COMPOSITION AND ABUNDANCE OF ZOOPLANKTON IN THE MERBOK ESTUARY, MALAYSIA IN RELATION TO TIDAL INFLUENCE

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Abstract

Influence of tides on the composition and abundance of zooplankton at three stations along the Merbok estuary, Malaysia was investigated. Arthropoda was the most dominant group followed by Chaetognatha, Mollusca, Annelida, Cnidaria, Nematoda, Rotifera and Chordata. Arthropoda showed the highest relative abundance of zooplankton group at each sampling station during 24 hours observation. Peak zooplankton abundance was found at Station 3 (downstream of the estuary) with the value of 176×10^3 and 230×10^3 ind. /m^3 and lower abundance was observed at Station 1 (upstream of the estuary) with 5.3×10^3 and 3.4×10^3 ind. /m^3during spring and neap tide, respectively. Zooplankton abundance was higher during neap tide compared to spring tide, but higher number of zooplankton species was observed during spring tide in compare to neap tide. Statistical analysis (Kruskal-Wallis H test; Mann-Whitney U test) also showed significant differences among stations, tides (spring and neap), day and night.

Key words: Zooplankton abundance, Merbok estuary, tide

INTRODUCTION

Zooplankton is an important biological component that is always present in most trophic models of aquatic ecosystem (Palomares *et al.* 1993). They play an important role in the pelagic food web as they transfer the organic energy produced by unicellular algae through photosynthesis to higher trophic levels such as pelagic fish stocks (Harris *et al.* 2000). They also play a major role in fish production as the larvae of most fishes feed mainly on zooplankton (Peterson and Ausubel 1984, Singh 2000).

The estuary is influenced by high and low tides. In the estuarine environment the two tides are natural event. These phenomena are caused by the gravitational force of the moon and to a lesser extent, the sun. When the bulges caused by the moon and those caused by the sun are lined up with each other, spring tides appeared, and when lined up oppose each other, causes neap tides (Gianesella *et al.* 2000). Tides have a major influence on the structure and density of zooplankton communities (Robertson *et al.* 1988). Variations in zooplankton composition and abundance are correlated to spring/neap tide alterations and tidal cycles (Villate 1997, Krumme and Liang 2004, da Costa *et al.* 2011, Davies and Ugwumba 2013). Zooplankton is used as bio-indicator assessing the health of estuarine ecosystem and zooplankton is one of the most important components of estuarine food web. Therefore, to protect natural setting of zooplankton composition, the study was undertaken to observe the impacts of natural event like tides (spring and neap) on zooplankton composition and abundance. This was aimed for better understanding of diurnal variation in tropical estuarine environment.

MATERIAL AND METHODS

Zooplankton samples were collected during the time period of four weeks (12th November to 3rd December, 2011). There were four samplings in each week of the duration. The samplings were made at six hours of interval. Station 1 (St 1, upstream), Station 2 (St 2, middle stream) and Station 3 (St 3, downstream) were selected to observe the effects of tidal and diurnal events on zooplankton abundance. In the present study, 7.00 am to 7.30 pm time-period was considered as sampling day- time. The remaining hours were night- time for the sampling as a whole. The study-stations are shown in Fig. 1.

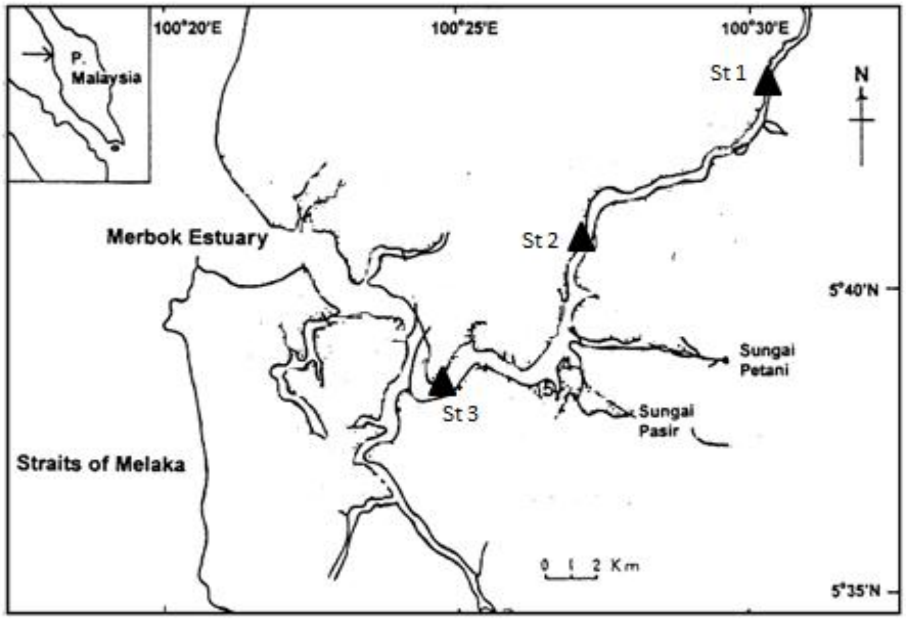

Fig. 1. Location of sampling stations of Merbok estuary, Penang, Malaysia

Zooplankton samples were taken from a few centimeter from the surface water by horizontal towing of plankton net (0.13 m in diameter), made up of bolting silk (mesh size 150μm) for 18 minutes. Three tows were made for each sampling station. For each tow, the filtered water volume (m^3) was measured using mouth area of the net and distance of towing. Then zooplankton samples were collected from the cod end by washing and dipping the net up and down in the sample water without submerging the mouth as a quick rinse down against current. Samples were immediately preserved in 4% buffered formalin.

Formula used for calculation of filtered water volume is $\mathbf{V= \pi r^2 L}$

Where, V= volume of water towed, r = radius of plankton net, L= distance of towing.

Zooplankton were identified to major taxonomic groups following Wickstead (1965), Arvin (1977), Harris *et al.* (2000), and counted in a Bogarov tray under a dissecting microscope. Density of the zooplankton from the subsample was standardized into the number of individuals per cubic meter (ind. /m^3) according to the following formula (Postel *et al.* 2000): N = n S/w Where, N = density of individual (ind. /m^3), n = the number of individuals in the sub-sample, S = the fraction of the subsample, w= volume of water filtered (m^3).

Nonparametric analysis (Kruskal-Wallis H test) was used to show significant differences among sampling stations. Significant differences of zooplankton density between spring and neap tide were determined using the Mann-Whitney U test. The same test was also used to determine significant differences of zooplankton density between day and night.

RESULTS AND DISCUSSION

The relative abundance of zooplankton group at each sampling station during 24 hours observation is shown in Table 1. Arthropoda showed the highest relative abundance at all sampling stations (97.54%, 96.16% and 97.86% at Stations 1, 2 and 3, respectively). At St 1, Arthropoda dominated with 97.54% of the relative abundance, followed by Mollusca (0.638%), Protozoa (0.544%), Rotifera (0.260%), Annelida (0.225%), Chordata (0.118%), Chaetognatha (0.106%), Nematoda (0.095%), Cnidaria (0.012%) and others (0.461%). At St 2, Arthropoda contributed 96.16% of the relative abundance, followed by Nematoda (1.1%), Mollusca (1.03%), Chaetognatha (0.75%), Protozoa (0.40%), Chordata (0.20%), Annelida (0.13%), Cnidaria (0.02%), Rotifera (0.02%) and others (0.19%). Arthropoda was the dominant group which contributed 97.54% of relative abundance, followed by Chaetognatha (0.946%), Protozoa (0.439%), Mollusca (0.33%), Chordata (0.149%), Annelida (0.06%), Cnidaria (0.04%), Nematoda (0.02%), Rotifera (0.012%) and others (0.141%) at St 3.

Table 1. Relative abundance of zooplankton phyla during 24- hour observation in the Merbok estuary in November-December, 2011

Zooplankton	Relative abundance (%)		
	St 1	St 2	St 3
Arthropoda	97.54	96.16	97.86
Chaetognatha	0.638	1.03	0.946
Protozoa	0.106	0.75	0.439
Mollusca	0.544	0.4	0.33
Annelida	0.095	0.13	0.06
Cnidaria	0.26	0.02	0.04
Nematoda	0.225	1.1	0.02
Rotifera	0.012	0.02	0.012
Chordata	0.118	0.2	0.149
Others	0.461	0.19	0.141

Zooplankton abundance was higher during neap tide compared to spring tide (Fig. 2). During spring and neap tides, peak abundance was found at St 3 with the values of 176×10^3 and 230×10^3 ind. /m^3, respectively at high tide. Lower abundance was observed at St 1 with 5.3×10^3 and 3.4×10^3 ind. /m^3 at low and high tide, respectively. Kruskal-Wallis H test showed that zooplankton abundance was significantly different ($p<0.05$) among the stations. Mann-Whitney U test found that zooplankton abundance was significant ($p<0.05$) between spring and neap tides; day and night.

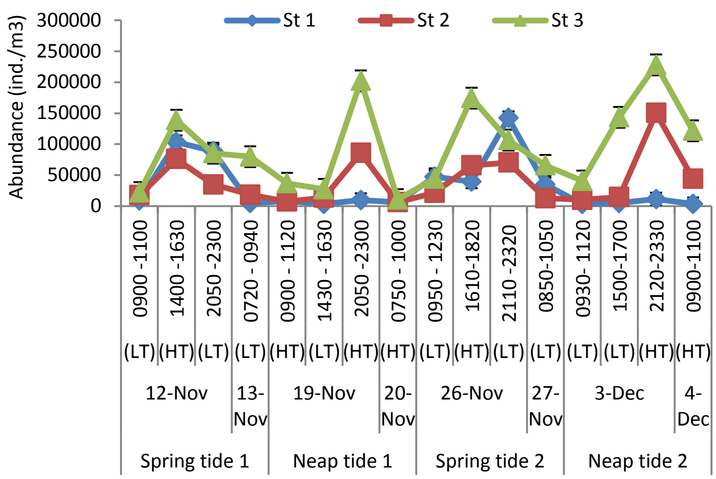

Fig. 2. Zooplankton abundance at all three stations in the Merbok estuary during 24 - hour observation (n=144)

Descriptions of different zooplankton groups in the Merbok estuary during the study period are given below-

Arthropoda

The average relative abundance of Arthropoda at all three sampling stations during the 24 hour period was 97.38%. Arthropoda was mainly represented by the orders Calanoida, Cyclopoida, Harpacticoida copepod, copepod (nauplius and copepodid stages) and cirripede larvae. Calanoida, Cyclopoida, and Harpacticoida contributed 83.46%, 0.220% and 0.170%, respectively of relative abundance, whereas, the relative abundance of copepod and cirripede larvae were 10.83% and 1.16%, respectively. Calanoid showed significant differences in abundance ($p<0.001$) while, cyclopoid, harpacticoid, copepodid and nauplius were insignicant ($p>0.05$) between day and night time and spatial distribution.

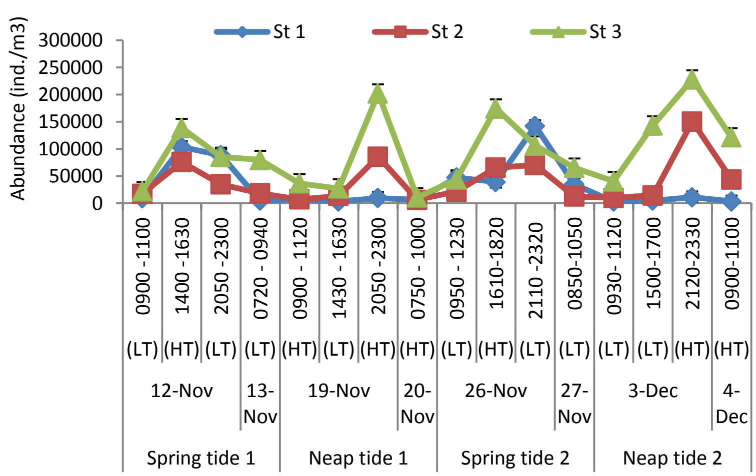

Fig. 3. Abundance of Arthropoda at all sampling stations in Merbok estuary during 24- hour observation (n =144); LT=Low tide, HT=High tide.

Variation in Calanoid and copepodid abundance was insignificant (p>0.05), but in cyclopoid, harpacticoid, nauplius and cirripede nauplius was significant (p<0.001) between spring and neap tides. Decapod and decapod larvae (*Lucifer* sp. carridean larva, brachyuran larva) also accounted for 1.06% of relative abundance. *Lucifer* sp. and carridean larvae showed significant differences in abundance (p<0.05) but abundance of brachyuran larvae was insignificant (p>0.05) between day and night times. Abundance of decapod and decapod larvae was insignificant (p>0.05) spatially. Carridean larvae showed significant differences (p<0.05) in abundance between spring and neap tides while, amphipod and *Lucifer* sp. were insignificant (p>0.05). Abundance of amphipods and ostracods (*Cypris* sp., *Moina* sp., *Penilia* sp.) occurred in the samples with small relative abundance of 0.138% and 0.331%, respectively. Amphipod and *Moina* sp. abundance were significantly different (p<0.001) meanwhile *Cypris* sp. and *Penilia* sp. were insignificant between day and night times. Ostracod showed significant differences (p<0.05) in abundance between spring and neap tides. The abundance of phylum Arthropoda at all sampling stations during 24 hours observation in the Merbok River estuary are shown in Fig. 3. The highest abundance (228× 10^3 and 174× 10^3 ind. /m^3) was recorded during high tide at St 3 while, the lowest abundance (3.1× 10^3 and 4.7× 10^3 ind. /m^3) was recorded during low tide at St 1 during neap and spring tides, respectively (Mann-Whitney U test; p>0.05).

Mollusca

Gastropod and bivalve larvae under the phylum Mollusca (Table 2) accounted for 0.268% and 0.275%, respectively of the relative abundance only. Mann Whitney U test result showed that there was a significant difference (p<0.001) in gastropod abundance between day and night, but abundance was insignificant in bivalve larvae. This test also showed that the gastropod and bivalve larvae showed significant differences (p<0.001) in abundance between spring and neap tides.

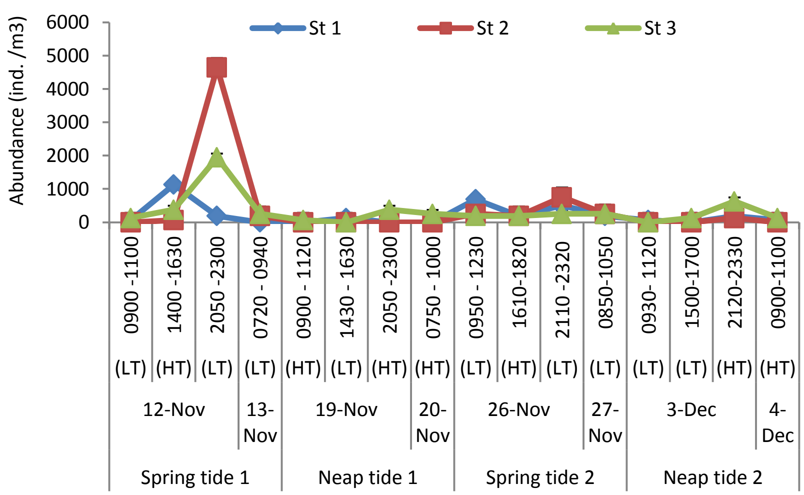

Fig. 4. Abundance of Mollusca at all sampling stations in the Merbok estuary during 24 - hour observation (n = 144); LT=Low tide, HT=High tide.

During spring tide, highest molluscan abundance (4.6× 10^3 ind. /m^3) was found at St 2 whereas at neap tide its highest abundance (0.6× 10^3 ind. /m^3) was observed at St 3. On the other hand, lowest abundance (63 ind. /m^3) was found at St 1 during both tides (Fig. 4). Molluscan abundance was higher in spring tide compared to neap tide. Kruskal-Wallis H test showed that gastropod and bivalve larval abundance were insignificant (p>0.05) spatially.

Chaetognatha

Chaetognatha mainly consisted of *Sagitta* spp. and accounted for 0.774% of the total relative abundance (Table 2). During spring and neap tide Chaetognatha abundance varied from 63 to 1947 ind. /m^3 and 63 to 2638 ind. /m^3, respectively (Fig. 5). The higher abundance was observed at St 3 and lower at St 1 and 2. Chaetognatha abundance was higher during neap tide compared to spring tide. Mann-Whitney U test result showed that abundance of chaetognaths was insignificant (p>0.05) between day and night time; spring and neap tide. Kruskal-Wallis H test showed that the Chaetognatha abundance was significant (p<0.001) spatially.

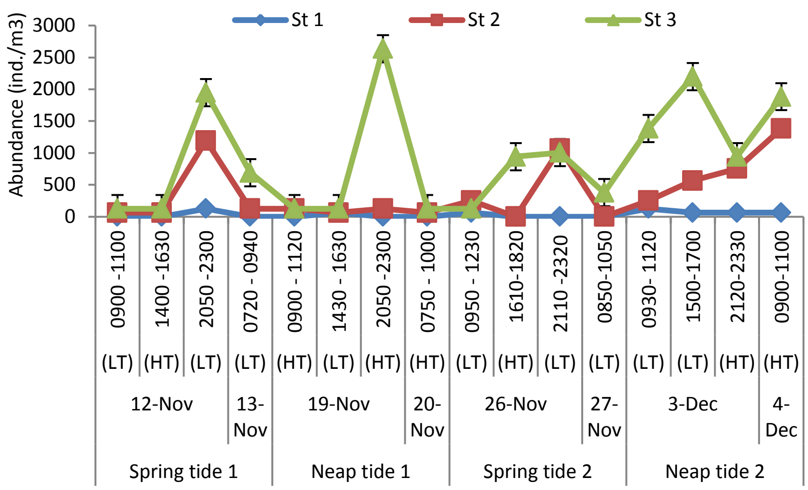

Fig. 5. The members of Chaetognatha at all sampling stations in the Merbok estuary (n=144); LT=Low tide, HT=High tide.

Protozoa

Protozoa was represented by *Tintinnida* species and contributed 0.461% of the relative abundance. Protozoan abundance abruptly increased on the 3rd of December (1500-1700 hr) at St 3 during neap tide (Fig. 6).

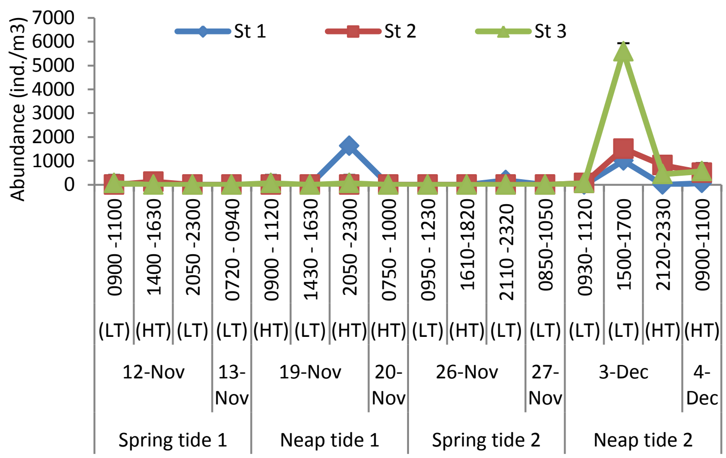

Fig. 6. Abundance of protozoans at all sampling stations in the Merbok estuary (n=144); LT=Low tide, HT=High tide.

The other two stations did not show any remarkable variation. Kruskal-Wallis H test showed that protozoans abundance were insignificant (p>0.05) between day and night, and spatial occurance. Mann - Whitney U test result showed that there were significant differences (p<0.001) between the abundance during spring and neap tide.

Cnidarians

Cnidarians contributed 0.030% of the relative abundance. The highest abundance was found at St 3 (188 ind. /m^3) during spring tide (Fig. 7). Abundance was greater during spring tide compared to neap tide. Kruskal-Wallis H test showed that cnidarians abundance was significantly different (p<0.05) spatially. Mann-Whitney U test results showed that cnidarians abundance was insignificant (p>0.05) between spring and neap tide; and between day and night.

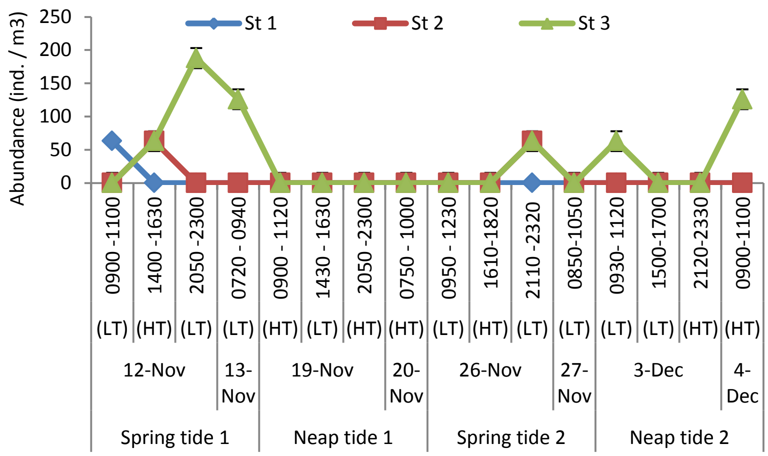

Fig. 7. The members of Cnidaria at all sampling stations in the Merbok estuary (n=144); LT=Low tide, HT=High tide.

Annelida

Annelida was represented by polychaetes and contributed 0.107% of the relative abundance. There was no remarkable variation in annelid abundance among the stations.

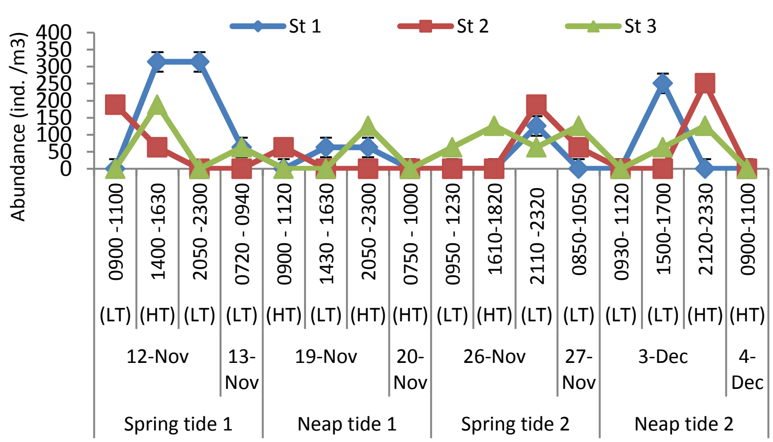

Fig. 8. The members of Annelida at all sampling stations in the Merbok estuary (n=144); LT=Low tide, HT=High tide.

During spring tide, higher abundance (314 ind. /m^3) was recorded at St 1. St 1 and 3 showed higher abundance (251 ind. /m^3) during neap tide (Fig. 8). Mann-Whitney U test result showed that variation in annelid abundance was insignificant (p>0.05) between spring and neap tide, but was significant (p<0.05) between day and night time. Kruskal-Wallis H test showed that the difference in annelid abundance was insignificant (p>0.05) spatially.

Nematoda

Nematoda contributed 0.279% of the relative abundance. St 2 showed high abundance during spring and neap tides compared to other two stations (Fig. 9). Kruskal-Wallis H test showed that nematoda abundance was insignificant (p>0.05) spatially. Nematoda abundance was insignificant (Mann-Whitney U test; p>0.05) between spring and neap tides; day and night time.

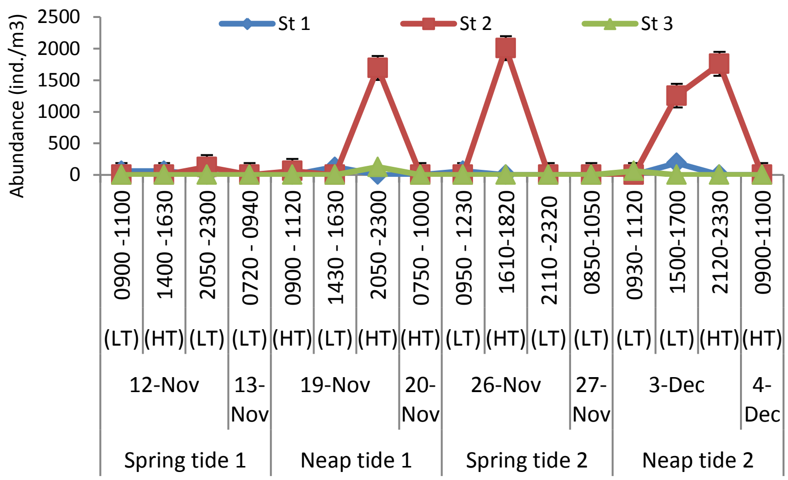

Fig. 9. The members of Nematoda at all sampling stations in the Merbok estuary (n=144); LT=Low tide, HT=High tide.

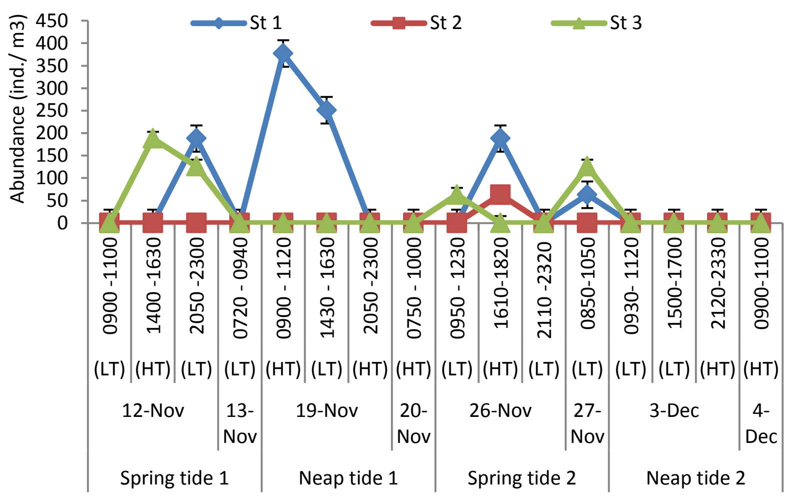

Fig.10. The members of Rotifera at all sampling stations in the Merbok estuary (n=144); LT=Low tide, HT=High tide.

Rotifera

Rotifera contributed 0.061% of the relative abundance. Station 1 showed significant variation in abundance of rotifer compared with other two stations during spring and neap tides (Fig.10). Kruskal Wallis H test showed that the difference in rotifera abundance was insignificant ($p>0.05$) spatially. Mann Whitney U test showed that rotifera abundance was insignificant ($p>0.05$) between day and night, but was significant ($p<0.01$) between spring and neap tides.

Chordata

Phylum Chordata composed of *Oikopleura* sp. and fish larvae contributing 0.070 and 0.082% of the relative abundance, respectively. Higher abundance (377 ind. /m^3) of chordata was found at St 2 and 3 during spring tide while at St 2, higher abundance (314 ind. /m^3) was recorded during neap tide (Fig. 11). Kruskal-Wallis H test showed that the difference in fish larvae abundance was insignificant ($p>0.05$), but *Oikopleura* sp. was significant ($p<0.001$) spatially. Mann-Whitney U test showed that there were no significant differences between spring and neap tides; day and night time.

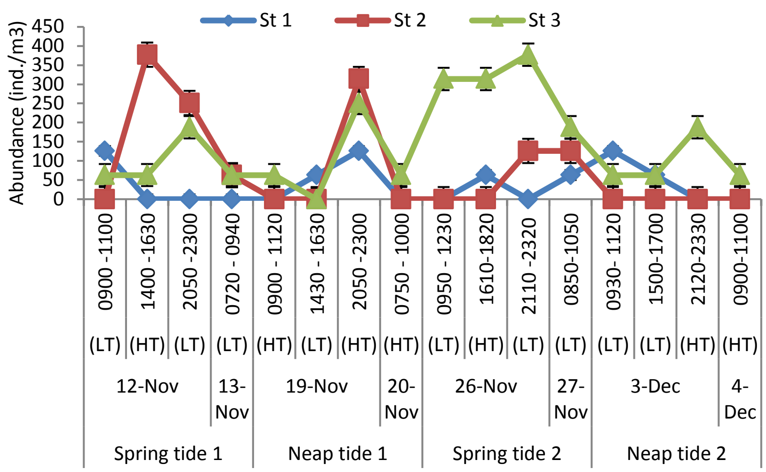

Fig. 11. The members of the Chordata at all sampling stations in the Merbok estuary (n=144); LT=Low tide, HT=High tide.

Other organisms

A group of other organisms was represented by larvae and aquatic adult insects which contributed 0.21% of relative abundance. Kruskal - Wallis H test showed that larva and insects abundance were insignificant ($p>0.05$) spatially. Mann Whitney U test showed that insect abundance was significant ($p<0.05$), but larva and echinoderm abundance was insignificant ($p>0.05$) between spring and neap tides. During spring tide, St 1, 2 and 3 recorded 20, 21 and 18 zooplankton species, respectively; whereas, total 26 species were identified. On the other hand, St 1, 2 and 3 recorded 18, 15 and 17 species, respectively during neap tide (Table 2). During spring tide higher zooplankton species were observed in comparison with neap tide. Cnidarian and nauplius were found only during spring tide while, *Moina* sp. was observed during neap tide. Tidal cycles had significant effects on the zooplankton density, composition and distribution.

Previous studies by Robertson *et al.* (1988) (in mangrove and other near shore habitats in tropical Australia) and Wang *et al.* (1995) (in a megatidal estuary Seine, eastern English Channel) observed higher zooplankton abundance at high tide than that of low tide. Present study showed that copepod abundance was higher in neap tide compared with spring tide. This might be due to influence of tide and diurnal vertical migration behavior of copepods. Previous study also reported the peak abundance of copepods at low tide and lowest at high tide (Krumme and Liang 2004, Villate 1997).

Table 2. The occurrence of zooplankton species at Stations 1, 2 and 3 during spring and neap tide.

Group	Category	Spring tide			Neap tide		
		St 1	St 2	St 3	St 1	St 2	St 3
Arthropoda	Calanoida	+	+	+	+	+	+
	Cyclopoid	+	+	+	+	+	+
	Harpacticoid	+	+	+	+	+	+
	Copepodid larvae	+	+	+	+	+	+
	Nauplius	+	+	+	-	-	-
	Cirripede larvae	+	+	+	+	+	+
	Amphipode	+	+	+	+	+	+
	Brachyuran larva	+	+	+	+	+	+
	Lucifer sp.	+	+	-	-	+	+
	Carridean larva	-	+	-	-	+	-
Ostracoda	Cirripedecypris	-	-	+	-	-	-
	Moina	-	-	-	+	+	+
Cladocera	*Penilia* sp.	+	-	-	+	-	-
Mollusca	Gastropod	+	+	+	-	-	+
	Bivalve	+	+	+	+	-	+
Chaetognatha	*Sagitta* sp.	+	+	+	+	+	+
Chordata Pisces	Fish larva	+	+	+	+	+	+
Larvacea	*Oikopleura* sp.	-	+	+	-	-	+
Annelida	Polychaete worm larvae	+	+	+	+	+	+
Cnidaria	Cnidarian	+	+	+	-	-	-
Rotifera	Rotifer	+	+	-	+	-	-
Nematoda	Nematod	+	+	-	+	+	+
Protozoa	Tintinnids	-	+	+	+	-	+
Others	Insects	+	-	-	+	+	-
	Larva	+	+	+	+	-	-

Sign: +: Present, - : Absent

The zooplankton abundance of the estuarine water varied among St 1 (upstream), St 2 (midstream) and St 3 (downstream) with the tidal variation (i.e. spring and neap tides). The present study revealed that zooplankton community was represented by Arthropoda, Protozoa, Chaetognata, Mollusca, Annelida, Cnidaria, Nematoda, Rotifera and Chordata. The abundance of Arthropoda was higher at downstream during high tide. This might be due to the high inflow of water from the sea containing estuarine zooplankton. Davies and Ugwumba (2013) also observed the higher densities of copepoda, cladocera, ostracoda and euphasiacea at high tide. Arthropoda and Chaetognatha abundance was higher during neap tide compared to spring tide. Mollusca, Cnidaria and Chordata abundance were higher in spring tide compared with neap tide. The highest Mollusca abundance was found at midstream during low tide. The highest cnidarian abundance was recorded at downstream during low tide. It might be due to retention mechanism, i.e. in the high settlement during low tide whereas low settlement during strong flow. Previous study by Krumme and Liang (2004) and Villate (1997) also supported these findings. The highest abundance of Chordata was found at midstream and downstream. During spring and neap tides, the higher abundance of Annelida and Rotifera were observed at the upper zone of the river system and Nematoda abundance was higher in the midstream. Other study also found that zooplankton community was related to the spring or neap tide (Krumme and Liang 2004).

This study revealed that tide affected the zooplankton community of the Merbok estuary in terms of abundance and composition. Arthropodial zooplanktons were in dominating group. It was represented by calanoid copepods. This study also showed that neap tide had higher total number of zooplankton, but spring tide had higher zooplankton diversity in comparison with neap tide. Finally, it may be concluded that zooplankton population varied according to tidal events.

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