

ABUNDANCE AND DIVERSITY OF CHAETOGNATHS FROM THE RODRIGUEZ TRIPLE JUNCTION AREA OF THE INDIAN OCEAN

Vijayalakshmi R. Nair*, K. V. Jayalakshmi* and Makoto Terazaki**

Abstract

Chaetognaths from the Rodriguez Triple Junction and adjacent parts of the Indian Ocean were studied based on zooplankton samples collected during July to September 1993. Chaetognaths population drastically reduced to the RTJ area (a 158/1000 m³) as compared to the Central Indian Ocean (a 639/1000 m³). A total of 15 species of chaetognaths belonging to the genera Eukrohnia, Krohnitta, Sagitta and Pterosagitta were found in the collections. Contribution of epi, meso and bathypelagic species were respectively 60, 33 and 7 percent to the total population. Species diversity was more in the upper 500 m water column than the 150 m stratum due to the mixing of mesopelagic species in the former. Statistical grouping of stations indicated the presence of ecologically significant factor groups. Community structure of chaetognaths indicated predominance of S.pacifica in the upper 150 m water column while in the 500 m S.hexaptera was the dominant species. At the RTJ area the predominance of S.hexaptera along with unusual congregations of P.draco area could be associated with the difference in temperature due to hydrothermal activity.

Keywords : Chaetognaths, Species diversity, Community structure, Rodriguez Triple Junction

Introduction

The Rodriguez Triple Junction is the world's most remarkable R.R.R. triple junction which has been controlling the evolution of the major portion of the Indian Ocean. Three ridges with different spreading rates, namely, the Central Indian Ridge, the Southwest Indian Ridge and the Southeast Indian Ridge meet at the junction (ORI, 1995). During July to September 1993 Ocean Research Institute, University of Tokyo conducted an expedition to Rodriguez Triple Junction

* National Institute of Oceanography, Regional Centre, Kochi (Kerala)

** Ocean Research Institute, University of Tokyo, Tokyo, Japan

and the zooplankton samples collected during this cruise of *R V Hakuho - maru* form the basis of the present communication. Informations on the chaetognaths of the subtropical Indian Ocean are limited as compared to the northern Indian Ocean (Pierrot - Bults and Nair, 1991; Terazaki, 1999). Most of the reports on chaetognaths of the southern Indian Ocean were based on that of the Monsoon Expedition (Alvavino, 1964) and the extensive information emerged from the International Indian Ocean Expedition (Nair, 1977 and 1978). Later, chaetognaths and astracods from the western Indian Ocean along a transect between 7° north and 20° south was studied by Nair and Madhupratap (1984) while the epipelagic chaetognaths from the EEZ of India was reported by Srinivasan (1990 and 1996).

Data sources and methodology

During the RTJ expedition of *R V Hakuho - maru* from July 8 to September 17, 1993 zooplankton samples were collected from 15 locations, of which 8 are exclusively within the RTJ area (Fig.No. 1a & b). Two sets of samples were collected. (a) from stations 1 to 15 oblique tows were made from 500 m to the surface using an ORI net having a mouth area of 2 m² and a mesh operature of 0.69 mm (Omori, 1965). (b) upper 150 m water column at station 1, 2 and 3 within RTJ were sampled using a twin NORPAC net with 45 cm mouth diameter and mesh size of 0.33 m (GG 54) and 0.1 mm (XX 113).

Zooplankton samples were preserved in 70 percent ethanol for the first set of samples and the second set was preserved in 4 percent formaldehyde/seawater solution buffered with sodium tetraborate. The volume of water filtered was estimated with a Tsurumi flow meter attached to the mouth of the nets. Chaetognaths from the collections were sorted out and identified into species. Population density is presented as number per 1000 m³. The data were subjected to three way ANOVA for comparison between stations, depths, nets, species and interaction between any of these (Snedecor and Cochran, 1967). Factor analyses were done for grouping of species (Harman, 1967; Morrison, 1978; Dagnelie, 1960). Community structure was described by richness factor (Margalef, 1968), concentration factor (Simpson, 1949), Shannon Weaver index (Shannon and Weaver, 1963), evenness index (Heip, 1974) and dominance factor (Pielou, 1971). Species niche breadth was calculated adopting the method of Ignatides (1994). Prior to numerical analyses the population density data were transformed to log (x+1) for obtaining homogeneity.

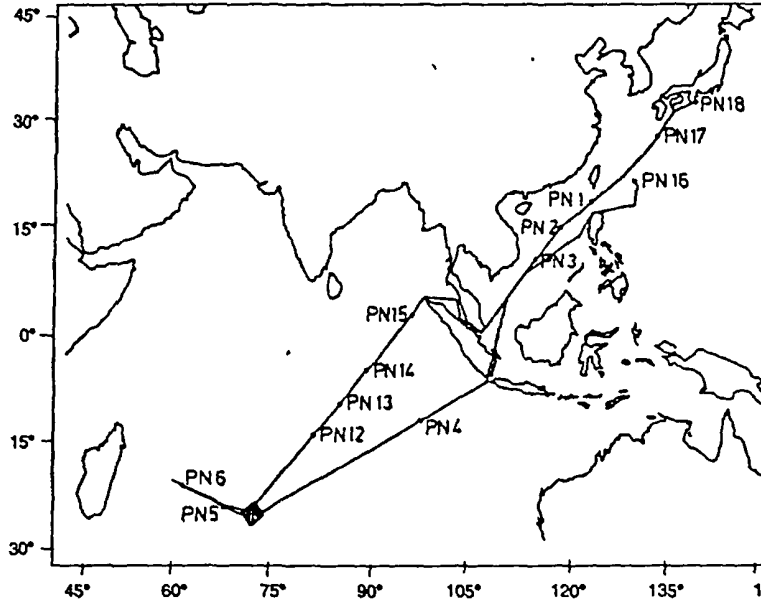


Fig. 1/A : Track chart of the cruise indicating station locations in the Indian Ocean.

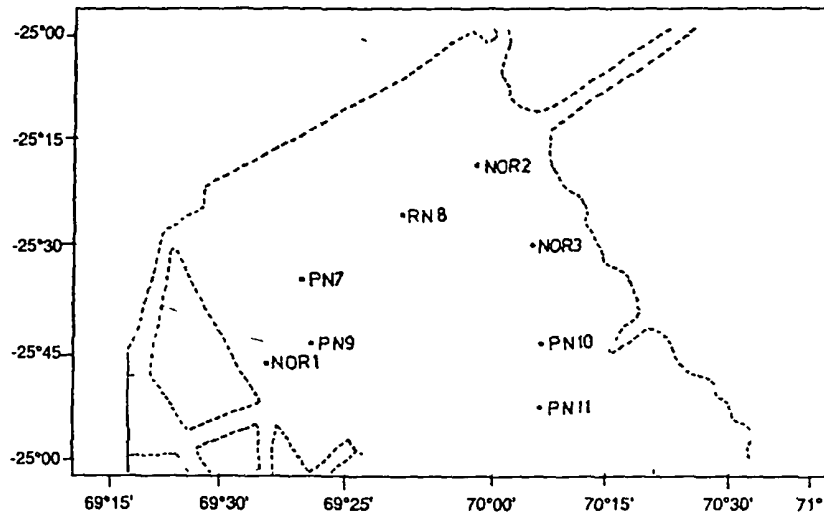


Fig. 1/B : Sampling location in the Indian Ocean.

Exposition

Ranges in various water quality parameters were comparable between stations (ORI, 1995). Within RTJ temperature, salinity and DO in the upper 500 m were respectively 13.2 to 20.1°C, 35.3 to 35.6 ‰ and 4.0 to 4.3 ml/l. Outside the RTJ the range in above parameters in the same order were 11.4 - 19.9°C, 35.0 - 35.7 ‰ and 3.8 - 4.1 ml/l. Existence of hydrothermal activity along the ridge axis and a distinct hydrothermal plume was detected for the first time in the Central Indian Ocean Ridge segment close to RTJ during the present expedition. The topographic features of the three rift valleys are quite different suggesting either the difference in the thermal structure of the underlying mantle or the difference in the crustal structure (ORI, 1995).

Chaetognath community in the upper 500 m

Data are available for 12 stations of which 7 (stations 4 - 6 and 12 - 15) are outside RTJ while 5 (stations 7-11) are within the RTJ. Population density of chaetognaths are comparable within RTJ (av 158/1000 m³) and in the vicinity (av 157/1000 m³) while the population in the Central Indian Ocean is 4 times higher (av 639/1000 m³). However, number of species indicated marginal variation of 13 to 14. In the Central Indian Ocean *Sagitta enflata* was the dominant species and the most common epipelagic species were *S.pacifica* and *Pterosagitta draco*. The predominant mesopelagic of the Central Ocean were *S.decipiens* and *S.lyra*. At RTJ area *S.hexaptera* was the predominant epipelagic species with fairly good contribution of *P.draco* and *S.pacifica*. *S.decipiens* and *S.lyra* formed the significant part of the mesopelagic species of the RTJ area also. *Eukrohnia hamata* was the only bathypelagic species found in the collections.

Factor analysis by Q mode for grouping of stations when applied divided the 12 stations into two factor groups (Table-1). Both sets are ecologically significant

Table-1 : Q Mode Factor Analysis

Factor	Stations	Variance explained (%)	Closeness Ratio (%)
(A) For grouping of stations for collections from 500 m depth			
1	4-6, 12-15	41.63	71.06
2	7-11	34.31	89.47
(B) For grouping of stations for collections from 150 m depth using GG54 and XX13 nets.			
1	GG1, GG2, XXI, XX2	52.59	90.99
2	GG3, XX3	39.12	97.98

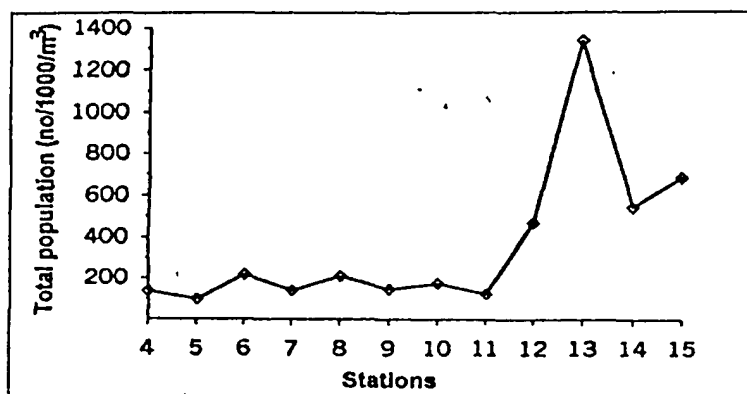


Fig. 2 : Distribution of chaetognaths in the upper 500 m water column at stations 4 to 15.

for the study of chaetognath species distribution explaining almost same amount of variation. However, factor 1 stations are more important since it could explain about 41.63 percent of the variations in the species distribution in the study area. R mode analysis applied for grouping of species has divided the species into three statistically significant factor groups with group 1 and group 2 species forming the differential factor groups (Table-2). Of the species included

Table-2 : R Mode Factor Analysis for Species Grouping

Factor	Stations	Variance explained (%)	Closeness ratio (%)
(A) Based on data collected from the upper 500 m water column			
1	K.subtilis, P.draco, S.bipunctata, S.enflata, S.hexaptera, S.minima	39.49	63.58
2	S.fyra, S.maxima, S.pacifica, S.zetesios	25.41	78.10
3	S.ferox	17.43	89.39
(B) Based on data collected by GG54 and XXI3 nets from the upper 150 m water column.			
1	K.subtilis, P.draco, S.enflata, S.hexaptera, S.minima	44.0	82.06
2	Ehamata, S.decipiens, S.ferox, S.regularis	36.6	95.20
3	S bipunctata, S.pacifica	18.0	98.90

in group 1, the relatively more abundant species are *K.subtilis* (3.18 percent), *P.draco* (11.30 percent), *S.decipiens* (18.8 percent), *S.hexaptera* (16.52 percent) occurring at stations 7-11 while *S.bipunctata* (16.92 percent), *S.enflata* (38.29 percent) and *S.minima* (4.73 percent) occurring at stations 4 to 6 and 12 to 15. In factor group 2, the species *S.lyra* (16.14 percent), *S.pacifica* (9.03 percent) and *S.zetesios* (4.06 percent) are dominating at stations 7 to 11. The factor group 3 contains the least abundant species, *S.ferox* in both sets of stations. This analysis, to a certain extent, separates the species (1) according to relative abundance in the two sets of stations (2) according to the overall abundance.

Chaetognath community in the upper 150 m

Stations 1, 2 and 3 in the RTJ zone were sampled using nets having different mesh sizes. Invariably population density of chaetognaths was 3 times more in samples collected by XX13 net (av 3064/1000 m³) as compared to the GG54 net (av 991/1000 m³). Number of species represented were also more in collections using XX13 net (8-11) as compared to the GG54 net (5-8). *S.pacifica* was the most dominant species and the other common species were *S.bipunctata*, *S.enflata* and *P.draco*. *S.decipiens* and *E.hamata* were rarely found in the collections. Representation of *S.minima* and *S.hexaptera* were more in collections made by XX13 net. Q mode factor analysis applied for the samples taken from 150 m depth using the nets GG54 and XX13, has also separated the stations into two factor groups with factor 1 including stations 1 and 2 sampled using

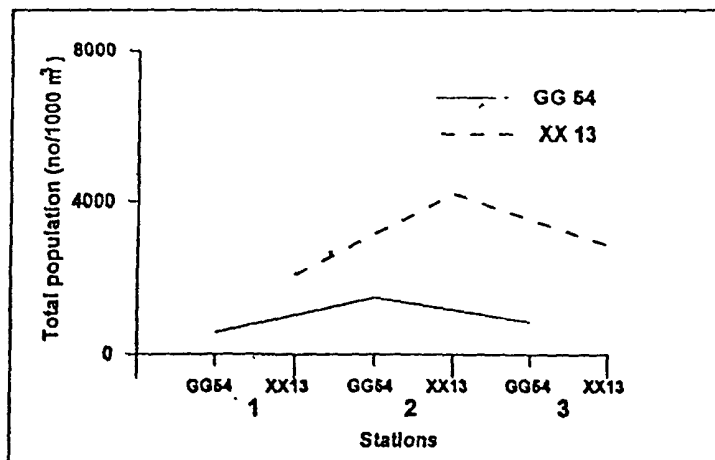


Fig. 3 : Distribution of chaetognaths in the upper 150 m caught by GG54 (0.3 mm mesh) and XX13 (0.1 mm mesh) at stations 1 to 3.

the two nets and factor 2 for station 3 sampled with the two nets implying that there is no significant difference between gears (Table-1). However, the group 1 stations are statistically and ecologically more significant, explaining about 52.5 percent of the spatial variations in the species distribution. This grouping further justifies the 3 way. ANOVA where we get difference between stations, but no difference between gears.

R mode analysis applied for grouping the species has divided the species into 2 significant factor groups, both together forming the differential species factor groups providing the maximum information about the species distribution in this study. Group 1 includes the species with relative abundance ranging between 3.33 percent and 15.17 percent whereas group 2 with very rare species with relative abundance < 0.52 percent Group 3 contains species which are largely abundant with % occurrence in the range, 18.64 to 38.28 with GG net. The corresponding relative abundance for XXI3 net varies between 4.92 to 11.72%, 0.31 to 5.9 percent and 9.20 percent to 43.47 percent for the same species groups. This further justifies the negligible difference between the nets.

Community structure of chaetognaths

Species community structure described by species richness (Margalef's index), species concentration (Simpson's index), species diversity (Shannon Weaver index), species evenness (Heip's index) and species dominance (Pielou's index) show that for the 500 m depth study, species richness ranges between 8.093 (station 13) to 11.589 (station 5) in set 2 stations whereas in set 1 it ranges between 9.933 (station 8) to 12.802 (station 9) showing higher species richness in set 1. Regarding species concentrations, it varies between 0.588 (station 15) to 0.881 (station 5) in set 2 while it varies between 0.851 (station 11) to 0.876 (station 7) in set 1, indicating high uniformity in the distribution of species in set 1. Regarding species diversity it is observed that set 1 stations are more diverse than set 2 with range 2.076 (station 15) to 3.222 (station 5) for set 2 and 3.057 (station 11) to 3.253 (station 9) for set 1, again implying higher stability for set 1. In the case of evenness in the species distribution, it is observed that species abundance are more uniformly distributed among the species in set 1 than in set 2, with range 0.6977 to 2.4089 for set 2 and 1.8108 to 2.3786 for set 1 stations. Spatial variations for all the indices is negligible (9.99 to 28.08 percent is the C.V. percent).

Species niche breadth, an index used to assess roughly how much area a species moves for its survival, it is found that it varies between 3.8127 (*S.bipunctata*) and 9.7806 (*S.hexaptera*) which occur with 16.67 percent relative abundance in set 2 stations and set 1 stations respectively. The species,

Table-3 : Community Structure Indices and Niche Breadth for the Upper 500m Water Column

(A) Community Structure						
Stations	Margalef	Simpson	Shamon	Heips	Pielou	S
4	10.776	0.773	2.660	1.330	0.921	11
5	11.589	0.881	3.222	2.409	0.934	11
6	8.869	0.860	3.010	2.144	0.874	10
13	8.093	0.802	2.817	1.429	0.826	12
14	8.410	0.739	2.544	1.173	0.789	11
15	8.107	0.588	2.076	0.697	0.985	11
12	10.333	0.864	3.174	1.910	0.996	13
7	10.729	0.876	3.210	2.379	0.965	11
8	9.933	0.867	3.111	2.144	1.009	11
9	12.802	0.865	3.253	2.072	0.969	13
10	12.346	0.859	3.124	1.811	0.949	13
11	12.140	0.851	3.057	1.842	0.644	12

(B) Species Niche Breadth			
Species	Niche Breadth	% Occurrence of Species	
		Set 1 (7-11)	Set 2 (4-6, 12-15)
E.hamata	8.843	1.144	0.427
K.subtilis	5.719	3.177	1.880
P.draco ...	8.016	11.309	9.316
S.bipunctata	3.813	2.160	6.923
S.decipiens	9.365	18.806	10.342
S.enflata	4.886	6.734	38.291
S.ferox	4.721	0	1.709
S.hexaptera	9.781	16.518	7.436
S.lyra	9.535	16.137	5.071
S.macrocephala	6.679	6.607	1.368
S.maxima	8.216	1.906	0.370
S.minima	5.039	2.414	4.729
S.pacifica	7.779	9.022	9.487
S.zetesios	8.915	4.066	2.650

S.decipiens, with relative abundance 16.13 percent have high values for niche breadth in the range 9.3646-9.7806 and these are more abundant in set 1. There is an increasing gradient for niche breadth with respect to species abundance.

For the data collected from 150 m depth using GG 54 and XX13 nets, it is observed that species richness is higher for XX 13 net than for GG 54 net ranging between 3.332 and 6.3524. Species concentration is almost uniform with 15.03 percent spatial variation. Species evenness is maximum for station

3 with GG 54 net (2.0905) and least for station 1 with XX13 net. Species diversity is almost same at all the stations regardless of the net with 2.4555 as average diversity. Similarly species dominance is least at station 3 by GG net (0.8892) and maximum at station 3 (1.3435) by XX13 net. In this study also, spatial variation for these indices is negligible, C.V. percent ranging between 11.49 to 24.85 percent. Species niche breadth varies between 1.9526 (*S.regularis* with < 0.305 relative abundance) and 5.608 (*S.bapunctata* with 18.64 percent and 9.20 percent as relative abundance for GG and XXnet). The species *S.enflata*, *S.ferox*, *S.hexaptera*, *S.pacifica*, *K.subtilis* and *P.draco* have niche breadth in the range, 4.0305 to 5.6508 thus implying a direct relation with the species abundance in the collection by the two nets. Chaetognath population decreased drastically towards the RTJ as compared to the Central Indian Ocean. This is on account of the diminishing trend in population density of chaetognaths towards the southern latitude (Nair, 1978; Pierrot-Bults & Nair, 1991). However, there was glaring difference in

Table-4 : Community Structure Indices and Niche Breadth for the Two Types of Net in the Upper 150 m Water Column

(A) Community Structure						
Station/Net	Margalef	Simpson	Heips	Shannon	Pielou	S
GG54 st.1	3.332	0.726	1.773	2.091	1.010	5
	25.066	0.743 -	1.415	2.389	1.151	8
	35.480	0.833	2.091	2.749	0.889	8
XX13 st 1	4.847	0.645	1.051	2.125	1.070	8
	26.352	0.736	1.189	2.556	1.181	11
	35.329	0.837	1.978	2.823	1.344	9

(B) Species Niche Breadth			
Species	Niche breadth	% occurrence of species	
		GG	XX
<i>E.hamata</i>	1.953	0	0.305
<i>K.subtilis</i>	4.237	7.436	7.213
<i>P.draco</i>	5.109	8.917	7.148
<i>S.bipunctata</i>	5.651	18.641	9.204
<i>S.decipiens</i>	2.299	0	0.849
<i>S.enflata</i>	4.872	15.175	11.717
<i>S.ferox</i>	4.031	5.182	5.951
<i>S.hexaptera</i>	4.289	3.331	4.917
<i>S.minima</i>	3.959	4.038	8.921
<i>S.pacifica</i>	4.646	37.281	43.473
<i>S.regularis</i>	1.953	0	0.305

the population density of chaetognaths in relation to the nets used for the collection. The GG54 and XX13 nets having smaller mesh size compared to ORI net and average populations for both the sets for RTJ area were respectively 2027 and 158/1000 m³ indicating an enhancement to the level of about 13 times with the former type of gears. A total of 15 species were found in the collections of which contribution of epi, meso and bathypelagic species were respectively 60, 33 and 7 percent. The number of species represented in the upper 500 m of RTJ and outside this area did not show much variation. Number of species represented in the 150 m water column was much less because of the absence of mesopelagic species. Community structure of chaetognaths indicated the predominance of *S.pacifica* in the upper 150 m water column while in the 500 m *S.hexaptera* was the dominant species. The other common species were *P.draco*, *S.bipunctata* and *S.enflata*. However, the representation or dominance of any mesopelagic species in the Central Indian Ocean and RTJ area did not show any difference.

The qualitative and quantitative distribution of epipelagic species found in the RTJ area are comparable to the IIOE report for most of the species (Nair, 1977). Surprisingly, *S.regularis*, a common species of the area was absent in the present collection except for a single record. Predominance of *S.hexaptera* is a unique feature of the present study while representation of *S.maxima* was also fairly high. Difference in thermal structure leads to drastic decrease in temperature and this can affect the species distribution leading to change in the normal community structure of the chaetognaths. In general, compared to the northern Indian Ocean, chaetognaths population density was low in the RTJ area. The populations of chaetognaths drastically reduced from the upper 150 m to 500 m. Progressive reduction in numerical abundance of chaetognaths from upper 125 m water column to 2000 m has already been reported (Nair, 1978). Also sudden drop in temperature in the thermal structure can also be a reason to bring down the population density. However, species representation was relatively more in the 500 m water column contrary to the earlier study (Nair, 1978). *S.hexaptera*, *S.pacifica* and *P.draco* were the most successful group in the RTJ area. *S.hexaptera* though an epipelagic species in the tropical zone of the Indian Ocean, they are more abundant below 200 m (Nair, 1978) and the species never dominated any area of the Indian Ocean. The predominance of this species in the RTJ area along with unusual congregations of *P.draco* could be associated with the difference in temperature. Further detailed study is required to confirm the changes in the community structure of chaetognaths associated with hydrothermal activity at RTJ area.

References

- Allvarino, A. (1965) : The Chaetognatha of the Monsoon Expedition in the Indian Ocean. *Pac. Sci.* 28. Pp. 336-348.
- Dagnelie, P. (1960) : Contribution a l'etude des communautés végétales par l'analyse factorielle. *Bull. Serv. Carte Phytogeogr.* B5: 7-71. Pp. 93-195.
- Harman, H.H. (1967) : *Modern Factor Analysis*. Univ. of Chicago Press, Chicago,
- Heip, C. (1974) : A New Index Measuring Evenness. *Mar. Biol. Ass., (U.K.)* 54. Pp. 555-557.
- Ignatiades, L. (1994) : Species Dominance and Niche Breadth in Bloom and Nonbloom Phytoplankton Populations. *Oceanologica Acta.* 17(1). Pp. 89-96.
- Morisson, D.F., (1978) : *Multi variate Statistical Methods*. Mc Graw - Hill International Book Company. Pp. 415
- Margalef, R. (1968) : Perspectives *In Ecological Theory*. Univ. Chicago Press. Pp. 111
- Nair, V.R. (1977) : Chaetognaths of Indian Ocean. *Proc. Symp. Warm Water Zoopl.* Spl. Publ. UNESCO/NIO. Pp. 168-195.
- Nair, V.R. (1978) : Bathymetric Distribution of Chaetognaths in the Indian Ocean, *Indian J. Mar. Sci.* 7. Pp. 276-282.
- Nair, V.R. and Madhupratap, M. (1984) : Latitudinal Range of Chaetognatha and Ostracoda in the Western Tropical Indian Ocean. *Hydrobiologia.* 112. Pp. 209-216.
- Omori, M. (1965) : A 160-cm Opening-closing Plankton Net. 1. Description of the gear, *J. Oceanogr. Soc. Japan: 21.* Pp. 20-26.
- ORI. (1995) : Preliminary Report on the Rodriguez Triple Junction Expedition in the Indian Ocean. Ocean Research Institute, University of Tokyo. Pp.183.
- Pielou, E.C. (1971) : Measurement of Structure in Animal Communities. In : *Ecosystem Structure and Function*, (J.A. Wiens Ed.). Proc. 31st Annual Biology Colloquium. Oregon state U.P. Portland
- Pierrot-Bults, A.C. and Nair, V.R. (1991) : Distribution Patterns in Chaetognaths. In *The Biology of Chaetognaths* (eds. Q.Bone, H.Kapp and A.C. Pierrot - Bults), Oxford Science Publications, Oxford University Press, Oxford, New York, Tokyo. Pp. 86-116.
- Shannon, C.E. and Weaver, W. (1963) : The Mathematical Theory of Communication. *University of Illinois Press, Urbana, Illinois.*
- Simpson, E.H. (1949) : Measurement of Diversity. *Nature.* Pp. 163: 688.
- Snedecor, G.W. and Cochran, W.G. (1967) : *Statistical Methods*. Oxford and IBH Publishing Company, New Delhi. Pp. 535 .
- Srinivasan, M. (1990) : Studies on the Quantitative Distribution of Chaetognatha from the Indian Seas, collected during the Cruise 1-44 of FORV Sagar Sampada. In. *Proc. First Workshop Scient. Result. FORV Sagar Sampada*, (ed. Mathew, K.J.). Pp. 81-84.
- Srinivasan, M. (1996) : Spatial and Temporal Distribution of Chaetognaths from the Eastern Arabian Sea *Proc. Second Workshop Scient. Result. Forv Sagar Sampada.* Pp 139-148.
- Terazaki, M. (1999) : Mass Occurrence of Bathypelagic Chaetognath *Eukrohnia fowleri* from the Arabian Sea and Bay of Bengal. *Indian J. Mar. Sci.* 28. Pp. 163-168.