Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

European Journal of Experimental Biology, 2011, 1 (3):49-57

ISSN: 2248 –9215

Vertical Distribution of Chaetognaths along the Arabian Sea and Bay of Bengal, India

K. Balamurugan; P. Sampathkumar*; P. Ezhilarasan; A. Kannathasan

Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai, Tamil Nadu, India

---

ABSTRACT

Vertical distributions of chaetognaths (or Chaetognatha) were investigated during cruise along the Bay of Bengal and Arabian Sea in relation to hydrographical parameters. The sampling was carried out onboard by FORV "Sagar Sampada" during November, 2008 (Cruise No.259). In the present investigation, 19 species of chaetognaths were sampled and of which, 15 species belongs to family Sagittidae, 2 species of family Krohnittidae, 1 species of family Pterosagittidae, and 1 species of family Eukrohniidae. The mean standing stock of the chaetognaths was contributed about 30-50% in the total zooplankton biomass. The chaetognaths were densely distributed in the isothermal and thermocline layer at all the stations of Bay of Bengal and Arabian Sea. In all the stations, Sagitta enflata was the dominant species.

Key Words: Chaetognaths, Distribution, Hydrographical parameters.

INTRODUCTION

The Phylum Chaetognatha commonly called “arrow worm” (Johnson 2005). They are exclusively marine organisms and majority of them are planktonic. They can be found in all oceans from the surface to great depths, and are often second or third in abundance after copepods (Kehayias, 2003). Chaetognaths are also known as excellent indicator of water masses because of their close relationships with certain environmental variables (e.g. salinity, temperature and dissolved oxygen) as well as their species-specific horizontal and vertical distribution (Terazaki, 1986). The impact of Chaetognaths predation on fish larvae may be exaggerated due to the relative scarcity of fish larvae in the plankton. They, nevertheless, contribute to the reduction of larval abundance during periods of fish production (Casanova,

1999).They also prey on other small crustaceans, larval fish and other chaetognaths. They play an important role in the transfer of energy from copepods to higher tropic levels (Bone *et al.*, 1991). Only early studies have been carried out from the Indian Ocean regions with respect to the distribution and abundance of Chaetognaths by John (1933), Subramanian (1937), Varadarajan and Chacho (1943), Rao and Ganapathi (1958), Nair and Rao (1973) and Vijayalakshmi (1976). Although the distribution of chaetognaths have been studied comprehensively in various parts of India. Hence the present study was intended to understand the vertical distribution of chaetognaths along the Bay of Bengal and Arabian Sea and its relationship with physical features.

MATERIALS AND METHODS

Study area: The present study was conducted in marine habitat. The study was conducted in 9 stations of Bay of Bengal (6 stations) and Arabian Sea (3 stations) during November, 2008 (Cruise No.259). The study area was situated between (14°Nto06°N) the Arabian Sea and (05°Nto20°N) Bay of Bengal (Fig.1).

Collection of samples: The zooplankton sampling was carried out onboard by FORV "Sagar Sampada" during November, 2008 (Cruise No.259). Vertical hauls (Multi Plankton Net, 0.25m² diameter and mesh size 300µm) were performed at 5 different depths from surface to 1000m depth. Isothermal layer depth was calculated according to a depth at which temperature of 1°C drop from SST in the Arabian Sea and density of 0.2 drop from the surface in the Bay of Bengal. Thermocline layer depth was calculated below from the isothermal layer to 15^0C of water temperature in all stations and also followed by middle layer, 300-500m depth and 500-1000m depth samples were collected in Arabian Sea and Bay of Bengal. After collection, samples were preserved in 5% formaldehyde solution and after transferred to laboratory.

Biological identification: All chaetognaths were isolated from the total zooplankton samples. The taxonomic observations were made on the preserved samples under a microscope (MSR-TR Magnus Zoom Stereo Binocular Microscope), using the keys of previous investigations (Alvarino 1967; Bieri 1991; Casanova 1999). The abundance was expressed as number of inds.100 m^{-3} in 5 different depths.

Hydrographical parameters analysis: The hydrographic surveys conducted along the Bay of Bengal (05°Nto20°N) and Arabian Sea (14^oN to 06^oN). The temperature, salinity and dissolved oxygen profiles were measured using the CTD probe (Sea Bird Electronics, Inc., USA, model: SBE - 911 plus). Diversity indices were calculated by Shannon and Weaver's (1949) and Pielou (1966).

RESULTS AND DISCUSSION

The hydrographic data profile viz temperature, salinity and dissolved oxygen of the Bay of Bengal and Arabian Sea were observed during the study period. The average temperature of 27° C was recorded at 50m depth. The temperature was decreased from surface to 200m depth gradually and constant from 200m to 1000m. The vertical profile of salinity suggested that the Bay of Bengal has comparatively less saltier than that of Arabian Sea because of the strong

influence of the seasonal rainfall (Northeast monsoon) and river runoff. But, the influence of freshwater could not be clearly seen because the sampling sites were too far away from the shore. The dissolved oxygen (DO) concentration was almost similar (4.3 ml. l^{-1}) from the surface to 80m. The DO concentration was decreased from 80 to around 100 m depth in the Bay of Bengal and around 130 m depth in the Arabian Sea (Fig.2).

The distribution and abundance patterns of chaetognaths are considerably varied between two areas. In general, both areas showed higher abundance and diversity of chaetognaths in the isothermal layer (upper 100m). During investigation, 19 species of Chaetognaths were recorded and of which, 15 species of family Sagittoidae, 2 species of family Krohnittidae, 1 species of family Eukrohnidae and 1 species of family Pterosagittoidae were identified. The Sagittoidae family consists of *Sagitta enflata, S.decipiens, S.pulchra, S.minima, S.ferox, S.robusta, S. bedoti, S.bipunctata, S.hexaptera , S. maxima, S. neglecta, S. pacifica, S. regularis, S. lyra* and *S .zetesios*, The Eukrohnidae family consists of *Eukrohnia fowleri* , the Krohnittidae family consists of *Krohnitta pacifica,* and *K. subtilis* and the Pterosagttoidae family consists only *Pterosagitta draco*. In the isothermal layer, the chaetognaths dominance varied from 1 to 27.46% in the Arabian Sea and 1.22 to 29.35% in the Bay of Bengal. The *Sagitta enflata* (27.46, 29.35%) was the dominant species in both areas at all the stations during the study period (Fig .3). In the thermocline layer, the dominance varied from 1.07 to 28.85% in the Arabian Sea and 2.38 to 23.4% in the Bay of Bengal. The *Sagitta enflata* (28.85 and 23.4%) was the dominant species in the Arabian Sea (28.85%) and Bay of Bengal (23.4%, Fig.4). In the middle layer, the dominance varied from 1.8 to 28.3% in the Arabian Sea and 2.7 to 25.2% in the Bay of Bengal. *Pterosagitta draco* (28.3%) was found as the dominant in the Arabian Sea whereas S. *enflata* (25.2%) was the dominant species in the Bay of Bengal (Fig.5). In the depth of 300-500m, the species contribution varied from 6.1 to 21.2% in Arabian Sea and 10.5 to 26.3% in the Bay of Bengal. The *Sagitta lyra* (21.2%) was the dominant species in Arabian Sea and *S. zetesios* (26.3%) in the Bay of Bengal (Fig. 6). In the depth of 500-1000m, the species contribution was from 6.3 to 37.5% in Arabian Sea and 5.2 to 31.0% in the Bay of Bengal and the dominant species was *S .zetesios* (37.5% and 31.0%, Fig. 7).

In isothermal layer, the chaetognaths density varied from 88 to 1010 (ind 100 $m^{-3)}$ in Arabian Sea and 86 to 635 (ind 100 m^{-3}) in the Bay of Bengal. In thermocline layer, the density varied from 114 to 306 (ind 100 m^{-3}) in Arabian Sea and 36 to 231 (ind 100 m^{-3}) in the Bay of Bengal. In the middle layer, the density varied from 51 to 97 (ind 100 m^{-3}) in Arabian Sea and 4 to 93 (ind 100 m^{-3}) in the Bay of Bengal. In 300 to 500 m depth, density varied from 14 to 30 (ind 100 m^{-3}) in Arabian Sea, and 2 to 12 (ind 100 m^{-3}) in the Bay of Bengal. In the depth between 500 and 1000 m, the density varied between 0 and 7 (ind 100 m^{-3}) in Arabian Sea and 3 to 9 (ind 100 m^{-3}) in the Bay of Bengal. From the overall observation, it is concluded that the maximum population density of chaetognaths were observed in isothermal layer when compared to other layers (Fig. 8-9).

The species diversity ranged from 1.413 to 2.286 in Arabian Sea and 1.497 to 2.425 in the Bay of Bengal. The highest species diversity was recorded in the isothermal layer of the Arabian Sea and in the thermocline layer of the Bay of Bengal. The lowest species diversity was recorded in 500-1000m depth layer of the Arabian Sea and the Bay of Bengal (Fig.10). The species richness ranged from 0.7219 to 0.8646 in Arabian Sea and 0.7598 to 0.8895 in the Bay of Bengal. The

highest species richness were derived from the isothermal layer of the Arabian Sea and from the thermocline layer of the Bay of Bengal. The lowest richness were from the 500-1000m depth of the Arabian Sea and the Bay of Bengal (Fig. 11). The species evenness ranged from 0.8289 to 0.9553 in Arabian Sea and 0.8464 to 0.969 in the Bay of Bengal. The highest species evenness was recorded in 300-500m depth of the Arabian Sea and the Bay of Bengal. The lowest were from the thermocline layer of the Arabian Sea and from the isothermal layer of the Bay of Bengal (Fig.12).

Chaetognaths are an enigmatic group of transparent planktonic components. They comprise a significant proportion of the total zooplankton stock. The vertical distribution and abundance of the chaetognaths is not fully understood with respect to hydrographical patterns. The present investigation attempted to elucidate the distribution pattern of chaetognaths in 5 different depths viz. isothermal layer, thermocline, middle layer, 300-500 and 500-1000m of the Arabian Sea and the Bay of Bengal India. The influence of temperature, salinity and dissolved oxygen on distribution and abundance of chaetognaths were observed in this study in which a decrease in distribution and abundance of chaetognaths with increasing depth as level of hydrographical parameters decreased. Totally 19 species of chaetognaths were observed in the present investigation. The earlier reporters of Rao and Ganapati (1958) were recorded 13 species of coastal waters of Waltair in Andhra Pradesh, Krishnamurthy (1967) was recorded 6 species from Portonovo waters and Vijayalakshmi *et al.,* (2002) were recorded 23 species in Indian Ocean. The Indo-Pacific species, *Sagitta robusta* belonging to the family Sagittoidae is mainly confined to isothermal layer previews reports in different study area by Alvarino (1974) and Nair (1978).
In waters of the Indian Ocean, Nair (1978) found maximum densities of chaetognaths between 0 and 125m depth. The maximum population density and abundance of chaetognaths was observed in the isothermal and thermocline layer during the study period. Similar observations were made by Padmavati *et al.,* (1998) in the central and eastern Arabian Sea. Pierrot-Bults (1997) and Ulloa *et al.,* (2000) have studied the greater abundance was observed in the epipelagic layer (0-200m), particularly from 0-100m, but conspicuously decreasing in depth of the water column are registered for all the oceans. This study was also conducted during monsoon season; consequently this may be due to the patterns of circulation in the Indian Ocean and receiving a mix of subtropical and equatorial subsurface origin, characterized by temperature and salinities as evidenced by earlier workers (Tokioka 1962; Stone 1969; Nair and Rao 1973; Alvarino 1974 and Ulloa *et al*., (2000)). The Indian Monsoon Current refers to the seasonally varying ocean current regime found in the tropical regions of the northern Indian Ocean. During winter, the flow of upper ocean is directed westward from near the Indonesian Archipelago to the Arabian Sea. During summer, the direction reverses with eastward flow extending from Somalia into the Bay of Bengal. These variations are due to changes in the wind stress associated with the Indian monsoon. The seasonally reversing open ocean currents that pass south of India are referred to as the Winter Monsoon Current and the Summer Monsoon Current (alternately, the Northeast Monsoon Current and the Southwest Monsoon Current) (Shankar et al., 2002).

In the present study, the Indo-Pacific species like *K.pacifica, S.ferox, S.pacifica ,S.pulchra* and *S.robusta* were observed and confined mainly to the upper 100m of the water column with limited incursion into the 400m stratum earlier reported by Nair (1978). The vertical distribution patterns indicated that about 73% of the population was confined from the surface to 400m depth and the remaining population occurs in below 400m- 800m depth and the

bathypelagic species like *S.maxima, S.decipiens, S.lyra, S.zetasios and E.fowleri* present only at 500-1000m depth strata as evidenced by Vijayalakshmi *et al.*, (2002).There are several species of chaetognaths were exist which depend on their ability to enter low oxygen waters (Escribano *et al.*, 2000). *Sagitta enflata was* the dominant species of the total chaetognaths population during the study period as evidenced earlier by Vijayalakshmi *et al.*, 2002 and Giesecke and Gonzalez (2004). *Sagitta enflata* is an epiplanktonic, temperate and warm water species (Alvarino, 1965; Nair 1978) with a wide distribution in the Indian Ocean, the Atlantic Ocean and the Pacific Ocean (Pierrot-Bults and Nair, 1991). It is usually the dominant species in regions where it occurs.

14 species have been recorded and all are the common to the Indo-Pacific and 7 of them viz. *S. bedoti, S. ferox, S. neglecta, S. pacifica, S. pulchra, S. regularis and S. robusta* are endemic to the Arabian Sea (Bieri 1959). A majority of chaetognaths appear to show a preference for higher salinity and temperature (Rao and Ganapati 1958). In the upper 100m of the water column, high species richness, high dominance and low evenness were recorded. High diversity and distribution of the Chaetognaths population found in the isothermal layer comparable to 1000m depth layer may be a stable environment. It can be observed that, there is evidence showing that the vertical distribution of chaetognaths is closely related to specific hydrographical characteristics, which is translated into a strong association with water masses at depth.

Acknowledgements

The authors are thankful to Ministry of Earth Sciences, Govt. of India and Centre for Marine Living Resources and Ecology, Cochin for financial support during the study period.

Fig.1. Map showing study area located in the Arabian Sea and Bay of Bengal.

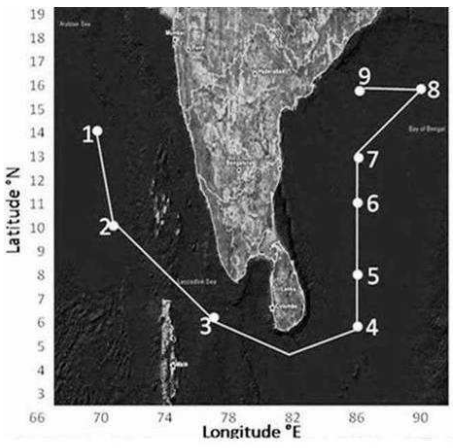

Fig.1.Map showing the study area located on the Arabian Sea and Bay of Bengal

ST. No.	Lat.	Long.	Depth range (m)
Arabian Sea			
1	05.817 N	86.268 E	3630
2	08.164 N	86.834 E	3630
3	11.745 N	86.698 E	3314
Bay of Bengal			
1	05.817 N	86.268 E	3890
2	08.164 N	86.834 E	3630
3	11.745 N	86.698 E	3314
4	13.415 N	86.128 E	3028
5	16.467 N	90.287 E	2433
6	16.138 N	86.656 E	2580

Fig.2. Hydrographical patterns (Vertical 0-1000m depth) at Arabian Sea and Bay of Bengal

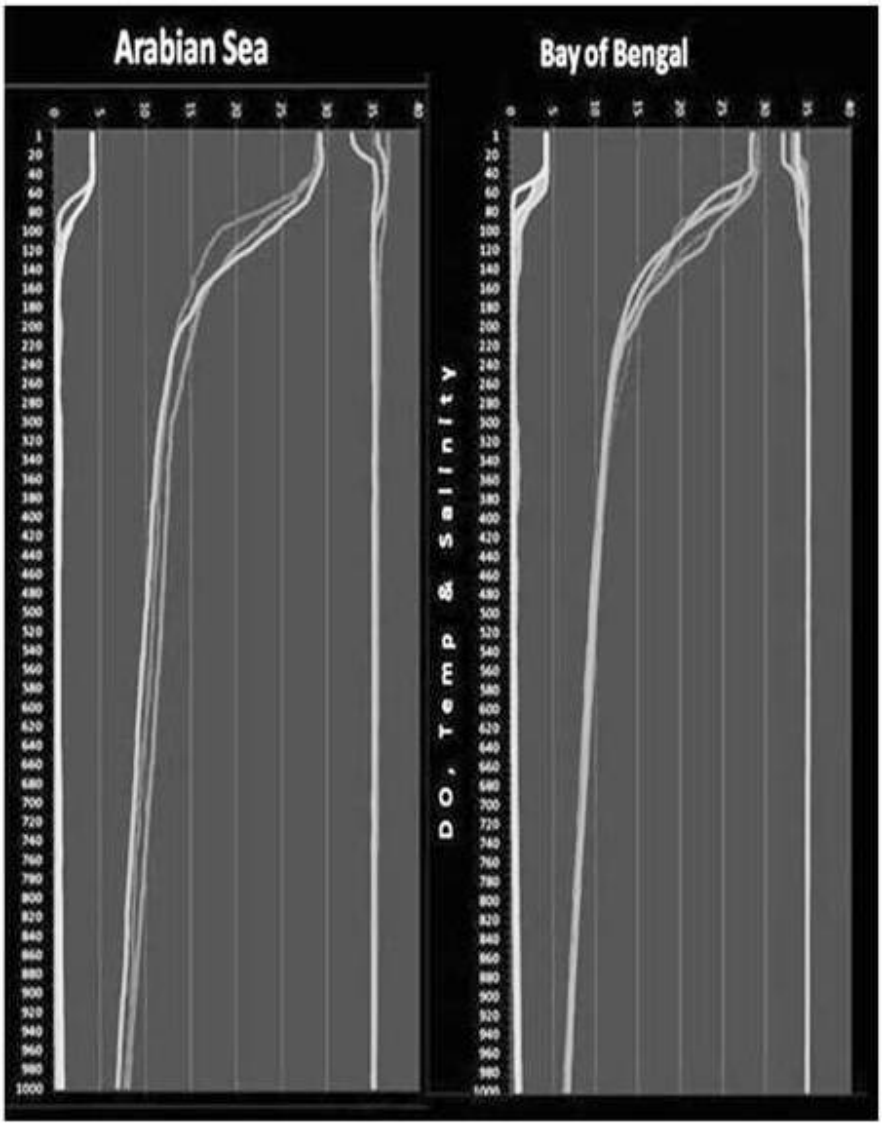

Fig.3-7. Depth wise Species Composition

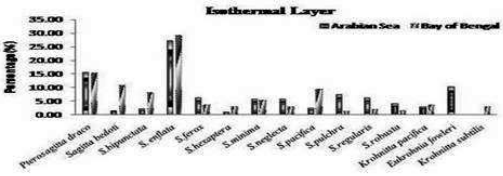

Fig.3. Species composition of Chaetognaths in Isothermal layer in the Arabian Sea and Bay of Bengal

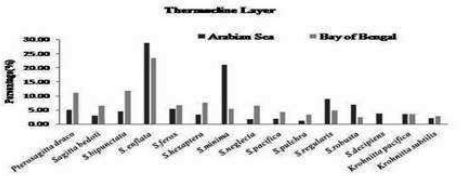

Fig.4. Species composition of Chaetognaths in Thermocline layer in the Arabian Sea and Bay of Bengal

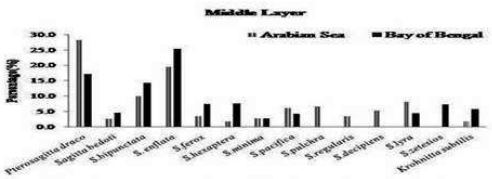

Fig.5. Species composition of Chaetognaths in Middle layer in the Arabian Sea and Bay of Bengal

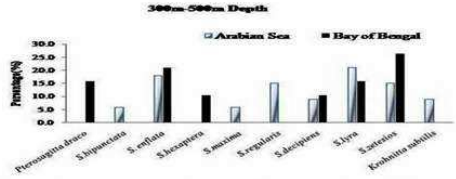

Fig.6. Species composition of Chaetognaths in 300-500m layer in the Arabian Sea and Bay of Bengal

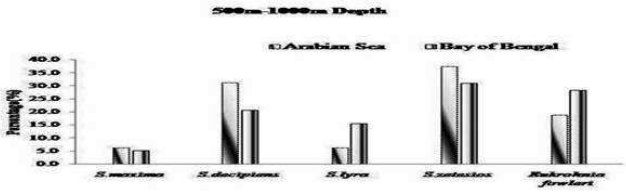

Fig.7. Species composition of Chaetognaths in 500-1000m depth in the Arabian Sea and Bay of Bengal

Fig.8-12. Population density and Diversity indices of Chaetognaths

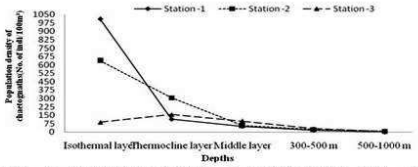

Fig. 8. Population density of Chaetognaths (No. of indi/100m³) at different depth strata from 3 stations in Arabian Sea

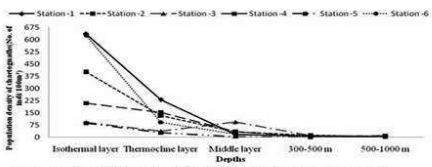

Fig. 9. Population density of Chaetognaths (No. of Indi/100m³) at different depth strata from 6 stations in Bay of Bengal

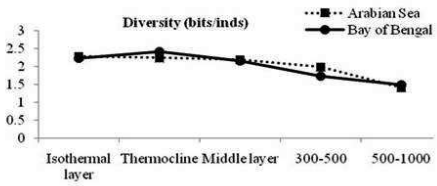

Fig.10. Vertical distribution of species diversity of Chaetognaths in the Arabian Sea and Bay of Bengal

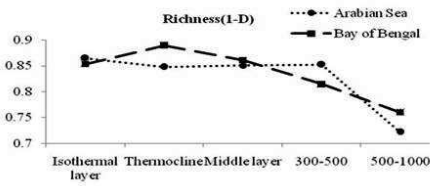

Fig.11. Vertical distribution of species richness of Chaetognaths in the Arabian Sea and Bay of Bengal

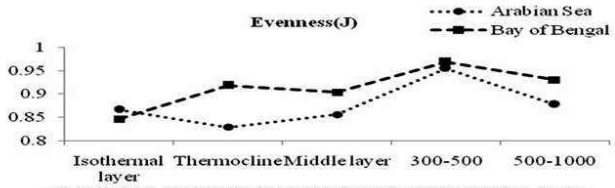

Fig.12.Vertical distribution of species evenness of Chaetognaths in the Arabian Sea and Bay of Bengal

REFERENCES

[1] Alvarino, *Pacif. Sci*., **1967a**, *21*, 474-485.
[2] Alvarino, The chaetognaths of the Naga expedition (1959-1961) in the South China Sea and the Gulf of Thailand. I. Systematics. Naga Rep. **1967b**, 4, 1-197.
[3] Alvarino, A., *Oceanogr. mar. Biol. a. Rev*., **1965**, 3, 115-194.
[4] Alvarino, A., *J.Mar.Bio.Ass.India*, **1974**, 14, 713-722.
[5] Bieri, R., *Limnol. Oceanogr*., **1959**, 4, 1-28.
[6] Bieri, R., Systematics of the Chaetognatha. In, The Biology of Chaetognaths, edited by Q. Bone, H. Kapp & A.C. Pierrot-Bults, Oxford University Press, Oxford, **1991**, 122-136.
[7] Bone,Q., Kapp, H. and Pierrot-Bults, A.C., Introduction and relationships of the group. The biology of Chaetonaths. ed. by Q. Bone et al. Oxford, Oxford University Press, **1991,** 1-4.
[8] Casanova, J.P., Chaetognatha. In, South Atlantic Zooplankton, edited by D. Boltovskoy, Backhuys Publishers, Leiden.**1999,** 1353-1374.
[9] Escribano,R., Marı´n. V. and Irribarren. C., *Sci. Mar*. **2000,** 64, 69–77.
[10] Ganapati, P. N. and Rao, T. S. S., *Mem. Oceanogr*. (Ser. 49), **1954,** 1, 143-150.
[11] Hida,T. S., Chaetognaths and pteropods as biological indicators in the North Pacific. Spec. scient. Rep. U.S. Fish Wildl. Serv. (Fish), **1957,** 215, 1-13.
[12] John, C., Sagitta of the Madras coast. Bull. Madras Govt .mas. (N.S) Nat. Hist.Ser., **1933,** 3, 1-10.
[13] John, C. C., Seasonal variations in the distribution of *Sagitta* of the Madras coast. Rec. Indian Mus, **1937,** 39, 83-97.
[14] Johnson, T. B., Ecological study of pelagic chaetogntahs in the Pacific Ocean. The University of Tokyo, Tokyo Japan. Unpublished doctoral dissertation, **2005,** 171.
[15] Kehayias, *J. Mar. Biol. Ass.* U. K, **2003,** 83, 559-569.
[16] Krishnamurthy, K., *Hydrobiologia* XXIX; **1967,** 226-238.
[17] Michael, Classification and vertical distribution of the Chaetognatha of the San Diego region including redescriptions of some doubtful species of the group. Univ. Calif. Publs Zool. **1911,** 8, 21-186.
[18] Moore, H. B., Owre, H., Jones, E.C. and Dow, T., *Bull. Mar. Sci*. Gulf Caribb, **1953,** 3, 83-95.
[19] Nair, R, *Indian J. Mar. Sci*. **1978,** 7, 276-282.
[20] Nair, R. Vijayalakshmi, *Indian J. Mar. Sci.*, **1976,** 5, 107-112.
[21] Nair, R. Vijayalakshmi and Rao, T.S.S., Chaetognaths from the laccadives with the new record of Spadella angulata. (tokioka, 1951). In: zeitzschel. b. (ed.) the biology of the Indian Ocean, **1973,** 3, 319-327. springer - verlag. berlin - heidelberg -new york.
[22] Nair,V.R., *J. Mar. Bio. Ass.* India, **1971,** 13(2), 226-223.
[23] Nair, V.R. and Rao T.S.S., Chaetognaths of the Arabian Sea. In. The biology of the Indian Ocean. Bent. Zeitzschal Ed., **1973,** 293-317.
[24] Owre, H., *Bull. Mar. Sci*. Gulf Caribb., **1960,** 10, 255-322.
[25] Padmavati and Goswami., *Indian J. Mar. Sci*., 1996**,** 25, 85-90.
[26] Padmavati.G., Haridas, P., Nair, K.K.C., Gopalakrishnan, T.C., Shiney, P. and Madhupratap M., *Journal of Plankton Research*, **1998,** 20(2), 343-354.
[27] Pielou, E.C., *J.Theoret.Biol.*, **1966,** 13, 144.
[28] Pierce, E. L., *J. mar. Res.*, **1953,** 12, 75-92.

[29] Pierrot-Bults, A.C. and Nair, R., Distribution patterns in Chaetognatha. *In* Q Bone, H Kapp, AC Pierrot-Bults, eds. The biology of chaetognaths. Oxford, UK: Oxford Univ. Press, **1991,** 86-116.
[30] Pierrot-Bults, Biological diversity in oceanic macrozzolplankton: More than counting species. In: Ormond, R.F.G., Gage, J. D., Angel, M.V. (Eds), Marine Biodiversity. Patterns and Processes, Cambridge University Press, London, **1997,** 69-93.
[31] Rao, T.S.S. and Ganapati, P.N., *Univ. mar. Oceanogr., Ser*. **1958,** 62, 147-163.
[32] Ricardo Giesecke and Humberto e. Gonzalez., *J. Plankton research*,**2004,** 26 (4), 475-486.
[33] Shankar, D., Vinayachandran, P. N. and Unnikrishnan, A. S., Progress In *Oceanography*, **2002,** 52(1), 63-120.
[34] Shannon, C.E. and Weaver's., The mathematical theory of communication. Uni. Of. Illinos press. Urbana. **1949,** 177.
[35] Stone, J.H, *Ecol.Monogr*.**1969,** 39, 433-463.
[36] Subramanian, M.K., *Curr. Sci*., **1937,** 6, 284-288.
[37] Sund, P. N., *Pacif. Sci*., **1959,** 13, 269-285.
[38] Terazaki, M, *Polar Biol.*, **1986,** 2, 51-60.
[39] Tokioka, T., *Bull. Plankton*, **1962,** 8, 5-11.
[40] Ulloa, R., Palma, S. and Silva, N., *Deep-Sea Res*. I, **2000,** 47, 2009–2027.
[41] Varadarajan, P.I. and Chacko, S., *Proc .Nat. Inst. Sci. India*., **1943,** 9(2), 245-248.
[42] Vijayalakshmi, R. Nair, Terazaki Makoto and Jayalakshmi, K. V., *Plankton Boil. Ecol.*, **2002,** 49 (1), 27-37.