

Variability in Distribution of Chaetognaths in the Arabian Sea

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Variability in the distribution of chaetognaths in the Arabian Sea and adjacent areas is studied in selected localities and along the latitudes. Seasonal variations in the total abundance and relative abundance of different species in 4 selected areas, viz. around Socotra, north Arabian sea, off the west coast of India and south of the Indian Peninsula, are analysed. The shifting of the maximum population of the surface layer chaetognaths towards the west or east is interpreted on the basis of the reversing system of currents for the two monsoon periods. Latitudinal variation in the distribution of different chaetognath species shows two categories of species, one having preference for northern latitudes and the other having higher abundance towards the southern latitudes. Statistical analyses of the variation in distribution indicate that seasonal difference, difference in areas and latitudinal variation affect the relative abundance of different chaetognath species.

VARIABILITY in plankton is enormous and is dependent on the changes in the environment. Thus, with changing environment it is only natural to expect variations in the composition of plankton, and this variability "provides the only source of information about the dynamics of natural populations of the plankton"¹. The numerical abundance of a species at a given locality in the ocean is the result of the interaction between a number of factors like water transport, changes in temperature, availability of food, diurnal vertical migration, rate of production, age of the ecosystem and survival.

The distribution of chaetognaths in the Arabian Sea and adjacent areas indicates that the south-west monsoon period sustains a higher population density for most of the epiplanktonic species (Vijayalakshmi R. Nair & Rao, T. S. S., unpublished data). This prompted further detailed investigations in selected localities and the relative abundance of the chaetognath species during the north-east and south-west monsoon periods. The reversing system of current is perhaps one of the most important factors affecting variation in the distribution of chaetognath species. This has been considered as the principal criterion to explain the variability in the distribution of chaetognaths. In the open ocean, changes in the composition of the plankton are generally more pronounced in the north-south direction than from east to west². This is specially significant in the case of chaetognaths³ and hence the north-south variation of the different species has also been attempted. Statistical approach was attempted with a view to giving a more reliable and a clearer picture of these variations.

Materials and Methods

The chaetognaths sorted out from the 614 standard samples collected from the Arabian Sea and adjacent areas (lat. 25°N to 10°S and long. 38° to 80°E) during the International Indian Ocean Expedition (1960-65) form the basis of the present investigation. The details of the net used, stations and collections

have already been published⁴. Even though the samples were taken during different years from widely distant geographical locations, they are suitable for quantitative and qualitative assessments owing to the uniformity of the gear and the mode of collection. For the study of variation in selected localities, samples from four five-degree squares were selected. The areas are: Area 1 — Around Socotra [067(1)]; lat. 10-15°N; and long. 50-55°E. Area 2 — North Arabian Sea [102(2)]; lat. 20-25°N; and long. 65-70°E. Area 3 — Off the west coast of India [065(3)]; lat. 15-20°N; and long. 70-75°E. Area 4 — South of Indian Peninsula [029(4)]; lat. 5-10°N; and long. 75-80°E.

During the expedition these four areas in the Arabian Sea received the maximum coverage for the two monsoon periods. The number of samples available for the four areas are: given below:

Area	Number of samples		Total
	SW monsoon	NE monsoon	
1	18	18	36
2	10	29	39
3	24	15	39
4	13	15	28

The average number of the different species in the selected areas was calculated separately for the two monsoon periods. For the study of latitudinal variation the percentage frequency distribution of the different species in each 5° increment of latitude was calculated. The rare species found in the collections were not considered for this study.

Results

Selected areas — The numerical values (av. number/std haul) for the different species in the whole of the Arabian Sea and the four selected areas are shown in Table 1. The first three localities, viz. around Socotra, north Arabian Sea and off the west coast of India, represent areas of high production. The last one (south of Indian Peninsula) covers the region where an admixture of the waters of the Arabian Sea and Bay of Bengal takes place.

TABLE 1 — AVERAGE NUMBER OF DIFFERENT SPECIES IN THE ARABIAN SEA ALONG WITH THE AVERAGE NUMERICAL VALUES FOR THE SELECTED 5^c SQUARES

Species	Whole Arabian Sea			Area 1			Area 2			Area 3			Area 4		
	NE	SW	Total	NE	SW	Total	NE	SW	Total	NE	SW	Total	NE	SW	Total
<i>I. pacifica</i>	23-00	23-00	46-00	27-86	11-15	39-01	13-45	14-50	27-95	31-24*	43-20†	74-44	22-53	32-70	55-23
<i>I. subtilis</i>	6-00	10-00	16-00	2-61	21-99†	24-60	1-62	—	1-62	1-00	—	1-00	12-53*	5-28	17-81
<i>H. araco</i>	92-00	114-00	206-00	116-27	78-90	195-17	3-54	6-50	10-04	58-61	30-70	89-31	130-88*	180-07†	310-95
<i>S. bedoti</i>	217-00	190-00	407-00	381-90*	215-94	597-84	116-51	31-30	147-81	75-06	21-05	96-11	232-78	505-37†	738-15
<i>S. bipunctata</i>	101-00	109-00	210-00	76-09	84-28†	160-37	75-71	9-80	85-51	168-23*	22-70	190-93	80-90	19-85	100-75
<i>S. enflata</i>	1445-00	1547-00	2992-00	1865-47*	1423-34	3288-81	682-77	211-40	894-17	905-43	416-75	1322-18	1315-37	2520-28†	3835-65
<i>S. ferax</i>	14-00	85-00	99-00	2-89	26-07†	28-96	0-14	8-20	8-34*	5-66	23-80	29-46	8-92*	4-43	13-35
<i>S. hexaptera</i>	11-00	15-00	26-00	17-26*	17-92	35-18	0-24	0-10	0-34	4-20	1-00	5-20	12-69	19-85†	32-54
<i>S. minima</i>	5-00	15-00	20-00	4-44*	12-92†	17-36	0-10	—	0-10	—	—	—	1-08	—	1-08
<i>S. neglecta</i>	33-00	22-00	55-00	8-94	65-29	74-23	94-74*	11-40	106-14	10-66	15-10	25-76	32-53	75-97†	108-50
<i>S. pacifica</i>	188-00	319-00	507-00	164-78	274-23	439-01	11-97	0-30	12-27	190-00*	3-30	208-95	184-41	425-54†	609-95
<i>S. pulchra</i>	13-00	9-00	22-00	21-65*	22-45	44-10	11-96	18-10	20-06	2-53	25-00	171-45	9-38	27-85†	37-23
<i>S. regularis</i>	88-00	115-00	203-00	67-60	71-82	139-42	7-71	4-50	12-21	146-45*	1-85	19-23	47-22	150-23†	197-45
<i>S. robusta</i>	30-00	36-00	66-00	98-68*	84-82	183-50	—	—	—	—	—	—	8-69	86-11†	94-80
Total	2266-00	2609-00	4875-00	2856-54*	2411-12	5267-66	1072-96	343-70	1416-66	1617-91	623-40	2241-31	2108-11	4053-53†	6161-64

*Maximum observed value during the NE monsoon period.
 †Maximum observed value during the SW monsoon period.

For a clearer understanding of the variations in the pattern of distribution of chaetognaths, each area has to be treated separately for the total abundance as well as the relative abundance of different species. High population densities of chaetognaths are found in the Area 4 (6161.64/std haul) and Area 1 (5267.66/std haul). If the seasonal abundance of the group is taken into account, Area 1 has the highest density for the NE monsoon period (2856.54/std haul) and Area 4 sustains the maximum abundance for the SW monsoon period (4053-53/std haul). Fourteen species belonging to three genera — *Krohnitta*, *Pterasagitta* and *Sag&a* are common to these four areas. All of them except *Krohnitta subtilis* and *Sag&a minima* are found during both the periods (Table 1). However, the numerical representation of the species shows variations corresponding with the seasonal density maxima, Area 1 having maximum values for 6 species during the NE monsoon and Area 4 having highest representation for 9 species during the SW monsoon period (Table 1). This indicates high population density of chaetognaths towards the western side during the NE monsoon and to the eastern side during the SW monsoon period.

This apparent seasonal difference prompted to analyse the problem statistically to see whether the seasonal difference affects the density of chaetognaths significantly. For all the calculations the average number of different species was taken to represent the number of specimens in the respective areas. A contingency table with the species and the monsoons as the two attributes was formed by the number of specimens for each area and then the chi-square test of independence was carried out. Since one of the attributes was only of two classes, to simplify the calculations, the formula developed by Brandt and Snedecor⁶,

$$\chi^2 = \frac{1}{pq} \{ \sum ap - n\bar{p} \}$$

was used where a is the observed number of specimens in any one of the species during the NE monsoon periods; a' is the observed number of specimens of the corresponding species during the SW monsoon period; n is the total number of specimens during the NE monsoon period; and n' is the corresponding number during the SW monsoon period.

$$p = \frac{a}{a+a'}$$

$$\bar{p} = \frac{n}{n+n'}$$

$$\bar{q} = 1 - \bar{p}$$

and
 The calculated values and their degrees of freedom are:

Area	Values of χ^2	Degrees of freedom
Whole Arabian Sea (north of 10° south)	156-00	13
Area 1	195-29	13
Area 2	134-45	13
Area 3	181-16	13
Area 4	404-00	13

Since all the values are found to be highly significant it may be concluded that the seasonal:

difference affects the distribution of the species in all the areas considered.

With the areas and species as the two attributes; one contingency table was formed by the number of specimens for each monsoon period and the χ^2 test of independence was applied. The formula used for the calculation was

$$\chi^2 = \sum \frac{O^2}{E} - N$$

where O is the observed number of specimens in each cell; E is the expected number of specimens in each cell; and N is the total number of specimens.

The calculated values and their degrees of freedom are :

Period	Values of χ^2	Degrees of freedom
NE monsoon	245.92	39
SW monsoon	803.42	39

Since the degrees of freedom exceeds 30, it is sufficient to assume that $\sqrt{2\chi^2}$ is distributed normally with mean $\sqrt{2n-1}$ (where n is the degree of freedom of the χ^2) and standard deviation unity⁵.

Period	$\sqrt{2\chi^2}$	$\sqrt{2n-1}$
NE monsoon	21.18	8.78
SW monsoon	40.08	8.78

The normal deviates work out to 13.40 and 31.30 respectively for the NE and SW monsoon periods. These are greater than the 1% value. Hence it may be concluded that the difference in areas is highly significant in the relative abundance of the chaetognath species.

Latitudinal variation — The relative abundance of the species of chaetognaths in each 5" increment of latitude is represented in Tables 2 and 3. On the basis of the frequency of occurrence along the latitudes, the species can be grouped into two categories, viz. A-forms having higher abundance towards northern latitudes, and B-forms having higher abundance towards the southern latitudes in the Arabian Sea.

A-forms: Data pertaining to this group is represented in Table 2. *K. pacifica*, *S. bedoti*, *S. enflata*,

S. neglecta, *S. pulchra* and *S. robusta* come under this category. The general trend for these forms is to increase towards the northern latitudes and there is a progressive decline towards the southern part of the Arabian Sea. The maximum frequency of occurrence for all the species is between 20-25°N except for *S. bedoti* which has the maximum value between 10-15°N.

B-forms: Eight species come under this category and they are *K. subtilis*, *Pt. draco*, *S. bipunctata*, *S. ferox*, *S. hexaptera*, *S. minima*, *S. pacifica* and *S. regularis* (Table 3). The percentage frequency of these show a general increase towards the southern latitude. The maximum values for *K. subtilis*, *S. bipunctata*, *S. hexaptera*, *S. minima*, *S. pacifica* and *S. regularis* is between 5" and 10°S lat. *S. ferox* has maximum frequency occurrence between the Equator and 5°S lat., while *Pt. draco* is abundant between 10°N and the Equator.

During the 6th cruise of 'Anton Bruun' in May 1964 a series of stations were worked along the 65°E meridian between 18°N to 6°S. The average abundance of the different species found in the collections are depicted in Table 4. The data obtained corroborate with what have already been shown in Tables 2 and 3. Category A shows low or zero values towards the southern latitudes, while the species coming under category B have better representation towards the southern latitudes.

The significance of latitudinal variation in the distribution of the species was tested for the whole area and for that along the 65°E meridian, using the equation

$$\chi^2 = \sum \frac{O^2}{E} - N$$

The values are:

Area	Values of χ^2	Degrees of freedom	$\sqrt{2\chi^2}$	$\sqrt{2n-1}$
Whole Arabian Sea (north of 10°S)	125687	78	15.85	12.45
Along 65°E meridian	853.164	65	41.31	8.00

TABLE 2 — LATITUDINAL VARIATION OF THE PERCENTAGE FREQUENCY DISTRIBUTION OF THE SPECIES BELONGING TO GROUP A

Latitude	<i>K. pacifica</i>	<i>S. bedoti</i>	<i>S. enflata</i>	<i>S. neglecta</i>	<i>S. pulchra</i>	<i>S. robusta</i>
25-20°N	2.1	8.2	71.2	5.0	0.8	2.9
20-15°N	1.5	4.0	65.6	1.9	0.3	2.0
15-10°N	1.1	11.0	58.7	0.8	0.6	1.6
10-5°N	0.9	8.5	54.8	0.9	0.5	1.2
5-0°	0.6	3.8	56.4	0.7	0.3	1.3
0-5°S	0.9	1.3	50.7	0.5	0.1	0.3
5-10°S	1.0		38.0	0.1	—	0.6

TABLE 3 — LATITUDINAL VARIATION OF THE PERCENTAGE FREQUENCY DISTRIBUTION OF THE SPECIES BELONGING TO GROUP B

Latitude	<i>K. subtilis</i>	<i>Pt. draco</i>	<i>S. bipunctata</i>	<i>S. ferox</i>	<i>S. hexaptera</i>	<i>S. minima</i>	* a & a	<i>S. regularis</i>
25-20°N	0.1	0.7	5.7	0.8	0.1	0.0	3.1	1.2
20-15°N	0.2	2.8	6.8	0.8	0.2	0.1	8.6	5.3
15-10°N	0.4	6.5	6.8	0.8	0.7	0.2	8.3	2.6
10-5°N	0.7	9.4	2.3	1.4	0.8	0.2	11.5	2.6
5-0°	0.2	9.4	2.2	3.5	0.7	0.5	14.2	4.4
0-5°S	0.1	6.5	5.4	7.9	1.0	1.8	15.3	5.6
5-10°S	1.2	6.0	8.9	3.1	1.2	4.0	27.2	7.7

TABLE 4 — AVERAGE ABUNDANCE OF THE DIFFERENT SPECIES FOUND ALONG THE 65°E MERIDIAN ('ANTON BRUUN' Cr. 6)

Species	20-15°N	15-10°N	10-5°N	5-0°	0-5°S	5-10°S
GROUP A						
<i>K. hacifera</i>	8	7	3	—	4	2
<i>S. bedoti</i>	9	6	4	—	—	—
<i>S. enflata</i>	325	294	301	274	252	120
<i>S. neglecta</i>	4	6	3	—	—	—
<i>S. pulchra</i>	8	3	2	1	—	2
<i>S. robusta</i>	8	10	6	—	—	5
GROUP B						
<i>K. subtilis</i>	—	4	6	10	12	20
<i>Pt. draco</i>	46	48	15	73	121	80
<i>S. bipunctata</i>	53	25	26	100	97	130
<i>S. ferox</i>	—	3	7	5	1	19
<i>S. hexaptera</i>	5	2	17	19	30	50
<i>S. minima</i>	—	2	—	—	—	50
<i>S. pacifica</i>	44	50	6	81	98	120
<i>S. regularis</i>	17	32	27	25	31	80

The normal deviates work out to 3.4 and 33.31 for the total area and along the 65°E meridian respectively. These are above the 5% value, Hence it can be inferred that there is a latitudinal variation in the relative abundance of different species.

Discussion

The abundance of chaetognaths in the four selected localities shows seasonal variation. Dependent on the prevailing monsoon there is a change in the maximum population density of chaetognaths. The statistical analyses also indicate that the difference in monsoon is significant in the density of chaetognaths.

This shifting of the peak occurrence of chaetognaths towards the western (Area 1) and eastern (Area 4) part of the Arabian Sea can be attributed to the seasonally changing monsoon gyre. In the open ocean during the SW monsoon the surface drifts in the Arabian Sea take a clockwise direction and currents are set easterly. This pattern of circulation is reversed to an anti-clockwise direction during the NE monsoon and currents are set in a westerly direction. Such a reversing system of currents results in the drifting of chaetognaths towards the west dependent on whether the flow is westerly or towards the east resultant on the easterly drift. It can, therefore, be presumed that the abundance of the chaetognaths in the west of the Arabian Sea during the NE monsoon period is consequent on the drifting of these organisms from the eastern part. Similarly, the predominance of chaetognaths towards the east during the SW monsoon is due to the overflow of oceanic waters from west to east. According to the findings of Wyrski⁶ the water in the gyre does not make a complete revolution during both the seasons. This type of incomplete revolution seems to support the above assumption that the drifting of chaetognaths to the west, or east is dependent on the seasonal drift.

The total representation of chaetognath shows a gradual lowering of the population density from north to south³. Although the number of each species varies considerably from sample to sample, if the average percentage frequency of the species is considered over the whole range of latitudes

between 25°N to 10°S, the figures can give a general picture on the latitudinal variation. This latitudinal variation is confirmed by statistical analysis.

It can be seen that except for *S. enflata* none of the species in group A are recorded from the Atlantic, while a majority of the species in group B are cosmopolitan. Data on temperature and dissolved oxygen at the lowest level of the water column sampled at each of the stations along the 65°E meridian during the 6th cruise of 'Anton Bruun' show a gradual decrease in temperature (17.27-12.06°C) and an increase in oxygen (0.01-2.58 ml/l) from north to south. Further comments on this can be made only after the analyses of the samples south of 10°S lat.

It is true that there are certain inevitable reservations imposed by the uneven sampling during the expedition. However, the study reveals certain variations in the geographical distribution of the group. Observations of this type do not give a precise measure of variability, but they do indicate variations in the total abundance and relative abundance of the different species consequent on the monsoonal changes and also due to the latitudinal disposition.

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