http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 15 (13): 647-652, 2012
ISSN 1028-8880 / DOI: 10.3923/pjbs.2012.647.652

Spatial Distribution of Copepods along the Salinity Gradient of Perai River Estuary, Penang, Malaysia

[1,2]I. Johan, [2]W.O. Wan Maznah, [2]M. Mashhor, [1]M.K. Abu Hena and [3]S.M.N. Amin
[1]Department of Animal Science and Fishery, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Campus, 97008 Sarawak, Malaysia
[2]School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia
[3]Department of Aquaculture, Faculty of Agriculture, Universiti Putra Malaysia, Serdang, 43400 Selangor, Malaysia

Abstract: Investigation on copepod communities in Perai river estuary was conducted from November 2005 to May 2006. Five stations were established for monthly sampling and were located from the river mouth to the upper reaches of the river. Copepod samples were collected from vertical tows using a standard zooplankton net. The Perai river estuary was slightly stratified and salinity decreases significantly from the mouth of the river towards the upper reaches of the river. A total of 28 species of copepods were recorded and comprised of 14 families, Paracalanidae, Oithonidae, Corycaeidae, Acartiidae, Calanidae, Centropagidae, Eucalanidae, Pontellidae, Pseudodiaptomidae, Tortanidae, Ectinosomatidae, Euterpinidae, Clausidiidae and Cyclopidae. A total of 10 species showed high positive affiliation towards salinity (R>0.60), *Acartia spinicauda*, *Euterpina acutifrons*, *Microsetella norvegica*, *Oithona nana*, *Oithona simplex*, *Paracalanus crassirostris*, *Paracalanus elegans*, *Paracalanus parvus*, *Pseudodiaptomus* sp. and *Hemicyclops* sp. The copepod species *Pseudodiaptomus dauglishi* were negatively affiliated towards salinity (R = -0.71). The copepod assemblages classified into two distinct groups according to salinity regimes, euryhaline-polyhaline group (25 marine affiliated species) and oligohaline-mesohaline group (3 freshwater affiliated species).

Key words: Copepod, salinity, river, estuary, marine, freshwater, Malaysia

INTRODUCTION

Estuaries are highly productive ecosystems, many of its functions as breeding, feeding and nursery grounds for many aquatic organisms including fish and shrimp species. Zooplankton plays an important key role in the aquatic food webs as primary grazers of phytoplankton and as food to higher trophic organisms. According to Nasser *et al.* (1998), salinity is the most important factor controlling species composition and distribution of a tropical estuary. Zooplankton composition varies throughout the salinity gradient thus giving rise to diverse population of zooplankton (Jayasinghe *et al.*, 2003). In addition, estuarine zooplankton can be divided into three main groups viz., (1) high saline or marine species concentrated at the river mouth (2) medium saline or brackish-water species at the middle and (3) low saline or freshwater species at the upper reaches of the estuary (Jayasinghe *et al.*, 2003).

The Perai river estuary opens into the northern and southern Penang Straits through its river mouth. The river is deepest at the river mouth and the sides of the river banks are filled with mud deposits of sand and silt particles caused by the tidal currents. The river meanders into the interior in the northeast direction cutting across wide area of urban, industrial and agricultural areas. The river exhibited a diverse assemblages of riparian plants from mangrove dominated (river mouth) to weed dominated (upper sections) (Abdul-Rahman *et al.*, 2010). Studies on zooplankton in Malaysian waters were more focused towards the marine environment (Rezai *et al.*, 2004; Johan *et al.*, 2002). In addition, the information on diversity and distribution of zooplankton especially of copepods in the coastal and oceanic waters of Malacca Straits is quite extensive and updated. However, there is very limited records and information on the zooplankton of estuaries in Malaysia (Chua, 1970, 1973; Sewell, 1933). This study analyzes the relationship

Corresponding Author: I. Johan, Department of Animal Science and Fishery, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia, UPM Bintulu Campus, 97008 Sarawak, Malaysia

between the spatial distribution of copepod assemblages with salinity regimes in the Perai river estuary, Penang, Malaysia.

MATERIALS AND METHODS

Five sampling stations (ST1-ST5) were established along the Perai river estuary and represented various section of the river system (Fig. 1). Sampling was carried out monthly from November 2005 to May 2006. Salinity was measured at different depths using SCT Meter YSI Model 33. Copepod was collected using a plankton net (mesh size: 150 μm, diameter 25 cm). The net was towed vertically from the bottom. The volume of water filtered by the net was derived from the line-length and net opening (Kuipers *et al*., 1993). Copepod samples were preserved in a bottle containing 4% of neutralized formalin diluted with seawater (Omori and Ikeda, 1984). In the laboratory, the copepod specimens were identified and enumerated under the stereo microscope and compound microscope. Identification were based on taxonomic descriptions (Boxshall and Hasley, 2004; Matsuo and Masaaki, 1997; Huys *et al*., 1996; Heron and Bradford-Grieve, 1995; Bradford-Grieve, 1994; Zhong, 1989; Yamaji, 1986; Boxshall, 1979).

Copepod absence/presence data were used for correlation analysis and cluster analysis. One-way analysis of variance was used to test the spatial and temporal differences in salinity variations for months and stations. Pair Samples t-test was used to study the differences between surface and bottom salinity. Spearman, Rho Correlation was performed to indicate relationships between salinity and copepod. All statistical analysis was run on SPSS version 13. Multivariate cluster analysis was conducted on spatial and temporal data of salinity and copepod occurrence data using Multivariate Statistical Package version 3.1 (MVSP).

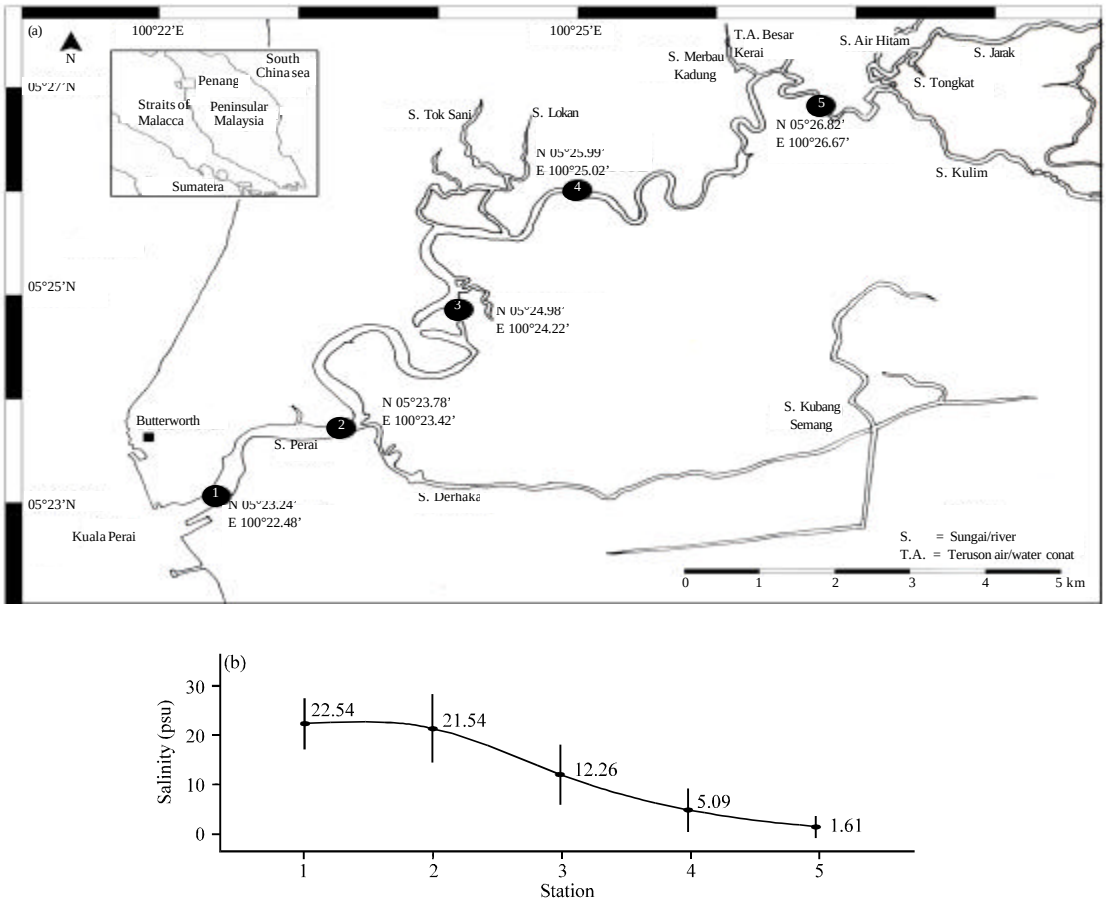

Fig. 1(a-b): (a) Location of study area showing sampling stations (b) Mean river water salinity (psu) according to sampling stations

RESULTS

The distribution of salinity in Perai river estuary is given in Fig. 1. Mean river water salinity from the river mouth (ST1) to the upper region (ST5) was found to range from 22.54 psu (maximum of 34 psu) to 1.61 psu (minimum of 0 psu). Results indicated that seawater moved into the estuary by tidal action to as far as the upper region (ST5) which is located approximately 20 km from the river mouth (ST1). One-way ANOVA showed that there were significant differences in salinity between stations. Paired-sample t-test showed that surface and bottom salinity readings were significantly different. No significant difference was found between months.

A total of 28 species of copepods were recorded from the samples (Table 1). They comprised of 14 families, Paracalanidae, Oithonidae, Corycaeidae, Acartiidae, Calanidae, Centropagidae, Eucalanidae, Pontellidae, Pseudodiaptomidae, Tortanidae, Ectinosomatidae, Euterpinidae, Clausidiidae and Cyclopidae. A total of 17 genera were recorded namely *Acartia*, *Canthocalanus*, *Corycaeus*, *Bestiolina*, *Labidocera*, *Centropages*, *Eucalanus*, *Acrocalanus*, *Parcalanus*, *Pseudodiaptomus*, *Halicyclops*, *Hemicyclops*, *Oithona*, *Microcyclops*, *Euterpina*, *Microsetella* and *Tortanus*.

Cluster analysis on copepod data revealed two groups of salinity regimes (Fig. 2). The Perai river could be separated into two groups (A) euryhaline-polyhaline (16-34 psu) and (B) oligohaline-mesohaline (0-14 psu). The separation of salinity regimes could be explained by the species composition of copepods in the salinity regime. Group A comprised of 25 euryhaline-polyhaline copepod species (marine affiliated) while Group B comprised of 3 oligohaline-mesohaline copepod species (fresh water affiliated).

The relationship between the distributions of copepod species and salinity were tested using Spearman's Rho correlation analysis. All species of copepod were found to be significantly correlated to the salinity gradient. However, the correlation coefficient varies from 0.24-0.82. Among these, eleven species were found having the correlation coefficient higher than 0.60 (Table 2). The copepod species which were correlated positively to salinity were comprised of *Acartia spinicauda*, *Euterpina acutifrons*, *Microsetella norvegica*, *Oithona nana*, *Oithona simplex*, *Paracalanus crassirostris*, *Paracalanus elegans*, *Paracalanus parvus*, *Pseudodiaptomus* sp. and *Hemicyclops* sp. The copepod species *Pseudodiaptomus dauglishi* were negatively correlated with salinity.

Table 1: Copepod species recorded from Perai river estuary

Family	Species
Acartiidae	*Acartia spinicauda*, Mori
Calanidae	*Canthocalanus pauper*, Giesbrecht
Centropagidae	*Centropages dorsipinatus* Thompson and Scott
Corycaeidae	*Corycaeus* (Ditrichocorycaeus) *dahli*, Tanaka
Corycaeidae	*Corycaeus* (Ditrichocorycaeus) *subtilis*, M. Dahl
Corycaeidae	*Corycaeus* (Ditrichocorycaeus) *andrewsi*, Farran
Cyclopidae	*Microcyclops* Claus
Cyclopidae	*Halicyclops* Norman
Clausidiidae	*Hemicyclops* Boeck
Ectinosomatidae	*Microsetella norvegica*, Boeck
Eucalanidae	*Eucalanus subcrassus*, Giesbrecht
Eucalanidae	*Eucalanus subtenuis*, Giesbrecht
Euterpinidae	*Euterpina acutifrons*, Dana
Oithonidae	*Oithona nana*, Giesbrecht
Oithonidae	*Oithona simplex*, Farran
Paracalanidae	*Acrocalanus gibber*, Giesbrecht
Paracalanidae	*Acrocalanus gracilis*, Giesbrecht
Paracalanidae	*Acrocalanus longicornis*, Giesbrecht
Paracalanidae	*Bestiolina similis*, Sewell
Paracalanidae	*Paracalanus crassirostris*, Dahl
Paracalanidae	*Paracalanus denudatus*, Sewell
Paracalanidae	*Paracalanus elegans* and Ronov
Paracalanidae	*Paracalanus parvus*, Claus
Pontellidae	*Labidocera euchaeta*, Giesbrecht
Pseudodiaptomidae	*Pseudodiaptomus* sp.
Pseudodiaptomidae	*Pseudodiaptomus dauglishi* Sewell
Tortanidae	*Tortanus barbatus*, Brady
Tortanidae	*Tortanus forcipatus*, Giesbrecht

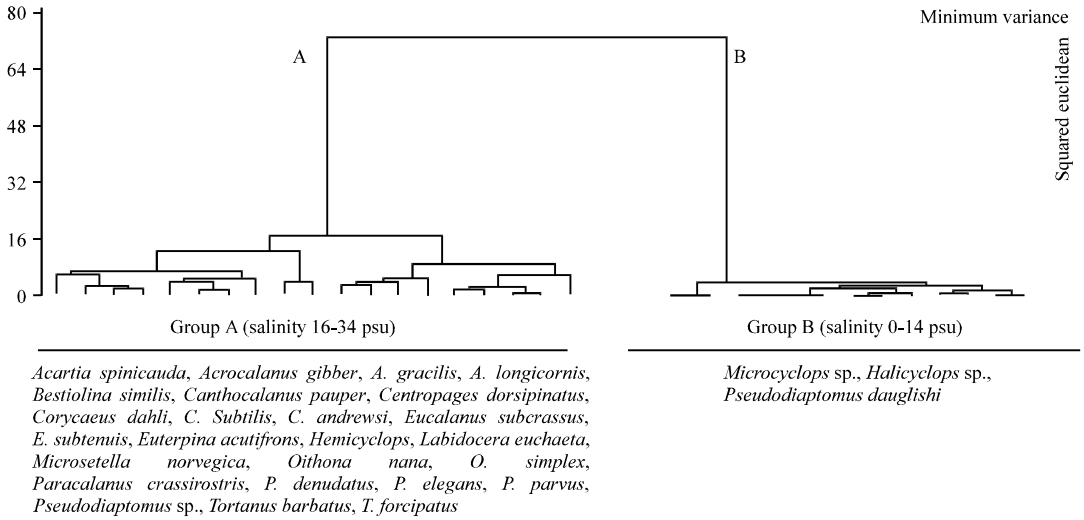

Fig. 2: Classification of copepod assemblages and salinity regimes based on minimum variance clustering and squared Euclidean distance

Table 2: Salinity range, frequency and correlation coefficient of copepod species distribution in Perai river estuary

Species	Salinity range (psu)	Frequency (%)	Spearman's rho correlation coefficient	Salinity regime
Acartia spinicauda	17-34	43	0.76	Euryhaline-Polyhaline
Euterpina acutifrons	14-34	49	0.82	
Microsetella norvegica	14-34	46	0.71	
Oithona nana	17-34	43	0.72	
Oithona simplex	15-34	40	0.62	
Paracalanus crassirostris	11-34	49	0.78	
Paracalanus elegans	15-34	40	0.74	
Paracalanus parvus	15-34	49	0.68	
Pseudodiaptomus sp.	16-34	29	0.64	
Hemicyclops sp.	14-34	26	0.63	
Microcyclops sp.	0-12	37	-0.57	Oligohaline-Mesohaline
Pseudodiaptomus dauglishi	0-7	26	-0.71	

DISCUSSION

The Perai river can be classified as a slightly stratified estuary and is heavily influenced by tidal movements. The Perai river exhibited salinity characteristics similar to definitions by Dyer (1997) where salinity varies along the estuary at any depth, but surface salinity is always lower than bottom salinity. This intrusion of seawater would affect the species composition and distribution of flora and fauna in the river system (Green, 1968). Chang and Fang (2004) found that copepod species, abundance and diversity were high correlated with salinity, where salinity varied according to tidal phases.

The copepod species of Perai river were primarily comprised of a mixture of marine and freshwater affiliated species. Copepod species from the genus *Pseudodiaptomus*, *Acartia*, *Paracalanus*, *Temora* and *Oithona* have been widely reported to be dominant in coastal estuarine waters including mangrove estuaries (Ara, 2004; Krumme and Liang, 2004). Marine affiliated species however, were more numerous representing 25 species out of 28 species of copepods which were correlated with salinity.

Copepod species in group A were positively correlated with salinity while species from B were negatively correlated with salinity. Copepod species group (A) dominated at stations located at the river mouth up to the middle reach of the river (ST1 and ST2). These stations were highly influenced by the intrusion of seawater, thus the species observed here are able to tolerate lower levels of salinity. Salinity at this station never dropped down below 10 psu. Copepod species found here such as *Acartia spinicauda*, *Microsetella norvegica*, *Oithona nana*, *Oithona simplex, Euterpina acutifrons* and *Paracalanus crassirostris* are well reported as the dominant estuarine copepods (Rezai *et al*., 2004; Tam *et al*., 2000). *Paracalanus parvus* has been known to be a dominant tropical copepod species in coastal waters (Nguyen and Truong-Si, 2006; Chang and Fang, 2004; Yahia *et al*., 2004). The copepod species *Acartia spinicauda* have been reported to prefer warmer

water conditions and lower water salinity compared to *Acartia pacifica* in Malaysian coastal waters (Yoshida *et al*., 2006). *E. acutifrons* is a copepod species with the ability to survive in a wider range of salinity (Moreira, 1975; Moreira *et al*., 1982; Turner, 1994).

The middle point of the river (ST3) exhibited fluctuating salinity condition. Salinity varies greatly from 2 psu to 18 psu thus indicating a transition area between freshwater to moderately saline water. The species composition of copepods here reflected this phenomenon. The copepod species that could tolerate such a change in salinity thrives at this station. Species such as *Halicyclops* sp., *Oithona nana* and *Oithona simplex* are characteristically found in inshore and shallow waters. These species were reported to suite low salinity water and dominant in mangrove estuaries (McKinnon and Klumpp, 1997; Nishida, 1985).

Species composition of copepod changes distinctly from the river mouth to the upper reaches as salinity decreased to zero at ST4 and ST5 (group B). At these stations, the composition of copepods were represented by three freshwater affiliated species namely, *Pseudodiaptomus dauglishi*, *Halicyclops* and *Microcyclops*. The copepods species, *Microcyclops* have been reported to be restricted to saline habitats while *Halicyclops* occurred in tidal saline waters of many Malaysian rivers (Fernando and Ponyi, 1981). The occurrence and distribution of *P. dauglishi* in the current study is similar to the findings by Sewell (1933), in which the species was found in an almost pure culture as in the Kurau river, Malaysia.

CONCLUSION

The Perai river estuary is a slightly stratified estuary with strong tidal influences where salinity is a major factor in influencing the spatial distribution of copepod species in the estuary. Two major groups of copepod assemblages can be clearly distinguished representing euryhaline-polyhaline (marine affiliated) and oligohaline-mesohaline (freshwater affiliated) species. A total of 11 species of copepod were found to be significantly correlated with salinity representing 10 marine affiliated species and 1 freshwater affiliated species.

ACKNOWLEDGMENTS

The authors are grateful to the technical staff of Universiti Sains Malaysia, Dr. Amir, Mr. Zarul, Mr. Yaakob and Mr. Hamzah for their assistances in the field works. This research was supported by "RESTORPEAT" No: 304/Pbio/650248/E104 (European Commission Research Grant).

REFERENCES

Abdul-Rahman, S.N., J. Ismail and M. Mansor, 2010. The distribution of riparian corridor plants and the relations to river water salinity along Perai river, Penang, Malaysia. Wetland Sci., 8: 48-56.

Ara, K., 2004. Temporal variability and production of the planktonic copepod community in the Cananeia Lagoon estuarine system, Sao Paulo, Brazil. Zool. Stud., 43: 179-186.

Boxshall, G.A. and S.H. Hasley, 2004. An Introduction to Copepod Diversity. The Ray Society, London, UK., Pages: 966.

Boxshall, G.A., 1979. The Planktonic Copepods of the Northeastern Atlantic Ocean: Harpacticoida, Siphonostomatoida and Mormonilloida. British Museum (Natural History), London, pp: 201-264.

Bradford-Grieve, J.M., 1994. The Marine Fauna of New Zealand: Pelagic Calanoid Copepoda: Megacalanidae, Calanidae, Paracalanidae, Mecynoceridae, Eucalanidae, Spinocalanidae, Clausocalanidae. National Institute of Water and Atmospheric Research (NIWA), New Zealand, ISBN-13: 9780478083330, Pages: 160.

Chang, W.B. and L.S. Fang, 2004. Temporal and spatial variations in the species composition, distribution and abundance of copepods in Kaohsiung Harbor, Taiwan. Zool. Stud., 43: 454-463.

Chua, T.E., 1970. A preliminary study on the plankton of the Ponggol estuary. Hydrobiologia, 35: 252-272.

Chua, T.E., 1973. An ecological study of the Ponggol estuary in Singapore. Hydrobiologia, 43: 505-533.

Dyer, K.R., 1997. Estuaries: A Physical Introduction. 2nd Edn., John Wiley and Sons, New York, USA., ISBN-13: 9780471974703, Pages: 195.

Fernando, C.H. and J.E. Ponyi, 1981. The freeliving freshwater cyclopoid copepoda (crustacea) of Malaysia and Singapore. Hydrobiologia, 78: 113-123.

Green, J., 1968. The Biology of Estuarine Animals. 3rd Edn., Sidgwick and Jackson, London, UK., Pages: 401.

Heron, G.A. and J.M. Bradford-Grieve, 1995. The Marine Fauna of New Zealand: Pelagic Copepoda: Poecilostomatoida: Oncaeidae. New Zealand Oceanographic Institute, New Zealand, ISBN-13: 9780478083507, Pages: 57.

Huys, R., J.M. Gee, C.G. Moore and R. Hamond, 1996. Marine and Brackish Water Harpacticoid Copepods. Linnean Society of London, UK., ISBN-13: 9781851532568, Pages: 352.

Jayasinghe, R.P.P.K., F.M. Yusoff and A. Arshad, 2003. Zooplankton Populations in Tropical Estuaries: A Review. In: Aquatic Resource and Environmental Studies of the Straits of Malacca: Managing the Straits through Science and Technology, Japar Sidik, B., Z. Mutaharah, A. Arshad and A. Kawamura (Eds.). Malacca Straits Research and Development Centre (MASDEC), Universiti Putra Malaysia, Serdang, Malaysia.

Johan, I., B.A.G. Idris, A. Ismail and H. Omar, 2002. Distribution of Planktonic Calanoid Copepods in the Straits of Malacca. In: Tropical Marine Environment: Charting New Strategies for the Millennium, Yusoff, F.M., M. Shariff, H.M. Ibrahim, S.G. Tan and S.Y. Tai (Eds.). (MASDEC). Putra Malaysia, Serdang, Malaysia, pp: 393-407.

Krumme, U. and T.H. Liang, 2004. Tidal-induced changes in a copepod-dominated zooplankton community in a macrotidal mangrove channel in Northern Brazil. Zool. Stud., 43: 404-414.

Kuipers, B.R., H.J. Witte and S.R. Gonzalez, 1993. Zooplankton distribution in the coastal upwelling system along Banic d'Arguin, Mauritia. Hydrobiologia, 258: 133-149.

Matsuo, C. and M. Masaaki, 1997. An Illustrated Guide to Marine Plankton of Japan. Tokai University Press, Tokyo, Japan, pp: 700-1000.

McKinnon, A.D. and D.W. Klumpp, 1997. Mangrove zooplankton of North Queensland, Australia. Hydrobiologia, 362: 145-160.

Moreira, G.S., 1975. Studies on the Salinity Resistance of the Copepod *Euterpina acutifrons* (Dana). In: Physiological Ecology of Estuarine Animals, Vernberg, F.J. (Ed.). University of South Carolina Press, Columbia, pp: 73-79.

Moreira, G.S., J.B. Jillet, W.B. Vernberg and M. Weinrich, 1982. The combine effects of temperature and salinity on the survival of *Euterpina acutifrons* (Dana) (Copepoda, Harpacticoida) from New Zealand and Brazilian coasts. J. Plank. Res., 4: 85-91.

Nasser, A.K.V., P. Siraimeetan and T. Matsumura-Tundisi, 1998. Dynamics of a perturbed estuarine zooplankton community: Port of Suape, PE Brazil. Proc. Int. Assoc. Theor. Applied Limnol., 26: 119-120.

Nguyen, C. and H.T. Truong-Si, 2006. Zooplankton abundance and species diversity in Qui Nhon coastal waters, South Central Vietnam in June 2004. Coast. Mar. Sci., 30: 328-335.

Nishida, S., 1985. Taxonomy and Distribution of the Family Oithonidae (Copepoda, Cyclopoida) in the Pacific and Indian Oceans. Ocean Research Institute, University of Tokyo, Japan, Pages: 167.

Omori, M. and T. Ikeda, 1984. Methods in Zooplankton Ecology. John Wiley and Sons, New York, Pages: 332.

Rezai, H., F.M. Yusof, A. Arshad, A. Kawamura, S. Nishida and B.H.R. Othman, 2004. Spatial and temporal distribution of copepods in the Straits of Malacca. Zoo. Stud., 43: 486-497.

Sewell, R.B.S., 1933. Notes on a small collection of marine Copepoda from Malay States. Bull. Raffles Museum, 8: 25-31.

Tam, P.F., C.K. Wong, Q. Chen, Y. Fu, L. Huang and J. Yin, 2000. Planktonic copepods of the zhujiang estuary, 1991-1996. Proceedings of the International Symposium on Marine Biology in Taiwan, May 26-27, 1998, Taiwan.

Turner, J.T., 1994. Planktonic Copepods of Boston Harbour, Massachusetts Bay and Cape Cod Bay, 1992. In: Ecology and Morphology of Copepods, Ferrari, F.D. and B.P. Bradley (Eds.). Kluwer Academic Publishers, Belgium, pp: 405-413.

Yahia, M.N.D., S. Souissi and O.D. Yahia-Kefi, 2004. Spatial and temporal structure of planktonic copepods in the bay of Tunis (Southwestern Mediterranean Sea). Zool. Stud., 43: 366-375.

Yamaji, I., 1986. The illustrations of the Marine Plankton of Japan. Hoikusha Publishing Co. Ltd., Osaka, Pages: 538.

Yoshida, T., T. Toda, F.M. Yusoff and B.H.R. Othman, 2006. Seasonal variation of zooplankton community in the coastal waters of the Straits of Malacca. Coastal Mar. Sci., 30: 320-327.

Zhong, Z., 1989. Marine Planktology. China Ocean Press, Beijing, Pages: 454.