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Distribution and abundance of major groups of zooplankton in relation to the physico-chemical parameters, in the coastal waters of Karachi, north Arabian Sea, Pakistan

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Abstract
The studies on zooplankton population structure, distribution and abundance are scare from Pakistani waters particularly from the near-shore waters off of Karachi. Most of the previous work is done on a few individual groups and species of zooplankton. The present study was proposed with an objective to assess the distribution and abundance of zooplankton from near-shore waters off of Karachi and also to correlate quantitative data with water quality parameters. This study showed higher population diversity of zooplankton groups. The seasonal abundance of zooplankton groups varied from station to station; the peak zooplankton abundance occurred in April (337.6 individuals/m³) at S2 and the lowest abundance was recorded in July (19.08 individuals/m³) at S1. In general, copepods (highest 67.74% at S1 and 73.51 at S3) always maintained dominance in the zooplankton population. Water parameters were variable through the year and showed low correlation with abundance data. The zooplankton population appears to be regulated by other factors (such as grazing pressure, etc.) and the water parameters had little contribution in controlling zooplankton population. For example, chlorophyll content (primary production) showed only weak positive correlation (r =0.170) with zooplankton abundance. The study area showed relatively stable environmental conditions and high zooplankton population which is beneficial for fisheries production. This study also provides the current and updated data, which helps to understand the marine ecosystem of coastal waters of Karachi coast of North Arabian Sea.

Keywords: Zooplankton abundance, inshore and near shore waters, Karachi coast

1. Introduction

Tropical aquatic ecosystems are the most productive areas with rich zooplankton population (Robertson and Blabber, 1992; Saravanakumar *et al*., 2007b) [26, 27]. The environmental conditions such as topography, water movement and stratification, salinity, oxygen, temperature and nutrients characterizing particular water mass also determine the composition of zooplankton biota (Karande, 1991) [15]. Usually in the near shore waters the seasonal variations depending on the local conditions of rainfall, tidal incursions, various abiotic and biotic processes, quantum of fresh water inflow affect the nutrient cycle of different coastal environments (Choudhury and Panigraphy, 1991) [6].

Zooplankton plays a key role in the aquatic food chain (Sharma, 1998) [31], nutrients recycling, and in transfer of organic matter from primary producers to secondary consumers like fishes (Krishnamurthy *et al*., 1979) [21]. Most fishes take zooplankton as food during their larval stages, and some fishes continue to eat zooplankton in their entire lives (Madin *et. al.,* 2001) [22], zooplankton represents the channel of transmission of the energy flux from primary producers to the top consumers (Nicoletta and Monica, 1999) [25], so zooplanktons are used as a tool to estimate the fishery resources and it is also bioindicator to understand water pollution status (Ahmed, 1951; Contreras *et. al.,* 2009) [1, 7]. The rate of zooplankton production can be used as a tool to estimate the exploitable fish stock of an area (Tiwari and Nair, 1991) [34]. The failure of fishery resources is attributed to the reduced zooplankton community.

Ecologically and geologically Pakistan has diverse coastline which is about 1050 km long, out of which 250 km belongs to Sindh province and 800 km to Baluchistan province with diversity in aquatic animal forms.

In Pakistan, the International Indian Ocean Expedition (IIOE) was made the first attempt to describe the quantitative geographic distribution and abundance of zooplankton in the Arabian Sea. Apart from the IIOE collections, other, more localized regions of the Arabian Sea have been sampled for zooplankton because Arabian Sea appears to be an ideal place to understand link between climatic oscillations and community structure of zooplankton and biodiversity. Many workers have studied the composition and structure of zooplankton in coastal waters of Karachi which includes those of Ahmed (1951) [1], Ali and Arshad (1966) [2] and then Haq (1968) [13]. Glolobov and Grobov (1970) [11], Fazal-ur-Rehman (1973, a&b) [8, 9], Haq and Fazal-ur-Rehman (1973) [14], Khan (1976) [19] and Khan and Kamran (1975) [20]. Khan (1974) [18] also worked on seasonal abundance of zooplankton.

The physico-chemical characteristics of the water bodies influence the distribution and abundance of zooplanktons. Although considerable information has been published on the groups of zooplankton which have been found in north Arabian Sea but that data is decade old and latest data on abundance of zooplankton in relation to physico-chemical parameters is not available.

This work represents the qualitative and quantitative study of different groups of zooplankton but not the individual species collection and the results are correlated with physico-chemical factors to get the better understanding and attempt is made to evaluate the existing knowledge of different zooplankton groups in inshore and near shore coastal waters of Karachi.

2. Materials and Methods

2.1 Study Area

For this study four stations were formed along the coast of Karachi (Fig: 1). Station 1 (S1; 24° 45′ 4.75″ N, 66° 59′ 9.29″ E),10m depth, inshore waters of Manora, station 2 (S2; 24° 52′ 6.18″ N, 66° 37′ 21.86″ E),10m depth, inshore waters of Mubarak village (MV), station 3 (S3; 24° 45′ 39.12″ N, 66° 26′ 13.38″ E),50m depth, near shore waters of Mubarak village (MV), station 4 (S4; 24° 35′ 5.91″ N, 66° 46′ 26.34″ E), 50m depth, near shore waters of Manora.

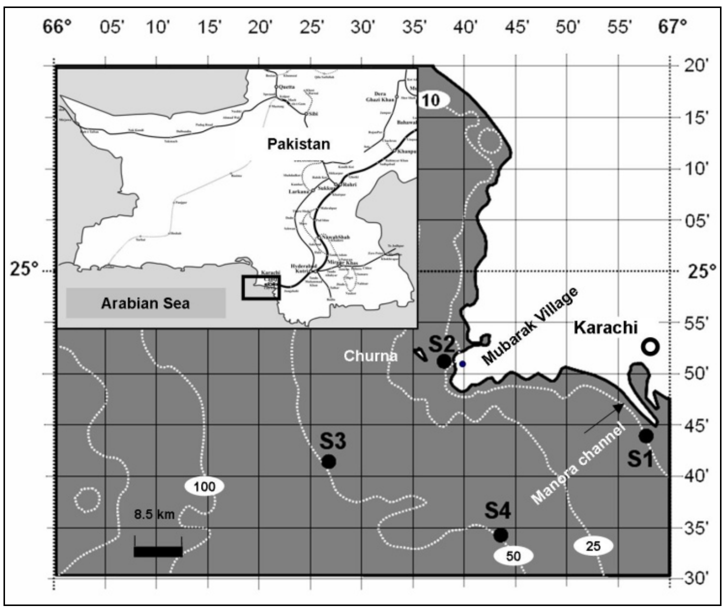


Fig 1: Map showing the study area of Karachi coast. The inshore waters and near shore waters off of Manora (S1, 10m contour line and S4, 50m contour line) and Mubarak village (S2, 10m contour line and S3, 50m contour line).

The vertical zooplankton samples were carried out at monthly intervals from four stations from Manora to Mubarak Village during the year 2008 to 2009, using 153 micro- mesh size zooplankton net. Zooplankton samplings were made on 50 m depth in near-shore waters and on 10 m depth in coastal waters and total 126 samples were collected from all four stations and preserve in 4% formalin (Parsons *et al*, 1984) [26] for analysis. Numerical zooplanktons were identified to major taxonomic groups by using Olympus CX-31 binocular microscope and abundance was estimated as (No. ind /m^{-3}) number per cubic meter (Goswami, 2004) [12]. The sampling in the months of June, July and August 2008 to 2009 was not taken because of rough season in sea and restriction on movement of boats from concerned authorities, in spite that bucket samples were taken from inshore.

For the analysis of chlorophyll- *a*, triplicate water samples were collected from the depth of 1 meter in bottles of 500ml by Niskin bottle (1.7), sample water was filtered by Whatman GF/F(0.7 µm), extracted with 90% acetone and absorbance was recorded (Shimadzu UV-visible spectrophotometer) in accordance with Strickland & Parsons (1972) [32]. Air and water temperature was measured by mercury filled centigrade thermometer. Secchi disc was used to measure the turbidity of water. Salinity was measured with the help of refractometer and pH was measured using Hanna, HI-9023. Dissolved oxygen was estimated by Wrinkle titration method (Strickland and Parsons, 1972) [32].

Correlation coefficient (r) was calculated for chlorophyll and other water parameters with zooplankton diversity and the mean number/10ml±standard deviation is calculated for different groups of zooplanktons and for physico-chemical parameters in relation to different stations.

3. Result

3.1 Seasonal Abundance

The monthly abundance (no.ind/m^3) of zooplankton groups varied from station to station during 2008 to 2009, but common trend shows that copepods are always major zooplankton group. The peak zooplankton abundance occurred in April 2008-9 (337 no.ind /m³) at coastal waters of Mubarak village (S2) and the lowest abundance was recorded in July 2008-9 (19 no.ind /m³) at (S1),coastal waters of Manora (Fig: 2). It is found that the coastal stations, S1 (332 no.ind/m³) and S2 (337 no.ind/m³) exhibit higher abundance of zooplanktons as compare to near shore stations S3 (256 no.ind/m³) and S4 (323 no.ind/m³) (Fig:3). Zooplankton community data shows high abundance during April and May. Percent contribution of zooplankton groups in total population evidently shows that copepods are dominant group. Stations, S1 (coastal water of Manora) 67.74% (Fig: 4), and S4 (near shore waters of Manora) 73.57% (Fig: 5), shows higher average contribution of copepods as compared to stations, S2 (coastal waters of Mubarak village) 63.02% and S3 (near shore waters of Mubarak village) 63.27%.

Table 1: List of zooplankton groups (mean number/10ml±standard deviation) recorded at four different stations during April 2008 to March 2009 along Karachi coast.

S. No.	G Groups of Zooplankton			Stations	
		S1	S2	S3	S4
1.	Copepoda				
	i. Cyclopoid	896.16(4.57±0.26)	892.91(3.65±0.28)	932.66(1.56±0.30)	1049 .31(1.31±0.28)
	ii. Calanoid	4239.8(4.86±0.30)	3978(6.96±0.32)	3678.25(0.91±0.30)	3692.8(0.70±0.33)
	iii. Herpacticoid	400.25(0.99±0.24)	453.33(3.78±0.23)	244.83(1.46±0.31)	374.33(1.00±0.29)
2.	Decapoda				
	Lucifer	10.83 (0.68±0.37)	9.91(2.36±0.36)	18.33 (1.41±0.32)	29.75 (2.50±0.35)
3.	Appendicularia				
	Oikopleura sp.	1381.08(19.70±0.30)	1441(20.85±0.30)	851.66(1.08±0.37)	1650.4(1.02±0.33)
4.	Isopoda	4.5(0.27±0)	0	7.25(0.94±0.28)	6.08(0.27±0)
5.	Cladocera				
	i. Evadna sp.	1015.91(12.19±0.31)	1461(13.04±0.33)	650.66(3.12±0.35)	1074.5(11.48±0.38)
	ii. Penilia	13.75(1.22±0.28)	17.83(2.45±0.35)	12.91(2.56±0.27)	4.41(0.52±0.34)
6.	Chaetognatha				
	Sagitta sp.	66.25(2.09±0.29)	35.83(1.51±0.25)	36.41(0.82±0.32)	70(1.40±0.40)
7.	Doliolids				
	Doliolum	5.25(3.19±0.27)	3.83(0.71±0.31)	3.33(0.27±0)	1.66(0.72±0.21)
8.	Pteropods				
	Creseis	80.33(0.78±0.31)	83.08(3.04±0.33)	104.83(1.24±0.31)	93.91(2.03±0.34)
9.	Siphonophora	0	2.08(0.26±0)	42.5(12.91±0.27)	2.91(0.27±0)
10.	Pelecypoda	21.66(0.81±0.36)	18.75(1.34±0.29)	1.66(0.27±0)	11.83(0.69±0.28)
11.	Foraminifera	24.66(0.52±0.30)	21.66(0.56±0.30)	0	8.33(1.56±0.27)
12.	Mysidae				
	Mysis	11.25(1.29±0.32)	29.16(2.16±0.29)	14.33(1.65±0.35)	16.76(1.10±0.38)

*S1 (Inshore Manora) *S2 (Inshore Mubarak Village)
*S3 (Near shore Mubarak Village) *S4 (Near shore Manora)

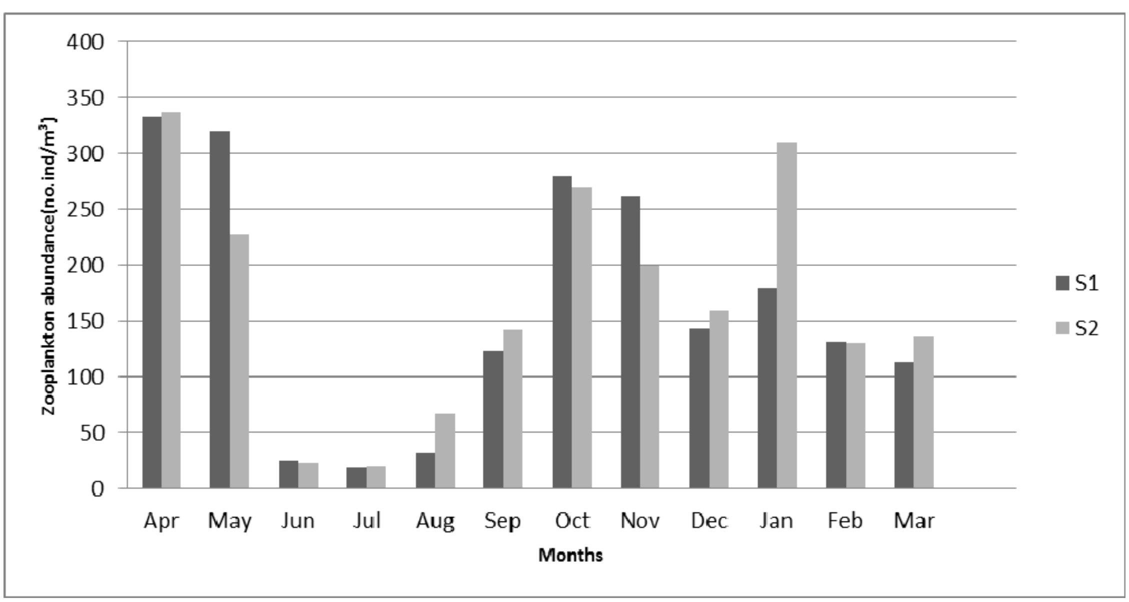


Fig 2: Seasonal variation in zooplankton abundance (no.ind/m³) during 2008-9 at coastal waters of Manora (S1) and Mubarak village (S2).

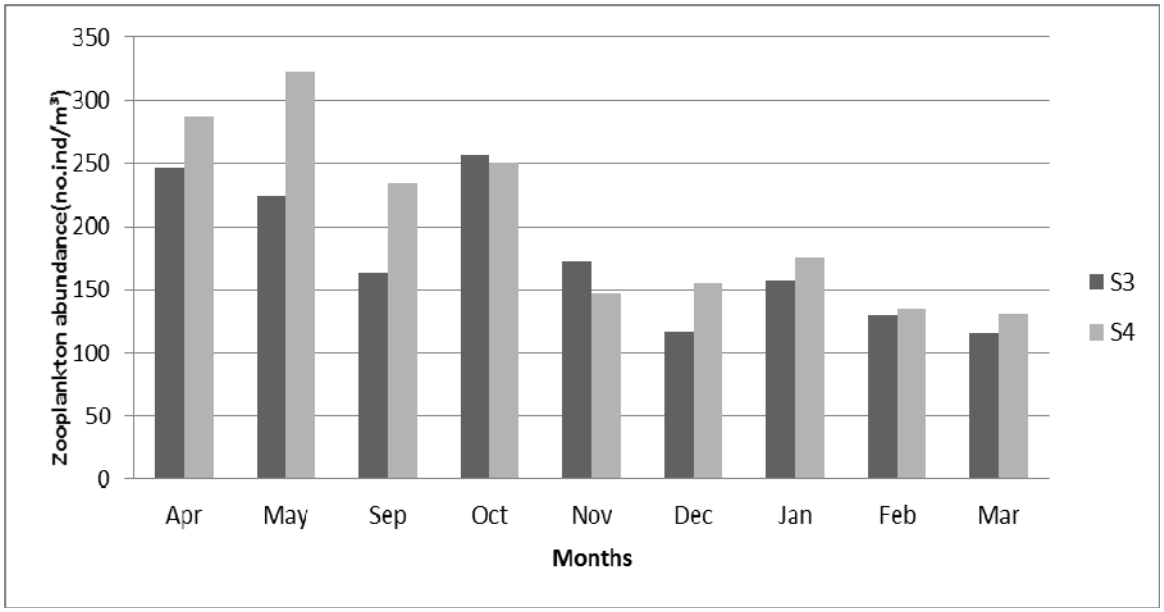


Fig 3: Seasonal variation in zooplankton abundance (no.ind/m³) during 2008-9 at near shore waters of Mubarak village (S3) and Manora (S4).

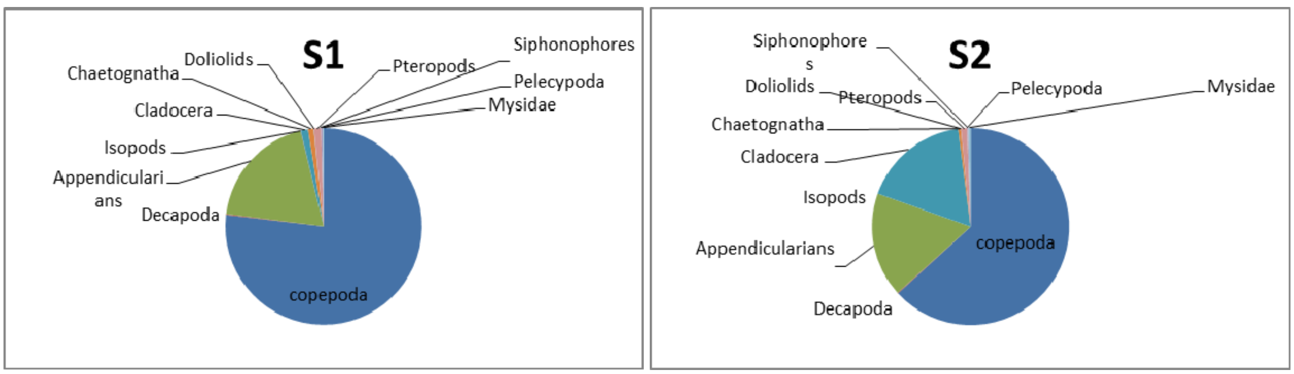


Fig 4: Higher percentage of copepods in total zooplankton community at coastal waters of Manora (S1: 67.74%) and MV (S2: 63.02%).

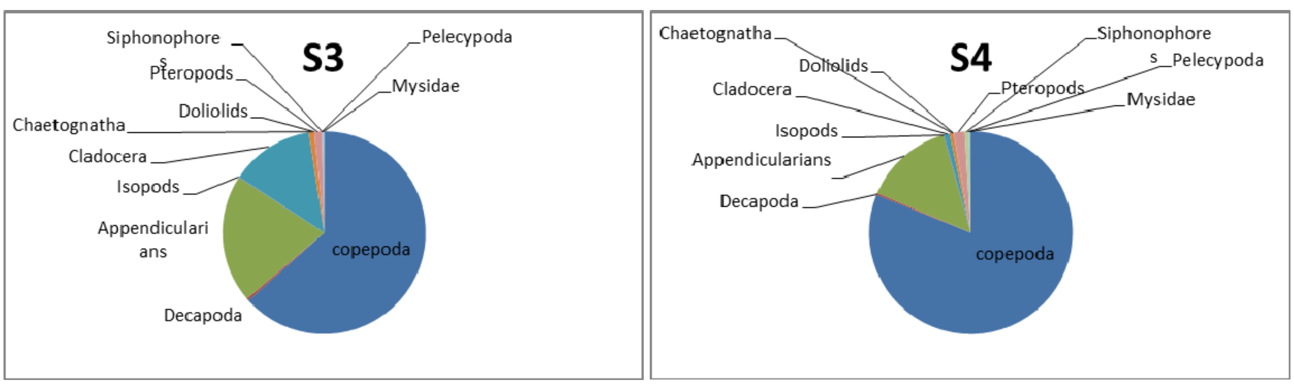


Fig 5: Higher percentage of copepods in total zooplankton community at near-shore waters of MV (S3: 63.27%) and Manora (S4: 73.57%).

3.2 Physico-chemical Parameters

The study was made to observe the correlation of zooplankton groups with physico-chemical parameters. The annual average air temperature at S1, S2, S3, and S4, during 2008-9 recorded was 24.58 °C, 25.2 °C, 25.97 °C, 24.7 °C, respectively, highest was in April 31 °C at S2 and lowest was in January 19.1 °C also at S2. Zooplankton abundance showed positive correlation with air temperature at different stations, S1(r =0.96), S2(r =0.27), S3(r =0.56) and S4 (r =0.54).

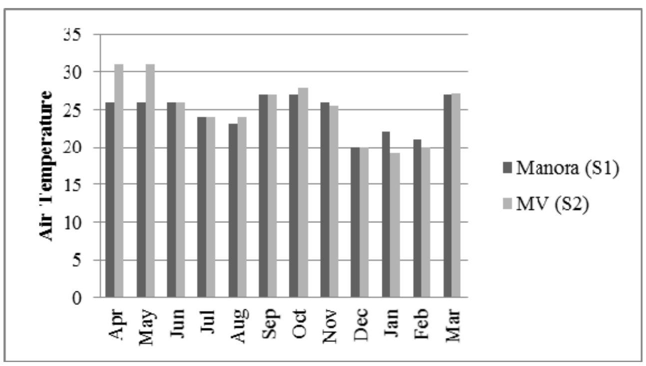
The annual average water temperature at S1, S2, S3 and S4 during 2008-2009 recorded was 24.33 °C, 24.4 °C, 25.95 °C and 23.96 °C, respectively, highest was in April 30 °C at S2 and lowest was in December 19 °C at S2, S4 and S1. Zooplankton abundance showed positive correlation with water temperature at all four stations, S1(r =0.43), S2(r =0.51), S3(r =0.50), S4(r =0.63).

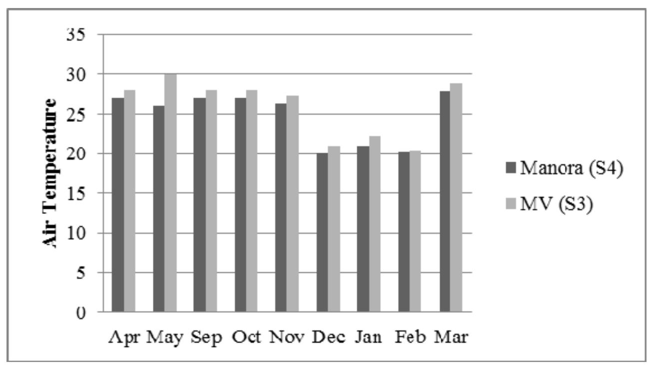
The annual average salinity at S1, S2, S3 and S4 during 2008-2009 recorded was 38.08‰, 38.08‰, 38‰, 37.77‰, respectively, highest was in August 40‰ and lowest recorded was 37‰ at all four stations. Zooplankton abundance showed inverse correlation with salinity (r = -0.54) at S1 and positive correlation at stations, S2(r =0.80), S3(r =0.78), S4(r =0.86). The annual average pH at S1, S2, S3 and S4, during 2008-2009 recorded was 7.37, 7.37, 7.27, and 7.27, respectively, highest recorded was 7.5 and lowest recorded was 7 at all four stations. Zooplankton abundance showed inverse correlation with Ph, (r = -0.18) at S2 and positive correlation at S3(R =0.58), S4(r =0.89), it also showed negative correlation at S1(r = -0.04).

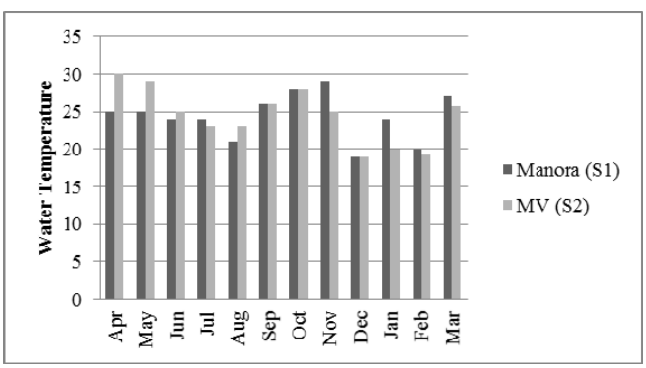
Table 2: Annual mean and standard deviation (mean ± SD) of different physico-chemical parameters from S1, S2, S3 and S4 stations during April 2008 to March 2009.

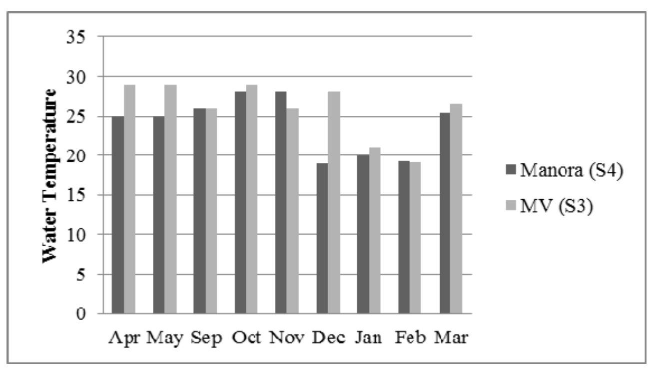
Stations	Air Temp. °C	Water Temp. °C	Salinity (‰)	pH	Transparency (m)	DO (mg/L¯¹)	Chlorophyll-*a* (µg/L¯¹)
S1 (Manora) Inshore	24.58±2.39 (27-20)	24.33±2.95 (29-19)	38.08±1.32 (40-37)	7.37±0.35 (7.5-7)	10.75±2.16 (15-6)	7.55±1.66 (10-4.5)	32.86±29.16 (1.35-120)
S2 (MV) Inshore	25.2±3.82 (31-19.1)	24.4±3.53 (30-19)	38.08±0.85 (40-37)	7.37±0.2 (7.5-7)	10.66±1.02 (13-11)	8.01±2.35 (10-3.4)	7.86±4.06 (0.005-20)
S3 (MV) Near shore	25.97±3.50 (30-20)	25.95±3.41 (29-19)	38±0.94 (40-37)	N 7.27±0.24 (7.5-7)	41.33±5.71 (50-34)	8.38±1.46 (10-5.5)	13.90±16.63 (1.23-60)
S4 (Manora) Near shore	24.7±3.08 (27-20)	23.96±3.36 (28-19)	37.77±0.91 (40-37)	7.27±0.33 (7.5-7)	42.88±5.38 (50-37)	7.72±1.73 (9.4-4.9)	19.87±18.66 (2.35-82)

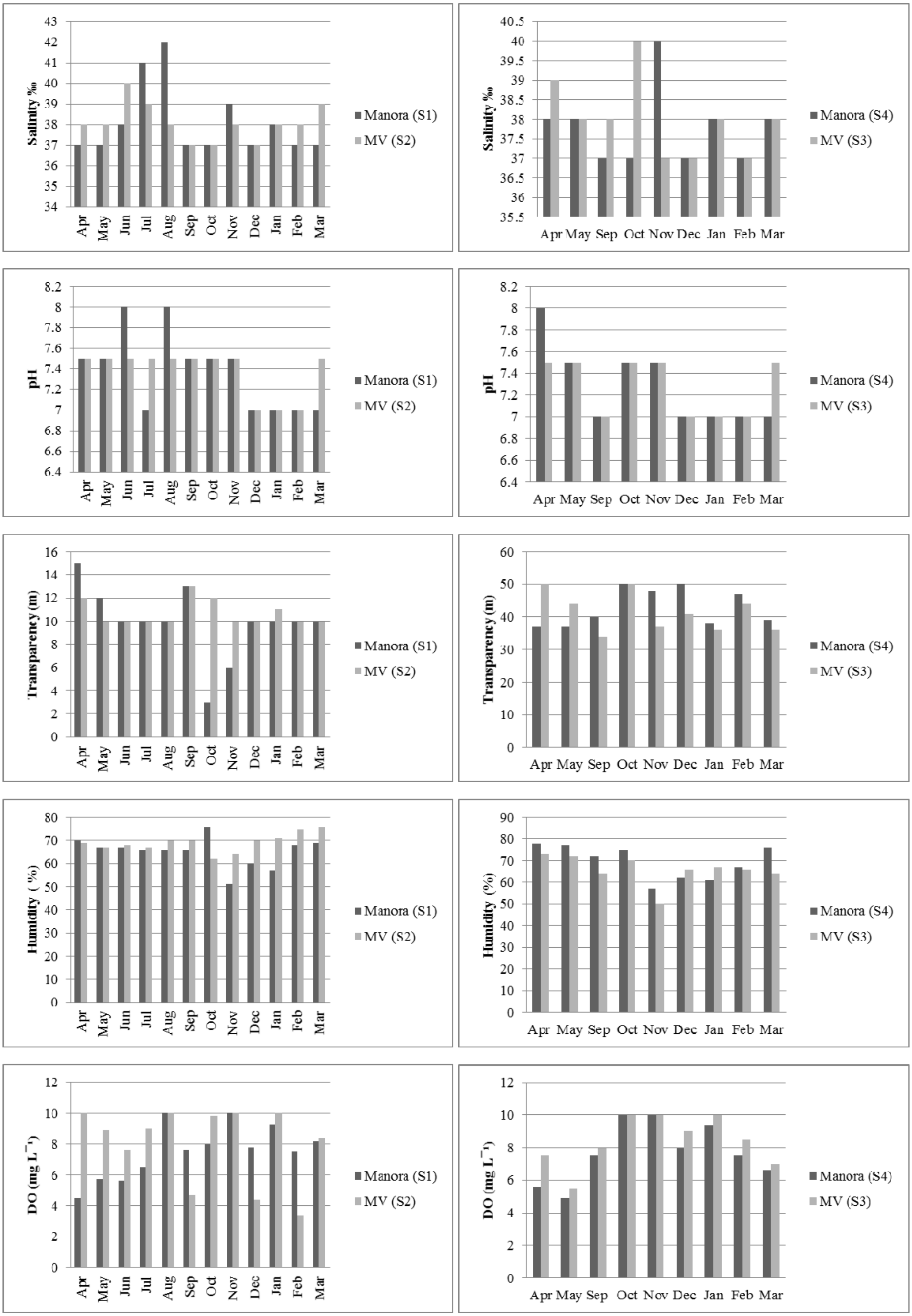
The variation in average dissolved oxygen contents were at S4 from 7.72 mg L¯¹ and 8.01 mg L¯¹ at S2. It is observed that the salinity and temperature affect the dissolve oxygen (Vijayakumar *et al*., 2000 [35]; Saravanakumar *et al*., 2007 a,b) [28, 29]. In this study, at all four stations higher values of dissolve oxygen were recorded in the months of April, August, October, November and January 10 mg L¯¹ and lowest values of dissolved oxygen were recorded in the months of March 7 mg L¯¹, April 4.5mg L¯¹, May 4.9 mg L¯¹ and February 3.4 mg L¯¹. Zooplankton abundance showed positive correlation with dissolved oxygen at S2(r =0.25), S3(r =0.08), S4(r =0.72) but it showed inverse correlation at S1(r = -0.19). The average chlorophyll *a* (µg/L¯¹) ranges highest for S1 was 32.86µg/L¯¹ and lowest for S2 was 7.86µg/L¯¹. A higher value of chlorophyll -*a* was observed during November for S1 was 120 µg/L¯¹, in January for S2 was 20 µg/L¯¹, in October for S3 was 60 µg/L¯¹, in February for S4 was 82 µg/L¯¹. The low value of chlorophyll- *a* was recorded for S1, S2, S3, and S4 were 1.35 µg/L¯¹, 0.0052 µg/L¯¹, 1.23 µg/L¯¹, 2.35 µg/L¯¹, respectively. This low level of chlorophyll- *a*, at S1 and S2 may be because of turbidity and less availability of light at inshore waters (Kawabata *et al*., 1993 [17]; Godhantarraman, 2002 [10]; Thillai Rajasekar *et al*., 2005) [33]. Zooplankton abundance showed positive correlation with chlorophyll *a* at S(r =0.18), S2(r =0.52), S3(r =0.90) and S4(r =0.08).










Salinity ‰
Manora (S1)
MV (S2)
Manora (S4)
MV (S3)
pH
Transparency (m)
Humidity (%)
Humidity (%)
DO (mg L⁻¹)
Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
Apr May Sep Oct Nov Dec Jan Feb Mar

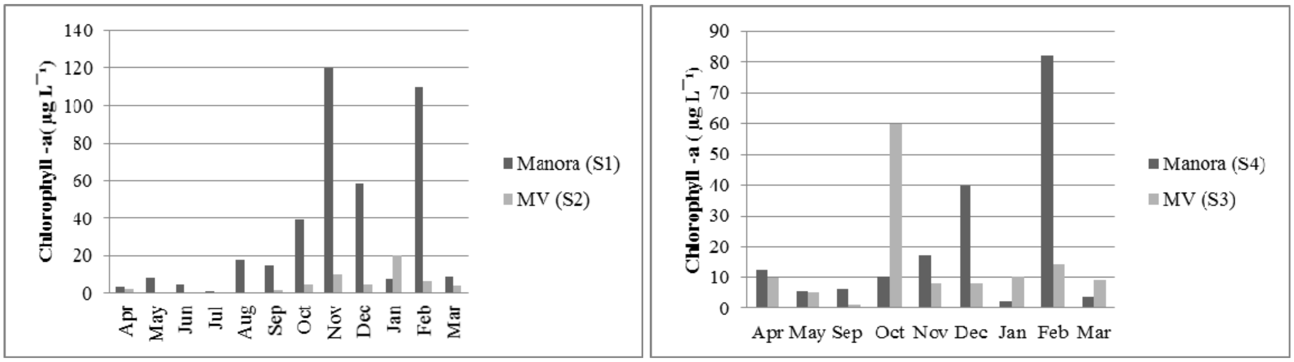


Fig 6: Seasonal variation in water parameters (air and water temperature (c°), salinity (‰), pH, humidity (%), transparency (m), dissolve oxygen (mgL⁻¹), and chlorophyll-*a* (µgL⁻¹) concentrations observed in the coastal Manora (S1) and Mubarak village (S2) and near-shore waters of Mubarak village (S3) and Manora (S4).

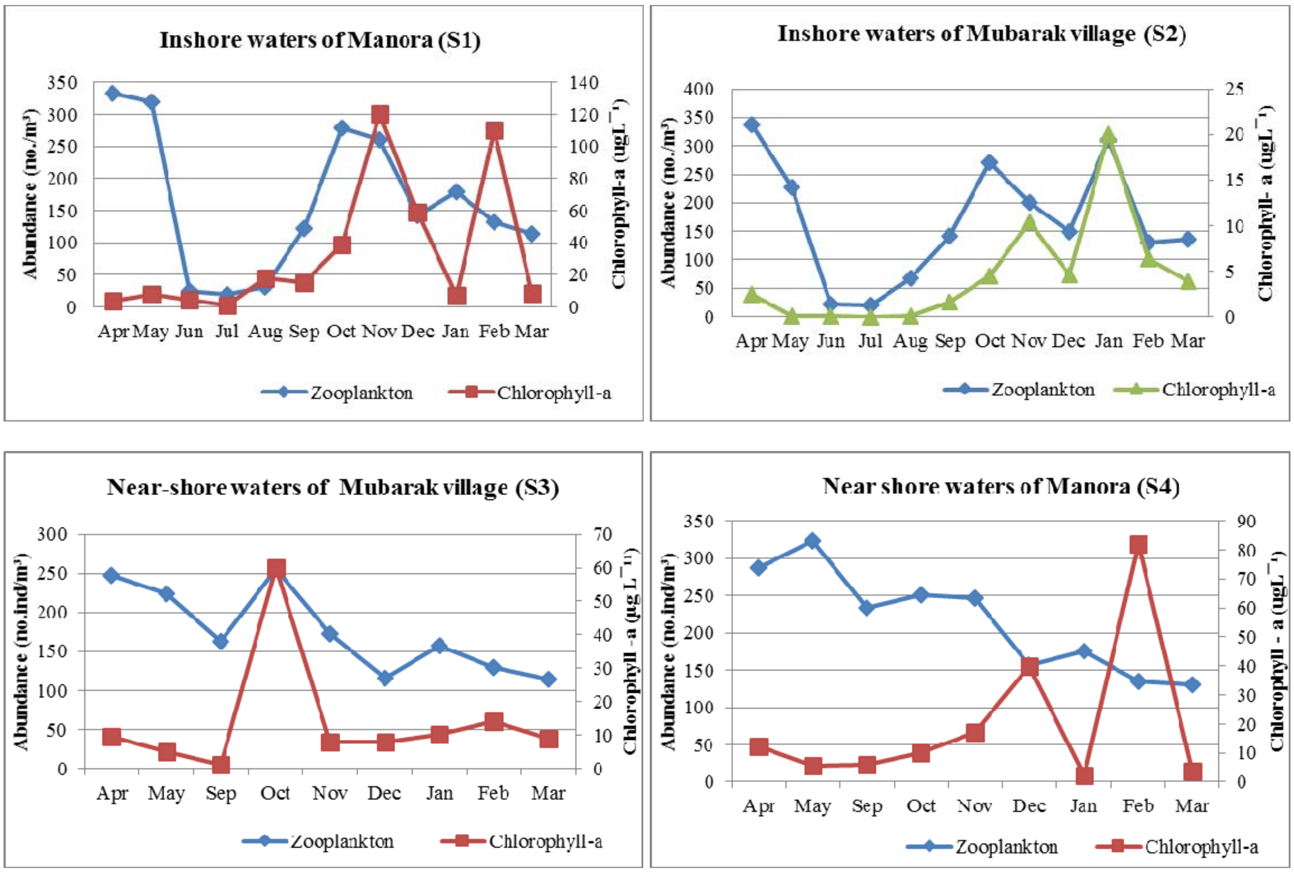


Fig 7: Seasonal variation in between the zooplankton abundance (no. ind/m³) and chlorophyll-*a* (µgL⁻¹) recorded from the coastal of Manora and Mubarak village (S1 & S2) and near-shore (S3 & S4) waters.

4. Discussion

The present study provides data on the distribution and abundance of zooplankton with physico-chemical parameters. The zooplankton abundance shows variations with season, the peak abundance is between hot, dry spring months, April and May and between October and November and January (Northeast monsoon) at coastal waters of Manora (S1) and Mubarak village(S2), it is may be because of upwelling in the North Arabian sea and enhance primary productivity of phytoplankton. During monsoon periods wind induced connective mixing and up-sloping of nutrients rich water which causes high productivity (Marra and Barber, 2005; Naz *et al,* 2013b) [23, 24] and support the distribution and abundance of zooplankton (Fig: 2). At near-shore waters of Mubarak village (S3), peak abundance is between April –May and between September – October, whereas at near-shore waters of Manora (S4), peak abundance of zooplankton shows between April and October (Fig: 3). Among all zooplankton groups, copepods shows highest percentage about 67.74% at S1 and 73.51% at S2 (Fig:4), whereas at S3, it is 63.02% and 63.27% at S4 (Fig:5). Most of the water parameters have significant correlation with zooplankton abundance.

The present data shows high chlorophyll-*a* concentration during November and February in coastal waters (Fig: 7), in October and February at near-shore waters (Fig: 7) with high zooplankton abundance. The abundance of zooplankton is significantly correlated with high chlorophyll-*a* concentration, this might be because of influence of dissolved nutrients comes from rivers in coastal waters (Karuppasamy *et al,* 2000) [16]. This causes high primary productivity (Cebrian &

Valiela, 1999) [5]. The coastal belt of this study area also receives discharges of Layari and Malir rivers (Beg *et al*, 1984-1992) [3, 4]. During this study higher community of zooplankton groups were observed at coastal waters (S1 & S2), it might be because of high load of domestic, agriculture and industrial effluents drained in manora channel which carry the large quantity of dissolve nutrients. The near-shore waters (S3 & S4) as compare to coastal waters shows stable environmental conditions so zooplankton abundance comparatively is less. Copepods are among the highest abundance percentage in all groups of zooplankton at all coastal (S1 & S2) and near-shore waters (S3 & S4).

The conclusion of this study is that the coastal waters of Karachi coast are very productive. In this study the zooplankton abundance shows the positive relationships with physico-chemical parameters at study area, Manora and Mubarak village. These both sites are important for fishing and this work is carried out for the benefit of fisheries production. This study provides the current and updated data, which helps to understand the marine ecosystem of coastal waters of Karachi coast of North Arabian Sea.

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