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TIDAL INDUCED VARIATION IN THE DISTRIBUTION, ABUNDANCE AND DIVERSITY OF MESOZOOPLANKTON ALONG THE KARACHI COAST, PAKISTAN

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ABSTRACT: Temporal variations in biomass, abundance, diversity and species composition of mesozooplankton in relation to the tidal state were studied. Mesozooplankton sampling was carried out twice at the ebb and flood tides at fixed stations closed to Phitti creek (P) and Manora channel (M) near the Karachi coast during February 1999. The average percent abundance of mesozooplankton was high at ebb tide i.e., 66% and 63% whereas, low on flood tide i.e.,34% and 37%, at both stations respectively. However, there were no differences in species composition with tidal fluctuations at both sites. The mesozooplankton community was typically composed of 22 groups, out of which copepod was the most abundant group (comprising % of the total zooplankton) at both sites. During the flood tide high diversity 0.11 ± 0.021 was observed in Phitti creek, but no difference was observed at Manora channel. The species richness was high (2.30 ± 0.01273 and 2.38 ± 0.502) in the Manora channel at both ebb and flood tides, respectively, whereas the dominance values were high at Phitti creek. Complete randomized design ANOVA showed that there was no significant difference in abundance of mesozooplankton between stations and tides nested in stations, but the difference was significant for the diversity and equitability. On the short temporal scale the tidal cycle additionally determines changes in the zooplankton composition.

KEYWORDS: Zooplankton, Distribution, Abundance, flood and ebb tide.

INTRODUCTION

Zooplankton community comprises of heterogeneous assemblage of many organisms covering various taxonomic groups. Zooplankton plays an important role as an intermediate component in estuarine food webs, acting as a trophic link between small particles (e.g. detritus and microalgae) and planktivorous fish on one hand and on the other hand, commercially important fish and invertebrate species produce larvae, which remains as part as the merozooplankton. Despite the great importance, relatively little work has been done on the zooplankton of mangrove habitats (Robertson and Blaber,1992). The distribution and population of zooplankton vary with the state of tide and physico-chemical factors Robin *et al*.(2009). In mangrove ecosystems, , the zooplankton community has to cope with continuous changes in water level, and current strength and direction due to variation in tides. Variations in zooplankton composition and abundance have been correlated to spring and neap tide alterations and to tidal cycles, ebb and flood tides (Wang *et al*.,(1995); Morgan *et al*.,(1997); (Villate, 1997).

These short and medium-term patterns of zooplankton abundance probably determine the availability of food for their predators and may this have significant implications for the foraging strategies of juvenile fish preying on zooplankton.

The Indus River, the sixth largest river in the world, drains into the northeastern Arabian Sea forming a large delta. The river discharge and nutrient rich sediment load have the great influence on marine life of the Indus estuary and on the near shore areas. The tides in the Indus delta are predominantly semidiurnal (Burbridge, 1989). Tidal exchanges have been known to be the single most important factor controlling the population size of zooplankton (Grindley, 1984; Costa, 2008). The distribution pattern of zooplankton determined by the strength of fresh water discharge and tides has a major influence on the structure and density of the zooplankton communities present within the estuary (Rodriguez, 1975). Macro-tides characterize the coastline of the Indus estuary. Tidal heights range from 3.4 to 3.9 m during spring tides and 1.5 to 2.5 m in neap tides. The coast has the 13th largest mangrove area in the world Spalding *et al.*(1997). Detailed studies on the zooplankton communities from the coastal area scant and focused on the taxonomy of copepods, chaetognaths, siphonophores (Masihuzzaman, 1975; Tirmizi and Nayeem, 1992; Ali-Khan, 1998, 2000; Ali-Khan and Shahnaz, 2001 a and b; and Kazmi, 2004). However, few zooplankton studies have been conducted in this extensive mangrove ecosystem. Tidal creeks connect the mangrove with adjacent areas and provide well-defined pathways for aquatic organisms and for water and material exchange. The two zooplankton communities, Phitti Creek and Manora Channel were studied and the extent of temporal variability in terms of the number of species, and abundance and biomass on a temporal scale such as the tidal cycle flood or high water and ebb or low water was also determine.

MATERIALS & METHODS

Study site: Karachi has a coastal belt nearly, 100 km long between the Indus delta and Hub River. Two sites were selected for this experimental study, Manora channel and Phitti creek (Fig. 1). The coast in the southeast has Korangi and Phitti creeks (24^{o}68'N, 67^{o}15'E), about 28 km long and its width ranging from 250 to 2,500 m. The Phitti-Jhari-Kadiro creek acts as the main waterway connected to the open sea at the southwestern and with an average depth 11.3 m. Manora Island is a small peninsula (2.5 km^2) located (24°47′N 67°59′E) south of the Port of Karachi, Pakistan. Manora is connected to the mainland by a 12 kilometer long causeway called the Sands-pit. Manora and neighboring islands form a protective barrier between Karachi harbor to the north and the Arabian Sea to the south. The western bay of the harbor contains endangered mangrove forests.

Sampling methodology: Mesozooplankton sample was collected twice at flood and ebb tide from each selected site during February 1999. Replicate samples were collected by using the standard plankton net of 234 µm mesh sizes, with a mouth diameter of 0.5 m. A flow meter (General Oceanic Model 2030R) was mounted at the center of the net opening to measure the volume of water filtered by the net. Sub-surface horizontal haul was made and the net was towed for 5 minutes at a uniform speed of 2 knots in a circular

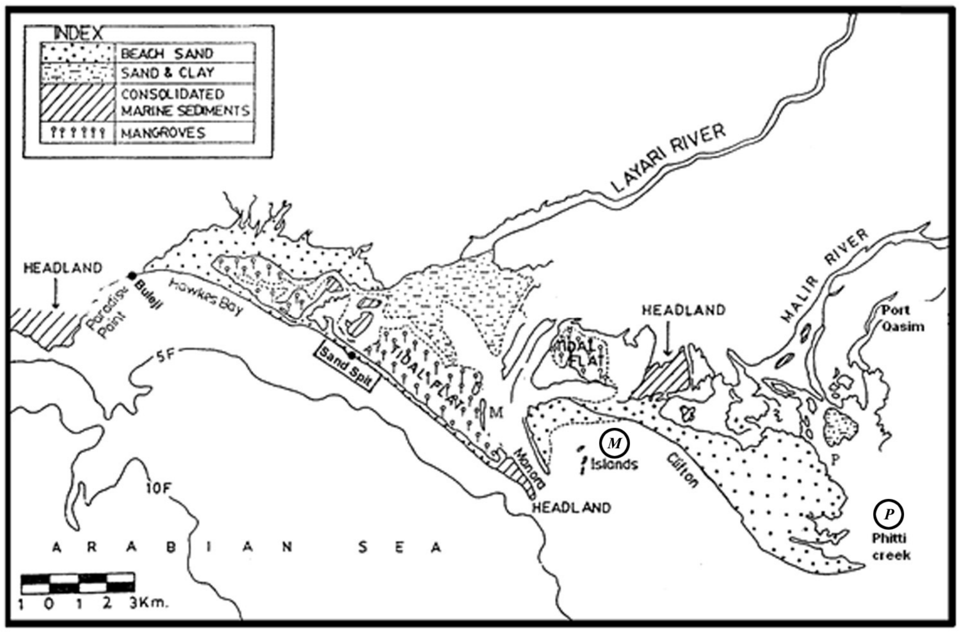


Fig. 1. Map of the Karachi coast showing sampling stations, Phitti creek (P) and Manora channel (M).

path to ensure that the same water mass was sampled. The samples were preserved in 4 % buffered formalin.

Temperature was measured by a simple hand held thermometer. The salinity was measured with an optical refractometer (with correction of 1 $^{o}/_{oo}$), pH was measured by pH meter (Hanna model 8314). Transparency or turbidity was measured with a Secchi disc. For analysis of suspended sediments, three replicates of 100 ml sample were filtered through a pre-weighed 0.45 µm Millipore filters. After blotting excess water filter was placed in a small petri dish, and wet weight was obtained. Filter was then dried at 60^{o}C for 24 hours and reweighed for dry weight. The amount of suspended load in water samples was then estimated as mg per 100 ml. Water samples were also collected for determination of dissolved oxygen, fixed in the field and later analyzed by the Winklers method (Strickland and Parsons, 1972).

Laboratory procedures: In the laboratory, plankton samples were split into two equal sub-samples with Folsom plankton sample splitter. One sub-sample was used for taxonomic identification and enumeration of various taxonomic groups and the second half was used to measure the biomass. Mesozooplankton biomass can be measured by volumetric method likes settled volume (X) and displacement volume (Y) that have been frequently used to estimate the standing crop of marine mesozooplankton (Omori and Ikeda, 1984). Biomass were estimated by the product of mesozooplankton density (individuals/100m^3).

Mesozooplankton and copepods were counted and identified up to possible taxonomic level (generic and species level) under a stereoscopic microscope with the help of available identification key (Ali-Khan, 1998). The species diversity H' (Shannon and Weaver 1949), evenness J' (Pielou, 1977), species dominance D', (Simpson, 1949), and species richness S' (Odum, 1971) were estimated.

Completely randomized design (CRD) analyses of variance (ANOVA) with a nested treatment arrangement were carried out by using the statistical package Minitab (Version 11.12) for differences between sites and tides and all hydrographic parameters. Test of significance was accepted as significant at alpha = 0.05 for statistical analyses.

RESULTS & DISCUSSION

RESULTS: Slight variations in environmental parameters were observed during ebb and flood tide, but no significant difference was observed between sites, tides and tides nested in the sites. High dissolved oxygen values were associated with the flood tide in comparison to ebb tide (Table 1) with significant difference between the stations ($F_{1,7}$ = 201.52, P<0.001) and tides nested in stations ($F_{1,7}$ = 5.76, P<0.01). Relatively higher mesozooplankton biomass were measured by displacement volume was observed at ebb tide 140 ml /100m^3 and 95.9 ml /100m^3 in comparison to flood tide 32.8 ml /100m^3 and

Table1. Environmental parameters, temperature, salinity, pH, Suspended sediments, Transparency, Dissolved Oxygen collected from Phitti creek (P) and Manora channel (M) at flood and ebb tide during February 1999.

Stations	Tides	Temp. Air	Temp. water	Salinity	pH	Suspended sediment	Secchi depthm	Dissolved oxygen
		(°C)	(°C)	(ppt)		(mg/100 ml)		(mgO_2/l)
Phitti Creek	Ebb	26.6	19.4	35	8.09	0.012	1.01	4.77
	Flood	24.6	19.1	35	8.10	0.010	1.15	6.28
Manora Channel	Ebb	25.4	21.2	34	8.14	0.003	9.10	5.77
	Flood	23.8	21.2	37	8.17	0.007	9.01	6.00

17.2 ml /100m^3 at Phitti creek and Manora channel, respectively. Settling biomass was higher than the displacement biomass and positive relationship between was observed, with a coefficient of correlation (r^2 = 0.90 and r^2 =0. 97) at Phitti creek and Manora channel, respectively (Fig. 2). Highest values of biomass by settling volume was found at ebb tide (442.4 ml /100 m^3 and 320.8 ml /100 m^3) and low value of settling volume was found at flood tide 214 and 143 ml /100m^{3}at Phitti creek and Manora channel, respectively. Complete randomized design (CRD ANOVA) was shown that

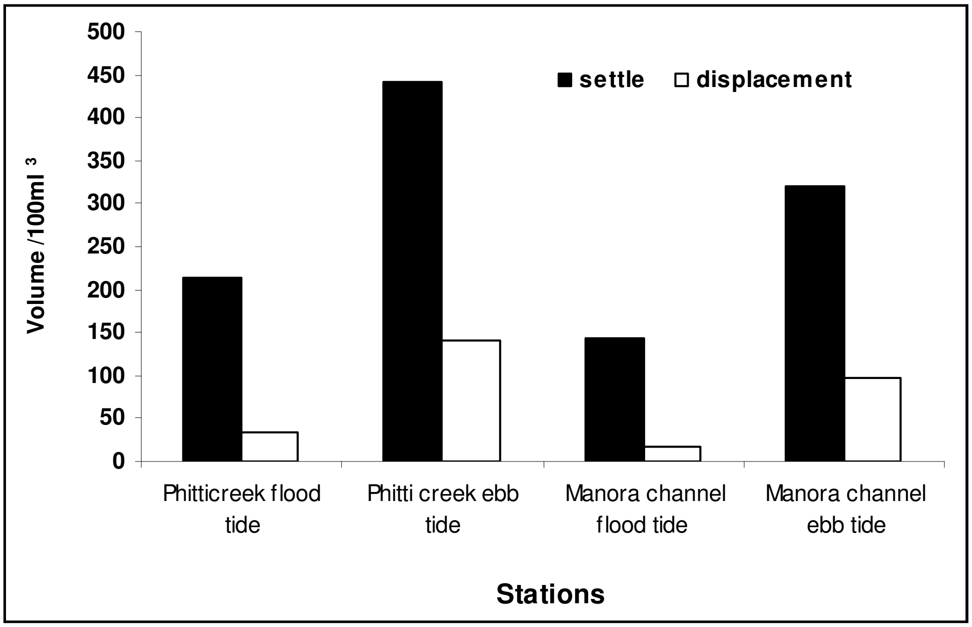


Fig. 2. Variation in settle volume and displacement volume for mesozooplankton samples collected from Phitti creek (P) and Manora channel) (M) at flood and ebb tide during February 1999.

settle and displacement biomass not significantly different ($F_{1, 7}$ = 3.91, $P<0.05$), between sites, were as the significant difference was shown in tides nested in sites ($F_{1, 7}$ = 12.56, $P<0.001$). The average percent abundance of mesozooplankton were high at ebb tide 15605 ± 892 (66%) and 3611 ± 2034 (63%) at both sites, Phitti creek and Manora channel, respectively. Whereas, the average percent abundance of mesozooplankton at flood tide was low; 8036 ± 501and 2119 ± 720 (34% and 37%) at Phitti creek and Manora channel, respectively. However, there were no differences in species composition with tidal fluctuations at both sites. The Diversity indices (H' and J') showed high values at ebb tide at Phitti creek, but no difference was observed at Manora channel. Species richness (S') was high in the Manora channel at both ebb and flood tide, but the dominance (D) values were high at the Phitti creek (Table 2). Completely randomized design ANOVA showed that Diversity (H') and equitability (J') were significantly different ($F_{1, 7}$ = 172.90, $P<0.05$), ($F_{1, 7}$ 3.95, $P<0.001$) between sites and ($F_{1, 7}$ = 437.40, $P<0.05$), ($F_{1, 7}$ 13.67, $P<0.001$) tides nested in sites respectively.

Copepod formed the most dominant group followed by meroplanktons or larvae of decapods, gastropods, and bivalves. The percent abundance of copepod was 98.38% and 95.62% at Phitti creek where as 82.32%and 85.85% on the Manora channel during ebb and flood tide, respectively. Total 21 species of copepods pertaining to fourteen genera were identified. The most dominant species were *Temora discaudata, Temora turbinita, Acartia amboinensis, Oithona plumifera, Centrophages dorsispinatus, C. furcatus,*

Table 2. Mean ± SD values of Settle volume, Displacement volume, Percent abundance, Diversity, Equitability, Species richness and Dominance, from Phitti creek (P) and Manora channel (M) at flood and ebb tide during February 1999.

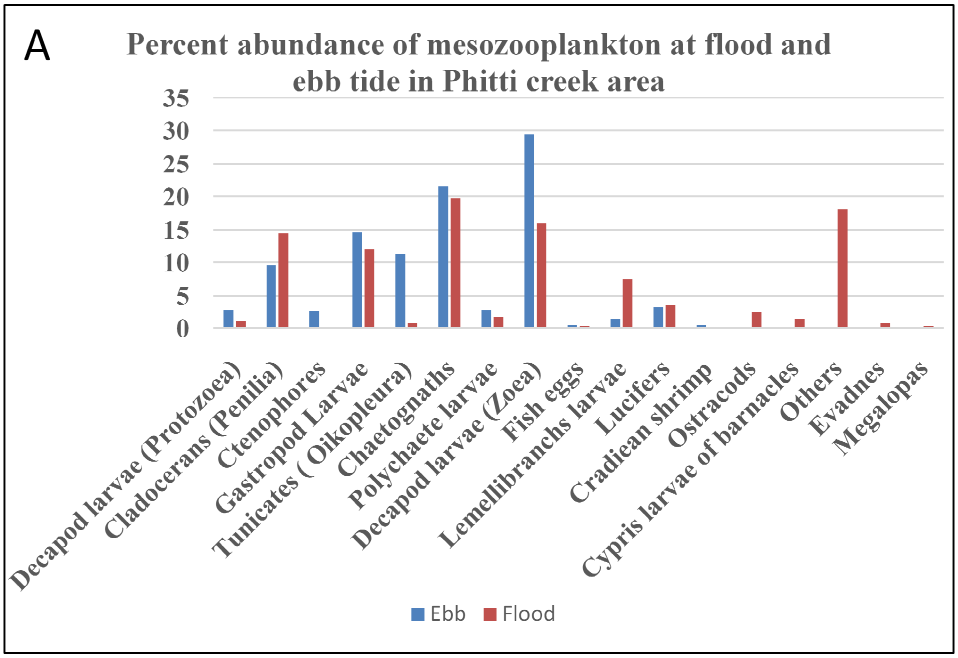
Station	Tides	Settle volume	Displacement	Total no of zooplankton	Abundance	Diversity	Equitability	Species richness	Dominance
		/100m^3	100m^3	/100m^3	(%)	(H)	(J)	(S)	(S)
P	Ebb	442.4±102.7	140±35.6	15605±892	33±1.34	0.05±0.020	0.045±.0212	1.695±0.049	0.097±0.014
	Flood	214±145	32.8±26.0	8036±501	17±7.50	0.1159±0.021	0.1100±.0141	1.890±0.127	0.9150±0.021
M	Ebb	320.8±91.2	95.9±25.3	3611±203	31.5±17.7	0..3150±0.021	0.26500±0.007	2..300.127	0.7400±0.141
	Flood	143.0±54.3	17.2±15.1	2119±720	18.49±6.29	0..3550±0.035	0.29500±0.007	2..385±0.502	0.6850±0.035

C. orsinii, Labidocera acuta, Oncaea, Eucalanus, Corycaeus, Scottolana and *Pleuro-mamma.* Excluding copepods in Phitti creek decapod zoea, chaetognath, gastropod larvae, and cladocerans, showed the highest percent abundance at ebb and flood tide with the exception of tunics *(Oikopleura),* which showed the lowest abundance at flood tide, where as in Manora channel cladocerans, tunicates *(Oikopleura),* decapod zoea, chaetognath, fish egg, gastropod larvae showed the highest abundance at ebb and flood tide. Caridean shrimp and decapod zoea, showed the lowest percent abundance at flood tide (Fig. 3). On the ebb and flood tide, the percent abundance of holoplankton was 42.22% and 7.33% at Phitti creek and 29.38% and 17.59% on Manora channel respectively (Fig. 4).

DISCUSSUION: Circulation pattern of water masses in estuaries has a profound influence on the horizontal spread and successful establishment of plankton species in tropical estuaries. On a medium time scale, temporal variations within the zooplankton community have been related to the tidal pulses, the key factor determining weekly differences in the zooplankton composition. Present study showed a definite increase in zooplankton biomass on ebb tide at both stations, similar result was found as the greatest abundance and biomass of zooplankton with reference to copepods were also found in Cul-de-sac channel at low water (Krumme and Liang, 2004). At flood tides, current velocities usually exceeded 1.5 m/s. At ebb tides, estuarine copepod species are apparently carried out of the channel, most likely because of the fast tide current speeds that may be sufficient to suspend and then transport them from the upper reaches of the mangrove channel. Variations in the zooplankton biomass collected from the creek of Versova, Bombay during the day (1.2 ml /100 m^{-3}) and night (12.13 ml /100m^{-3}) have been observed(Gajbhiye *et al*., 1984);the difference in biomass values was related with tides and found low numbers at ebb tide, which is in contradiction to the present study.

Certain groups dominated during low tide such as estuarine species and others at high tide as of inshore water species (Pillai and Pillai, 1973). The highest abundance and biomass were found during ebb tide, when the number of species was the lowest, and conversely the lowest biomass at a flood when the number of species were high, suggesting that retention of zooplankton and copepods, the net upstream drift due to high flood tide velocities apparently promotes the retention of species from one tide to the next (Krumme and Liang, 2004). The highest dilution and concentration of biomass during ebb is in contrast to Robertson *et al*.,(1988 and Wang *et al*.(1995) who found higher densities and total abundances at high tide than at low tide, respectively.

In the present study a total of 22 groups of zooplankton species were recorded. Among different groups of zooplankton copepods contributed to the maximum numerical percent abundance as in Phitti creek and form up to 85% and 82%,whereas, in Manora channel they formed 98% and 95% of all samples at ebb tide and flood tide, respectively. Goswami (1985 a, b) and Robin *et al*., (2009) related the numerical abundance of copepods in zooplankton sample to the relatively stable environmental conditions and good standing crop of phytoplankton. The copepod assemblages exhibited a rather uniform structure. The copepod species concerning to following genera were



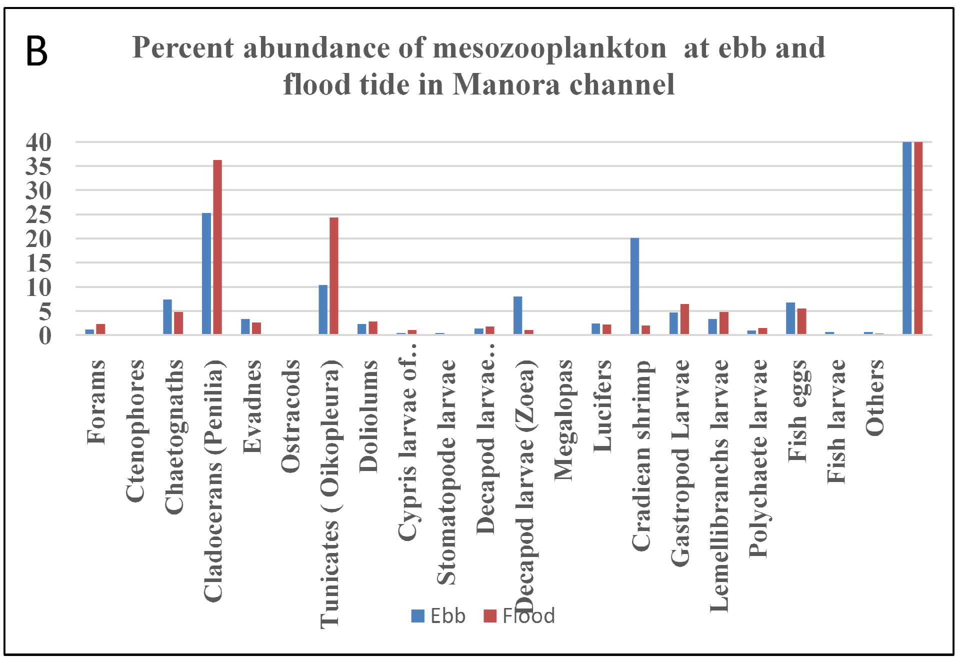


Fig. 3. Percent abundance of mesozooplankton at flood and ebb tide in Phitti creek (A) and Manora channel (B) area during February, 1999.

found: *Acrocalanus and Paracalanus, Temora, Acartia, Oithona, Centrophages, Lebidocera, Oncaea, Eucalanus, Corycaeus, Harpacticoid* and *Metridia Acartia spinicuda, Calanus finmarchicus, Paracalanus gracilis,* and *Euterpina acutiferons* andwere similar to earlier studies (Naz *et al*., 2012). Unlike open estuarine environments, the semi-enclosed creeks and channels with a net upstream drift due to higher flood tide velocities apparently promotes the retention of copepods from 1 tide to the next.

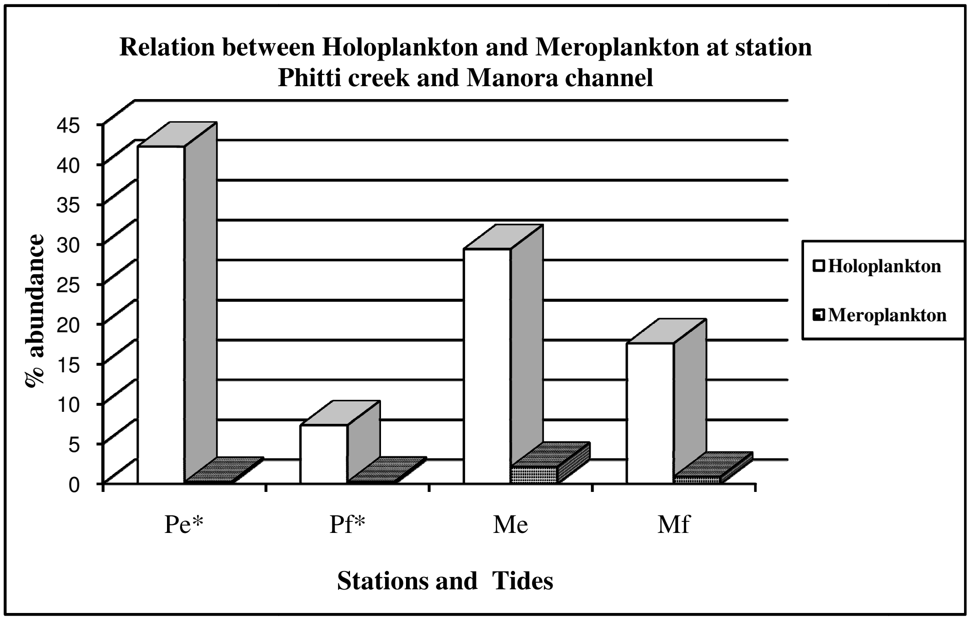


Fig. 4. Percent abundance of holoplankton and meroplankton at flood and ebb tide in Phitti creek and Manora channel area during February 1999.

Species composition of mesozooplankton community after the removal of the copepods revealed the abundance of meroplankton decapod's larvae and gastropod. The estuarine species included brachyuran zoea and nauplii of cirripeds and appendicularians. The decapods larvae were presented in greater numbers at ebb tide, especially in the samples collected from Phitti creek, whereas, the greater number of inshore species chaetognaths, *Lucifer* and a few species of copepods were collected. Robin *et al*. (2009) also observed higher population of copepods and decapods during ebb tide due to low pH and high temperature while chaetognaths and appendicularians were in significant numbers during the flood tide.

On the short-term, the tidal cycle additionally determines changes in the zooplankton composition. It remains unclear, however, if water level or salinity determines the short-term changes in the zooplankton community, and whether high abundance at ebb tides is related to the salinity. In the present study the highest percent abundance of holopalnktonic organisms was observed at flood and ebb tide as compare to meroplanktons at both sites. Our study covered limited temporal scale have shown that there are apparently some tidal variations in the distribution of zooplankton. Since the fisheries are dependent on the characteristics and availability of zooplankton population a comprehensive study of diurnal and seasonal changes along with environmental variability's is essentially needed for proper management of these resources.

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