

**DISTRIBUTION OF CHAETOGNATHS, WITH SPECIAL REFERENCE TO
SAGITTA DECIPIENS AS AN INDICATOR OF UPWELLING ALONG
THE WEST COAST OF INDIA**

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ABSTRACT.

The occurrence, distribution and abundance of 14 species of Chaetognatha, belonging to the genera, *Sagitta* Quoy and Gaimard (1827), *Pterosagitta* Ritter-Zahony (1911) and *Krohnitta* Ritter-Zahony (1911), in space and time along the west coast of India, collected during the cruises of R.V. *VARUNA* between December, 1966 and December, 1967, are discussed. Attention is also drawn to the possibility of using *Sagitta decipiens* Fowler (1905) as an indicator of upwelling along the south-west coast of India.

INTRODUCTION

CHAETOGNATHS from the zooplankton collections, made during the cruises of Research Vessel *VARUNA*, from the continental shelf and adjacent oceanic waters between December, 1966 and December, 1967, along the west coast of India and the Laccadive Sea, were studied to understand their occurrence, distribution and seasonal abundance. Though the taxonomy of chaetognaths of the west coast of India has been studied by several workers (Lele and Gae, 1936; George, 1952; Silas and Srinivasan, 1968, 1969, 1970 and Srinivasan, 1972) little attention has been paid to their ecology, distribution and seasonal abundance in the plankton. The present investigation has been carried out, with the view to find out, whether any of the species of chaetognaths occurring in this area could be used as indicator species of the movement of water masses.

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MATERIAL AND METHODS

The material for this investigation has been obtained from the zooplankton samples collected during 12 cruises of R. V. *VARUNA* (7 cruises from the shelf area and 5 cruises from the oceanic waters including the Laccadive Sea). The samples were obtained by vertical tows with the Indian Ocean Standard net, between December, 1966 and December, 1967. During each cruise, zooplankton samples were collected from 30 stations in the shelf region and from 20 stations in the oceanic region,

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the former from 5 metres above the bottom to the surface and the latter from 200 metres to surface. Due to the loss of nets, samples could not be collected from 20 of the 30 stations in the shelf region and from 8 of the 20 stations in the oceanic region during June, 1967.

SPECIES COMPOSITION.

Fourteen species of Chaetognatha belonging to the genera *Sagitta*, *Pterosagitta* and *Krohnitta* are present in the samples in the following proportions.

TABLE 1. *Species of Chaetognatha in the order of abundance.*

No.	Species	Number of specimens	Percentage (Total)	Percentage	
				Shelf	Oceanic
1.	<i>S. inflata</i> , Grassi (1881)	74420	44.5	56	44
2.	<i>S. bedoti</i> Beraneck (1895)	28208	17.0	65	35
3.	<i>S. decipiens</i> Fowler (1905)	14784	9.0	16	84
4.	<i>S. pacifica</i> Tokioka (1940)	14758	9.0	30	70
5.	<i>P. draco</i> (Krohn) 1853	12468	7.5	36	64
6.	<i>S. hispida</i> Conant (1895)	6951	4.0	31	69
7.	<i>S. regularis</i> Aida (1897)	4122	2.4	22	78
8.	<i>S. ferox</i> Doncaster (1903)	3583	2.1	82	18
9.	<i>K. pacifica</i> (Aida) 1897	2763	1.6	23	77
10.	<i>S. robusta</i> Doncaster (1903)	2537	1.5	7	93
11.	<i>S. pulchra</i> Doncaster (1903)	1181	0.7	49	51
12.	<i>S. hexaptera</i> d'Orbigny (1834)	561	0.3	13	87
13.	<i>K. subtilis</i> (Grassi) 1881	500	0.3	65	35
14.	<i>S. lyra</i> Krohn (1853)	169	0.1	0	100
Total number of specimens		167,005	100.0		

Among these 14 species, *S. lyra* is present only in the oceanic samples.

SPATIAL DISTRIBUTION AND ABUNDANCE

The general pattern of distribution of chaetognaths shows that they were more abundant in the shelf region (Fig.1) than in the adjacent oceanic waters. The maximum number of chaetognaths are present in the samples collected during February, from both the shelf and oceanic waters and the minimum during August and June from the shelf waters and oceanic waters respectively. As will be seen from the ensuing discussion on the species, they show different patterns of distribution and abundance.

Sagitta inflata (Figs. 2 and 3)

This is the dominant species in the shelf as well as in the oceanic areas and forms about 44.5% of the total chaetognaths. Out of the total *S. inflata* obtained (74,420) about 56% is from the shelf area and only 44% from the oceanic area. Its maximum in the shelf region is during April (forms about 66% of chaetognaths collected

in April) and its minimum is in October (41%). Its occurrence in the oceanic waters is more or less uniform during the period of investigation.

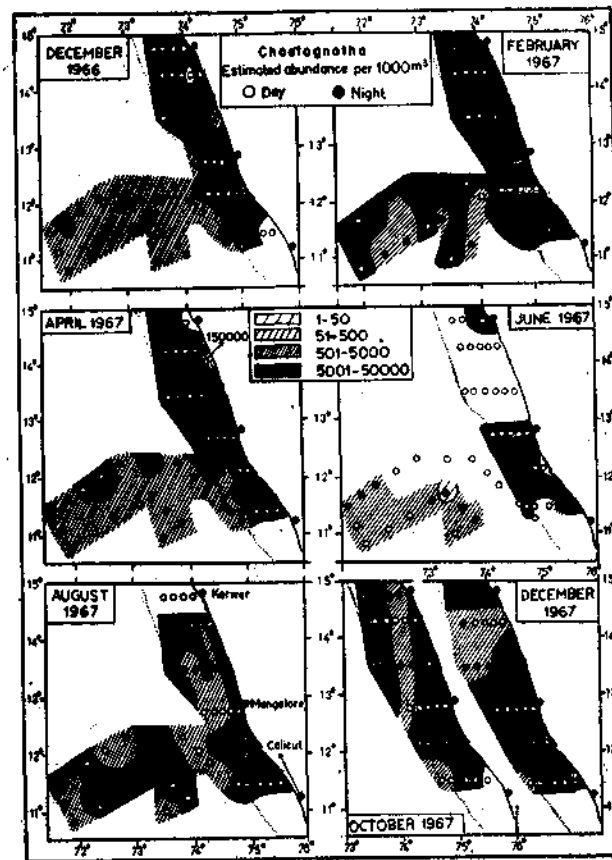


Fig. 1. Spatial distribution and abundance of Chaetognatha from the shelf and the oceanic waters along the south-west coast of India and the Laccadive Sea.

The concentration of this species along the shelf region is more during the pre-monsoon period (February-April) and less during the monsoon and post-monsoon periods (June-December). This observation agrees with that of Nair and Rao (1973), who have stated that the concentration of *S. inflata* is poor in the eastern part of the Arabian Sea during the south-west monsoon period.

Specimens of various maturity stages (Stages O-IV) are present in the samples collected during all months (Fig.3). As reported by Rao and Kelly (1962) and Srinivasan (1972), the availability of all the stages of maturity throughout the year points to the protracted breeding habit of this species. Fully mature specimens are of three types. One with very short ovary, the second with long ovary and the third with an intermediate type.

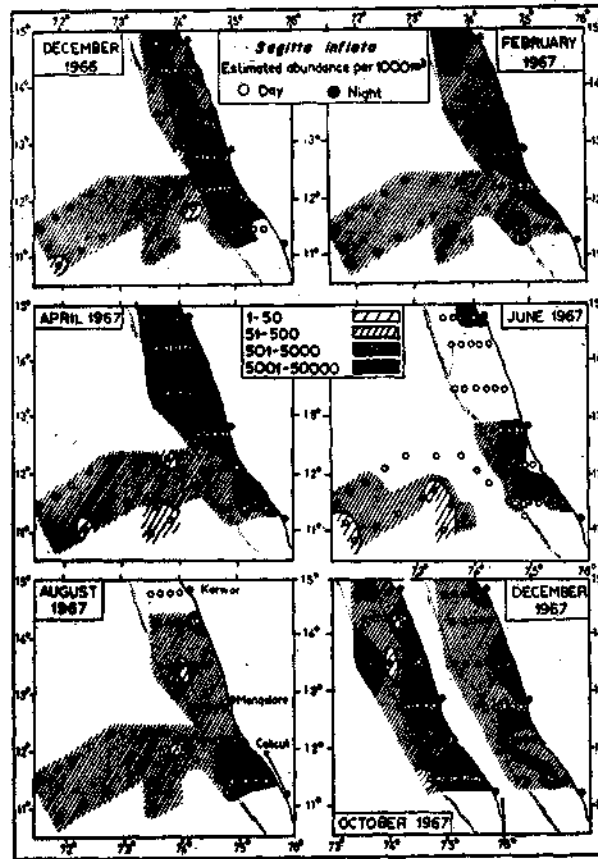


Fig. 2. Spatial distribution and abundance of *S. inflata* from the shelf and the oceanic waters along the southwest coast of India and the Laccadive Sea.

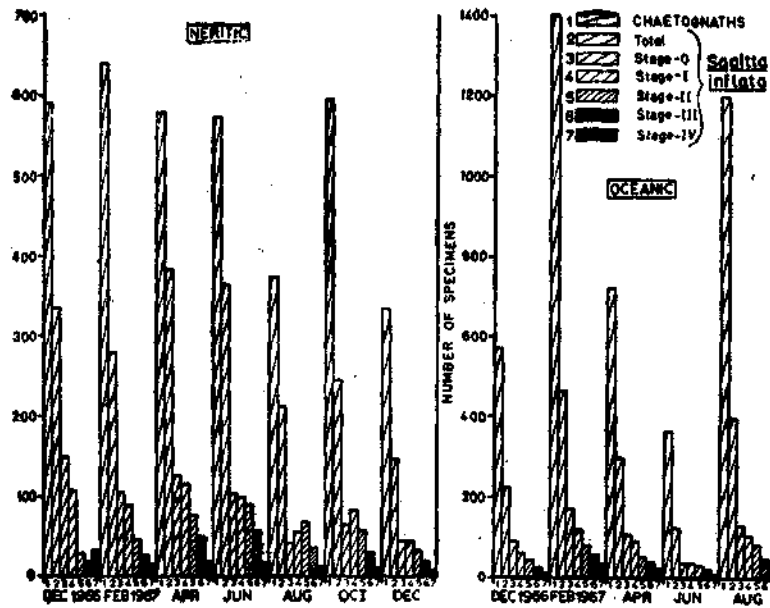


Fig. 3. Frequency of occurrence of maturity stages of *S. inflata*, from the shelf and the oceanic waters, along the southwest coast of India and the Laccadive Sea.

Sagitta bedoti (Figs. 4 and 5)

S. bedoti is next in importance and like *S. inflata*, it is more abundant in the shelf region. Out of the 28,208 specimens obtained in the samples, about 65% is from the shelf area. The maximum occurrence is in October (40%) and minimum in April (7%) from the shelf waters and in the oceanic waters it is in August (17%) and June (2%), respectively. This species most commonly occurs in the shelf waters of the west coast of India during the post-monsoon period (October-December), as reported by Nair and Rao (1973).

In the shelf waters, specimens of all the maturity stages are present in all months, except in April and June (Fig. 5), whereas in the oceanic waters fully mature specimens (Stage—IV) are present only in the samples collected during August. Specimens of other stages (O-III) are present in the samples collected during all months.

Sagitta decipiens (Figs. 6 and 7)

Unlike *S. inflata* and *S. bedoti*, *Sagitta decipiens* is not present in the shelf waters, where the depth is less than 150 metres, in the samples collected during December, (1966), February, April and June (1967). Out of the total number of 14,784 specimens collected from both the regions, about 84% is from the oceanic waters and only 16% is from the shelf waters. In the shelf area it is present only in the August, October and December (1967) collections. Again, only in October, 2,742 specimens have been obtained from the shelf waters. Though this species is obtained in large numbers, in October collections, its occurrence is not uniform in all the 6 sections of the area sampled (Fig. 6) and it is not present in all the 6 stations of section IV (13°30' N). It was interesting to find that in October, the concentration of this species is at about 90 metres depth, where the temperature is below 19°C.

S. decipiens is well represented in the oceanic waters and it occupies the second place in the order of abundance among the oceanic chaetognaths and the third place among the shelf and oceanic chaetognaths considered together. It forms about 21% (maximum) of the December oceanic samples and its minimum (9%) is in June. Nair and Rao (1973) have stated that *S. decipiens* is a rare species which they obtained from only 2 stations in the Arabian sea. Contrary to what they have stated, it would appear that this species is fairly abundant in the oceanic waters (Fig. 6), particularly off the west coast of India and the Laccadive Sea. In the shelf area, it is not found during the pre-monsoon and monsoon periods.

Specimens collected during October from the shelf area contain all the stages of maturity, whereas the oceanic samples collected during all months contain all the stages of maturity (Fig. 7). The importance of *S. decipiens* as an indicator species is discussed elsewhere in the paper.

Sagitta pacifica (Figs. 8 and 9)

S. pacifica is the 4th most common species in the samples examined. Unlike, *S. inflata* and *S. bedoti*, it is more abundant in the oceanic waters. Out of the total of 14,758 specimens of *S. pacifica* obtained from the entire samples, it forms about 70% of the oceanic samples and only 30% is from the shelf area. Except in the samples collected during February, it is not present in the shelf stations, where the depth is less than 20 metres. Its maximum in the shelf area is during February

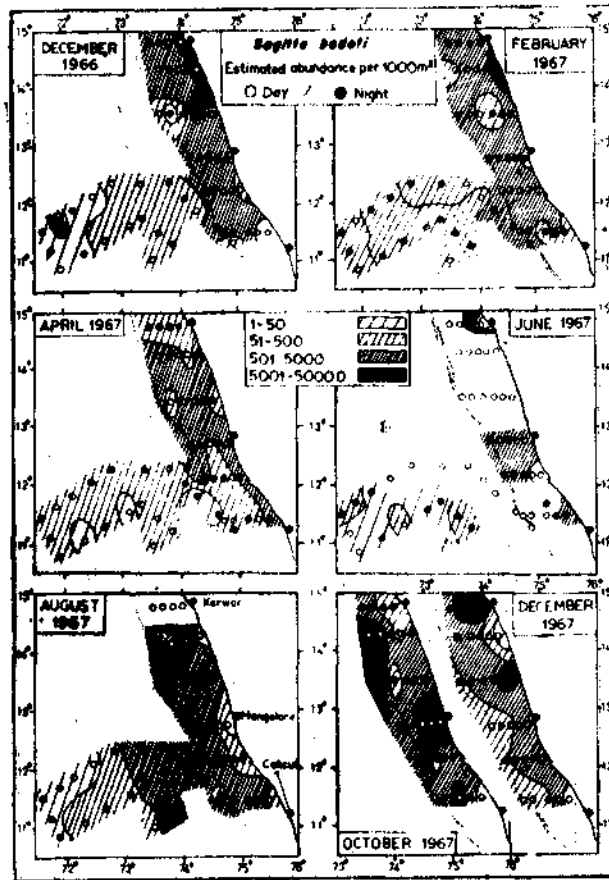


Fig. 4. Spatial distribution and abundance of *S. bedoti* from the shelf and the oceanic waters along the southwest coast of India and the Laccadive Sea.

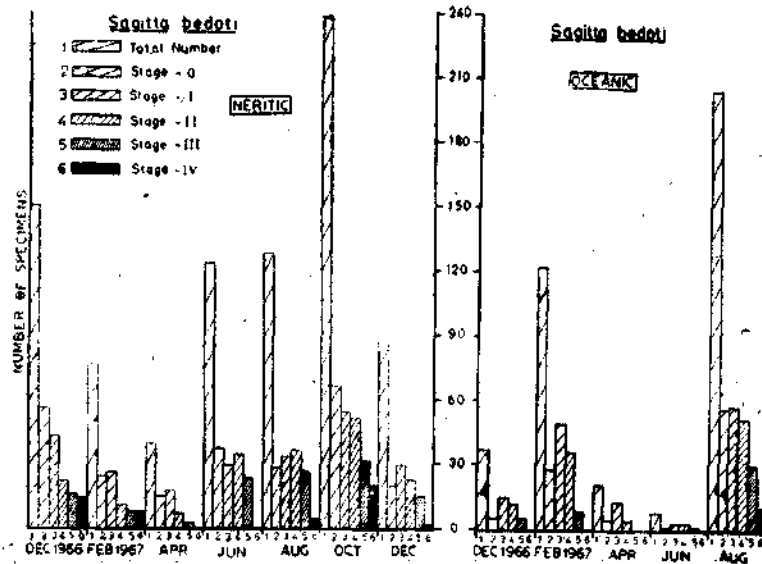


Fig. 5. Frequency of occurrence of maturity stages of *S. bedoti* from the shelf and the oceanic waters along the southwest coast of India and the Laccadive Sea.

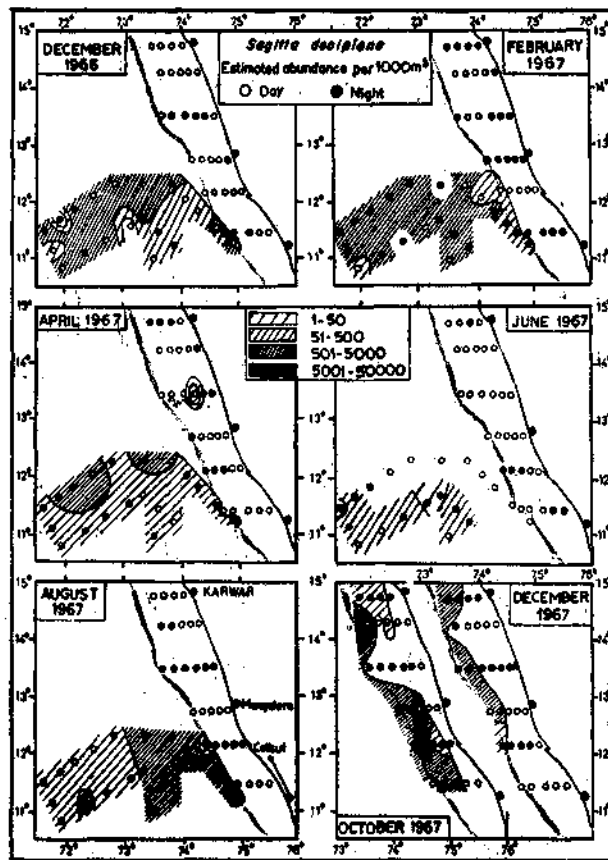


Fig. 6. Spatial distribution and abundance of *S. decipiens* from the shelf and the oceanic waters along the southwest coast of India and the Laccadive Sea.

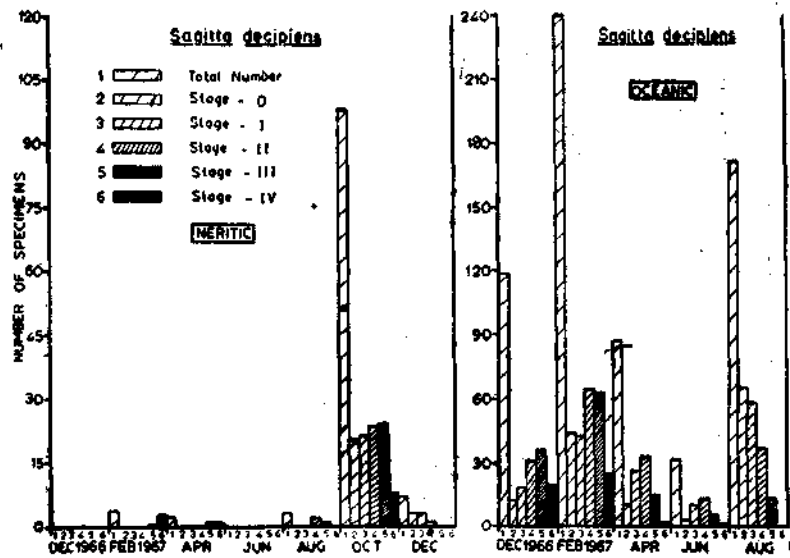


Fig. 7. Frequency of occurrence of maturity stages of *S. decipiens* from the shelf and the oceanic waters along the southwest coast of India and the Laccadive Sea.

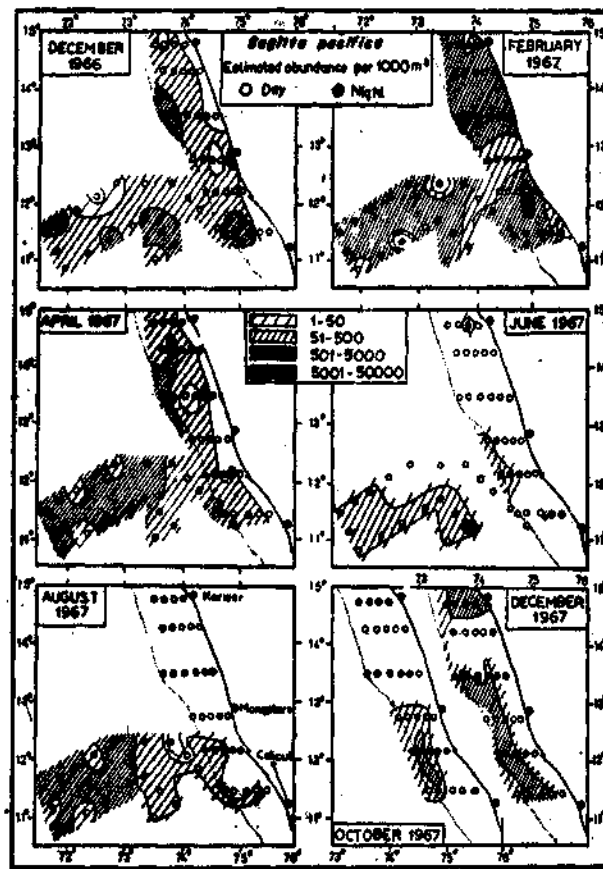


Fig. 8. Spatial distribution and abundance of *S. pacifica* from the shelf and the oceanic waters along the southwest coast of India and the Laccadive Sea.

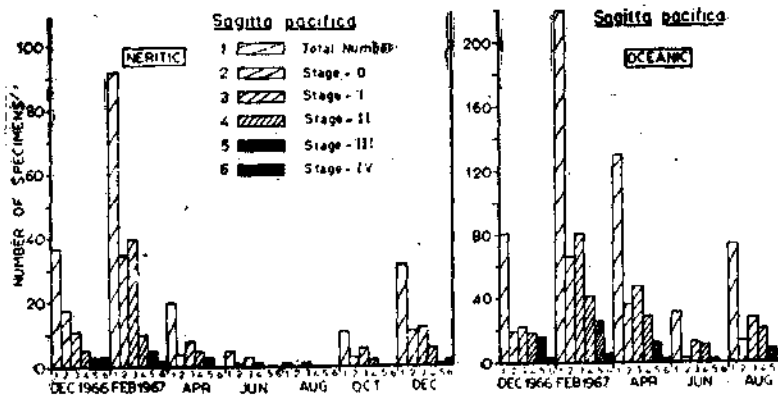


Fig. 9. Frequency of occurrence of maturity stages of *S. pacifica* from the shelf and the oceanic waters, along the southwest coast of India and the Laccadive Sea.

(14%) and minimum is during August (less than 1%) and it forms about 18% of the April collections and 6% (minimum) of the August collections from the oceanic waters.

This species is well represented in the shelf and oceanic samples collected during the pre-monsoon period (February-April) and post-monsoon period (October-December). The present investigation also agrees with that of Nair and Rao (1973), who have stated that this species is not present in both the shelf and adjacent oceanic waters, during the southwest monsoon period along the west coast of India, north of Mangalore.

In the oceanic collections, all the maturity stages are present in the samples collected during all months, whereas in the samples collected during June, August and October from the shelf area, only immature specimens (Stage O - II) are noticed (Fig. 9).

Pterosagitta draco (Figs. 10 and 11)

The distribution of *P. draco* is more or less like that of *S. pacifica*. *P. draco* is more abundant in the oceanic area. Out of the 12,468 specimens of *P. draco* collected from all samples of the oceanic and shelf waters, about 64% is from the oceanic waters. It is not obtained in the stations, where the depth is less than 20 metres. It is very interesting to note that this species is not present in 29 of the 30 shelf stations during August as well as in June and in October, it is not present in 3 of the 6 shelf sections.

Like *S. pacifica*, *P. draco* is well represented during the pre-monsoon (February-April) and post-monsoon (October-December) collections and their distribution is very scanty during the southwest monsoon period (June-August). The pattern of distribution noted for this species in the present investigation agrees with that, presented by Nair and Rao (1973).

In the shelf area, all the stages of maturity are seen in December, February and April and in the oceanic waters all the stages are seen in December, February, April and June (Fig. 11).

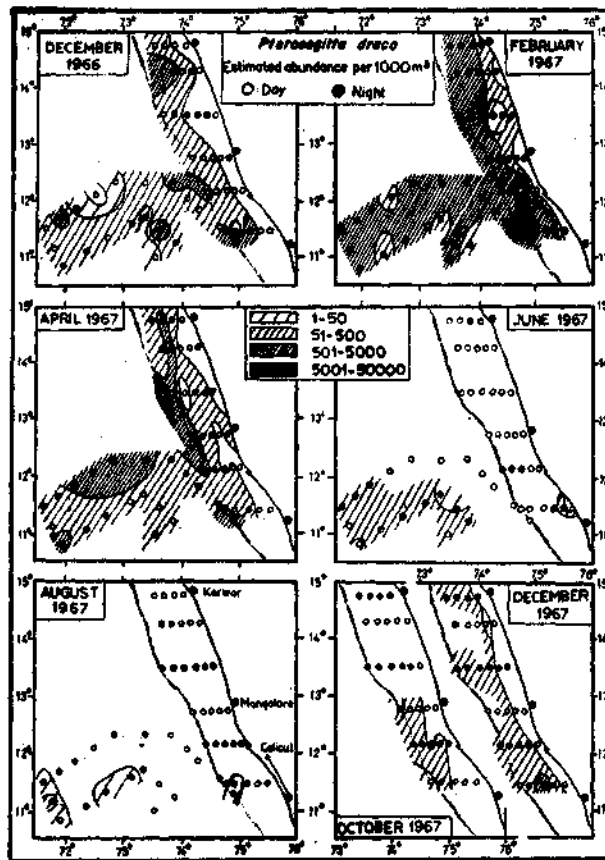
Sagitta hispida (Figs. 12 and 13)

S. hispida ranks 6th in the order of abundance and out of 6,951 specimens encountered in the collections, about 69% is from the oceanic waters (Fig. 12). Just as *P. draco* and *S. pacifica*, this species also occurs widely during the pre-monsoon (February-April) and post-monsoon (October-December) periods and is distributed scantily during the monsoon period (June-August), particularly in the shelf waters.

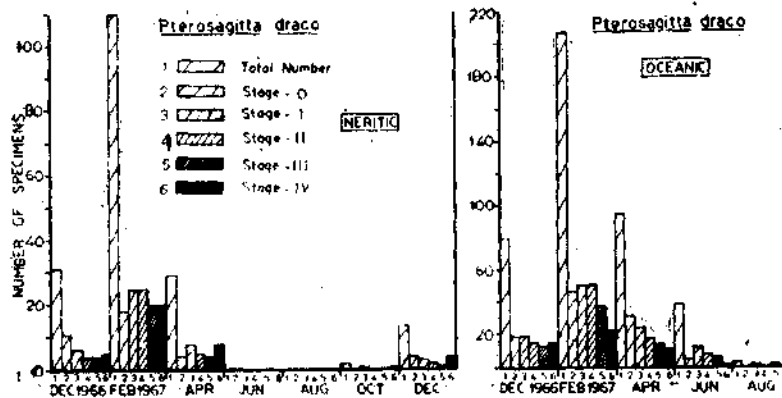
December, February and April collections from the shelf area and February, June and August collections from the oceanic area contain specimens in all stages of maturity (Fig. 13).

Sagitta regularis

S. regularis like *S. hispida* is also more abundant in the oceanic waters, than in the shelf waters, as out of the 4,122 specimens obtained in the samples, 78% is from



10. Spatial distribution and abundance of *Pterosagitta draco* from the shelf and the oceanic waters, along the southwest coast of India and the Laccadive Sea.



11. Frequency of occurrence of maturity stages of *P. draco* from the shelf and the oceanic waters, along the southwest coast of India and the Laccadive Sea.

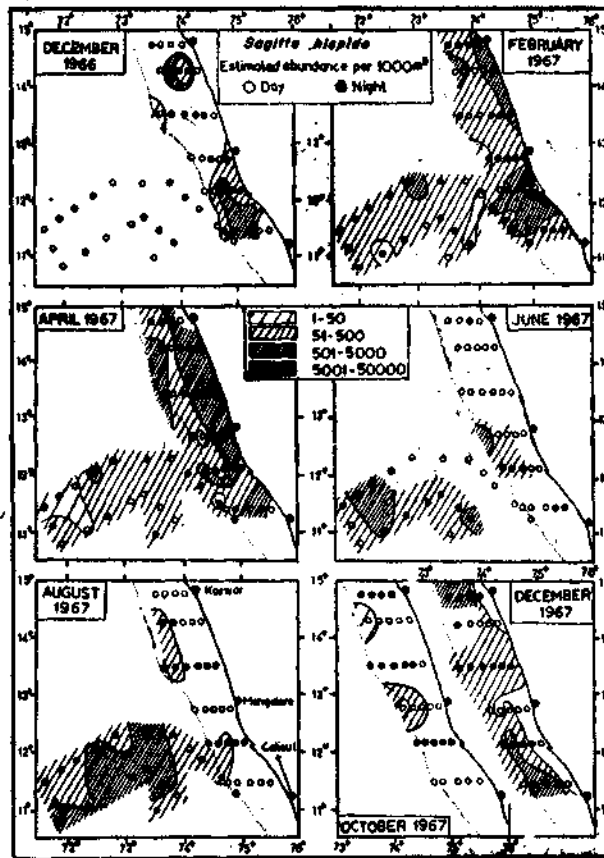


Fig. 12. Spatial distribution and abundance of *S. hispidula* from the shelf and the oceanic waters along the southwest coast of India and the Laccadive Sea.

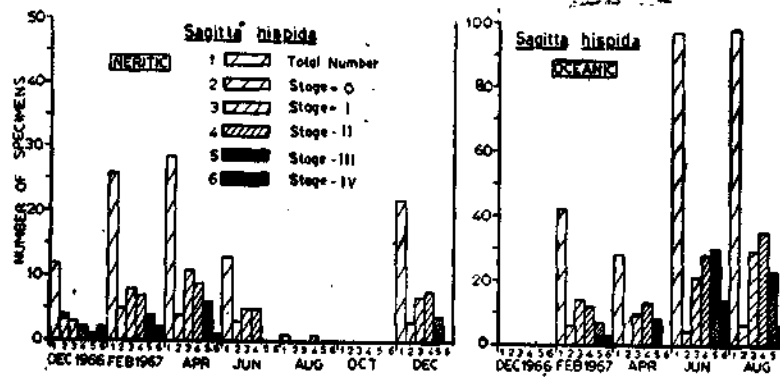


Fig. 13. Frequency of occurrence of maturity stages of *S. hispidula* from the shelf and the oceanic waters, along the southwest coast of India and the Laccadive Sea.

the oceanic region. This species is not at all seen during August and October collections of the shelf area and scantily present in other months, whereas in the oceanic samples, it is present during all months. As in the case of *P. draco* and *S. pacifica*, *S. regularis* is also not present in the collections from the shelf stations, where the depth is less than 20 metres. In addition, it is not present in the shelf waters during the southwest monsoon period, though it is present in good numbers in the collections from the oceanic waters, even during the monsoon period. Recent observations by Nair and Rao (1973) also seems to indicate this trend.

In the oceanic samples the specimens of the O-stage are not seen during December, February, April and June. Only the August collections contain all the stages of maturity (O-IV).

Sagitta ferox

S. ferox is well represented in the samples collected from the shelf area, but not so from the oceanic area. Out of 3,583 specimens obtained, about 82% is from the shelf area. In the shelf samples its maximum is in June (10%) and it is interesting to note that it is not present in the oceanic area during this month. Nair and Rao (1973) have shown (*vide* their Figs. 7a and 7b) that *S. ferox* is not present in the shelf and oceanic waters during the southwest and northeast monsoon periods. On the contrary, the present investigation shows that, this species is present in the shelf area, throughout the period of investigation (pre-monsoon, monsoon and post-monsoon) and in the oceanic waters, it is seen in all months, except June.

Only in the samples collected during June from the shelf area, specimens of all the stages of maturity are seen and in other months, only immature (O-II) specimens are found in both the areas.

Krohmita pacifica

K. pacifica is more abundant in the oceanic area, than in the shelf area. Out of the 2,763 specimens obtained in the samples, only 23% is from the shelf samples. It is present in all the months in the shelf collections, though in much fewer numbers. In the oceanic collections, it is seen in all months, except December (1966). Its maximum in the oceanic region is during August (6%).

Only the samples collected from the oceanic area during August contain specimens in all the stages of maturity.

Sagitta robusta

The occurrence of *S. robusta* is very scanty in the shelf area. Out of 2,537 specimens encountered in the samples, as much as 93% is from the oceanic waters.

Nair and Rao (1973) have shown (*vide* their Figs. 14a and 14b) that this species is not present in most of the stations located along the west coast of India. But the present study points to the fact that it is present in the samples collected during all months from the oceanic waters.

More or less all the maturity stages are found in the collections obtained from the oceanic area, except the fully mature specimens (Stage-IV) during December, February and April.

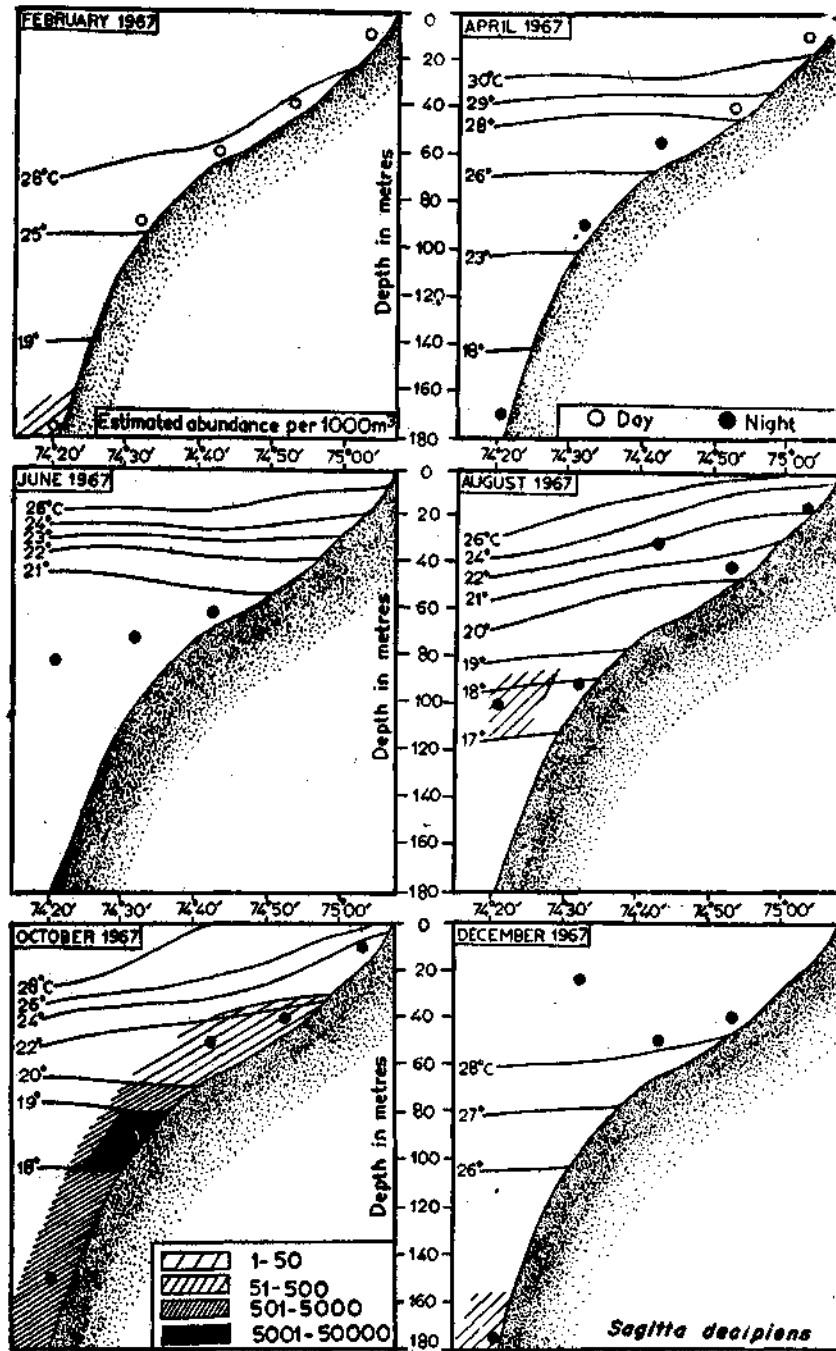


Fig. 14. Vertical section of temperature plotted, against the distribution of *S. decipiens* at 12° 12' N.

Sagitta pulchra

S. pulchra is the only species, that is more or less uniformly distributed and present during all months though in very few numbers in the shelf and oceanic waters. Among the 1,181 specimens obtained in the shelf and oceanic areas, about 49% is from the shelf waters. None of the specimens are fully mature (Stage IV).

The occurrence of this species during the pre-monsoon, monsoon and post-monsoon periods in the area investigated, is contrary to the observations of Nair and Rao (1973), who have stated that it is rarely represented near the Indian coast.

Sagitta hexaptera

This species occurs more in the oceanic collections. Out of the 561 specimens obtained in the collections, 87% is from the oceanic area. In the oceanic region, it is present in the collections made during all months, whereas in the shelf region, it is present only during December, February and April. Only the December collection from the oceanic area contains specimens in all the stages of maturity.

Krohnitta subtilis

K. subtilis is more common in the shelf area, than in the oceanic area, as out of 500 specimens obtained from both the areas, about 65% is from the shelf area. In the shelf waters it is seen only during April and June, while in the oceanic waters, it is present in all months, except June. On the whole, its occurrence is rare.

Sagitta lyra

This meso-planktonic species is not present in the shelf collections and is found only in the samples from oceanic waters. Specimens were collected during December, February and April and all specimens were found to be immature (Stage O-III).

DAY AND NIGHT COLLECTIONS

Day and night samples from the shelf and the oceanic areas were studied separately to find out the frequency of occurrence of individual species in these collections. From Table 2, it will be evident that there is not much difference in the occurrence of the species such as, *S. inflata* and *S. bedoti*, both in the shelf and in the oceanic waters. This may possibly be due to the fact that these species are distributed throughout the epi-pelagic realm in the shelf and the oceanic waters.

Considerable amount of variation between the day and night samples is seen in *S. pacifica* especially in the shelf area. 79 specimens per 100 m³ of water filtered have been obtained from the night samples, whereas only 34 specimens have been obtained from the collections in the shelf area. In *S. decipiens*, in both the shelf and oceanic samples, the number of specimens obtained during the day hauls is greater. This condition is also true for *S. pulchra*, whereas in species such as, *S. pacifica*, *P. draco* and *S. hispida*, more specimens have been obtained from the night collections, in both the shelf and oceanic waters.

In *S. regularis*, *S. ferox*, *K. pacifica* and *S. robusta*, the number of specimens is more in the night collections from the shelf area, but the reverse in oceanic waters.

TABLE 2. *Chaetognath species obtained from the day and night collections.*

No.	Species	Number of specimens per 100 m ³ of water filtered			
		Shelf area		Oceanic area	
		Day	Night	Day	Night
1.	<i>S. inflata</i>	730	730	145	148
2.	<i>S. bedoti</i>	235	234	40	37
3.	<i>S. decipiens</i>	25	17	77	51
4.	<i>S. pacifica</i>	34	79	50	55
5.	<i>P. draco</i>	33	41	41	46
6.	<i>S. hispida</i>	27	36	23	26
7.	<i>S. regularis</i>	12	15	17	15
8.	<i>S. ferox</i>	52	62	2	1.4
9.	<i>K. pacifica</i>	19	21	12	9.0
10.	<i>S. robusta</i>	1.5	3	12.3	12.0
11.	<i>S. pulchra</i>	24.6	12.6	3.1	2.5
12.	<i>S. hexaptera</i>	0.3	1.2	2.3	3.0
13.	<i>K. subtilis</i>	0.1	3.1	0.9	0.6
14.	<i>S. lyra</i>	-	-	1.3	0.3

DISCUSSION

On the basis of distribution, the species of chaetognaths present in these collections, could be divided under 5 categories. (Table 1).

I. Species present in both the shelf and oceanic waters, but dominant in the shelf areas. The species that come under this category are: (1) *S. inflata*, (2) *S. bedoti*, (3) *S. ferox*, and (4) *K. subtilis*.

II. Species present in both the shelf and oceanic waters, but dominant in the oceanic waters. e.g. *S. pacifica*, *P. draco*, *S. hispida*, *S. regularis*, *S. robusta*, *S. hexaptera* and *K. pacifica*.

III. Uniformly distributed species, both in the shelf and oceanic regions. e.g., *S. pulchra*.

IV. Species present only in the oceanic waters, but not present in the shelf area. e.g., The meso-planktonic species *S. lyra*.

V. Species present only in the oceanic area, but occasionally invades the shelf area, during certain seasons, e.g., The mesoplanktonic species, *S. decipiens*.

This investigation on the distribution of the species of chaetognaths, has revealed that some species, such as, *S. pacifica*, *S. hispida*, *S. regularis* and *P. draco* show a rhythmical movement from one season to another season. These species are widely distributed both in the continental shelf and the adjacent oceanic waters, during the pre-monsoon (February-April) and post-monsoon (October-December), whereas during the southwest monsoon period (June-August) they are sparsely distributed or absent, particularly in the shelf waters. This may probably be due to the reason that these species move towards the deep oceanic waters, during the monsoon period and come back to the shelf waters after the monsoon.

Another interesting feature is the occurrence of *S. decipiens* in large numbers, along the west coast of India from the shelf waters, during a restricted period. This is a meso-planktonic oceanic species, cosmopolitan in temperate and warm oceanic regions (Alvarino, 1965). To find out the possible reason for its occurrence in the shelf area, the hydrographical features based on the data collected at the sampling stations were examined (Fig. 14). The minimum depth from which the specimens of this species were obtained during October, 1967 is 40 metres. The temperature at this depth was 22°C and the dissolved O₂ content of the water was 0.3 ml/L (Whereas in other months at 40 metres depth the temperature was well above 22°C). Further, the maximum number of specimens (700) has been obtained from open tows from 90 metres depth, where the temperature was below 19°C, salinity at this depth, 34.42‰ and the dissolved O₂ content 2.5 ml/L.

Nair and Rao (1973) have stated that they have obtained *S. decipiens* at 09°00' N and 72°40' E during 5th November, from 200 metres open collection. The temperature at this station at 200 m was 15.1°C and the dissolved O₂ content, .05 ml/L. Sund (1961) has suggested that as *S. decipiens* is an inhabitant of the waters of low temperature, low oxygen and high salinity, it could be made use of to identify the movement of deep waters. Here too, the very low dissolved O₂ content of the water and lower temperature of 22°C at 40 metres depth indicate that, the colder water has been transported to this area from the oceanic deeper region. As *S. decipiens* is always associated with the colder waters, with lower temperature and dissolved O₂, its influx over the shelf area, should have been along with the intruding cold water into the continental shelf. The absence of this species in other months at this relatively shallow depth is a supporting evidence, that this species could be used as an indicator of incursion of oceanic sub-surface waters, into the shelf region.

Banse (1968) is of the opinion that the upwelling off the southwest coast of India, starts with the onset of the southwest monsoon, in June and it lasts throughout the southwest monsoon. Further, he has stated that only in the latter half of October, the cold water retreats. In the present instance, it may be noted that the October collections, containing large number of *S. decipiens* in the shelf waters, were sampled during the first half of October (on 5th, 6th and 7th of October, 1967). Ramamirtham and Jayaraman (1961) have reported that the upwelling along the west coast of India, starts in August and lasts till the first half of October. Alvarino (1964, 1967) has stated that the presence of *S. decipiens* in the upper 100 metres off California, indicates the process of upwelling. So the presence of *S. decipiens*, in early October along the shelf waters of the west coast of India, is significant, especially as it occurs during the latter phase of upwelling and it could be used as an indicator of upwelling along the west coast of India. Needless to say, more intensive observations on the distribution of this species will be fruitful.

The present investigation draws attention to some important problems. The actual reason for the absence or scanty distribution of species, such as *S. pacifica*, *S. regularis*, *S. hispidus* and *P. draco* during the monsoon season in the shelf needs further study. The presence of *S. decipiens* in the shelf regions needs further detailed investigations based on stratified collections of successive years.

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