

4.6

Chaetognaths of the Arabian Sea

V. R. NAIR and T. S. S. RAO

During the IIOE (1959–1965) the Indian Ocean Biological Centre (IOBC) received 1927 zooplankton samples, of which 1548 are standard ones (IOBC, 1969). Of these, 614 samples belong to the area extending from 10° S to 25° N lat. between 20° E and 80° E long. The chaetognaths identified from these 614 samples form the basis of the present study. The figures given refer to catch per unit standard haul.

I. Distribution of Species

A total of 19 species belonging to 4 genera *Eukrohnia*, *Krohnia*, *Pterosagitta*, and *Sagitta* are present in the collections analysed.

Table 1 represents the total counts, percentage and maximum density of the different species. The seasonal differences for the different species are shown in Table 2.

Table 1. Total counts, percentage and maximum density of the different chaetognaths species from the IIOE collections

Species	Total abundance		Range of abundance per 5° Sq. %	Maximum observed density (No. per std. haul)	
	Number	Percentage		SW monsoon	NE monsoon
<i>E. fowleri</i>	7	negligible	negligible	—	4 (Laccadive Sea)
<i>K. pacifica</i>	10 847	1.0	0– 5.7	250 (near Kenya)	425 (Red Sea)
<i>K. subtilis</i>	3 780	0.3	0– 3.1	400 (off Somalia)	100 (off Ceylon)
<i>Pt. draco</i>	48 319	5.1	0–19.1	1 940 (off Somalia)	810 (Gulf of Aden)
<i>S. bedoti</i>	94 709	8.3	0–35.8	4 160 (off Somalia)	2 960 (near Kenya coast)
<i>S. bipunctata</i>	48 815	4.3	0–23.6	3 620 (off Somalia)	735 (off Arabia towards north)
<i>S. bombayensis</i>	2	negligible	negligible	—	2 (off the northwest coast of India)
<i>S. decipiens</i>	26	negligible	negligible	—	16 (off South Arabia)
<i>S. enflata</i>	697 810	61.0	31.6–86.3	9 000 (off Somalia)	18 585 (Red Sea)
<i>S. ferox</i>	23 654	2.1	0–31.0	2 221 (South eastern part at 10° S–75° E)	820 (off Somalia)

Table 1 (continued)

Species	Total abundance		Range of abundance per 5° Sq. (%)	Maximum observed density (No. per std. haul)	
	Number	Percentage		SW monsoon	NE monsoon
<i>S. hexaptera</i>	6 228	0.5	0-2.4	192 (off Somalia)	140 (off Somalia)
<i>S. lyra</i>	10	negligible	negligible	10 (mouth of Gulf of Aden)	—
<i>S. minima</i>	4 837	0.4	0-10.5	800 (southwestern part at 3° S lat. and 54° E long.)	500 (southwestern part at 8° S lat. and 54° E long.)
<i>S. neglecta</i>	12 700	1.1	0-8.3	640 (off Arabia towards north)	820 (near Arabia towards north)
<i>S. pacifica</i>	119 049	10.4	0.3-38.3	4 400 (near Arabia towards north)	2 440 (off Somalia)
<i>S. pulchra</i>	5 022	0.4	0-1.2	280 (near Somalia)	200 (Gulf of Aden and off Somalia)
<i>S. regularis</i>	41 495	3.6	0-17.1	1 600 (off Somalia)	1 004 (Gulf of Cambay)
<i>S. robusta</i>	16 774	1.5	0-8.3	730 (near Arabia towards north)	606 (off Somalia)
<i>S. zetesios</i>	10	negligible	negligible	—	10 (off Arabia towards north)

Table 2. Numerical abundance of the different epiplanktonic species of chaetognaths during the two monsoon periods

Species	SW monsoon		NE monsoon		Total No. irrespective of seasons
	Total	Average No. per haul	Total	Average No. per haul	
<i>K. pacifica</i>	5 481	23	5 366	23	10 847
<i>K. subtilis</i>	2 492	10	1 288	6	3 780
<i>Pt. draco</i>	27 444	114	20 875	92	48 319
<i>S. bedoti</i>	45 639	190	49 070	217	94 709
<i>S. bipunctata</i>	26 068	109	22 747	101	48 815
<i>S. enflata</i>	371 291	1 547	326 519	1 445	697 810
<i>S. ferox</i>	20 395	85	3 259	14	23 654
<i>S. hexaptera</i>	3 645	15	2 583	11	6 228
<i>S. minima</i>	3 651	15	1 186	5	4 837
<i>S. neglecta</i>	5 342	22	7 358	33	12 700
<i>S. pacifica</i>	76 622	319	42 427	188	119 049
<i>S. pulchra</i>	2 179	9	2 843	13	5 022
<i>S. regularis</i>	27 582	115	13 913	88	41 495
<i>S. robusta</i>	8 721	36	8 053	36	16 774
Total:	626 552	2 609	507 487	2 272	1 134 039

1. *Krohnitta pacifica* (AIDA, 1897)
(Figs. 1 a and 1 b)

This species is occasionally encountered in the collections and the range of abundance is 0–5.7% of the total chaetognaths. The general pattern of distribution shows a scattered representation of the species with isolated areas of high values. The maximum value is at

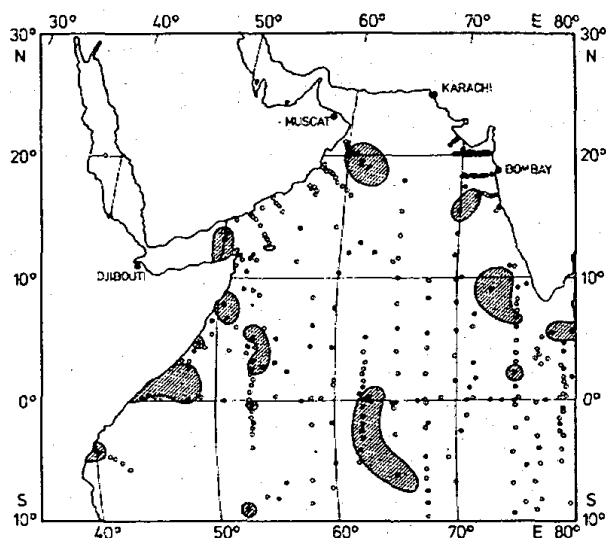


Fig. 1 a. Geographical distribution of *K. pacifica* during the SW monsoon
No. of specimens per standard haul. For symbols see Fig. 14, p. 310

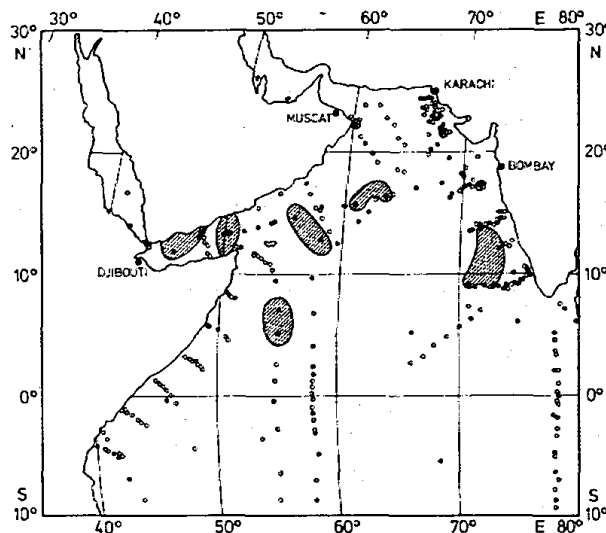


Fig. 1 b. Geographical distribution of *K. pacifica* during the NE monsoon

the mouth of the Red Sea (425 per std. haul). The distribution of the species for the 2 monsoon periods does not show much variation, except that the Somalian region is better populated during the SW monsoon, otherwise it seems to have a patchy distribution

and the position of the patches is comparable in both periods. The average number of specimens per standard haul is the same in both seasons (Table 2). This suggests that on average the abundance of the species in the surface layer is not directly affected by the monsoons.

2. *Krohnitta subtilis* (GRASSI, 1881)

(Figs. 2a and 2b)

This species is occasionally represented in the samples, the range of abundance being 0–3.1% of the total chaetognaths in the samples. *K. subtilis* has higher representation in the western Arabian Sea, particularly near Somalia (400 per std. sample), but is very scarce in the collections taken off the coasts of India and in the SE part. The SW monsoon

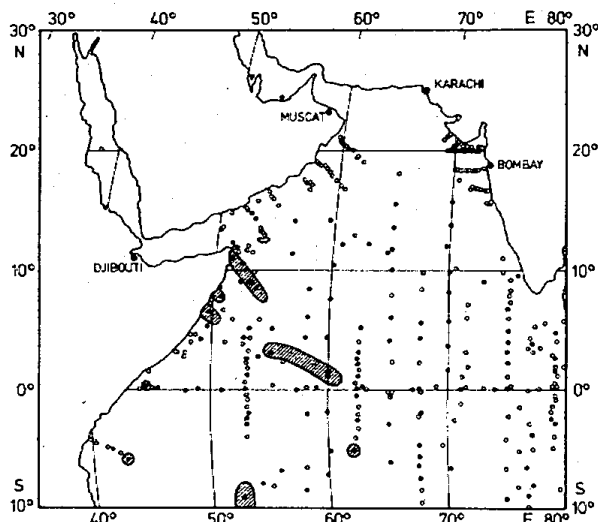


Fig. 2a. Geographical distribution of *K. subtilis* during the SW monsoon

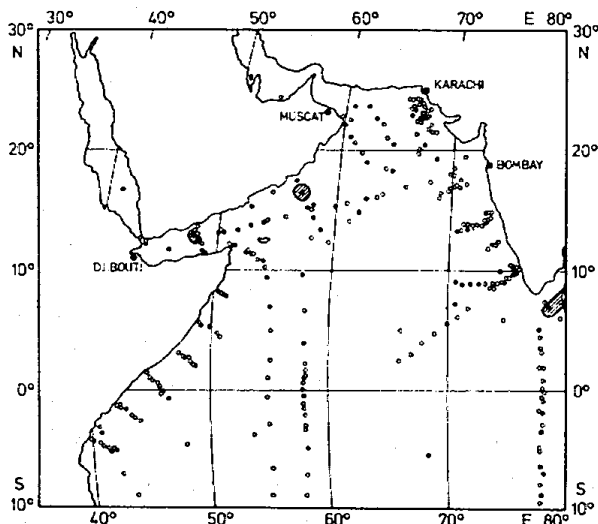


Fig. 2b. Geographical distribution of *K. subtilis* during the NE monsoon

period shows higher representation of the species along the western half of the Arabian Sea excluding the northern part. The maximum values are in the Somalia region. However, during the NE monsoon this species is encountered in the north Arabian Sea. The distribution is totally different during the 2 seasons, and during the SW monsoon the species is found to be on average 1.7 times more abundant per haul. The distribution tends to show that it is limited to highly productive waters.

3. *Pterosagitta draco* (KROHN, 1853)

(Figs. 3 a and 3 b)

Comparatively small mature individuals (length at maturity 5.4 mm) are encountered in a few samples taken from the Laccadive Sea. The species is common in the Arabian

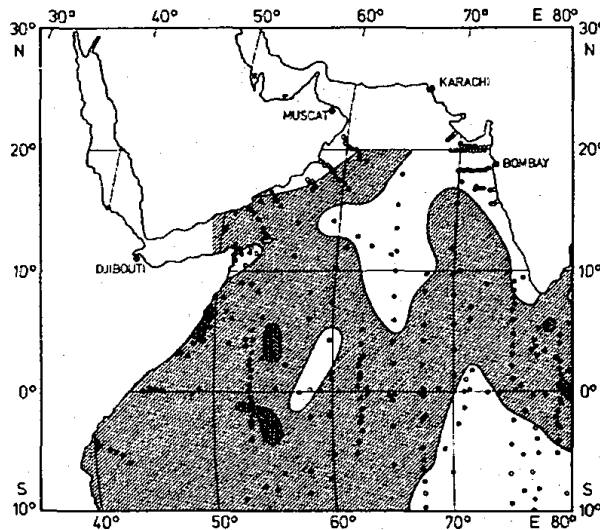


Fig. 3 a. Geographical distribution of *Pt. draco* during the SW monsoon

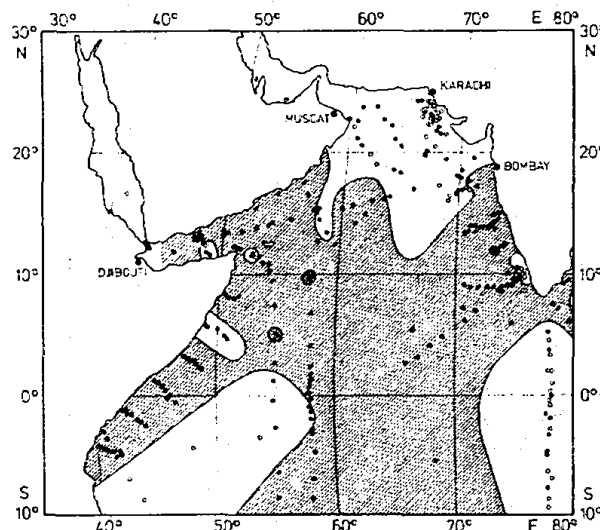


Fig. 3 b. Geographical distribution of *Pt. draco* during the NE monsoon

Sea. The range of abundance of the species is 0–19.1%. The maximum values are represented by small patches near and off Somalia (1940 per std. haul), off Kenya, off Ceylon and far south of Ceylon. *Pt. draco* is poorly distributed in the northern and southeastern part. The general pattern of distribution for both periods is roughly the same. The Somali region has high values of *Pt. draco* during the SW monsoon which is not so marked in the other season. The average number per haul during the SW monsoon is 1.2 times more abundant than that in the NE monsoon period.

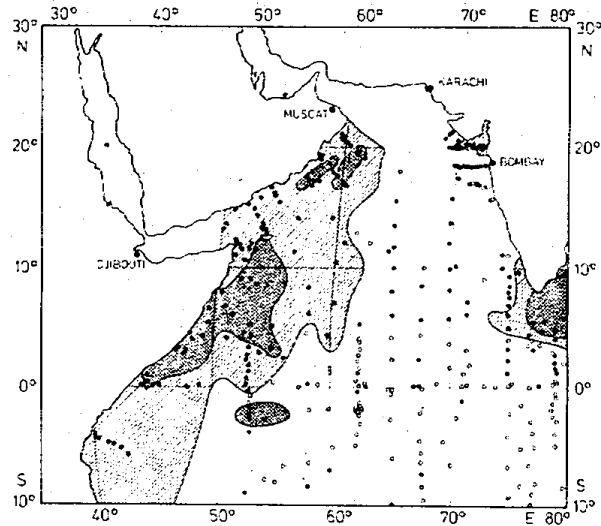


Fig. 4 a. Geographical distribution of *S. bedoti* during the SW monsoon

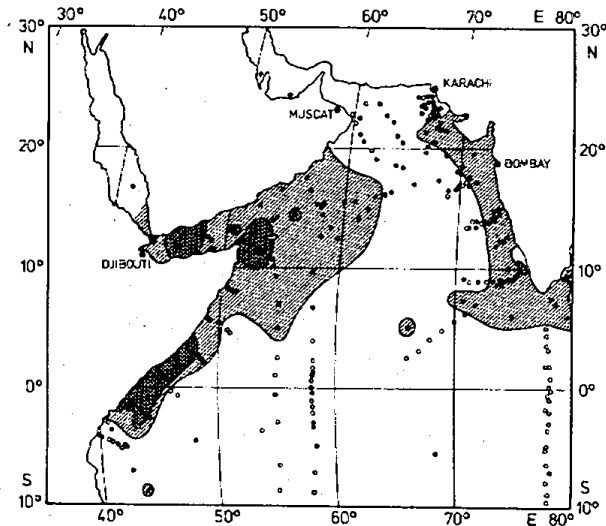


Fig. 4 b. Geographical distribution of *S. bedoti* during the NE monsoon

4. *Sagitta bedoti* (BÉRANECK, 1895)

(Figs. 4 a and 4 b)

This is a very common species, constituting 0–35.8% of the total chaetognaths in the samples. In one “Varuna” sample (20° 19' N and 72° 29' E) they are dominant. The general pattern of distribution of the species shows that they are more abundant in the areas adjacent to continents. The western side of the Arabian Sea shows almost uniform high density population. The maximum number is along the Somali coast (4160 per std. haul). Scattered patches of high values are observed particularly in the Gulf of Aden, near Arabia, in the Gulf of Mannar and off Tanganyika. The western coast of India and Ceylon also maintain a comparatively high concentration. Most of the northern, central and southern parts are poor in the representation of the species. The pattern of distribution for the different periods is more or less the same except that the maximum density at Somalia extends over a wider area during the SW monsoon period. Comparatively better representation of the species is seen along the west coast of India during the NE monsoon period. This species is 1.14 times more abundant during the NE monsoon. It seems to avoid poor waters but is not tied to specially productive waters.

5. *Sagitta bipunctata* (QUOY and GAIMARD, 1827)

(Figs. 5 a and 5 b)

This is another common chaetognath from the Arabian Sea. The abundance ranges from 0–23.6%. This species exhibits scattered distribution with localized concentrations. Maximum number is seen off Somalia (3620 per std. haul) and off the Bombay coast. The central part of the ocean is poorly populated, while the northern and southwestern parts are moderately represented. The 2 monsoon periods show differences in the distribution pattern of the species. The SW monsoon has higher density off and along the coast of Somalia and Kenya, while the NE monsoon sustains a higher population along the western coasts of India. During the SW monsoon a few patches of high values are found that are absent during the NE monsoon. Although *S. bipunctata* is absent or rare in zones

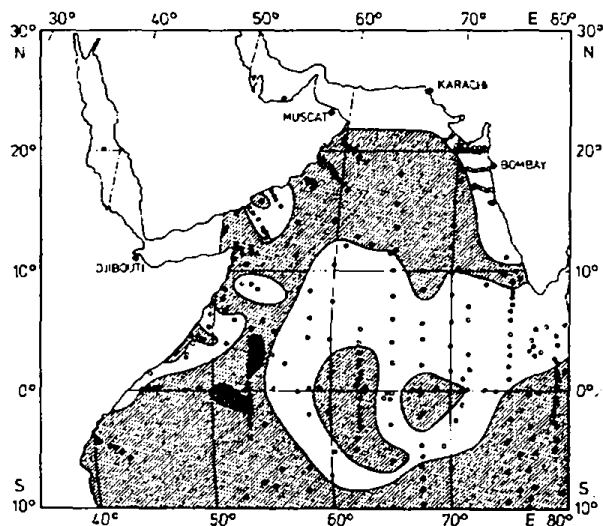


Fig. 5 a. Geographical distribution of *S. bipunctata* during the SW monsoon

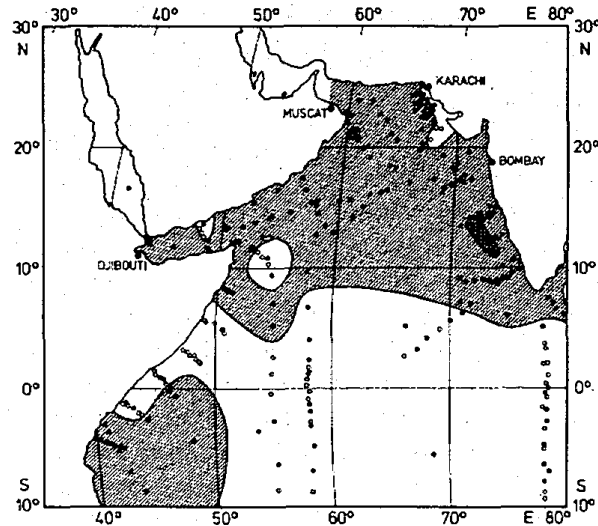


Fig. 5b. Geographical distribution of *S. bipunctata* during the NE monsoon

of low production, it also seems to avoid the areas of maximum zooplankton abundance. The average catch per haul is about the same during both seasons. This species shows a special type of widespread distribution which was called "anti-equatorial" (BIERI, 1959). It was found to be less abundant in most of the stations occupied in the equatorial region, similar to some of the observations for the Pacific (BIERI, 1959).

6. *Sagitta bombayensis* (LELE and GAE, 1936) (Fig. 15)

Two specimens were obtained from a single station in the Gulf of Cambay ($20^{\circ} 20' N$ and $72^{\circ} 00' E$) during the cruise of "Varuna" in 1963. The species is considered to be endemic to the west and east coasts of India (TOKIOKA, 1962). The hydrographical data relating to these stations show shallow depth (30 m), temperature $28.7-28.0^{\circ} C$, salinity 35–35.4‰ and high O_2 values of 5.2 ml l^{-1} . The available data suggest that this is a rather rare species in the Arabian Sea and it seems to prefer shallow waters with relatively low salinity.

7. *Sagitta enflata* (GRASSI, 1881) (Figs. 6a and 6b)

When fully mature the size ranges from 8–24 mm. The gonads in this species may mature periodically (MICHAEL, 1919; THOMSON, 1947). As ALVARIÑO (1965, 1967) and FURNESTIN and BALANÇA (1968) pointed out, this species seems to have more than one sexual cycle in the course of its life. This phenomenon is met with in the present collections also. Usually 2 forms occurred, one with short and the other with long ovaries. However, the long ovary forms appeared in comparatively small numbers. Occasionally intermediate forms are also encountered.

S. enflata is the dominant species in all except a few samples. It constitutes about 32–86% of the total chaetognaths in the sample. The distribution shows a nearly uniform population density along the western half of the Arabian Sea during the SW monsoon, while the eastern part has relatively poor concentrations of *S. enflata*. The maximum

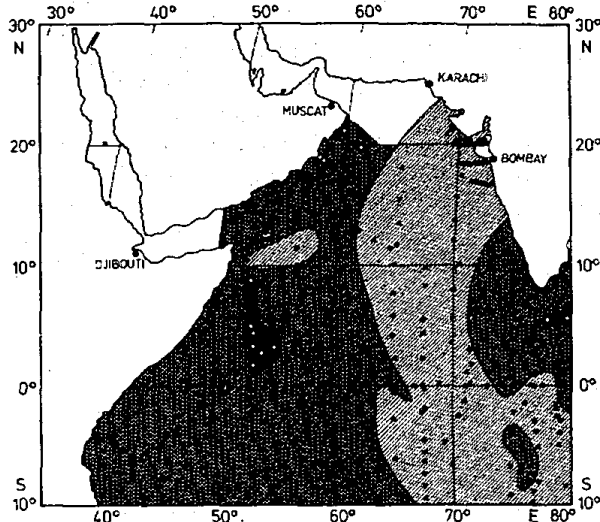


Fig. 6a. Geographical distribution of *S. enflata* during the SW monsoon

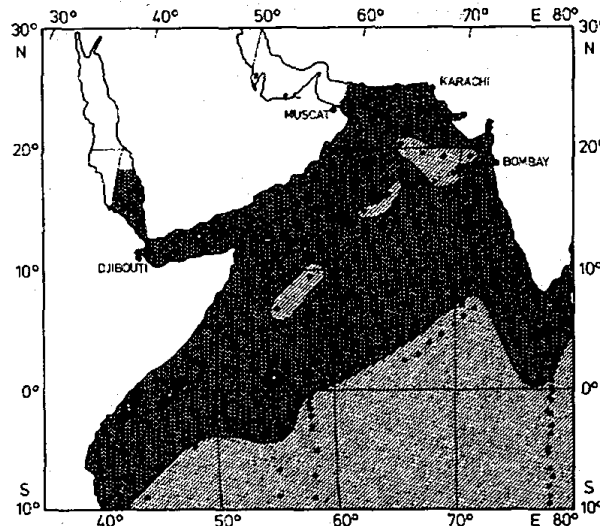


Fig. 6b. Geographical distribution of *S. enflata* during the NE monsoon

density is off the Somali coast and small areas of maximum density are observed in the vicinity of Somalia (9 000 per std. haul), mouth of Red Sea (18 585 per std. haul), Gulf of Aden, Arabian coast and near Ceylon. The lowest representation of *S. enflata* is seen during the SW monsoon period and is restricted to a small area near Gujarat. Compared to the NE monsoon period the SW monsoon period shows a greater representa-

tion of the species. However, the average number of specimens per unit haul is about the same for both periods. The 2 seasons have maximum density of *S. enflata* towards the western part of the Arabian Sea off Somalia and Kenya. During the NE monsoon low values extended along the southern part and in the SW monsoon low density spreads uniformly from the SE part towards the Indian coast.

8. *Sagitta ferox* (DONCASTER, 1903) (Figs. 7a and 7b)

Fairly common in the Arabian Sea. They constitute about 0–31.0% of the total chaetognaths in the sample. This species shows a higher density along the Equator. The

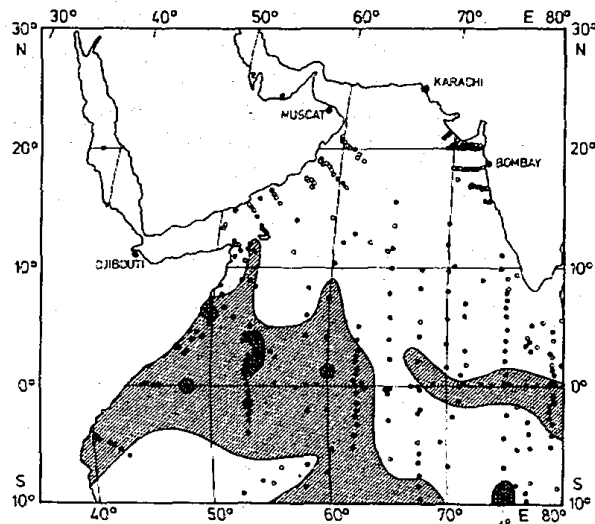


Fig. 7a. Geographical distribution of *S. ferox* during the SW monsoon

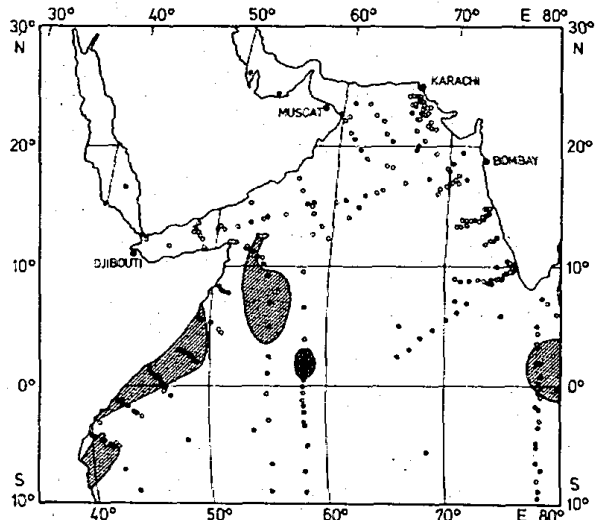


Fig. 7b. Geographical distribution of *S. ferox* during the NE monsoon

maximum observed density is in the SE part (2221 per std. haul). The whole of the northern part of the Arabian Sea has low values for *S. ferox*. The SW monsoon period sustains a 6 times higher population and an almost uniform value prevails along the equatorial region. The NE monsoon period has moderately high values near and off Somalia, and off the southern tip of the Indian peninsula. A single patch of high density is present near the Equator at about 58° E during the NE monsoon period.

9. *Sagitta hexaptera* (d'ORBIGNY, 1843)

(Figs. 8 a and 8 b)

Even though this species is found in many of the samples, its numerical representation is usually low. In the collections it ranges from 0–2.4%. This species is represented

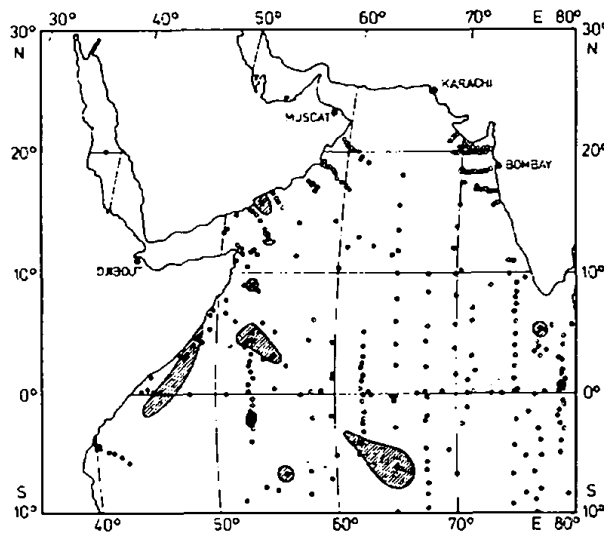


Fig. 8 a. Geographical distribution of *S. hexaptera* during the SW monsoon

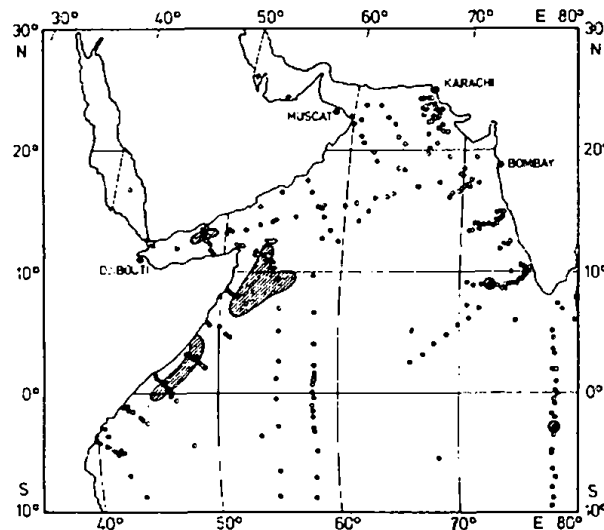


Fig. 8 b. Geographical distribution of *S. hexaptera* during the NE monsoon

by patches along the western part of the Arabian Sea in the equatorial area, off the Somalian and Arabian coasts and in the SE part. Higher values are restricted to the western part of the Arabian Sea, particularly off the Somali coast (192 per std. haul). The average number per haul is 1.4 times greater during the SE monsoon.

10. *Sagitta minima* (GRASSI, 1881) (Figs. 9a and 9b)

This species is only occasionally encountered in the samples, its range of abundance varied from 0–10.5%. Maximum density is seen along the southern part of the Arabian

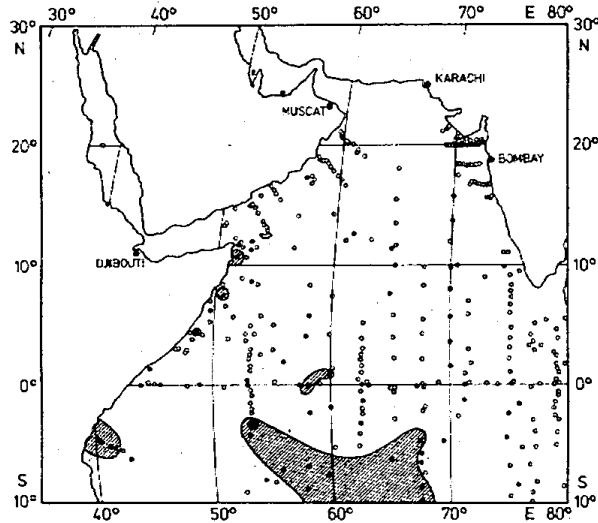


Fig. 9a. Geographical distribution of *S. minima* during the SW monsoon

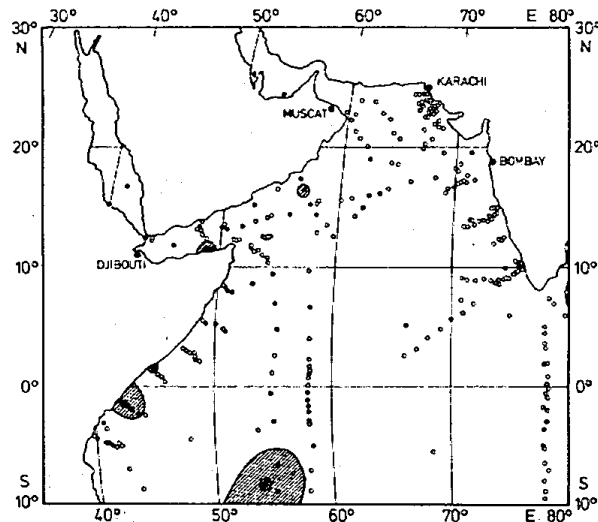


Fig. 9b. Geographical distribution of *S. minima* during the NE monsoon

Sea (800 per std. haul), at the mouth of the Gulf of Aden and off and near Somalia, Kenya and Tanganyika. *S. minima* is absent near and off the coasts of India except for a single station near the SW coast of India. It is found to be 3 times more abundant during the SW monsoon.

Several authors considered this to be a coastal species (THOMSON, 1948; FURNESTIN, 1952, 1953; PIERCE, 1953). However, the present distribution shows a different pattern since a large population seems to be fairly stable south of the Equator from about 50° to about 70° E and includes the highest densities found. ALVARINO'S interpretation (1965) of it being a boundary species seems to be confirmed.

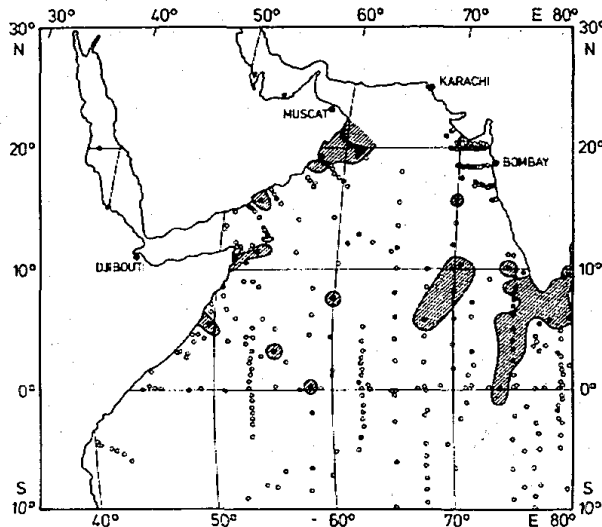


Fig. 10 a. Geographical distribution of *S. neglecta* during the SW monsoon

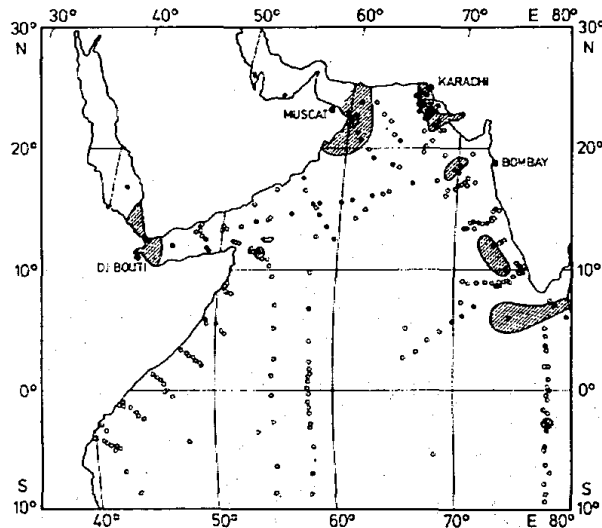


Fig. 10 b. Geographical distribution of *S. neglecta* during the NE monsoon

11. *Sagitta neglecta* (AIDA, 1897)

(Figs. 10a and 10b)

This species is moderately common, having a range of 0–8.3% of the total chaetognaths. The distribution of the species shows an affinity towards the coastal region. Highest density is noticed on the southern part of the Indian Peninsula and near Arabia and Persia. The maximum number (820 per std. haul) of specimens is obtained from a station near Arabia. They are very scarce south of the Equator. Better representation of the species was noticed during the NE monsoon when the average number of the specimens per haul is 1.5 times higher. During the NE monsoon high values are found near Arabia and Persia, at the mouth of the Red Sea and off the coast of India. The SW monsoon period has a greater density near and off Somalia and Arabia, the southern part of India and isolated patches north of the Equator. In the "Sealark" material (BURFIELD and HARVEY, 1926) *S. neglecta* was scarce, probably because the collections were taken far away from the coast.

12. *Sagitta pacifica* (TOKIOKA, 1940)

(Figs. 11a and 11b)

S. pacifica reported from the Pacific (ALVARIÑO, 1961) South China Sea and Gulf of Thailand (ALVARIÑO, 1967) has ovaries reaching the level of the ventral ganglion, and even to the neck region in fully mature specimens. In the present specimens the ovaries are found to extend up to the middle of the anterior fin, rarely up to the ventral ganglion, and never beyond that.

S. pacifica is very common in the Arabian Sea and comes second to *S. enflata* in the order of abundance. The percentage range of abundance in the sample is 0.3–38.3. Numerical representation of the species is greater south of 10° N. Maximum densities observed are near Arabia (4400 per std. haul) and the Somalia region (2440 per std. haul).

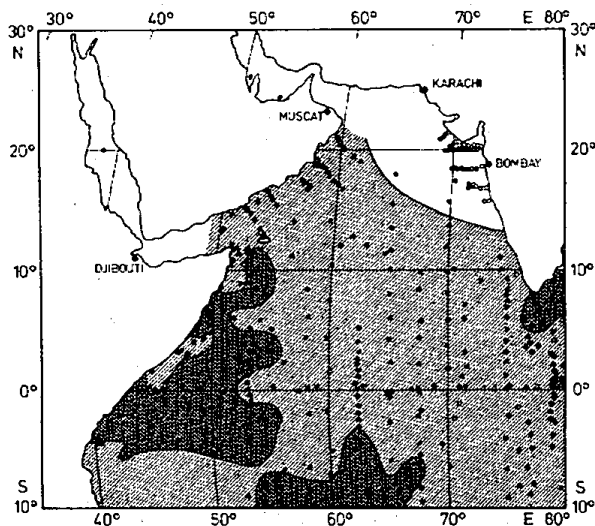


Fig. 11 a. Geographical distribution of *S. pacifica* during the SW monsoon

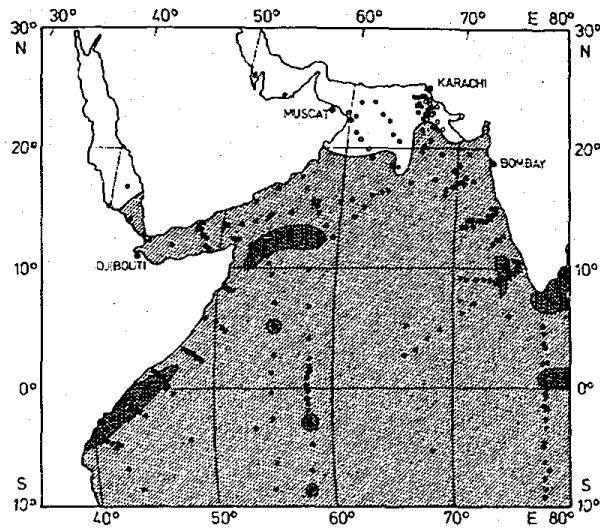


Fig. 11 b. Geographical distribution of *S. pacifica* during the NE monsoon

haul). Central parts of the southern and eastern Arabian Sea also have high values. On average the SW monsoon period has a population density 1.7 times greater than in the NE monsoon period. The maximum density of *S. pacifica* during the SW monsoon covers large areas, while during the NE monsoon maximum density was noted as isolated patches. In both periods the values were very low in the northern Arabian Sea.

13. *Sagitta pulchra* (DONCASTER, 1903)

(Figs. 12 a and 12 b)

This is not a very common species, the percentage range of abundance being 0–1.2. Isolated patches are observed near Somalia (280 per std. haul), Gulf of Aden, near Arabia

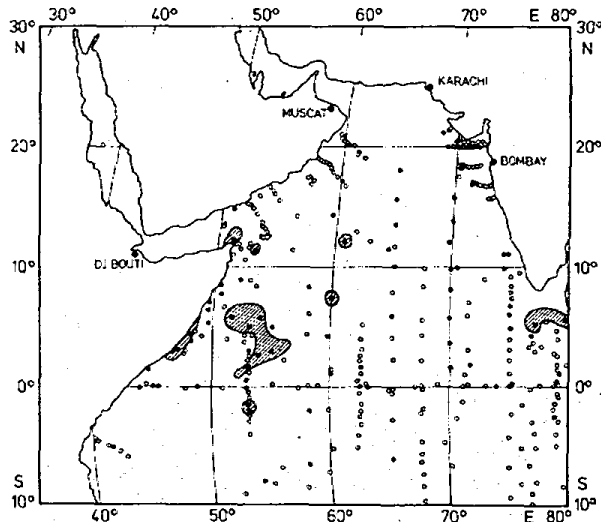


Fig. 12 a. Geographical distribution of *S. pulchra* during the SW monsoon

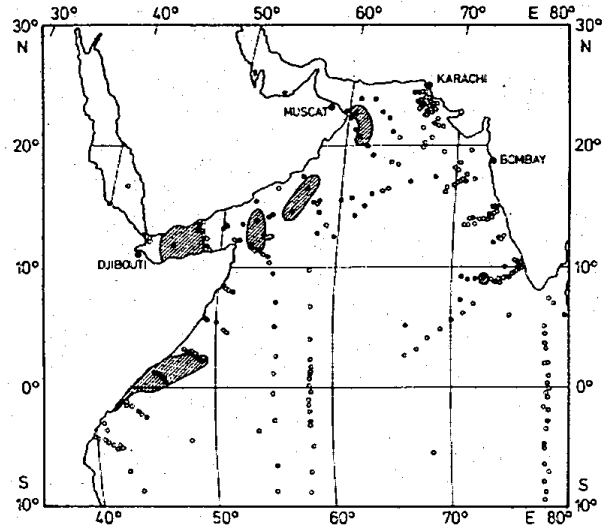


Fig. 12b. Geographical distribution of *S. pulchra* during the NE monsoon

and south of the Indian Peninsula. It is rarely represented near the coasts of Indian and central and south eastern part of the surveyed area. The NE monsoon period has higher numerical values for the species off the Arabian coast. On the whole the average number per haul is 1.4 times greater during the NE monsoon.

14. *Sagitta regularis* (AIDA, 1897)

(Figs. 13 a and 13 b)

Size at maturity varies from 4.8–6.0 mm. Stumpy forms of this species (3.2–3.6 mm) are encountered in a few samples. Such stumpy forms were obtained from 14 stations, all located towards the coast (south of the Indian Peninsula, west coast of India, near

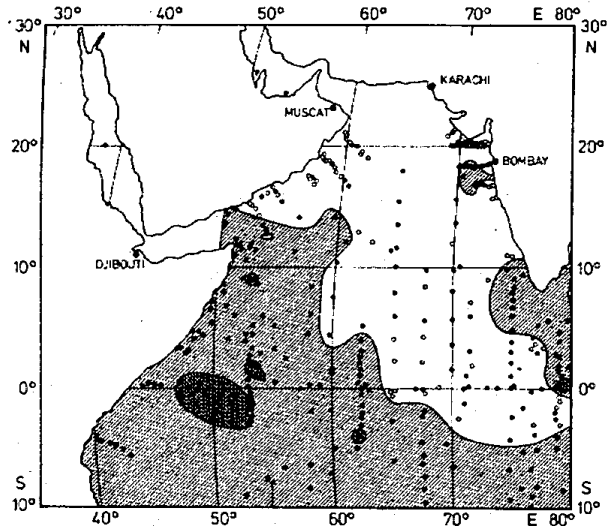


Fig. 13 a. Geographical distribution of *S. regularis* during the SW monsoon

Somalia and Gulf of Aden). These samples were taken mostly during the NE monsoon period (11 samples) and a few (3 samples) in the later part of the SW monsoon period (August–September–early October).

S. regularis is among the most common species in the Arabian Sea, represented in most of the samples and the abundance ranged from 0–17.1%. The general pattern of distribution of the species shows an almost uniform concentration along the southwestern part of the Arabian Sea and western coast of India and Ceylon. The maximum density is

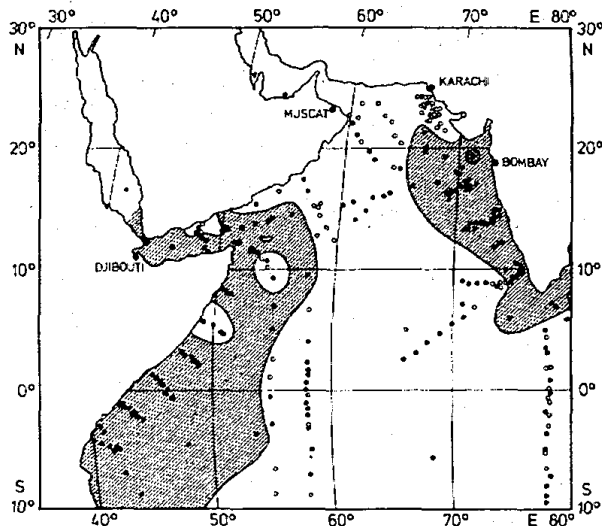


Fig. 13 b. Geographical distribution of *S. regularis* during the NE monsoon

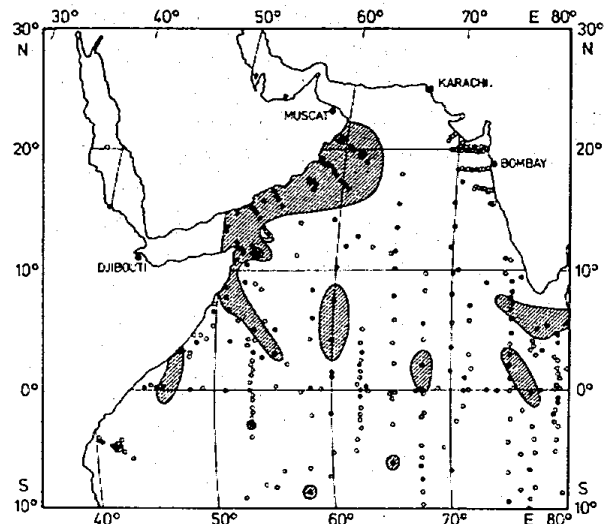
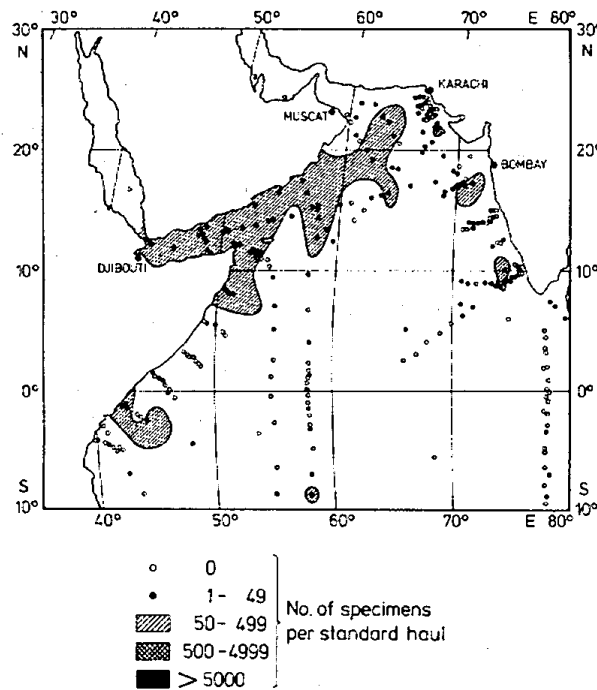
near Somalia and Kenya (1600 per std. haul) with small areas of high density at isolated areas in the Arabian Sea but a poor representation in the northern and central parts. The species is found to be 1.4 times more abundant during the SW monsoon than in the NE monsoon period. During the SW monsoon period the whole of the south and southwestern part extending to the Somalian region and western coast have relatively better population density. The NE monsoon period sustains a better representation of the species along the west coast of India.

15. *Sagitta robusta* (DONCASTER, 1903)

(Figs. 14 a and 14 b)

Size at maturity varied from 9.8–14.2 mm. However, comparatively short mature forms (8.5–8.8 mm) were obtained from 4 samples taken between 5–20° N lat. and 60–76° E long. Of the 4 samples, 2 were taken during SW monsoon and the other in NE monsoon period.

This species is moderately common in the Arabian Sea, representing 0–8.3% of total chaetognaths. The general pattern of distribution shows a steady population occupying a large area along the coasts of Arabia, northern Somalia and the Gulf of Aden, otherwise the distribution is patchy. The southern part of the Indian Peninsula has high population during the SW monsoon period. The maximum representation is near the

Fig. 14 a. Geographical distribution of *S. robusta* during the SW monsoonFig. 14 b. Geographical distribution of *S. robusta* during the NE monsoon

Arabian coast (730 per std. haul). This species is sparse in the stations south of the Equator. The 2 monsoon periods show the same numerical representation with regard to average numbers per haul. The northern half of Somalia and the coast of Arabia maintained a uniform high density for both seasons.

While the above-mentioned species are all known to be epipelagic, the following

4 are known to inhabit greater depths. They are; *Eukrohnia fowleri* described as a bathyplanktonic form and 3 other species—*Sagitta decipiens*, *S. lyra* and *S. zetesios*—reported as mesoplanktonic chaetognaths. All of them are cosmopolitan forms in temperate and warm oceanic regions (ALVARIÑO, 1965). Tables 3 and 4 show the data for these species.

16. *Eukrohnia fowleri* (RITTER — ZÁHONY, 1909)

(Fig. 15)

This species was found at 2 stations, located off the southern coast of India and worked on 2 successive days (Table 3). Three specimens were taken at "Varuna" station 2009 on November 5, 1963, at 09° 04' N and 74° 00' E where the temperature at 200 m depth was 16.5° C, salinity 34.9‰ and O₂ content 4.5 ml l⁻¹ (Arabian Sea subsurface water mixed with Indian Ocean equatorial water). Four specimens were taken on the following day at "Varuna" station 2014 at 09° 10' N and 70° 40' E at 200 m; 14° C temperature, salinity 35.2‰ and 0.45 ml l⁻¹ O₂ indicate Arabian Sea subsurface water.

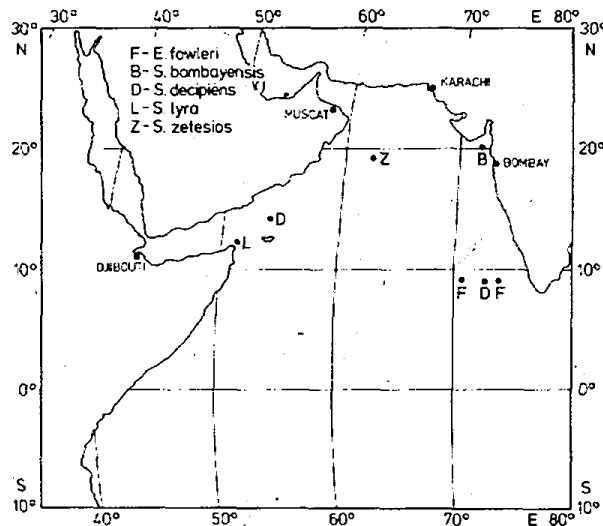


Fig. 15. Chart showing the location of stations from which rare forms were obtained

17. *Sagitta decipiens* (FOWLER, 1905)

(Fig. 15)

S. decipiens was encountered in 2 stations (Table 3), one off Saudi Arabia and the other off the southern coast of India. The first sample was taken by "Anton Bruun" cruise A, station 5, 27 February off Socotra in upwelling waters at 14° 03' N and 54° 00' E. At 200 m the water was Arabian Sea Subsurface Water and temperature was 15.1° C. More specimens were obtained from this haul. The second was "Varuna" station 2011 at 09° 00' N and 72° 40' E occupied on November 5, the water at 200 m depth was also Arabian Sea Subsurface Water and the temperature was 13.48° C. At both stations the dissolved O₂ content at 200 m depth was low, the values being 0.6 and 0.5 ml l⁻¹ respectively.

Table 3. Station data for the rare species

Ship	Cruise No.	Station number	Latitude	Longitude	Date	Time	Depth m	Species Name	No. per hauls
"Varuna"	104	2 009	09° 04' N	74° 00' E	5-11-63	11.10	200	<i>E. fowleri</i>	Juvenile-3
"Varuna"	104	2 014	09° 10' N	70° 40' E	6-11-63	20.10	200	<i>E. fowleri</i>	Juvenile-4
"Varuna"	30	1 793	20° 20' N	72° 00' E	10-5-63	12.02	2.5	<i>S. bombayensis</i>	Stage IV-2
"Anton Bruun"	A	5	14° 03' N	54° 00' E	27-2-63	04.47	200	<i>S. decipiens</i>	Stage I-2
"Varuna"	104	2 011	09° 00' N	72° 40' N	5-11-63	02.00	200	<i>S. decipiens</i>	Juvenile-7 Stage I-2
"Anton Bruun"	4A	170	12° 04' N	51° 31' E	9-10-63	06.16	200	<i>S. lyra</i>	Juvenile-4 Stage I-2
"Anton Bruun"	4A	198	19° 17' N	62° 29' E	5-11-63	01.26	200	<i>S. zetesios</i>	Juvenile-5 Stage I-1 Juvenile-5

Table 4. Environmental data for the chaetognaths described as meso- and bathyplanktonic forms

Species	Previous data		Present data		Depth from which recorded in the Indian Ocean
	Temperature °C	Salinity S‰	Temperature °C	Salinity S‰	
<i>E. fowleri</i>	13.4–14.5 (OWRE, 1960)	34.65 (SUND, 1961)	13.99 16.51	35.23 34.90	600 and below to 1300 m. (SILAS and SRINIVASAN, 1969) Mainly below 450 m (BURFIELD and HARVEY, 1926)
<i>S. decipiens</i>	8.9–18.0 (SUND, 1961)	34.4–34.9 (SUND, 1961)	15.14 13.48	35.54 34.99	Maximum at 405 Spread at 720 m (BURFIELD and HARVEY, 1926)
<i>S. lyra</i>	14.7–24.2 (PIERCE and WASS, 1962)	35.8–36.8 (PIERCE and WASS, 1962)	15.51	35.41	225, 270 (BURFIELD and HARVEY, 1926) 100 or 200 to the surface (TOKIOKA, 1956) 0–50 m (TSURAT, 1963) 300 and below to 1300 m (SILAS and SRINIVASAN, 1969)
<i>S. zetesios</i>	12.4 (FAGETTI, 1958)	34.6 (SUND, 1961)	16.05	35.85	—

18. *Sagitta lyra* (KROHN, 1853)

(Fig. 15)

Seven specimens were obtained from a single station near the mouth of the Gulf of Aden (12° 04' N and 51° 31' E) in Oct. 1963. The hydrographical data indicate upwelling at the time of collection. Comparatively cold water (22.88°C) was present at 40 m. The recorded temperature at 227 m was 13.6°C, salinity 35.6‰ and dissolved O₂ 0.89 ml l⁻¹ (Arabian Sea Subsurface Water mass).

19. *Sagitta zetesios* (FOWLER, 1905)

(Fig. 15)

Six specimens of this species were found in a sample taken in the North Arabian Sea (19° 17' N lat. and 62° 29' E long.) in November 1963. The data show the presence of upwelling waters at the time of sampling. Temperature at 40 m was 23.4°C and O₂ content was low from 75 m (0.70 ml l⁻¹) downwards. The temperature and salinity at 199 m were 16.05°C and 35.85‰ respectively while dissolved O₂ content was 0.40 ml l⁻¹ (Arabian Sea Subsurface Water).

II. Discussion

The collection includes 15 epiplanktonic species, 3 mesoplanktonic and 1 bathyplanktonic species, the 2 latter groups being very rare and represented by a few stray individuals. *S. enflata* is the dominant species in this area, constituting 32–86% of the total chaetognaths. *S. pacifica*, *S. bedoti*, *Pt. draco*, *S. bipunctata* and *S. regularis* are the other

common species in the order of their numerical abundance (Table 1). *S. ferox*, *S. robusta*, *S. neglecta* and *K. pacifica* are moderately common, while *S. hexaptera*, *S. pulchra*, *S. minima* and *K. subtilis* are occasionally encountered, *S. bombayensis* is endemic to the coasts of India but specimens were obtained only from a single collection taken from the Gulf of Cambay.

The Arabian Sea is in the NW of the monsoon area of the Indian Ocean and its surface currents and upwelling systems are regulated by the monsoonal regime. The western Arabian Sea, especially the Somalian and Arabian areas, has the maximum density for all abundant and frequent species excluding *S. ferox* and *S. minima* (Table 1). During the SW monsoon upwelling occurs along the east coast of Africa and west coast of India. According to PANIKKAR and JAYARAMAN (1966), upwelling is prevalent along the coast between 7–10° N lat. during August to early October. Even during the NE monsoon period, the western Arabian Sea and coast of India are rich in most of the chaetognath species. Investigations made during the IIOE indicate that the Arabian Sea has a very high concentration of nutrients (BEZRUKOV, 1961; RYTHER and MENZEL, 1965). The western side of the Arabian Sea is more productive (LA FOND, 1965; WOOSTER, SCHAEFER and ROBINSON, 1967) and hence it is no wonder that the chaetognaths, which occupy a high level in the food web, also have maximum abundance in this part of the Arabian Sea. The region 40–60° E between the Equator and northern limit of the ocean is richest in chaetognaths during both seasons (NAIR, 1969). The IIOE data on zooplankton (IOBC, 1968 a, b) suggest that primary production is able to support a good standing stock of higher organisms in the northern and western part of the Arabian Sea, with a peak during the SW monsoon upwelling season. The biomass values (IOBC, 1968 a, b) for both monsoon periods show the highest values along Somalia, Arabia and SW coast of India. However, during the NE monsoon period the areas of highest values for biomass are located further south than in the SW monsoon period.

In attempting to determine the primary cause or causes of abundance it is important to compare the distribution with that of zooplankton. Examination of the stomach content of the chaetognaths in the IIOE samples indicates that copepods form the main food item (see also VARADARAJAN and CHACKO, 1943; THOMSON, 1947; REEVE, 1966). Chaetognaths feed mainly on calanoid copepods, the commonest forms being *Centropages*, *Eucalanus* and *Lucicutia*, and cyclopoid copepods like *Corycaeus*, *Oithona* and *Oncaea*. Rarely harpacticoid copepods and other groups like fish larvae, ostracods, euphausiids and polychaete larvae were found inside the gut. The IIOE data on copepod distribution for the NE and SW monsoon periods show maximum population along the Somalian coast of Africa extending northwards to the Arabian coast (IOBC, 1970 a). Lowest population density for both monsoon periods was observed in the central part of the Arabian Sea. Most of the chaetognath species except *S. enflata*, *S. pacifica* and *Pt. draco* also have sparse representation in the central part of the Arabian Sea. In general, the abundance and scarcity of different chaetognath species corresponds to the pattern of distribution of copepods.

Although the distribution of each species is different in itself, based on the distribution pattern, the various species can be grouped by their regional dominance as follows:

- a) Widely distributed: *S. enflata*, *S. pacifica*;
- b) Localized areas: *S. bedoti*, *S. bombayensis*, *S. neglecta*, *S. robusta*;
- c) Patchy: *K. pacifica*, *K. subtilis*, *S. bipunctata*, *S. hexaptera*, *S. pulchra*;
- d) Equatorial: *S. ferox*;

- e) South of the Equator between 50–68° E: *S. minima*;
- f) Southwest Arabian Sea and western side of India and Ceylon: *Pt. draco*, *S. regularis*;
- g) Deep and subsurface waters: *E. fowleri*, *S. decipiens*, *S. lyra* and *S. zetesios*.

The distribution of certain species shows seasonal variation (Table 1 and Figs. 1–14). Tables 1 and 2 show that maximum density is to be found in areas and seasons where secondary production is high, such as the western boundary area, the equatorial upwelling off India. The exceptions are few and apparently not too significant. They are *S. ferox* and *S. minima* (Table 1) during the SW monsoon, and *E. fowleri*, *K. subtilis*, *S. ferox*, *S. minima* and *S. regularis* during the NE monsoon. The numerical distribution of chaetognaths as shown in these tables illustrates that numerical abundance is correlated to food availability, while species presence or absence may be attributed to suitability of the environment and tolerance of the species.

Table 2 shows that the average number per haul is higher during the SW monsoon for nine species. In 2 species (*K. subtilis* and *S. pacifica*) the average number per haul during the SW monsoon is 1.7 times that of the NE monsoon, while *Pt. draco*, *S. bipunctata*, *S. enflata*, *S. hexaptera* and *S. regularis* showed an increase in number per haul by a factor of 1 to 1.4. *S. ferox* is 6 times and *S. minima* 3 times more abundant during the SW monsoon period. The average numbers per haul for the 2 species (*S. robusta* and *K. pacifica*) are equal in both seasons. *S. bedoti*, *S. neglecta* and *S. pulchra* have more numbers per unit haul in the NE monsoon period by a factor of 1.14 to 1.5 although 2 of them showed highest density during the SW monsoon. This indicates that patterns of distribution and swarming can be due to factors other than food availability. Species like *E. fowleri*, *S. decipiens* and *S. zetesios* are obtained in small numbers only during NE monsoon. *S. lyra* was found in small numbers at a single station in the SW monsoon period. *K. pacifica*, *S. enflata* and *S. neglecta* showed maximum density (measured as number of specimens per haul) during the NE monsoon. Further detailed studies on the individual species should clarify the ecological factors involved.

It is significant that 2 of the 3 species showing affinity for the coastal area (*S. bedoti* and *S. neglecta*) have an average number per haul greater during the NE monsoon, while the other (*S. robusta*) has the same average number, because coastal species are more affected by local factors other than large-scale upwelling.

There is remarkable similarity in the Indo-Pacific chaetognath fauna (TOKIOKA, 1952; 1965; HYMAN, 1959). In the present collections all the 15 epiplanktonic species are common to the Indo-Pacific and 7 of them (*S. bedoti*, *S. ferox*, *S. neglecta*, *S. pacifica*, *S. pulchra*, *S. regularis* and *S. robusta*) are endemic to this region. A critical study of earlier work dealing with the Indo-Pacific reveals the fact that it sustains a variety of species and many species are exclusive to this region. The maintenance of the Indo-Pacific fauna may be due to the pattern of circulation in the Indian Ocean. The main part of the Agulhas Current flowing along the SE coast of Africa is directed towards Australia across the southern part of the Indian Ocean. During the NE monsoon there is a strong flow of water from the Pacific to the Indian Ocean through the straits of Malacca into the Andaman Sea and then to the Bay of Bengal (SEWELL, 1948). During the SW monsoon the direction of the currents is reversed and there is a westward flow between the Malay Archipelago and Australia (SEWELL, 1948). Recent studies based on IIOE data also indicate the influx of Pacific Ocean water through the Indonesian Archipelago (WYRTKI, 1973). There is much interchange of water between the 2 oceans, resulting in a wide distri-

bution of chaetognaths in the Indo-West-Pacific. Thus the similarity of the fauna can naturally be expected.

There is a distinct difference in the distribution of chaetognaths in the Arabian Sea and the Red Sea. There are 2 samples available from the Red Sea, 5 from the Bab-el-Mandeb and 12 from the Gulf of Aden. All the epiplanktonic forms (excluding *S. bom-bayensis*) recorded from the Arabian Sea are found in the Gulf of Aden. *S. enflata*, *S. bedoti*, *S. robusta* and *Pt. draco* are the common forms in these samples. At Bab-el-Mandeb all the species found in the Gulf of Aden (except *K. subtilis*) are encountered. In these samples *S. enflata*, *S. regularis*, *S. bedoti* and *K. pacifica* are the common species and *S. hexaptera*, *S. pulchra* and *S. ferox* are sparse. In the Red Sea samples *S. enflata*, *S. pacifica*, *S. bipunctata*, *S. regularis*, *S. neglecta*, *S. ferox*, *S. heraptera*, and *S. bedoti* are found. These collections from the Gulf of Aden and Red Sea are comparable since they cover the NE monsoon period, except the one located towards the northernmost part. Along with the reduction in specific number, there is a general lowering of population density of the different species of chaetognaths from the Gulf of Aden into the Red Sea. The hydrographic conditions prevailing in the Red Sea are high salinity (36.66–40.50‰) and high temperature (21.96–29.53°C) down to 200 m depth, and thus may not be congenial for all the species which occur in the Arabian Sea and Gulf of Aden. FURNESTIN and BALANÇA (1968) have commented on the sporadic transportation of chaetognaths from the Gulf of Aden into the southern section of the Red Sea. STUBBINGS (1938) has reported mass mortality of pteropods entering the Red Sea from the Arabian Sea. The hot, highly saline waters of the Red Sea, and perhaps other unfavourable physical and chemical factors, are a barrier to the survival of many chaetognath species. The species which are able to withstand this peculiar environment might have maintained the population due to lack of competition from other species and availability of abundant food, as is evidenced by the copepod distribution in the area (IOBC, 1970 a).

All the samples from which mesoplanktonic and bathyplanktonic chaetognaths were taken belong to the upper 200 m. The 0–200 m water column includes the Arabian Sea surface water (ASSW), extending from the surface to 100–150 m depth, and the Arabian Sea subsurface water (ASSSW) extending from a depth below the ASSW. At "Varuna" station 2009, where *E. fowleri* is found, the surface water is diluted by run-off from the Cochin backwater system down to 30–40 m depth and O₂ content is high down to 200 m depth. ASSSW has an unusually high dissolved O₂ content.

According to GALLAGHER (1966) the ASSSW has a temperature range of 10–19°C, salinity varies from 35.0–36.0‰ and O₂ content from 0.21–2.09 ml l⁻¹. The lowest level in the column sampled in the present collection had temperatures 13.5–16.5°C. These features may explain the presence of species described as meso- and bathyplanktonic at depths as low as 200 m.

At the stations from which *S. decipiens* (station AB5 only), *S. lyra* and *S. zetesios* were taken, upwelled waters were present; however, since these species were not taken when and where upwelling was at its peak intensity, or in upwelled waters only, other factors must have been involved. Temperatures at 40 m at stations 170 and 190 were 22.88°C and 23.41°C, respectively. At the station at which *S. decipiens* occurred, temperature was low even at the surface (25.32°C). Previous records of these species from the Indian Ocean are from depths below 200 m except for *S. lyra* (Table 4) which has already been reported from the upper 200 m (TOKIOKA, 1956; TSURUTA, 1963). *E. fowleri* is considered to be bathyplanktonic and BURFIELD and HARVEY (1926) found it mainly

below 450 m. According to ALVARIÑO (1965), it is abundant at depths below 800 m. SILAS and SRINIVASAN (1969) noted its occurrence at 600 m and down to 1300 m.

These meso- and bathyplanktonic species are known to be cosmopolitan. The earlier relevant records, summarized with the present data in Table 4, show that the temperature range varies little, while the difference in the salinity pattern may indicate a certain tolerance to salinity changes associated with habits of vertical migration.

All hauls except for "Varuna" station 2009 (Table 3) were made at night or in the early morning and all specimens are either juvenile or stage I. Diurnal migration is well known in chaetognaths (MICHEL, 1911; MOORE, 1949; HAMON, 1956 and others), and it is likely that at dawn the young follow the adults in this downward migration. The specimens may be late migrants caught in the top layer of the population range, or those brought up to a shallower depth by the upwelling of deep water.