam and is observed in fairly good numbers in the Gulf of Mannar for a considerable part of the year. It is common during the months when salinity and temperature are low, *i.e.*, January-March and thereafter a general decline is observed till July-August when it appears in small numbers for a short period. In 1957, however, its pattern of occurrence was different from that in the other three years and comparatively fewer numbers were observed during January and February. It was absent for a short period in March only to appear again from the latter half of March and April followed by another decline. During May and June it reached the maximum for the year. Fairly good numbers were encountered during October-December. In Palk Bay *S. robusta* is less common having a somewhat irregular pattern of distribution. It was fairly common only in 1956 showing two peaks one in April and the other during October-November. In 1955, 1957 and 1958 it was absent in the plankton for more than half of the year.

Sagitta tenuis (Figs. 5 and 6).—This occurs both in the Gulf of Mannar and Palk Bay, being relatively more common in the former. In the Gulf of Mannar it shows a peak of occurrence between January and April (low salinity, low temperature period) except in 1957 in which year this species

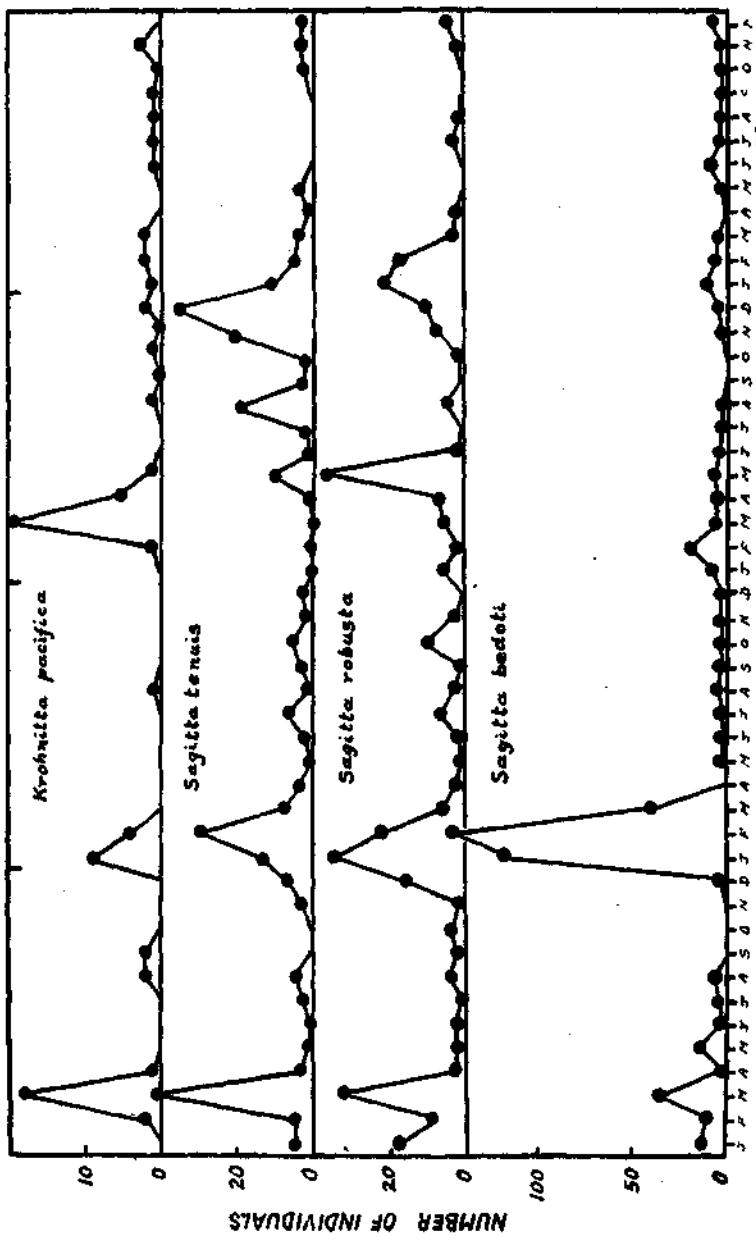

Fig. 5. Seasonal distribution of *Sagitta bedoti*, *S. robusta*, *S. tenuis* and *Krohnitta pacifica* in the Gulf of Mannar.

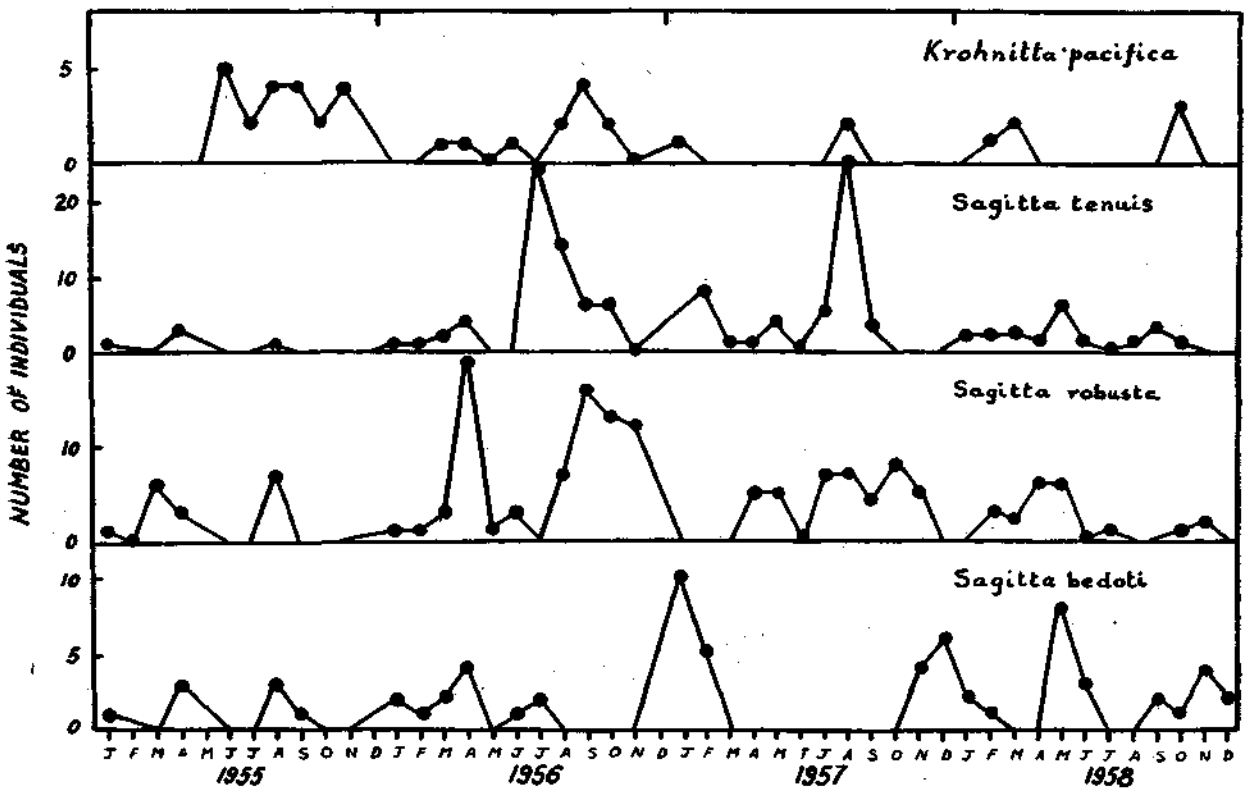

FIG. 6. Seasonal distribution of *Sagitta bedoti, S. robusta, S. tenuis* and *Krohnitta pacifica* in Palk Bay.

was encountered in fairly large numbers in November-December, May and July-August. For the rest of the year it is either few, rare or absent. In Palk Bay it is not present in the plankton for a larger part of the year than in the Gulf of Mannar. In 1955 and 1958 it was poorly represented. In 1956 and 1957 however, the species occurred in very moderate numbers in July and August, being rare or absent during the rest of the months.

Krohnitta pacifica (Figs. 5 and 6).—Of the two species of *Krohnitta* occurring at Mandapam, *K. pacifica* is more common and is fairly frequently seen in the samples from the Gulf of Mannar during January-March. Just as in the case of the other five species of chaetognaths its peak also coincides with the general chaetognath maximum. Appreciable numbers of *K. pacifica* are never encountered in the samples from Palk Bay and its occurrence here is very irregular.

Discussion

From the foregoing account on the Chaetognatha of the Mandapam waters it is evident that they occur in the plankton of the Gulf of Mannar and Palk Bay throughout the year with certain qualitative and quantitative fluctuations during the different months and between different years. Earlier studies from the different parts of the country (Lele and Gae, 1936; John, 1937; Subramaniyam, 1937; Varadarajan and Chacko, 1943; George, 1952; and Rao, 1958 *a* and *b*) reveal that the chaetognaths are present in the Indian coastal waters all round the year. The chaetognath maxima and minima are observed in different months of the year in the different centres. At Bombay *Sagitta* is abundant during January, April-September and December. Menon (1945) observed huge swarms occurring irregularly during May to September with the onset of the South-West Monsoon. Off Calicut, George (1952) recorded a major peak during October-November. According to John (1937) April to August is the peak period at Madras. At Lawson's Bay, off Visakhapatnam, Rao (1958 *a*) observed the maximum right in the middle of the South-West Monsoon during July-August. In the Gulf of Mannar maximum occurrence of Chaetognatha is during November-March, whereas in Palk Bay the peak occurs during July-September. Whether the fluctuations in Chaetognatha as a group are directly related to the changes in salinity has not been adequately explained by the earlier workers. The investigations at Mandapam bring out certain interesting features. Prasad (1956) referred to the significant time difference in the occurrence of maxima in the Gulf of Mannar and Palk Bay. In the former area they are at their maximum when the temperature

and salinity are low, whereas in Palk Bay the peak falls in the high salinity months. Further, the fluctuations of total chaetognaths from month to month are greater in the Gulf of Mannar than in Palk Bay just as in the case of total plankton volume (Prasad, *loc. cit.*). A detailed investigation reveals that while the maximum during January-March (low salinity — low temperature) in the Gulf of Mannar is a result of the simultaneous occurrence of many species (*Sagitta enflata, S. robusta, S. bedoti, S. neglecta* and *S. tenuis*) in sufficient numbers, the peak in Palk Bay is due to the large–scale occurrence of *S. neglecta* and *S. enflata.* Off Calicut the major peak during October-November (period of high salinity) is due to the occurrence of *S. enflata* and *S. neglecta* in large numbers, just as in Palk Bay. Off Trivandrum *S. enflata* and *S. tenuis* are conspicuous from May to September which is the peak period off that coast. At Madras all the seven species recorded reach their maximum during the summer months thus contributing to a total chaetognath maximum. The salinity during these months at Madras is high (Thirupad and Reddy, 1959). Off Visakhapatnam large numbers of *S. enflata* and *S. bedoti* contribute to the major peak during July-August when the salinity and temperature are fairly high. At Bombay *S. bombayensis, S. enflata* and *S. bedoti* are the species constituting the maximum.

John (1937) is of the opinion that the period of maximum of *Sagitta* species depends on the nature of the local rainfall. But observations made from Palk Bay and the Gulf of Mannar, where conditions of rainfall are similar, reveal that rainfall (which directly influence salinity) is not the major factor affecting the occurrence of the maxima and minima. Menon (1945) observed " .... swarms of *Sagitta* have been recorded during the monsoon months when the salinity of the coastal waters is naturally lower than that during the rest of the year. It therefore seems probable that the intensity of *Sagitta* during the rainy season is not much to be attributed to the changes of salinity as to the other factors....." It may here be pointed out that at Mandapam the peak period of Chaetognatha in both the bodies of water coincide with the periods when the respective waters are calm (*see* Prasad, 1958). It is quite probable that this physical factor is of consequence in controlling the abundance of these forms.

A comparison of the fluctuations of Chaetognatha in Palk Bay and the Gulf of Mannar with those of the copepod populations reveals a close relationship. Prasad (1956) observed that in the Gulf of Mannar the copepods exhibit a dicyclic pattern with a major peak during January-March and a minor peak during September-October and that in Palk Bay they show a

steady increase during the early part of the year reaching a maximum during September-October. Kartha (1959) confirmed these observations. Thus it may be seen that the chaetognath cycles in both the areas closely follow those of the copepods. Prasad and Kartha (1959) studied the breeding of copepods and found that it is to a very large extent dependent upon the diatom cycle. According to them the maximum breeding of copepods takes place during September and March in the Gulf of Mannar and May-September in Palk Bay. Chaetognath maxima at both the places fall during the period of maximum breeding of copepods. Chaetognaths are known to feed on copepods, larval fish and probably diatoms. Bigelow (1926) said that reduction of copepod numbers may be more due to the feeding by chaetognaths than by fish. Nauplii, copepodites and adult copepods were frequently observed in the guts of *Sagitta* spp. during the present investigations. Diatoms, fish larvae, pteropods and *Sagitta* spp. were the other items encountered. From the above it may be inferred that the seasonal abundance of Chaetognatha is influenced by the copepod cycle particularly in view of the fact that the latter forms an important item of food of the former.

A closer examination of the fluctuations of the individual species at different places of the Indian coast enables certain generalizations to be made. Off Bombay, Calicut, Visakhapatnam, Madras and in Palk Bay, *Sagitta enflata* occurs in large numbers only when the salinity and temperature are fairly high and steady. But off Trivandrum and in the Gulf of Mannar it is seen not only to tolerate lower salinities but occur in huge swarms during July-September and November-March respectively. Regarding the sporadic occurrence of *S. enflata* in large numbers off Calicut during the monsoon months George (*loc. cit.*) remarks that it may " be correlated with the abnormal salinity, pH, phosphates and silicate values recorded during the period, indicating the possibility of a sudden influx of oceanic water affecting inshore areas". The difference in the behaviour of *S. enflata* in the Gulf of Mannar and Palk Bay, despite the similarity in the salinity-temperature features, suggests the possibility that the populations of *S. enflata* in these two areas are different. It is also probable that this species is tolerant of a wide range of temperature and salinity. However, further investigations have to be carried out before these possibilities are confirmed. *S. neglecta* occurs in the plankton in large numbers off Calicut, Madras and in Palk Bay when the salinity is high. In the Gulf of Mannar appreciable numbers of *S. neglecta* are not encountered. Off Visakhapatnam this species occurs in good numbers only in the offshore region. Rao (1958 *b*) suggested the possibility of considering this species as an indicator of offshore waters off the Visakhapatnam coast. Palk Bay being more or less an enclosed body

of water is not subjected to any great influence from the offshore waters of the Bay of Bengal. Off Madras this species reaches its peak during May-June. In Palk Bay this species has its peak during July-September. It is quite probable that *S. neglecta* is brought down from the north by coastal currents flowing south. Until a better knowledge of the coastal currents affecting these waters is obtained it would be difficult to satisfactorily explain the abundance of *S. neglecta* in Palk Bay during July-September or to substantiate the above probability.

In the Gulf of Mannar and off Calicut, *Sagitta bedoti* and *S. robusta* occur in the low salinity months in sufficiently good numbers. However, at Lawson's Bay *S. bedoti* is abundant only when the salinity is quite high. This difference in the behaviour of *S. bedoti* cannot be adequately explained at present in the absence of details regarding its biology. Rao (1958 *a*) suggested that this species may be considered as an indicator of near-shore waters of Visakhapatnam. In the waters off Mandapam *S. bedoti* does not appear to be of any indicator value. But this species seems to thrive better in low salinity and low temperature water at Mandapam. Off Visakhapatnam also *S. robusta* is found to occur in fair numbers during the low salinity months just as in the Gulf of Mannar. Hence it would appear that *S. robusta* prefers lower temperature and salinity. Similarly in the case of *S. tenuis* also the observations from Calicut, Trivandrum and Gulf of Mannar indicate that lower salinity is favourable for the success of this species. Pierce (1958) considered *S. tenuis* and *S. hispida* as characteristic of inshore waters off North Carolina. Detailed investigations into the feeding and reproductive habits of the different species may be of use for a better understanding of their seasonal fluctuations.

Rao (1958 *b*) considered *Sagitta serratodentata* var. *pacifica* as an indicator of oceanic waters off the Visakhapatnam coast. The absence of this form as well as other typical oceanic species like *S. planktonis* is interesting in view of the fact that the Gulf of Mannar is an open body of water known to have oceanic influence. The latter-named species was recorded at Madras by John (1937).

Varadarajan and Chacko (1943) observed that the major peak for Chaetognatha around Krusadai occurs during September-December and they suggested that chaetognaths are brought down by the southward flowing current from Palk Bay through the Pamban channel. The peak at Krusadai thus follows the peak in Palk Bay which occurs during July-September. *Sagitta enflata, S. tenuis, S. robusta* and *S. neglecta* are the species responsible for the peak at Krusadai. In Palk Bay *S. enflata* and *S. neglecta* are the

two species constituting the peak. Thus the two species responsible for the peak in Palk Bay are well represented in the Krusadai samples and as such it is probable that the presumption of Varadarajan and Chacko is correct.

For a fuller and better understanding of the part played by the chaetognaths in the Indian coastal waters as indicators, a clear picture of the oceanic currents, particularly those which are of significance in the coastal areas, is essential. Till now most of the studies in the Indian waters have been based on plankton collections made not far from the shore and as such no more than broad generalizations on the relationship between the chaetognath species and the prevailing hydrological conditions are possible. Examination of samples from wide areas extending far out into the sea will be of considerable value in assessing their importance as indicator species in the Indian coastal waters.

SUMMARY

Observations on the Chaetognatha of the Gulf of Mannar and Palk Bay were made. Weekly surface plankton samples from January 1955 to December 1958 formed the material for this study.

Ten species, *Sagitta enflata*, *S. neglecta*, *S. robusta*, *S. bedoti*, *S. tenuis*, *S. hispida*, *S. pulchra*, *Krohnitta pacifica*, *K. subtilis* and *Spadella cephaloptera* are recognised from the samples. The first nine species are common to both the Gulf of Mannar and Palk Bay but the last-mentioned species is recorded only from Palk Bay. The record of *K. subtilis* is new for this area. Of the two areas studied Gulf of Mannar is quantitatively richer in Chaetognatha, November to March being the period of abundance. In Palk Bay Chaetognatha are invariably more abundant in the second half of the year, the peak period being July-September.

The maximum during January–March in the Gulf of Mannar is constituted by *Sagitta enflata*, *S. bedoti*, *S. neglecta*, *S. robusta* and *S. tenuis*. In Palk Bay the peak is mainly a result of the large-scale occurrence of *S. neglecta* and *S. enflata*. A study of the seasonal fluctuations of the different species in relation to the hydrological conditions suggests that *S. robusta*, *S. bedoti* and *S. tenuis* prefer lower salinities.

The existence of a close relationship between the chaetognatha and copepod cycles in both the Gulf of Mannar and Palk Bay is pointed out. The probability of *Sagitta neglecta* being brought down from the north into Palk Bay by coastal currents is indicated. The possibility of the existence

of two different populations of *S. enflata* in the Gulf of Mannar and Palk Bay is also suggested.

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