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Composition, Abundance and Seasonality of Zooplankton in Mida Creek, Kenya

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Key words: zooplankton, phytoplankton, composition, abundance, diversity, Mida creek, Kenya.

***Abstract*—**Samples were collected monthly at four fixed stations in Mida creek from May 1996 to April 1997, in order to determine the species composition, abundance and diversity of phytoplankton and zooplankton collected with 20- and 332-µm mesh size plankton nets respectively. Sampling also included measurement of salinity and temperature.
Peaks in phytoplankton abundance occurred in May and January, following the long rains in April–May and the short rains in November–December. Zooplankton densities followed the phytoplankton peaks with the main peak occurring in February after the major phytoplankton bloom. Similarly, smaller peaks occurred in May and March.

Copepods dominated the zooplankton forming up to 60% of total species composition. High zooplankton diversity occurred in June–July when zooplankton abundance was lowest as compared to February–March. Spatially, the highest diversity was recorded at station 1 located towards the open sea as compared to the other stations located farther inshore.

INTRODUCTION

Information on the marine zooplankton of the Eastern Coast of Africa is scanty, except for the works of Sewell (1929, 1932, 1947, 1948) and Smith and Lane (1981) who worked in the western Indian Ocean and did not include inshore waters. Wickstead (1961, 1962 &1965) studied tropical plankton, while Okera (1974) reported on the inshore zooplankton of Tanzanian waters, and Paula et al. (1998) studied the seasonal cycle of planktonic communities at Inhaca Island in Southern Mozambique. In Kenya, zooplankton species composition, abundance and diversity have been documented for Port Reitz, Tudor creek and Gazi bay, by Reay & Kimaro (1984), Kimaro (1986), Okemwa & Revis (1986), Revis (1988), Kimaro & Jaccarini (1989), Okemwa (1989), Okemwa (1990), Osore (1992, 1994; Osore et al., 1997), Mwaluma (1993) and Kasyi (1994). Mwaluma (1997) documented offshore zooplankton during the Netherlands Indian Ocean Expedition.

This paper presents the results of the spatial and temporal variability in species composition, abundance and diversity of zooplankton in Mida creek, Kenya.

MATERIALS AND METHODS

Study site

Mida Creek (Fig. 1) is located at the north coast of Kenya in East Africa (03°22' S and 39°58' E). The total creek area including that covered by mangroves is 32 km^2. There is no river drainage into the creek but groundwater enters through seepage along the shores and within the channel bed (Kitheka et al., 1999). In addition to ground water there is also surface runoff inflow during rainy seasons. The dominant water circulation is tidal with a maximum tidal range of 3.2 m at the entrance and 2.0 m in the mid-section of the creek

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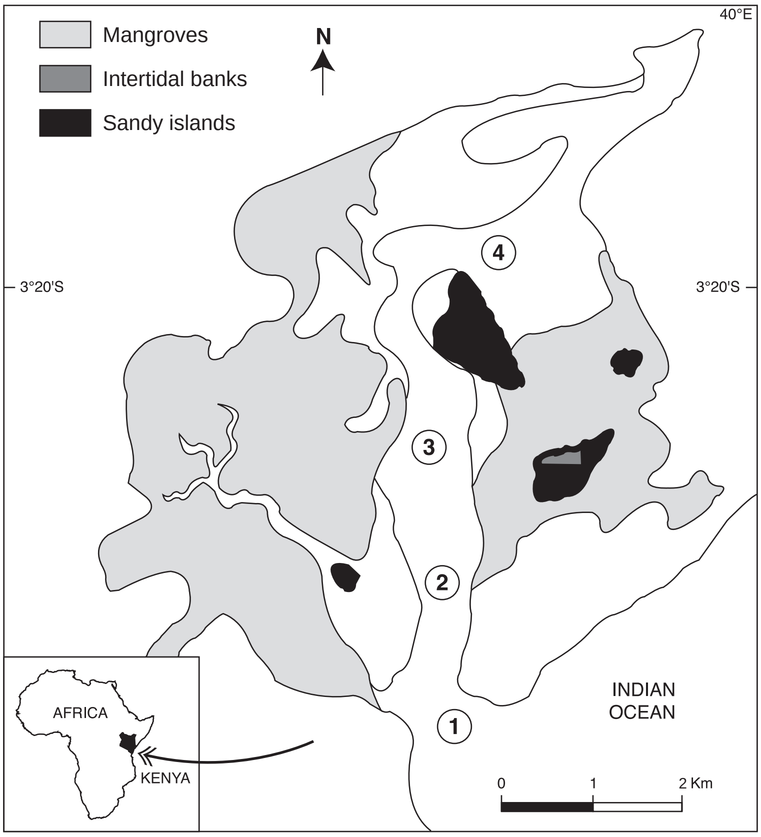

Fig. 1. Location of Mida creek in Kenya, and the sampling stations 1–4 located in the main Mida creek channel

(Kitheka et al., 1999). The dominant climatic seasons are the southeast monsoon (March–September) and the northeast monsoon (September-March). Annual rainfall is normally 600–1000 mm (G.O.K, 1989), with the highest monthly rainfall normally recorded in May. The evaporation rate is on average 200mm per year with a monthly range of 160–210 mm. Air temperature ranges between 24^{o} C in July and 32^{o} C in February. Mida creek forms an important nature conservation site, as it is part of the Watamu Marine National Park and Reserve under the management of Kenya Wildlife Service.

In order to obtain a comparative account of zooplankton from the different biotopes, four stations were established in April 1996, approximately 2 km apart beginning at the mouth of the creek to the backwaters (Fig. 1).

Phytoplankton

Population estimates of surface micro-phytoplankton were conducted monthly at stations 1, 3 and 4 (Fig. 1). Water samples were collected using a Niskin vertical sampler and sieved through a 20 mm plankton net. In the laboratory, phytoplankton cells were counted and estimated as number of cells/l after concentrating the sample and taking 1 ml aliquots of the concentrate in a Sedgwick rafter cell.

Zooplankton

Zooplankton samples were collected monthly from May 1996 to April 1997. Towing for zooplankton was done using a rubber dingy at constant speed of 0.5 m/s during high tide, using a 1.5-metre-long Bongo net, with a mouth diameter of 45 cm and 332 mm mesh size. The volume of water flowing through the net was measured on a digital

Hydrobios flow meter. At each station, environmental variables such as salinity and temperature were determined. Salinity was measured using an Artago hand refractometer and temperature using a mercury thermometer. Collected samples were preserved in 5% buffered formalin for further analysis. In the laboratory, samples were sorted out into different taxonomic groups, identified to the lowest taxa possible and counted under a stereomicroscope after subsampling. The keys and identification references used were obtained from Giesbrecht (1892), Sars (1901), Scott (1909), Sewell (1929, 1932, 1947, 1948), Wickstead (1965, 1976) and Owre & Foyo (1967), Species diversity was calculated using the Shannon-Weiner diversity index, H (Shannon & Weiner, 1963).

RESULTS

Hydrographic parameters

The highest mean surface water temperature recorded was 31.0 ± 0.5 ºC in March 1997 during the dry northeast monsoon season, and the lowest temperature was 24.6 ± 0.1º C, recorded in July 1996, during the wet southeast monsoon season (Fig. 2). Salinity was similarly highest during the dry spell in February with a mean of 37.3 and lowest in May during the rainy season with a mean of 32.0 ± 3.2 ‰ (Fig. 2). During this season however, salinity in the inner creek stations 3 and 4 was lower (27.8–31.4 ‰) than that in the outer stations 1 and 2 (34.5 ‰) due to increased ground water influence and surface runoff.

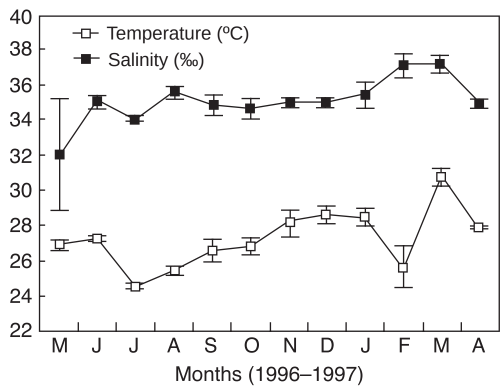

Fig. 2. Monthly variation of temperature (ºC) and salinity (‰) in Mida creek.

Phytoplankton abundance

Two peaks in total phytoplankton abundance were observed (Fig. 3). The highest peak was 68,515 cells/l in May 1996 during the long rains, and the other was 65,260 cells/l observed in January 1997 during the dry spell. Two phytoplankton species that were associated with these peaks were *Chaetoceros* spp. (Bacillariophyta) and *Chroccocus limneticus* (Cyanophyta) for May and January respectively.

Zooplankton abundance

Monthly average abundance of zooplankton varied considerably (Fig. 4). A significantly (P = 0.125) higher abundance of zooplankton was found during the NE monsoon (September–March) compared to

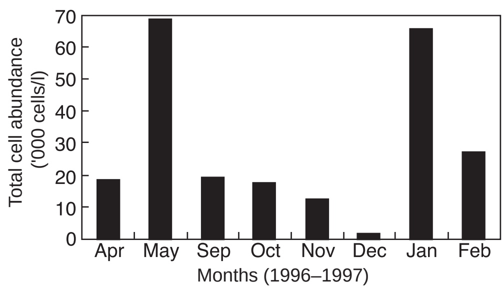

Fig. 3. Total abundance of phytoplankton (10^3 cells/l) in Mida creek

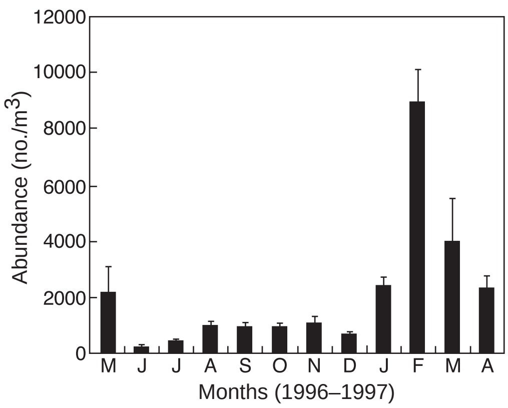

Fig. 4. Mean zooplankton abundance (No./m^3) in Mida creek

the SE monsoon (March–September) period.

Peak zooplankton abundance occurred in February 1997, while the lowest abundance was recorded in June 1996 during the cooler intermonsoon period (Fig. 4). Other peaks were recorded in May 1996, March and April 1997 respectively during the rainy season.

Species composition and diversity

Twenty-seven major zooplankton groups were identified. The dominant groups are shown in Fig. 5. Other groups were Decapoda, including Brachyuran zoea and megalopae, Siphonophora, Euphausiscea, Mysiidacea, Stomatopoda, Amphipoda, Isopoda, Ostracoda, Appendicularia, Sergestidae, Cumacea, Polychaeta, Cirripaedia, Bryozoa, Nematoda, Arachnida and Salpa.

Copepoda dominated zooplankton in abundance throughout the year, forming 35–60% of total zooplankton composition (Fig. 5). Other dominant zooplankton groups, in order of abundance, were Brachyuran zoea (forming between 10–40%), Mollusca larvae, Medusae, Chaetognatha, Foraminifera, Caridea larvae and Pisces (fish eggs and larvae).

Copepoda

The most dominant copepod species were *Acartia* spp., *Eucalanus* spp., *Paracalanus* spp., *Temora turbinata* and *Corycaeus* spp. In general, copepod species flourished at different seasons of the year. Most notable was *Acartia* spp., which had peak density of 1452/m^3 in May during the rainy season and *Eucalanus* spp. which thrived best in February during the dry season with a peak abundance of 952/m^3. Cyclopoida were represented by *Oithona* spp. *Oncaea venusta*, *Corycaeus* spp., *Sapphirina* spp., *Saphirella* spp., *Porcellidium* spp. and *Peltidium* spp. Harpacticoids were represented mainly by *Methis ignea* and *Setella gracilis*.

Brachyuran zoea

Brachyuran zoea occurred throughout the year, but had maximum abundance (40% of total zooplankton) in March during the dry season. They were represented by the families Ocypodidae, Portunidae, Porcellanidae, Grapsidae, Xanthidae, Pimnotheridae, Majidae, Callapidae, Leucosiidae, Hymnosomatidae and others. Amongst the most dominant species were *Dotilla fenestrata*, *Uca vocans*, *U. annulipes*, *Macrophthalmus* spp., *Perisesarma guttatum*, Sesarmidae (n.d.) and *Phylira* spp.

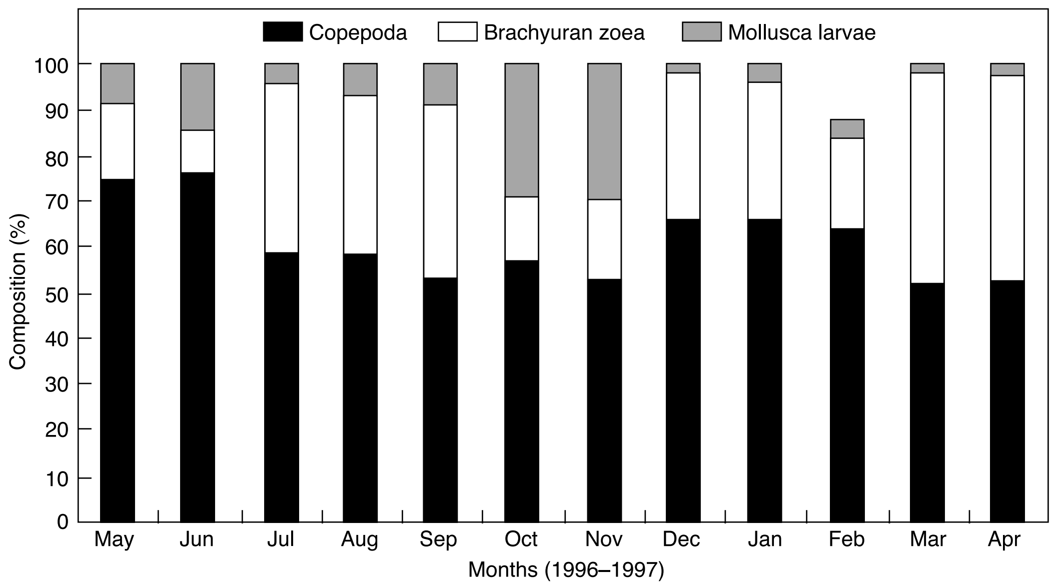

Fig. 5. Percentage composition of dominant zooplankton groups in Mida creek

Other families

The mollusca were represented by gastropod larvae and bivalve larvae, heteropods, pteropods, and cephalopod larvae. Medusae were common throughout the year except in June; the highest occurrence was in May during the rainy season. Chaetognatha were found throughout the year, represented mainly by *Sagitta* spp. mainly during the dry period in February. Foraminifera were present throughout the year except in September. Peak abundance occurred in February during the dry season, represented mainly by *Globigerina* spp. Caridea larvae were found throughout the year. Peak abundance occurred in February during the dry season. Fish eggs and larvae occurred throughout the year, but had peak abundance in January (Fig. 5).

Statistical analysis

A Pearson product correlation matrix was calculated in order to determine whether any relationship existed between dominant copepod species and other zooplankton groups. The output is presented in Table 1. From the correlation values (r) obtained, *Paracalanus* spp. was found to be significantly positively correlated to *Eucalanus* spp., Mollusca larvae, Caridea larvae, Chaetognatha, Pisces, Brachyuran zoea and Foraminifera. *Paracalanus* spp. was, however, negatively correlated with *Acartia* spp. and Medusae. Similarly, abundance of *Eucalanus* spp. was significantly positively correlated to Mollusca larvae, Caridea larvae, Chaetognatha, Pisces, Brachyuran zoea and Foraminifera. *Eucalanus* spp. was negatively correlated to *Acartia* spp. and Medusae. *Acartia* spp. was significantly correlated to abundance of Medusae and negatively correlated to *Temora turbinata*, Mollusca larvae, Caridea larvae and Foraminifera. *Temora turbinata* was negatively correlated with Brachyuran zoea, whereas Medusae was negatively correlated with Mollusca, Caridea, Pisces and Foraminifera. Correlation between Mollusca larvae and Caridea larvae, Chaetognatha, Pisces, Brachyuran zoea and Foraminifera was significantly positive. Caridea larvae were positively correlated to Chaetognatha, Pisces, Brachyuran zoea and Foraminifera.

Mean zooplankton diversity was found to be inversely related to zooplankton abundance (Fig. 6a). High zooplankton diversity was observed between June and July. Peak diversity occurred in July followed by June 1996, this being the period with the lowest zooplankton abundance. Between August 1996 and February 1997, diversity was low (Fig. 6a). During this period however, zooplankton abundance was high, especially in February–March 1997. Mean zooplankton diversity declined from the creek mouth (station 1) to the upper reaches of the creek (Fig. 6b).

Table 1. Correlation coefficients between the abundance of major copepod species and dominant zooplankton groups at Mida creek

	Pa	E	A	T	Me	Mo	Ca	Ch	Pi	B	F
Pa	1.000										
E	*0.996	1.000									
A	-0.103	-0.087	1.000								
T	0.217	0.213	-0.131	1.000							
Me	-0.193	-0.181	*0.812	0.176	1.000						
Mo	*0.962	*0.972	-0.121	0.256	-0.173	1.000					
Ca	*0.994	*0.999	-0.076	0.211	-0.176	*0.969	1.000				
Ch	*0.968	*0.965	0.114	0.227	0.000	*0.929	*0.963	1.000			
Pi	*0.644	*0.625	0.206	0.419	-0.007	*0.584	*0.631	*0.666	1.000		
B	*0.510	*0.539	0.259	-0.045	0.095	*0.520	*0.561	0.468	0.426	1.000	
F	*0.995	*0.998	-0.067	0.231	-0.178	*0.971	*0.997	*0.967	*0.674	*0.544	1.000

Pa, *Paracalanus* spp.; E, *Eucalanus* spp.; A, *Acartia* spp., T, *Temora turbinata*; Me, Medusae; Mo, Mollusca; Ca, Caridea; Ch., Chaetognatha; Pi, Pisces; B, Brachyuran larvae; F, Foraminifera.
Marked correlations(*) are significant at $P < 0.05$. N=12 (Casewise deletion of missing data).

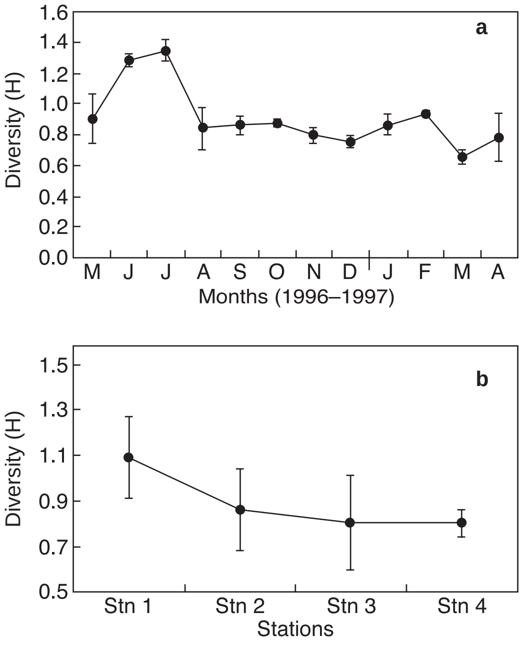

Fig. 6. Mean zooplankton diversity (a) by month and (b) by station in Mida creek

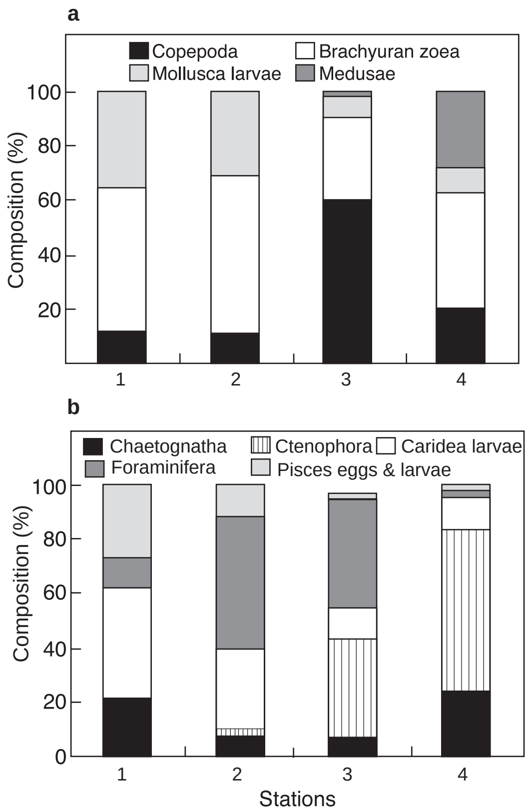

Fig. 7. Distribution (a) and percentage composition (b) of major zooplankton groups at stations 1–4 in Mida creek, May 1996 – April 1997

Zooplankton distribution

Copepoda were distributed in all stations, but the highest distribution was in station 3, where they formed up to 60% of total zooplankton composition (Fig. 7a). Brachyuran zoea were more evenly distributed in all the stations compared to any other group. Mollusca larvae were dominant in stations 1 and 2 compared to other stations, whereas Medusae were largely found in station 4 (Fig. 7a).

Chaetognatha were abundant in station 1 and Ctenophora were common in stations 3 and 4. Caridea larvae were abundantly distributed in stations 1 and 2 and were less common in the backwaters. Foraminifera were common in stations 1 and 2 (Fig. 7b), whereas Pisces were mainly concentrated in stations 1 and 2.

DISCUSSION

The abundance of zooplankton and phytoplankton populations in Mida creek follows a cycle closely related to the seasonal cycle of rainfall, as shown by Kitheka et al. (1996) for Gazi bay, Kenya. However, there is no river discharge into Mida creek and nutrients become significantly higher during the rainy season due to surface runoff and increased groundwater flow from the Mida creek basin (Kitheka et al., 1999). Similarly, peaks in abundance of zooplankton and phytoplankton were seen to follow this trend.

The variation in physico-chemical parameters in Mida creek was also attributed to this seasonality. Salinities were lower during the rainy season, and in the backwaters of the creek vertical salinity stratification was found to occur (Kitheka, 1998). Though generally salinity was constant at 35 ‰, during the rainy season it dropped to 33 ‰ in the frontal zones (stns 1 and 2) and to about 28 ‰ in the backwaters. This drop in salinity was largely attributed to surface runoff and increased groundwater flow in the aquifers that supply the creek.

Similarly, lower water temperatures at 25–26 °C were experienced from June to September during the SE monsoons, when there was high cloud cover, and higher temperatures occurred during the NE monsoon (November to March). Zooplankton in Mida creek seemed to thrive best in the high salinity of the NE monsoon period, though smaller peaks were observed during the rainy season. However, different species seem to be responsible for these peaks, for example the copepods *Eucalanus* spp. in February (dry NE monsoon season) and *Acartia* spp. in May (wet SE monsoon). In tropical embayments and estuaries in India, accelerated zooplankton production during periods of high salinity was documented by Madhupratap (1980), Baidya & Choudhury (1984) and Tiwari & Nair (1993).

In this study, the copepod families Paracalanidae and Eucalanidae showed a strong positive correlation with each other. They were also positively correlated to other groups like Mollusca larvae, Caridea larvae, Chaetognatha, Pisces, Brachyuran larvae and Foraminifera. A positive correlation between any one or pair of groups indicates that the number of species can increase or decrease in conjunction with one another. This positive correlation provides evidence that these families combine to form a group. The same copepod families were negatively correlated to *Acartia* spp. and Medusae, meaning that when the number of species in one group increases, the number in the other decreases.

Acartia spp. and Medusae seem to form another group, as they were both negatively correlated to most of the other groups, while remaining significantly positively correlated with each other. *Temora turbinata* on the other hand seems to have existed on its own, as it was negatively correlated with all the other groups. The group Medusae and Pisces showed negative correlation with each other, meaning the decline in Pisces may have been caused by predation by the Medusae.

Paracalanus spp. and *Eucalanus* spp. thrived well in the more highly saline NE monsoon season, which may indicate that they were indeed marine in origin. *Acartia* spp., on the other hand, thrived well during the low-salinity monsoon periods indicating their affinity for brackish waters. Salinity hence, was considered a strong factor governing their seasonality. Tranter & Abraham (1971, cited in Pillai et al., 1973) identified four factors, which they considered to be important for the coexistence of *Acartia* spp. in the estuary, viz. tolerance to variable salinity, food supply, generation length and flow. Similarly, the close association of families Paracalanidae, Eucalanidae and other groups may be closely linked to the phytoplankton bloom which occurred in January and May due to their herbivorous nature. These blooms may similarly have contributed as food for the other zooplankton species.

Zooplankton diversity was inversely related to abundance, which was generally higher during the SE monsoon period as compared to the NE monsoon. The lower diversity in the NE monsoon period was caused by high abundance of zooplankton species such as *Eucalanus* spp. and other dominant groups that emerged during this period. High species diversity was recorded closest to the ocean (station 1) than more inshore (Fig. 6a) as Okemwa (1990), Osore (1992), Osore (1994) and Mwaluma (1997) reported in Tudor and Gazi bay respectively. In India, in the Bay of Bengal and Cochin backwaters, similar trends were reported by Pillai et al. (1973), Nair et al. (1981) and Tiwari & Vijayyalakshmi (1993), who attributed this high diversity to the calmer, more stable oceanic waters.

The incidence of fish eggs within the entire Mida creek suggests the existence of a breeding ground in the vicinity of this creek. On average, the outer station 1 had a relatively higher abundance of fish eggs than the interior stations (Fig. 7b). Peak abundance occurred in January and February, suggesting a peak breeding season. The occurrence of high numbers of fish eggs in stations 1 and 2 is contrary to the assumption that the inner creek areas are used as nursery grounds. However, the possibility of predation of fish eggs in the inner part of the creek cannot be ruled out, as also highlighted by the negative correlation obtained between Pisces and some of their predators like Medusae.

One limitation of this study was that plankton samples were collected monthly, whereas most plankton processes have a faster time frame. It is therefore difficult to interpret these results conclusively. Dynamic characteristics of plankton distributions in coastal habitats are strongly influenced by tidal currents and salinity gradients, and thus timing of sampling together with spatial location in relation to salinity and coastal environment mosaics would determine plankton type and concentration (Paula et al. 1998). For a more in depth analysis, one would need to take into account in the sampling design, a combination of factors like tides (spring and neap), different plankton mesh sizes (500 mm for fish eggs & larvae), diel cycles and vertical distributions in order to compare variability at various scales.

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