Oceanography/Vol.1/No.2/Summer 2010/9/ 11-19

Abundance and distribution of planktonic chaetognaths in the Strait of Malacca

Rezai, Hamid[1]; Mohammed Yusoff, Fatimah[1]; Kawamura, Akito[3]

1- Department of Marine Biology, Iranian National Institute for Oceanography
2- Department of Biology, Faculty of Science and Environmental Studies, University Putra Malaysia
3- Faculty of Bioresources, Mie University, Japan

Abstract

Abundance and distribution of chaetognaths was investigated from zooplankton samples collected from a series of four cruises (during the period November-December 1998, March-April 1999, August 1999 and July-August 2000) in the Straits of Malacca. The collections were made by vertical haul using NORPAC net of mesh size 140 µm. Planktonic chaetognaths constituted 2.93%, 5.60%. 2.23% and 3.66% of total zooplankton population during cruises I, II, III and IV, respectively. Highest mean abundance of chaetognaths was recorded during cruise II (pre-SW monsoon) (mean of 724±430 ind. m^{-3}) and lowest during cruise III (post SW monsoon) (mean of 189±32 ind. m^{-3}). Two-way ANOVA showed no significant difference ($p>0.05$) in abundance of planktonic chaetognaths between the cruises but significant difference ($p<0.05$) between geographic locations within the Straits; the interaction of these (cruise x geographic location) was also significant ($p<0.05$). Except for cruise II, with localized high abundance near Klang area, no consistent pattern of distribution was apparent among the cruises. Cluster analysis of the stations revealed two types of assemblages: low to moderate and high abundances, the latter being found in near-coastal areas. Except for the central part (with higher abundances in deeper waters), higher chaetognath abundance was found in 10-20 m depth stratum in the northern and southern parts of the Straits.

Keywords: *Chaetognaths, Abundance, Straits of Malacca, Monsoons*

1. Introduction

Planktonic chaetognaths are recognized major components of open oceans and continental shelf zooplankton, where they are generally second only after the copepods in both displacement volumes and numbers (Bigelow and Sears, 1939; Grice and Hart, 1962). Because of their occurrence in marine habitats and their potential predation pressure on copepods, chaetognaths are an important factor in the structuring of most plankton communities (Pearre, 1980). They are also frequently qualified as an important food link between copepods and larger predators, including larval fish (such as Herring) and several species of commercial fish (Lebour, 1922, 1923; Reeve, 1970; Nagasawa and Muramo, 1981), and thus are considered good indicators of potentially important fishery areas (Boltovskoy, 1981). It is possible that chaetognaths in the Straits of Malacca are predators on some fish larvae as well as being part of the diet of some larger fish such as mackerel. They have been used traditionally as valuable indicators of water mass and water movements (Russell, 1935; Fraser, 1952;

* Email: rezaihamid@hotmail.com

Alvariño, 1962; Motoda and Marumo, 1966, Ulloa et al., 2000).

Major reviews of the phylum have been made by Hyman (1959); Beauchamp (1960), Alvariño (1965), and Ghirardelli (1968). The taxonomy of chaetognaths of the Straits of Malacca is relatively well known; Wickstead (1961) reported several species of chaetognaths. among his collection of zooplankton in the Straits of Malacca, Pathansali and Tokioka (1963), and Tokioka and Pathansali (1963a, b) listed 24 species from the Straits. However, except for Pathansali (1974) who made some discussion on the distribution of Chaetognatha west of Penang Island, very little is known about distribution and seasonal abundance of chaetognaths in the Straits of Malacca.

The purpose of this study is to determine the spatial and temporal distribution and abundance of the chaetognaths in the Straits of Malacca in relation to the monsoonal changes during the year 1998-2000 and examine the hypothesis that abundance and distribution patterns of Chaetognatha weres related to the abundance of copepod.

2. Materials and Methods

Zooplankton sampling and general surveys were conducted at stations located between 05o 59’ N, 99o 59’ E and 01o 10’ N, 103o 29’ E (Fig. 1) during 4 oceanographic cruises (November 23-December 2, 1998; March 20-April 6, 1999; August 20-29, 1999; July 29-August 8, 2000) along the Straits of Malacca. The periods of the consecutive cruises coincided with NE monsoon (cruise I), pre-SW monsoon (cruise II), post- SW monsoon (cruise III) and SW monsoon (cruise IV),respectively. Details of sampling stations were dealt with elsewhere (Rezai et al., 2003).

Samples were collected in vertical hauls using the NORPAC net (mesh size 140 µm with mouth area 0.159 m^2) from near bottom to the surface at each station. Plankton samples were removed from the nets and fixed immediately in 4-5% neutral formalin, buffered to a pH of 8 with sodium tetraborate (borax). Samples were slowly filtered through 1-mm mesh gauze and counted entirely (including juvenile chaetognaths). For smaller individuals passed through the filter, subsampling was performed on aliquots varying from 1/2 to 1/8th of the total sample. Each subsample was transferred into a Bogorov’s plate and counted under a dissecting stereoscope. Abundance was calculated as numbers m^{-3}.

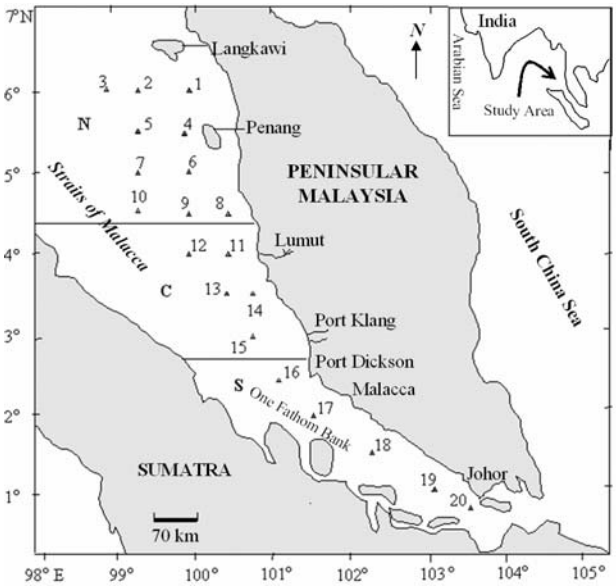

Fig 1. Location of sampling stations. Divisions referred to in the text are: N, north; C, centre; S, south. No samples were taken from stations 4, 5, 6 and 11.

Vertical distribution of chaetognaths was determined from a series of vertical hauls undertaken at representative stations in the northern, central and southern parts of the Straits during cruise II. The following depth strata were sampled: 0-10 m, 10-20 m, 20-40 m and >40 m. The sampling procedure and processing of samples were the same as those described above. Measurements of temperature and salinity of the entire water column were made synchronously with the zooplankton samplings using Hydrolab Surveyor 3.

Statistical differences in abundances during the study period and between the sampling stations in geographic locations along the Straits (north, central and south) were assessed using two-way ANOVA. Data were transformed using log10 [x+1] to normalize their distribution for statistical analysis (Zar, 1984;

Cassie, 1963). Regional distribution of planktonic chaetognaths was calculated using SURFER (Version 6) software. Non-parametric Mann-Whitney U-test was performed to compare near-coastal and neritic abundances. The data on chaetognaths were compared and correlated with those obtained previously for the copepods (Rezai, 2002).

Cluster analysis and non-metric multidimensional scaling (MDS) techniques in conjunction with the Bray-Curtis similarity and square root transformation of the abundance data were applied to the species matrix to determine similarities among stations. A measure of goodness-of-fit of the MDS ordination was given by the stress value. A low stress factor (<0.2) corresponded to a good ordination with no real prospect of a misleading interpretation (Clarkeand Warwick, 1994).

3. Results

Planktonic chaetognaths constituted 2.93%, 5.60%. 2.23% and 3.66% of total zooplankton population during cruises I, II, III and IV, respectively. Regional distribution of chaetognaths (Fig. 2) showed that except for cruise II with a high-localized abundance in near-coastal area of Klang, there was no consistent pattern of distribution among cruises. Also, there was neither any consistent pattern in abundance data among different geographic locations in the Straits nor any north to south gradient, though as it was mentioned in above the variations of abundance was higher in the central part of the Straits during pre-south west monsoon (Fig. 3). In addition, except for cruise II (pre-SW monsoon), no near-coastal/offshore decrease in chaetognath abundance was evident. Likewise, Mann-Whitney U-test showed that except for cruise II ($p<0.05$), there was no significant difference ($p>0.05$) in chaetognath abundnces between near-coastal and offshore stations.

Two-way ANOVA showed no significant difference ($p>0.05$) in abundance of planktonic chaetognaths between the cruises but significant difference ($p<0.05$) between geographic locations within the Straits; the interaction of these (cruise x geographic location) was also significant. In other words, chaetognath population was spatially significant but temporally insignificant. However, non-parametric Wilcoxon's matched paired test showed significant difference ($p<0.05$) between the cruises and between the geographic locations in the Straits.

Cluster analysis of the stations revealed two types of assemblages: high abundance (consisting of stations 18 and 24) and low (stations 3, 7, and 12) to moderate (the rest of stations) abundances (Fig. 4). The results of multidimensional scaling (MDS) configurations (Fig. 5) for all stations in combined cruises confirmed a clear separation of the three groups of stations, but again no geographic separation of northern, central and southern part was apparent.

Highest mean abundance recorded for total chaetognaths (juveniles and adult) was 723.79 ind. m–3 in April-March (cruise II). The variation of total chaetognath abundance during the cruises followed almost the same pattern as that previously described for copepods (Rezai et al., 2002) (Fig. 6). Except for cruise III ($r = 0.31$, $p > 0.05$), significant correlations ($p<0.01$, Spearman's Rank Correlations) were obtained between total chaetognath and total copepod abundances during other cruises (cruise I, $r= 0.53$; cruise II, $r = 0.83$ and cruise IV, $r = 0.72$). In addition, with the combined cruises, significant correlation ($r = 0.59$, $p< 0.01$) was obtained between total chaetognath and copepod abundances. However, correlations of chaetognath abundances with salinity and temperature were not significant ($p> 0.05$).

Vertical distribution of total chaetognaths showed that except for the central part (with higher abundances in deeper waters) of the Straits, higher chaetognath abundances were found in 10-20 m depth stratum in the northern and southern parts (Fig. 7).

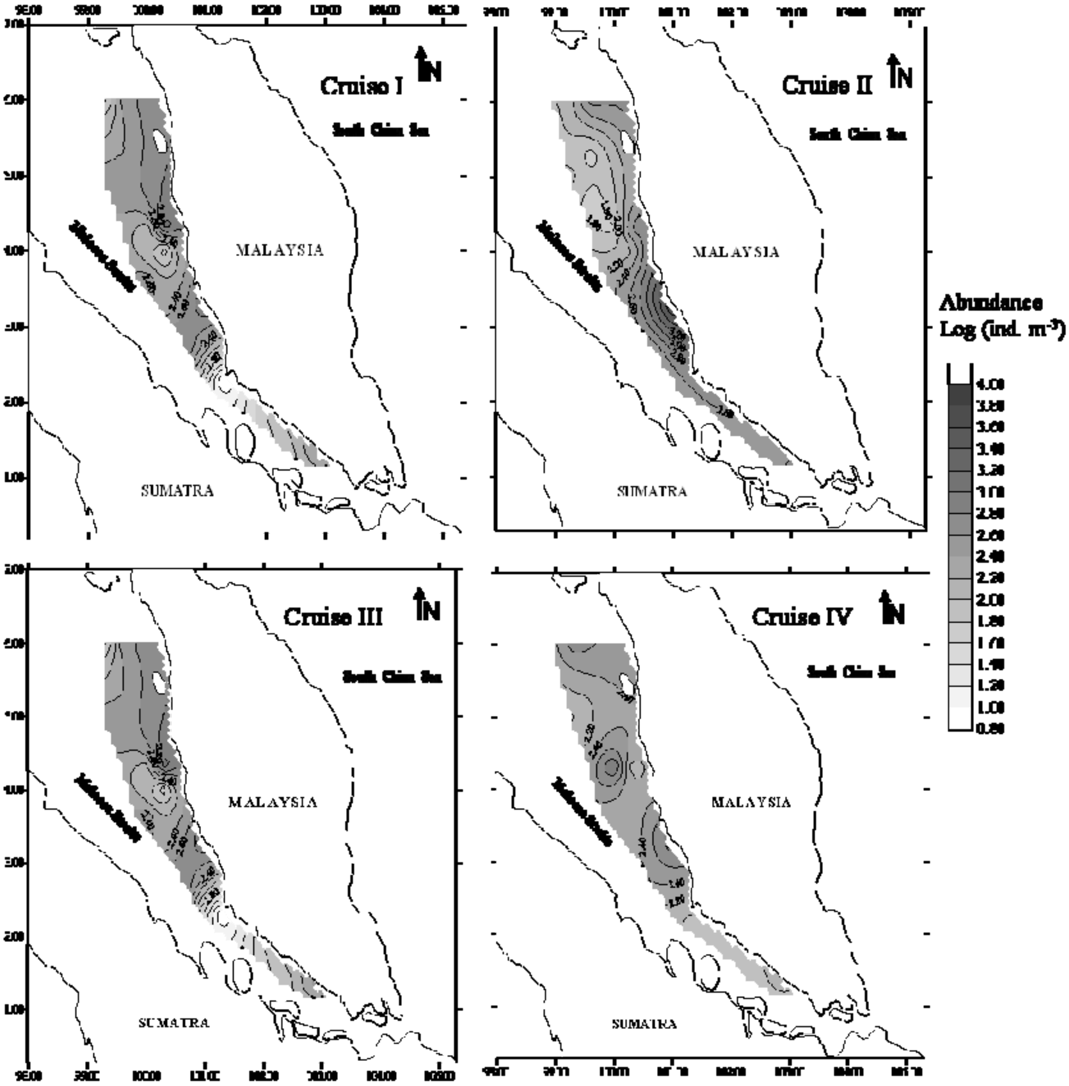

Fig 2. Regional distribution of planktonic chaetognaths in the Straits of Malacca.

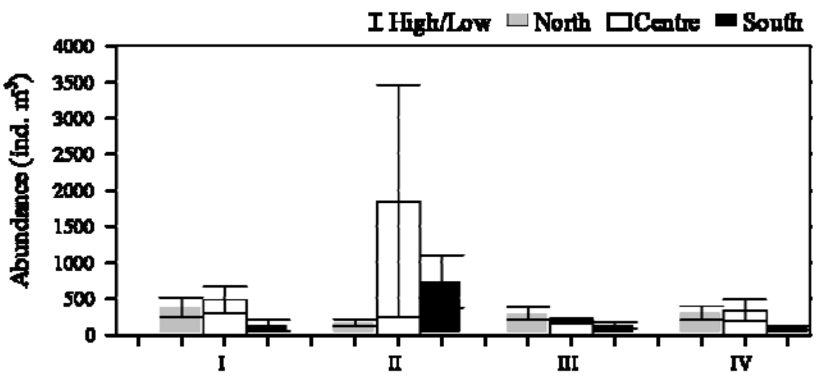

Fig 3. Mean abundance of chaetognaths during different cruises in combined stations in the northern, central and southern parts of the Straits of Malacca. Vertical bars indicate standard errors.

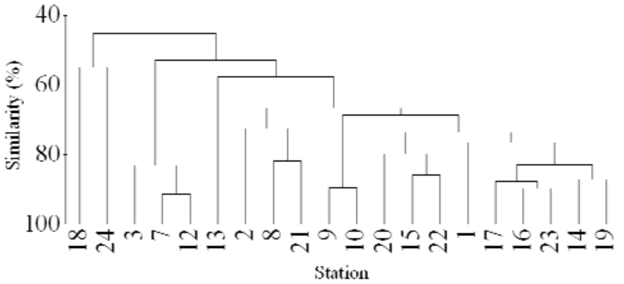

Fig 4. Dendrogram from Bray-Curtis similarity matrix of stations abundance data.

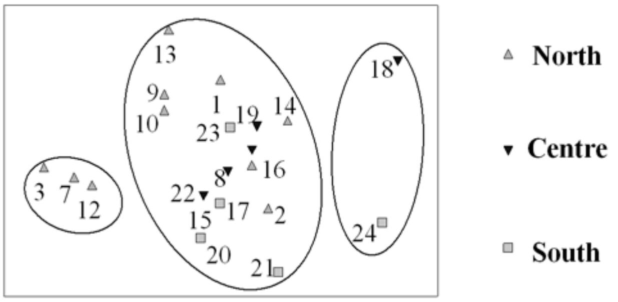

Fig 5. Multidimensional scaling (MDS) ordination of Bray-Curtis similarity matrix of station abundance data. Different geographic regions are represented by symbols.

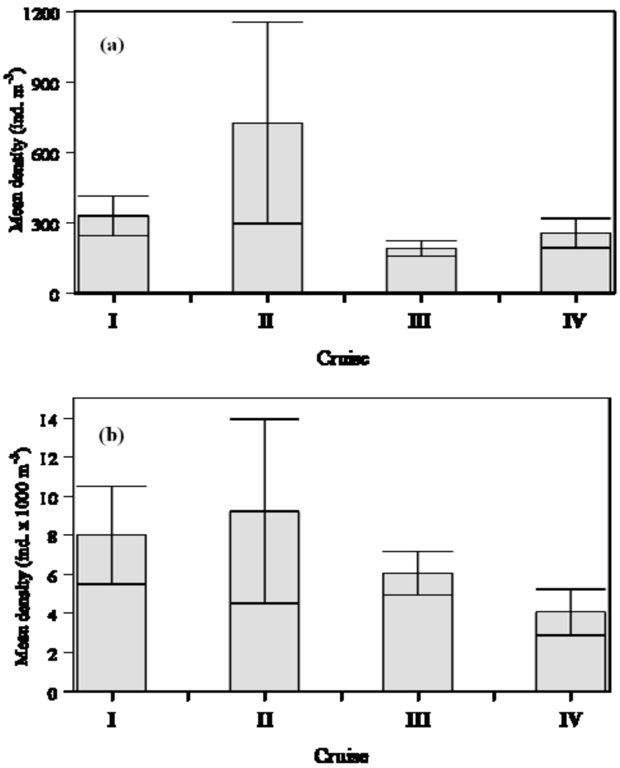

Fig 6. Mean abundance of chaetognaths (a) and copepods (b) (averages from all stations combined) during the cruises in the Straits of Malacca. Vertical bars indicate standard errors.

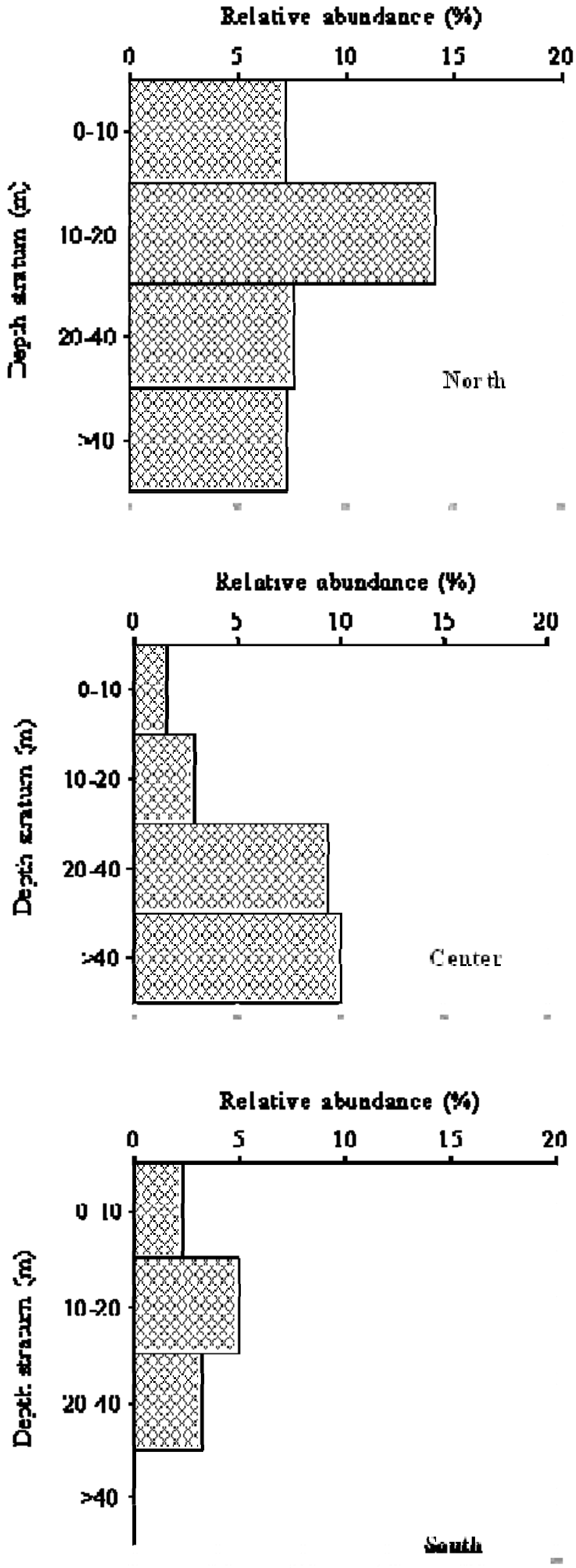

Fig 7. Vertical distribution of planktonic chaetognaths in the northern, central and southern parts of the Straits of Malacca.

4. Discussion

The Straits of Malacca have been classified as a tropical sea with partially mixed waters and a circulation pattern dominated by monsoon winds (Wyrtki, 1961). The chaetognaths are quite abundant in the surface plankton of the Straits of Malacca (Chua and Chong, 1975). Pathansali (1968) following reports by Ommaney (1961), Wickstead (1961) based the distribution of chaetognath species on the differences in the hydrography of the northern and southern parts of the Straits of Malacca. However, in the present study, no conclusion was drawn in the absence of species identification on relationships between chaetognath distribution and hydrographic conditions of the regions.

Temperature and salinity are commonly considered as factors limiting distribution of marine plankton species; However, the present data did not show any significant relationship with physical parameters of temperature and salinity. Water masses can not be characterized by temperature and salinity alone because they may have characteristic planktonic communities even without remarkable hydrological differences. Distribution of planktonic chaetognaths, has been generally related to different water masses (Alvariño, 1969). Several species of chaetognaths are strongly related to specific water masses and are thus, useful as indicators of water mass movements (Russel, 1937; Mulkana and McIlwain, 1973; Cheney, 1985; Grant, 1991). Pathansali (1968) indicated that in the Straits of Malacca the neritic-inshore species showed the presence and seaward extent of low salinity inshore water while neritic-offshore forms indicate the presence and the extent of the incursion of oceanic water.

Distribution and abundance of chaetognaths also showed strong relationships with their food supply (Alvariño, 1969). Chaetognaths were abundant in areas where there was a great abundance of copepods, their main food item (Mulkana and McIlwain, 1973; Stuart and Verhey, 1991). The highly localized abundance of chaetognaths near Klang area (Stn. 18) might be attributed to the high occurrence of copepods(Rezai, 2002). Whilst the copepods and chaetognaths were always present in the plankton of the Straits, they were extremely abundant during certain periods of the year, particularly during March-April period (cruise II or pre-SW monsoon). Thus, the abundance and scarcity of chaetognaths may correspond to the distribution pattern of copepods.

Recently, it was shown that chaetognaths were able to consume daily up to 5% of copepod standing stock, or up to 10% of copepod production daily (Froneman and Pakhomov, 1998). Examining stomach content of the chaetognaths indicated that copepods formed the main food item (Thomson, 1947; Reeve, 1966). Chaetognaths feed on calanoid copepods, the commonest forms being Centropages, Eucalanus and Lucicuita; on poecilostomatois copepods like Corycaeus and Oncaea; and on cyclopoid like Oithona. Rarely harpacticoid copepods and other groups like fish larvae, ostracods, euphausiids and polychaete larvae were found inside the gut (Nair and Rao, 1973). However, recently Ohtsuka et al. (1996) found chaetognaths in the gut of large Oncaea species.

Except for higher abundance in deeper water (>40m) in the central part of the Straits, the depth profile of chaetognaths followed almost the same pattern as that of copepods (Rezai, 2002). Chaetognaths decrease in abundance generally correlated with increase in depth (Alvariño, 1964). Thiel (1938) also found greater biomass of chaetognaths in the upper 50 m. In the Indian Ocean, Nair (1978) found maximum abundances of chaetognaths between surface and 125 m depth.

More recently, Ulloa et al. (2000) showed that the vertical distribution of chaetognaths was closely related to specific hydrological characteristics, meaning a strong association with water masses at depth. On this subject, Cheney (1985) indicated migrations were associated with spatial and temporal differences of the population structure rather than with environmental conditions. However, Stuart and Verheye (1991) in their study of chaetognath Sagitta friderici off the west coast of South Africa found that juvenile chaetognaths occupied a somewhat shallower zone, and exhibited limited vertical migrations patterns. Russell (1933) noticed that adult chaetognaths were either more sensitive to light than young or that their optimal range was more restricted;. Later, he reported Sagitta elegans became more sensitive to light with age.

4. Conclusions

High abundances of chaetognaths correlated high copepod abundances, suggesting the existence of a trophic relationship between these organisms. Our data suggested that copepod abundance in the Straits might be a key factor influencing the spatial and temporal distribution of chaetognaths. Further research is underway to describe the community structure of chaetognaths in the Straits and the possibility that certain species of chaetognaths could be served as biological indicators of oceanographic conditions of the region. Additional collections of chaetognaths are needed from points far out into the Straits and at various depths in order to be able to better define the offshore range of species.

5. Acknowledgements

This work was supported by JICA-UPM funds through the Universiti Putra Malaysia and the Government of Malaysia (IRPA project No 01-02-04-0165). Field assistance was given by F. Alasvandi and P. Kuppan.

References

Alvariño, A. 1962. Taxonomic revision of Sagitta robusta and Sagitta ferox Doncaster, and notes on their distribution in the Pacific. Pac.Sci. 16:186-201.

Alvariño, A. 1964. Bathymetric distribution of chaetognaths. Pac.Sci. 18:64-82.

Alvariño, A. 1965. Chaetognaths. Oceanogr. Mar. Biol. Ann. Rev. 3:115- 194.

Alvariño, A. 1969. Los quetognathos del Atlantico. Distributiony notas esentiales de sistematica. Trab.Inst.Esp.Oceanogr. 37:1-290.

Beauchamp, P.de. 1960. Chaetognathe. In: Grassé, P. Traité de Zoologie, Masson, Paris. 5:1500-1520.

Bigelow, H.B. and Sears, M. 1939. Studies on the waters of the continental shelf, Cape Cod to Chesapeake Bay. III. A volumetric study of the zooplankton. Mem. Mus. Compar. Zoo. Harvard. 54:183-378.

Boltovskoy, D. (ed.) 1981. Atlas del zooplankton del Atlantico Sudoccidental y Methods de Trabajo con el Zooplankton Marino. INIDEP. Argentina. 401 pp.

Cassie, R.M. 1963. Multivariate analysis in the interpretation of numerical plankton data. New Zeal. J. Sci. 6:36-59.

Cheney, J. 1985. Spatial and temporal abundance patterns of oceanic chaetognaths in the western north Atlantic. Vertical distribution and migrations. Deep-Sea Res. 32:1061-1075.

Chua, T.E. and Chong, B.J. 1975. Plankton distribution in the Straits of Malacca and itsadjacent waters. In: Anon (ed.., Proc. Pac. Sci. Assoc. Mar. Sci..Symp., December 1973, Hong Kong. 17-23.

Clarke, K.R. and Warwick, R.M. 1994. Change in marine communities: an approach to statistical analysis and interpretation. National environment research council, United Kingdom. 144 pp.

Fraser, J.H. 1952. Chaetognaths and other zooplankton of the Scottish area, and their values as biological indicators of hydrographical conditions. Mar.Res.Scot. 2:5-52.

Froneman, P.W. and Pakhomov, E.A. 1998. Trophic importance of the chaetognaths, Eukrohnia hamata and Sagitta gazella in the pelagic subsystem of the Prince Edward Island (Southern Ocean). Pol. Biol. 19:242-249.

Ghirardelli, E. 1968. Some aspects of the biology of the chaetognaths. Adv.Mar.Biol. 6:271-375.

Grant, G.C. 1991. Chaetognatha from the central and southern middle Atlantic Bight. Species composition, temperature-salinity relationships and interspecific associations. Fish.Bull.Nat.Fish.Ser.US 89:33-49.

Grice, G.D. and Hart, A.D. 1962. The abundance, seasonal occurrence and distribution of the epizooplankton between New York and Bermuda. Ecol.Monogr. 23:287-309.

Hyman, L.H. 1959. The invertebrates: Smaller Coelomate Groups, Vol. 5. Am.Mus. Nat. Hist., New York. 71 pp.

Lebour, M.V. 1922. The food of plankton organisms. J.Mar. Bio. Assoc. UK. 12:644-677.

Lebour, M.V. 1923. The food of plankton organisms. II. J.Mar. Bio. Assoc.UK. 13:70-92.

Motoda, S. and Marumo, R. 1966. Plankton of the Kuroshio water. Ocean Res. Inst. Univ. Tokyo. 4:40-61.

Mulkana, M.S. and McIlwain, T.D. 1973. The seasonal occurrence and abundance of Chaetognatha in Mississippi Sound. Gulf Res.Rep. 4:264-271.

Nagasawa, S. and Muramo, R. 1981. Chaetognaths as food of demersal fishes in the East China Sea. Bull. Seikai Reg. Fish. Res. Lab. 56:1-13.

Nair, V.R. 1978. Bathymetric distribution of chaetognaths in the Indian Ocean. Ind. J. Mar.Sci. 7:276-282.

Nair, V.R. and Rao, T.S.S. 1973. Chaetognaths of the Arabian Sea. In: Zeitzschel, B. (ed.. The Biology of the Indian Ocean, Springer-Verlag, Berlin. 293-317.

Ohtsuka, S. Bottger-Schnack, R. Okada, M. and Onbe, T. 1996. In situ feeding habits of Oncaea (Copepoda: Poecilostomatoida) from the upper 250 m of the central Red Sea, with special reference to consumption of appendicularian houses. Bull. Plank. Soc. Jpn. 43:89-105.

Ommaney, F.D. 1961. Experimental fishing cruises of the Fisheries Research Vessel Manihine in Malayan and Borneo waters, 1955-56, with a note on temperature and salinities in the Singapore Strait. Fish. Pub. London.

Pathansali, D. 1968. Some observations on the distribution of Chaetognatha west of Penang Island. Pub.Seto Mar. Biol.Lab. 15:391-397.

Pathansali, D. 1974. Chaetognatha in the coastal waters of peninsular Malaysia with descriptions of two new species. Fish.Bull.Min.Agri.Rural Dev.Malaysia 2:1-30.

Pathansali, D. and Tokioka, T. 1963. A new chaetognath, Sagitta johorensis n. sp. from Malay waters. Pub.Seto Mar. Biol.Lab. 1:106-108.

Pearre, S.Jr. 1980. Feeding by Chaetognatha: The relation of prey size to predator size in several species. Mar.Ecol.Prog.Ser. 3:125-134.

Reeve, M.R. 1966. Observations on the biology of a chaetognath. In: Barnes, H. (ed.) Some contemporary studies in Marine Science. George Allen and Unwin Ltd., London. 613-630.

Reeve, M.R. 1970. The biology of Chaetognatha. I. Quantitative aspects of growth and egg production in Sagitta hispida. In: Steele, J.H. (ed.) Marine food chains. Oliver and Boyd, Edinburgh. 168-189.

Rezai, H. 2002. Ecological studies on zooplankton from the Straits of Malacca with special reference to copepods. PhD Thesis. Universiti Putra Malaysia. Malaysia. 265 pp.

Rezai, H.; Yusoff, F.M.; Arshad, A.; and Kawamura, A. 2003. Zooplankton biomass in the Straits of Malacca. Ind. J. Mar. Sci. 32:222-225.

Russel, F.S. 1937. The seasonal abundance of the pelagic youngs of teleostean fishes in the Plymouth area. Part IV The year 1936. with notes on the conditions as shown by the occurrence of plankton indicators. J.Mar.Biol.Asso.UK. 21:679-686.

Russell, F.S. 1935. On the value of certain planktonic animals as indicators of water movements in the English Channel and North Sea, J.Mar.Biol.Asso.UK 20:309-331.

Russell, F.S. 1933. On the biology of Sagitta. III. A further observation on the growth and breeding of Sagitta setosa in the Plymouth area. J.Mar.Biol.Asso.UK. 18:559-574.

Stuart, V. and Verheye, H.M. 1991. Diel migration and feeding patterns of the chaetognath, Sagitta friderici. off the west coast of South Africa. J.Mar.Res. 49:493-515.

Thiel, M.E. 1938. Die chaetognathen-Bëvolkerung des Südatlantischen Ozeans. Wissensch. Ergnbnisse D. deutschen Atlant.Exped. auf dem Forschung- u. Vermes-Sungsschiff METEOR, 1925-1927. Biol.Sonder.suchun. 13:1-110.

Thomson, J.M. 1947. The chaetognatha of south-eastern

Australia. Rep. Div.f Fish. Oceanogr.CSIRO, Austr. 14:1-43.

Tokioka,T.R. and Pathansali, D. 1963a. A new form of Sagitta bedoti Beraneck found in the littoral waters near Penang. Bull.Nat.Mus.Singa. 33:1-5.

Tokioka,T.R. and Pathansali, D. 1963b. Another new chaetognath from Malay waters with a proposal of grouping some species of Sagitta into subgenera. Pub.Seto Mar. Biol.Lab. 11:119-123.

Ulloa, R.; Palma, S.; and Silva, N. 2000. Bathymetric distribution of chaetognaths and their association with water masses off the coast of Valparaiso, Chile. Deep-Sea Res. I 47:2009-2027.

Wickstead, J.H. 1961. A quantitative and qualitative study of some Indo-West-Pacific plankton. Colonial Office Fishery Publications. No. 16, Her Majesty's Stationery Office. p 200.

Wyrtki, K. 1961. Physical oceanography of Southeast Asian waters. Naga Rep. Vol. 2. Scripps Institute of Oceanography. La Jolla. California. 180 pp.

Zar, J.H. 1984. Biostatistical Analysis. Prentice-Hall International Inc. Englewood. N.J. 620 pp.