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Temporal variations in the mesozooplankton species composition, inhibiting the mangrove creek areas near the Karachi coast, Pakistan

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Abstract
Temporal variations in the mesozooplankton species composition, inhibiting the mangrove creek areas near the Karachi coast, Pakistan were observed during January 1998 to December 1999. The mesozooplankton community typically composed of twenty eight groups, of which copepod, formed the dominant group especially the genus *Acrocalanus* and *Paracalanu*s, two species of *Temora discaudata*, and *T. turbinita,* three species of *Centrophages dorsispinatus, C. furcatus, C. orsinii, Acartia amboinensis, Oithona plumifera, Labidocera acuta, Oncaea, Eucalanus, Corycaeus, Scottolana* and *Pleuromamma*. Three species of Chaetognatha were also found in *Sagitta enflata, Sagitta hexapter* and *Sagitta Kroni.* The cladocerans: *Penilia avirostris* and *Evadne tergestina*, in addition to the appendicularians: *Oikopleura longicauda* and *O. dioica*. Over all Copepods, Gastropods, Cypris larvae of banicles, Nauplii, Evadne, Zoea, Cradiean shrimp accounted for more than 92.53% of community biomass.

Keywords: Temporal variations, mesozooplankton, species composition, mangrove, Karachi, Pakistan.

Introduction
Mangroves represent a unique tropical environment and they have received increasing attention since the relationship between the primary productivity of mangrove forest and the productivity of near shore fisheries (Harrison *et al*. 1994 [15]) was first established (Odum and Heald 1971 [24],Turner 1977 [31], and Martosubroto and Naamin 1977 [21]). Mangroves are open-ended ecosystem with an overall transport of matter and energy from land to sea. The coastal mangrove creek systems are shallow and nutritionally rich, providing an ideal habitat for a variety of marine animals in addition to commercial fish and shrimp. The biological productivity at the highest tropic levels ultimately depends on photosynthetic primary production (Radhakrishna *et al*. 1978 [25]). Measurements of primary and secondary production are essential for the estimation of level of fish production and potential of exploitable fisheries. The plankton provides the first link between the food chain of the marine ecosystem. Zooplankton plays a major role in the functioning and the productivity of aquatic environment through its impact on the nutrient dynamics and its key position in pelagic food chains serving as the connecting link between primary producers and secondary consumers (Keister *et al.*, 2012 [18]; Sahu, *et al.*, 2013 [29]). The zooplankton biomass studies are also important for gaining insight into the fish production of the oceans (Lenz 1973) [19]. High biomass values indicate high fish production. Elevated secondary production may likely be supported by higher primary productivity. The zooplankton biomass of the region, to a large extent depends on the abundance of meroplanktonic biomass that in turn indicates the fishery potential of these groups in the area of study. The presence of higher zooplankton biomass indicates presence of higher quality food for larval fish (Frank 1988) [11]. Copepod nauplii, copepodites and other zooplankton are known to be an important component of the diet of many other fish larvae (Govoni and Chester 1990) [12]. The relationship between fish larvae and invertebrate plankton is two folds. Small zooplankton, particularly the larval stages of crustacean, molluscs and appendicularians, are the only food organisms important to larval fish. Their abundance at the right time and in the right layer determines the year class strength in many fish species. On the other hand, large carnivorous zooplankton constitutes a major group of predators of fish larvae (Ali-Khan and Hempel 1974) [1]. Many species of zooplankton can be used as biological indicators of water pollution, water quality and eutrophication (Bonnet and Frid, 2004) [6].

Information with respect to the zooplankton of along the northern Arabian Sea and coastal waters of Karachi is meager and primarily have been studied by Mohammed and Arshad (1966) [22], Haq *et al.* (1973) [14], Ali-Khan and Hempel (1974) [1], Ali-Khan and Ali-Khan (1978) [2-3], Tirmizi and Nayeem (1992) [30], and Rizvi *et al*. (1994) [26], Amjad *et al*. (1995) [4], and mostly limited to species composition and geographical and seasonal influences on population density and biomass of zooplankton (Naz *et al.*, 2014) [23]. General presentation of mesozooplankton distribution and abundance and species composition data covering the larger creeks area has clearly been lacking. The objectives of the present paper illustrate the species composition of the mesozooplankton in the mangrove creek area along the coastal waters of Pakistan.

Material and Methods

Study Area

The Pakistan coastline extends over 1010 km in the Western province of Baluchistan and Sindh, of which the most prominent coastal feature is the delta of the Indus River in the province of Sindh. The Karachi coast constitutes a coastal belt of about 100 km long between the Indus delta on the south east coast and the Hub River on the west of Karachi. The coast in the southeast has Korangi and Phitti creeks, which represent characters of the Indus delta (United Nations 1996) [32]. The Korangi and Phitti creeks, has an extensive monospecific mangrove vegetation (*Avicennia marina*) while the mangrove environment is considered to be one of the most productive areas in coastal ecosystem not a great deal is known about its zooplankton production. Two stations were selected in the Pitti-Jahri creek.

Field Sampling

Sampling for mesozooplankton was regularly conducted at monthly intervals from both stations during January 1998 to December 1998. Samples were collected from 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 in the centre of the net opening to measure the volume of water filtered by the net. The subsurface horizontal haul was taken and the net was towed for 5 minutes at a uniform speed of 2 knots in a circular path to ensure that the same water mass was sampled. The samples from each station were preserved on board with 4 % buffered formalin in large mouth polyethylene jars for later analyses.

Laboratory Analysis

In the laboratory, plankton samples were treated in the following order. All samples were split with the help of Folsom plankton sample splitter into two equal sub-samples. One half or sub-sample was used for taxonomic identifications and enumeration of various taxonomic groups and the second half (sub-sample) was subjected to biomass measurement, the volume of water filtered estimated from the calibrated flow meter readings to standardized biomass values. The samples were counted and identified up to major taxonomic groups, and the density was expressed as individual per m^3.

Statistical Analyses

Statistical analysis was carried out by using the statistical package Minitab (Version 16). The word “Significant” or “Statistically significant” means that differences were detected at (< 0.05) percent level of probability. Completely randomized design (CRD) analyses of variance (ANOVA) with a nested treatment arrangement were to test all parameters for the effect of stations, seasons, and station*season interaction on the species composition of mesozooplankton.

Results

The foregoing account indicates that mesozooplankton in the mangrove area near the Karachi coast are quite rich. The composition, abundance, distribution, seasonal variation in standing crop and total population density of mesozooplankton was studied. The abundance distribution of dominant mesozooplankton exhibited seasonal trends at both stations. At S2 the highest abundance was estimated in the post monsoon (8726.66 m^3) and lowest values of abundance were found in the southwest monsoon (2123.61 m^3). Whereas, at S1 a clear trend of high density (4079.9 m^3), in pre-monsoon to low abundance (687.66 m^3) in southwest monsoon were observed (Fig 1A).

The mesozooplankton community typically composed of 28 genera, of which Copepod, formed the dominant group especially the genus *Paracalanus*. Overall Copepods (71.96), Gastropods (6.51), Cypis larvae of banicles (4.40), Nauplii (3.68), Evadne (2.65), Zoea (2.20), Cradiean shrimp (1.11) and Chaetognaths (0.98) relative abundance and accounted for more than 90% of community biomass. Copepods dominated and formed the most important group of mesozooplankton. The mangrove creeks areas was showed significant seasonal differences in different groups of mesozooplankton including Copepods ($F_{3,\ 23}$ = 17.31, P < 0.05), Chaetognaths ($F_{3,\ 23}$ = 17.31, P < 0.05), Cladocerans ($F_{3,\ 23}$ = 4.27, P < 0.05), Evadne ($F_{3,\ 23}$ = 4.44, P < 0.05), Ostracode ($F_{3,\ 23}$ = 3.09, P < 0.05), Mysids ($F_{3,\ 23}$ = 3.49, P < 0.05), and Gastropod larvae ($F_{3,\ 23}$ = 11.09, P < 0.05) and Caridean shrimps ($F_{3,\ 23}$ = 8.95, P < 0.05). Echinoderm larvae ($F_{1,\ 23}$ = 3.77, P < 0.05) were showing significant differences between stations and season, chaetognaths was showing a significant difference between stations ($F_{1,\ 23}$ = 3.64, P < 0.05) Whereas other groups was shown a nonsignificant result with the station and the seasons(Table 1). Percent abundance of mesozooplankton collected from Rato Kot (S1) and Phitti creek (S2) mangrove area described in (Table 2 and 3). Maximum numbers of copepods occur in the month of January (97.35 %) at S2 and (93.54 %) at S1 in February and minimum numbers of copepod occurred in the month of March 34.83 % and 35.70 % at S1 and S2, respectively (Fig 1B). The average percent abundance of *Evadne* was 4.12 % at S1 and 3.48 % at S2. The highest percent abundance of *Evadne* was 17.52% and 18.67 % in March both, at S1 and S2. The maximum densities of Chaetognatha occurred in January (204.55 m^3) at S1 and in November (94.24 m^3) at S2. The lowest densities of Chaetognatha occurred in May (2.20 m^3) at S1 and in August (2.14 m^3) at S2 (Fig 1 C). The average densities of caridean shrimps observed were 24.75 m^3 at S1 and 63.11 m^3 at S2, whereas average percent frequencies of occurrence were 1.80 % and 1.38 % at S1 and S2, respectively. The maximum densities of Chaetognatha occurred in January (204.55 m^3) at S1 and in November (94.24 m^3) at S2. The lowest densities of chaetognatha occurred in May (2.20 m^3) at S1 and in August (2.14 m^3) at S2. Three species of chaetognatha were found are *Sagitta enflata*, *Sagitta Hexapter* and *Sagitta Kroni*. *Sagitta enflata* of which was found abundantly and was well represented in the collection at S1 and S2 (Fig 1D). Lucifer constitutes the 1.32 % at S1 and 0.78 % at S2 of total mesozooplankton during the study period (2A). The average percent abundances of Mysids were 0.17 % and 0.18 % at S1 and S2. The percent frequency of occurrence of Oikopleura was 0.65 % and 1.26 % at S1 and S2. Doliolums were found at S2 in only three months during the study period Jan. to Dec. 1998. The average percent abundance of fish eggs was 0.18 % at S1 and 1.04 % at S2. Average percent abundance of fish larvae formed the 0.54 % and 0.33 % at S1 and S2. Cypris larvae of barnacles formed the second most abundant group of mesozooplankton after Copepods. The average total numbers of cypris larvae during January to December were 65.65 m^3 and 282.38 m^3 at S1 and S2. The average percent abundances of nauplii were 5.65 % and 5.54 % at S1 and S2 (Fig 2B).

The percent abundance of veliger larvae ranged from 0.16 % to 24.62 % at S1 and 0.62 % to 21.23 % at S2. Highest number of brachyuran zoea were observed in March 562.80 m^3 and 423.86 m^3 at S1 and S2, respectively (Fig 2C). The average percent distribution of decapod (Protozoea) was 1.76 % and 0.97 % at S1 and S2. The average percent abundances of Otracods were 1.29 % and 0.60 % at S1 and S2 (Fig 2D) whereas, average percent abundance of Ctenophores recorded were 0.56 % and 1.05 % at S1 and S2, respectively. Megalopae were a less dominant group of mesozooplankton and were occasionally collected is contributed average percent abundance of 0.12 % and 0.11 % at S1 and S2. Porcelanid zoea formed 1.49 % and 0.94 % of total mesozooplankton at S1 and S2. Polychaete larvae were found in each month except in January at both stations. The percent frequency at S1 was 2.64 % times greater than at S2. Echinoderm larvae were found only at S1 in September and October (0.23 m^3) and formed 0.05 % of the total mesozooplankton biomass. Nematodes were found only in November at both stations. Some of those zooplanktons that were not identified they were few and categorized as others and the average density of others was 7.66 m^3 and 6.55 m^3 at S1 and S2, respectively.

Table 1: Average Mesozooplankton abundance (Mean±SD), Relative abundance (RA) and Cumulative abundance (Cum) and completely randomized design (CRD) analyses of variance (ANOVA) (F is the F-statistics, and P is the probability) collected from the coastal waters of Pakistan during Jan. to Dec. 1998.

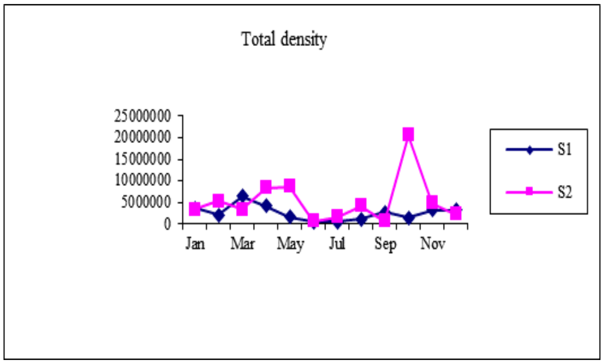
Mesozooplankton taxon	**n**	**Abundance Mean±SD**	**% (RA)**	**Cum%**	**F**	**Significance at P<0.05**
Copepod	24	2845442±3346309	71.96183	71.96	17.31	0.000
Gastropod larvae	24	38989±49022	6.512684	78.47	11.09	0.000
Cypris larvae of barnacles	24	174011±471230	4.400774	82.88		
Nauplli	24	145733±584777	3.685608	86.56		
Evadne	24	104886±268112	2.65258	89.21	4.44	0.019
Zoea	24	87242±137802	2.206364	91.42		
Cradiean shrimp	24	43929±67597	1.110983	92.53	8.95	0.001
Chaetognatha	24	38989±49022	0.986038	93.52	3.64	0.074
Lamellibranch	24	38950±106072	0.985058	94.50		
Ostacode	24	34432±59586	0.870804	95.37	3.09	0.057
Protozoea	24	34306±45721	0.867599	96.24		
Lucifer	24	33479±40345	0.846696	97.09		
Cladocerans (pinnella)	24	23991±54757	0.606744	97.69	4.27	0.021
Polychaete worm	24	22120±34220	0.559418	98.25		
Tunicates	24	15519±40907	0.392467	98.65		
Ctenophore	24	13476±45126	0.340802	98.99		
Fish egg	24	12115±45909	0.306389	99.29		
Porcelanid zoea	24	7670±23942	0.193968	99.49		
Others	24	7103±14527	0.179635	99.67		
Brachyuran larvae	24	3923±3756	0.099203	99.77		
Mysid	24	2537±1292	0.06417	99.83	3.49	0.040
Fish larvae	24	2294 ±5770	0.058017	99.89		
Doliolids	24	2018±9058	0.051047	99.94		
Amphipod	24	894±2536	0.022621	99.96		
Podon	24	788±3862	0.019939	99.98		
Megalopa	24	486±1182	0.012285	99.99		
Nematode	24	131.2±447	0.003318	100.00		
Echinoderm larvae	24	116.9±399.9	0.002956	100.00	3.77	0.032

Table 2: Percent abundance of mesozooplankton collected from Rato Kot (S1) mangrove area during Jan. to Dec. 1998.

Mesozooplankton	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chaetognatha	5.64	2.50	2.00	0.48	0.14	1.56	4.17		0.29	0.48	2.68	0.49
Cladocerans (pinnella)	0.09		0.80	1.58		0.26	0.00					
Evadne	0.27		17.52	6.65			0.00	0.11			0.17	
Ostacode	0.31	0.23	3.30	5.08	0.68	0.26	0.69	0.11	0.06	2.30		1.18
Copepod	90.56	93.54	34.83	35.94	59.92	66.41	43.06	62.11	90.44	64.39	89.00	88.85
Mysid	0.04	0.12		0.55	0.14		0.00					
Nauplli				2.40			0.00			19.90		0.28
Brachyuran larvae				2.13			0.00					
Megalopa	0.09	0.06					0.00	0.32				
Zoea	0.49		8.81	2.67	0.96	2.08	11.11	9.89	1.06	4.12	1.36	2.97
Gastropod larvae	0.45	0.64	24.62	24.28	15.60	3.39	4.17	1.58	1.23	3.25	1.06	0.16
Lamellibranch			0.20	11.66	0.14	0.52	0.69	0.32		0.16	1.32	0.33
Fish egg	0.18	0.06	0.10	0.07			0.00			0.79		0.04
Fish larvae	0.22	0.06		0.07		0.26	2.08					
Cypris larvae of barnacles	0.04		1.90		13.68	22.14	8.33	17.26	3.87		0.04	
Lucifer	1.57	0.99	1.80	1.10	1.23		0.00	0.11	0.35		1.61	4.48
Porcelanid zoea	0.04	1.63		0.14			4.17					
Doliolids							0.00					
Polychaete worm		0.17	1.00	2.06	0.68	0.78	9.03	0.11	0.29	0.08	0.21	0.12
Others			1.00		0.27		0.00				0.13	0.61
Cradiean shrimp			1.30	0.96	0.82	1.30	4.17	5.79	0.29	2.62	0.55	0.16
Protozoea			0.30	1.44	4.38		4.17	2.11	1.64	0.32	1.44	0.08
Tunicates			0.40	0.34	0.96	1.04	1.39	0.11	0.41	1.51	0.08	0.24
Podon							0.00					
Ctenophore			0.10	0.41	0.41		2.08	0.11			0.25	
Amphipod							0.69				0.04	
Nematode							0.00				0.04	
Echinoderm larvae							0.00		0.06	0.08		

Table 3: Percent abundance of mesozooplankton collected from Phitti creek (S2) mangrove area during Jan. to Dec. 1998.

Mesozooplankton	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chaetognatha	1.16	0.93	0.87	0.75	0.34	0.35	0.35	0.05		0.25	1.96	0.50
Cladocerans (pinnella)		1.16	5.02	2.43	0.14						0.04	
Evadne	0.26		18.67	4.85	0.27					0.02	0.07	0.25
Ostacode	0.13	0.93	1.53	1.12	0.14	0.35	0.17	0.10	2.02	0.20	0.18	0.31
Copepod	97.35	92.11	35.70	52.40	59.30	80.28	83.41	79.43	54.55	81.94	88.34	95.35
Mysid				0.23	0.14							
Nauplli		0.46		2.24						13.91		
Brachyuran larvae				0.05								
Megalopa			0.11									
Zoea		0.46	12.23	2.05	2.30	0.53		1.12		0.14	1.70	0.12
Gastropod larvae		2.55	0.98	21.23	5.75	9.33	2.61	2.60	10.61	1.00	3.44	0.62
Lamellibranch			0.11	2.29	0.14		6.34	0.20		0.02	0.80	0.12
Fish egg	0.13		6.55	0.09	0.07		0.26			0.02	0.14	
Fish larvae	0.06		0.76				0.17					
Cypris larvae of barnacles			1.86	4.15	26.64	4.93	0.35	11.20	21.72			0.06
Lucifer	0.84		0.44	0.23	0.14		1.04	0.31	0.25	0.41	2.14	1.99
Porcelanid zoea				1.35			0.52					
Doliolids	0.06									0.22	0.04	
Polychaete worm		0.23	0.55	0.89	1.56	1.41	0.17	0.20	0.51	0.08	0.22	0.25
Others		0.46			0.14		0.70		3.54			0.25
Cradiean shrimp		0.23	0.76	1.73	0.41	1.58	2.69	3.46	2.27	1.45	0.51	0.06
Protozoea		0.46	0.98	1.45	2.23		0.87	1.17	2.02	0.35	0.11	0.06
Tunicates			5.90	0.14	0.07	1.06	0.17	0.10	2.53		0.11	
Podon			0.55									
Ctenophore			6.44	0.28	0.14		0.17	0.05			0.18	0.06
Amphipod				0.05	0.14	0.18						
Nematode											0.04	
Echinoderm larvae												



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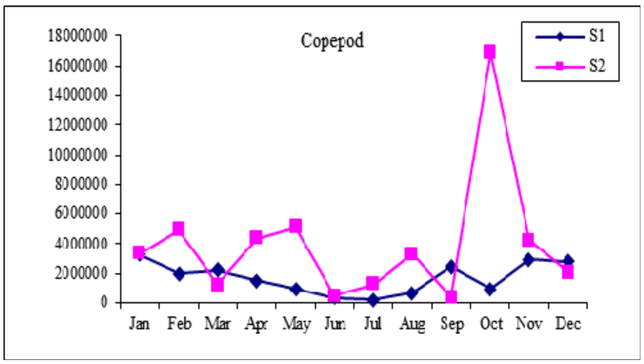

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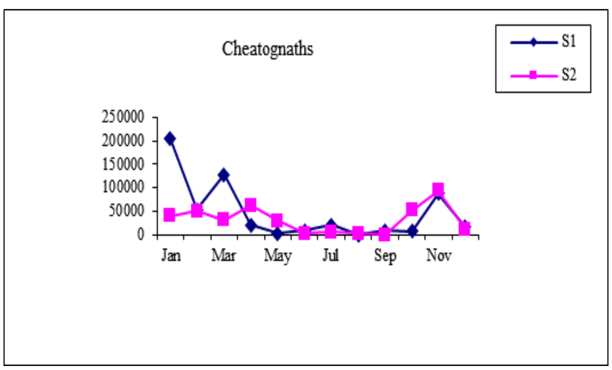

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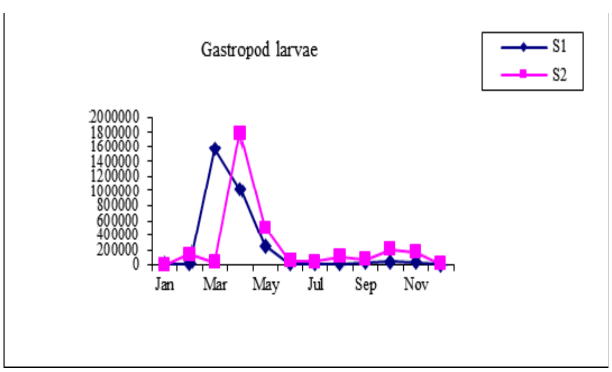
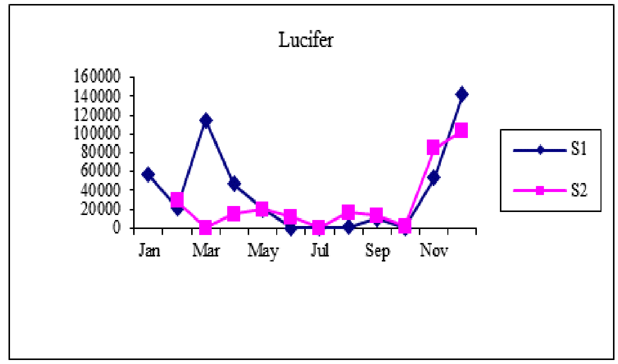


D

Fig 1: Monthly abundance and distribution of dominant mesozooplankton individuals per m^3 collected from Rato Kot (S1) and Phitti creek (S2) mangrove creek area during January to December 1998. A Total density per m^3, B. Copepod, C. Cheatognaths, D. Gastropod larvae.



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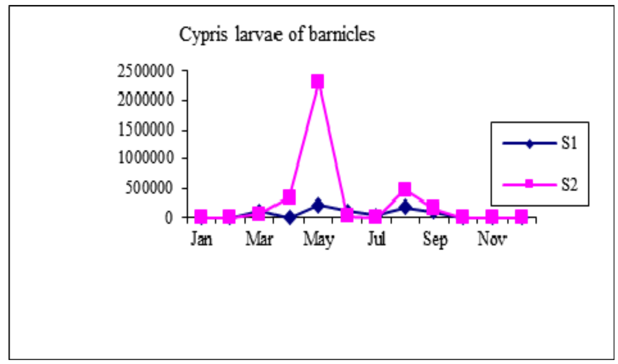

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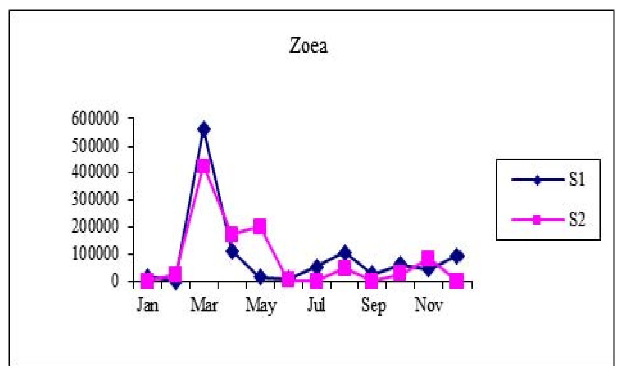

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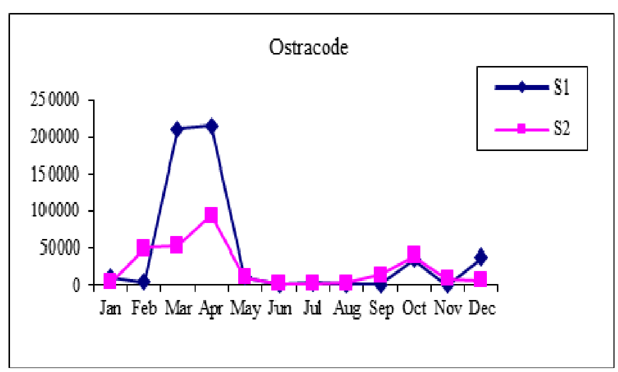

D

Fig 2: Monthly abundance and distribution of dominant mesozooplankton individuals per m^3 collected from Rato Kot (S1) and Phitti creek (S2) mangrove creek area during January to December 1998. A Lucifer, B Cypris larvae of barnicles, C. Zoea, D. Ostracode.

Discussion

Our findings on mesozooplankton standing stock (abundance and biomass) are in agreement with this final statement since no marked a difference was observed between the two stations. Total mesozooplankton abundance was less variable within the study period, whereas the evidence of clear significant seasonality was found in only some group of mesozooplankton including cladocerans, Evadne, Ostracode, Copepods, Mysids, Gastropod larvae and Cradiean shrimp. The mesozooplankton community was typically founded to be composed of 28 groups, of which copepod, gastropod larvae, cypris larvae of barnacles, Evadne, Zoea and Cradiean shrimp accounted for more than 90 % of the community biomass. The copepods were by far the most important group collected and usually constituted the bulk of the biomass (comprising 71.96 % of the total zooplankton) followed by gastropod larvae (6.5 %), cypris larvae (4.4 %), nauplii (3.68 %), and Evadne (2.65 %), Zoea (2.2 %) and Cradiean shrimp (1.1%). The presence and dominance of marine copepods support the use of the copepods as an indicator of the movement of water masses and usually constitute the main taxa (Calbet *et al.*, 2001 [7]; Dalal & Goswami, 2001 [8]; Ferna´ndez de Puelles *et al.*, 2003 [10]; Gaudy, 2003 [13]; Dur *et al*., (2007) [9]. During the present study the observed drop in zooplankton biomass from June to September in Phitti creek could have been due to southwest monsoon related changes in hydrographic parameters and repeated changes in water masses or it could be the result of predation. In the Mondego estuary the abundance of zooplankton reveals the seasonal variation of the copepods population that dominated at all stations throughout the year. A decrease was observed in copepod population during the summer attributed to the higher abundance of copepod predator, such as Siphonophora and Hydromedusae (Azeiteiro *et al.*, 1999 [5]; Vieira *et al.*, 2003 [33]; Marques *et al.*, 2007) [19]. Yaqoob *et al.*, 2013 [34] also describes the zooplankton population under both low and high tide conditions and nine groups of zooplankton including Copepods, Brachiopods, Cladocerans, Amphipods, Euphausiids, Ctenophora Cnidaria, Pteropods, Radiolarians were observed in North Arabian Sea along the coast of Pakistan. Many factors also influence the abundance and distribution of zooplankton such as strong winds, current patterns and turbulence. Different change in the composition of mesozooplankton was also controlled by predation and is yet another factor that may complicate the interpretation of population dynamics of mesozooplankton (Hassel 1986) [16]. Small zooplankton, particularly the larval stages of crustacean, molluscs and appendicularians are the food organisms important to larval fish, their abundance at the right time and in the right layer determine the year class strength in many fish species (Ali-Khan and Hempel 1974) [1]. On the other hand, large carnivorous zooplankton constitutes a major group of predators of fish larvae (Ali-Khan and Hempel 1974) [1]. The presence of chaetognaths, siphonophores, ctenophores and salps, even though not in greater numbers, but as they formed significant portion of the biomass were of considerable importance due to predation on the smaller zooplankters and contribution in energy transfer (Santhakumari and Saraswathy 1981) [27]. The success of a population depends not only on availability of food and abundance of predators, but also upon the dynamics of its physical environment, which influence feeding efficiency, susceptibility to predation, transport and recruitment success (Kane 1993) [17]. Studies have shown that there are apparently some seasonal variations in the distribution with time and space. Since the fisheries are dependent on the characteristics and availability of plankton population a detailed study along with ancillary hydrographic data is essentially needed for proper management of these resources.

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