Pakistan Journal of Marine Sciences, Vol. 24(1&2), 37-50, 2015.

# ABUNDANCE AND DIVERSITY OF MAJOR ZOOPLANKTON GROUPS DURING PREMONSOON SEASON IN THE PORT QASIM CREEK SYSTEM – KARACHI

**Qadeer Mohammad Ali and Quratulan Ahmed**
The Marine Reference Collection and Resource Centre, University of Karachi,
Karachi - 75270, Pakistan
email: taxonomist@hotmail.com, marine.taxonomist@gmail.com

**ABSTRACT:** A preliminary study was conducted on the occurrence and faunastic composition of zooplankton in two creeks of Port Qasim creek system during January to April 1998 (pre-monsoon season). Total 14 major groups were recorded during the study period. Despite the importance of zooplankton in aquatic food web meager information is available on the assemblage of zooplankton in the port Qasim creek system. Highest mean (%) compositions (38.96) were recorded in copepod at station # 1 and chaetognath (23.95) at station # 2. Copepods, chaetognath and zoea were the major component of zooplanktonic groups at both the stations. The hydrographic parameters such as air temperature ($^{o}$C), water temperature ($^{o}$C), salinity (ppt), dissolved oxygen (mg/L), pH, and transparency (cm) were recorded on monthly basis. No significance correlation at ($P < 0.05$) was observed in between zooplankton with hydrographic parameters, locality and months. The number of zooplankton/100m$^3$ found in order at station #1: copepod > chaetognath > zoea > penaeid PL > amphipoda > hydromedusae > caridean PL > fish larvae > lucifer > megalopa > fish eggs > mysids > acetes > squilla larvae. At station # 2: chaetognath > copepod > zoea > mysids > Lucifer > hydromedusae > megalopa > penaeid PL > fish larvae > fish eggs > amphipoda > caridean PL > others > acetes > squilla larvae.

**KEYWORDS:** Port Qasim creek system, diversity, major zooplankton groups**,** pre-monsoon.

## INTRODUCTION

Zooplanktons are the important component of an aquatic food web by forming link in the food chain as secondary producers. They play a vital role in the conservation of energy from primary to secondary level. They themselves are an important food source for large animals (Day *et al.,* 1989) and are important in the demineralization and transport of nutrients (Harris, 1959) which is very important in the conservation of modern oceanic food webs (Perumal *et al.,* 1999; Rajasegar *et al.,* 2000). The pelagic fishery potentials influenced by the occurrence, community structure and distribution of zooplankton. According to Gannon and Stemberger, 1978 they are good indicator of changes in water quality, because they are strongly affected by the environmental conditions and it is quickly responded to changes in environmental quality.

The Port Qasim creek system forms the westward extension of Indus delta. The system is typically characterized by long and narrow creeks, islands, mudflats and mangrove forests. The creek system is nutritionally rich and serves as important breeding and nursery grounds for a wide range of organisms including commercially important

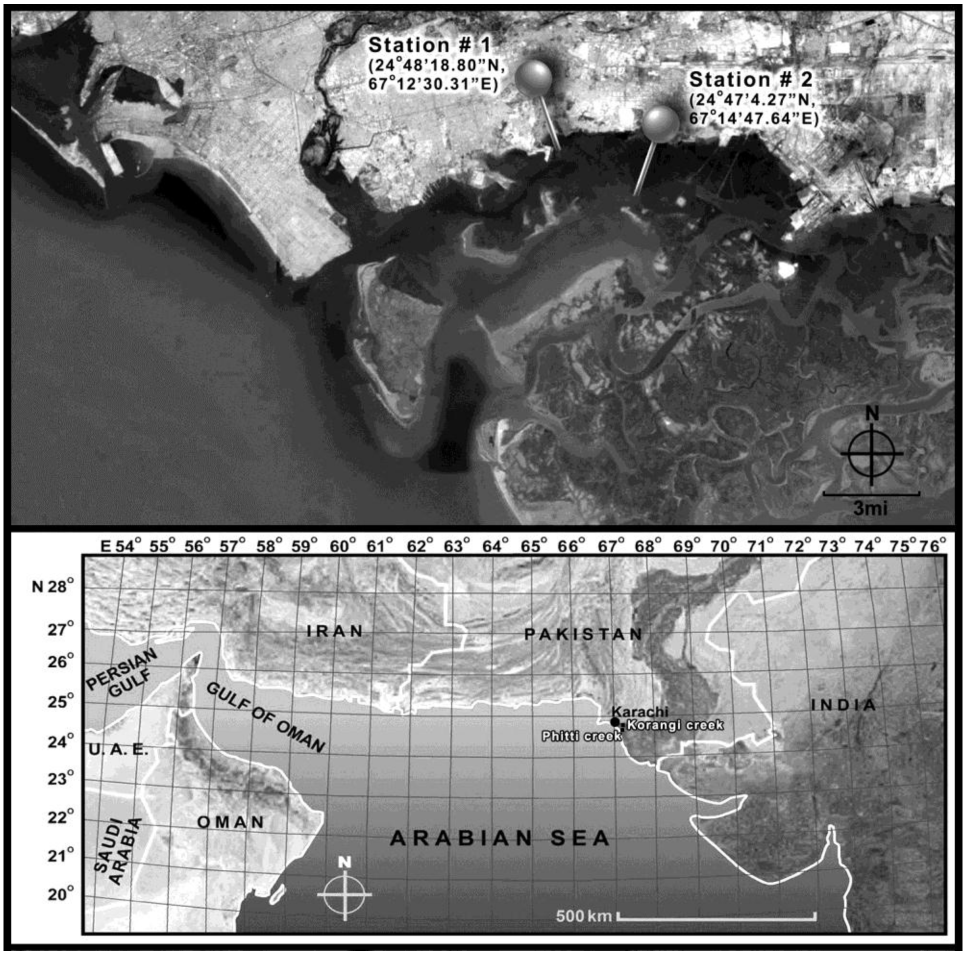



Fig. 1. Map of Port Qasim creek system showing two sampling creeks, Indus deltaic area, Pakistan.

species. Mangrove ecosystem has been recognized as an incredible natural resource for its ecological and biodiversity dynamics. It plays a vital role in fisheries and coastline protection as a natural barrier against cyclones and storms. It also constitutes a central role in transferring organic matter and energy from terrestrial to marine ecosystems.

Present study will be an addition to the knowledge on distribution and abundance of zooplanktonic groups occurring in two major creeks of Port Qasim creek system; Korangi creek and Phitti creek during January to April 1998 (pre-monsoon season).

## MATERIALS & METHODS

**Study area:**

Sampling was conducted during pre-monsoon season (January – April, 1998) from two permanent stations in Port Qasim creek system; station # 1 Korangi creek (24°48'18.80"N, 67°12'30.31"E), and station # 2 Phitti creek (24°47'4.27"N, 67°14'47.64"E) (Fig. 1). The port Qasim creek system is a typical mangrove habitat and constitutes the western most part of the Indus delta. The creek system has been facing harsh ecological conditions due to heavy load of untreated domestic and industrial effluents. The raw untreated sewage enters Korangi creek through Malir River whereas the source of pollution in Phitti creek is effluents from steel mill, chemical industries and shipping activities.

**Sampling procedure:**

Physico-chemical parameters including air temperature (°C), water temperature (°C), salinity (ppt), dissolved oxygen (mg/L), pH and Transparency (cm) were recorded on monthly basis. Air and water temperature values were recorded using a mercury-in glass thermometer graduated in units (50°C) by immersing the thermometer slightly under the surface of water (10 cm) for five minutes until mercury stabilized at one place. Salinity (ppt) was measured with the help of a temperature compensated hand-held Refractometer (S/Mill- E, Atago Co. Ltd., Tokyo, Japan). Dissolved oxygen (mg/L) was measured with the help of portable DO meter (Orion Model 820). pH recorded with the help of a pocket pH meter (HACH pH tester, USA) by dipping into the water until the screen showed a fixed/stable reading as described by the manufacturer. Water transparency was measured with the help of Secchi disc (Hydro-Bios, 443590).

Zooplankton sampling was done with the help of Hydro-Bios Ring trawl net of 500 μ mesh size through horizontal towing of 10 minutes haul at constant speed of 0.5 m/s in the surface waters during high tide. Hydro-Bios digital flow meter was used to record the volume of water passed through the net. Samples were immediately preserved in 5% buffered formalin in the field and kept in plastic containers. In the laboratory, samples were split into aliquots (sub samples) which were sorted out into different major taxonomic groups, identified and counted in counting tray under a stereomicroscope (Nikon SMZ 10). The keys and identification references used were obtained from practical guide of (Newell and Newell, 1977).

## RESULTS & DISCUSSION

The hydrographic parameters were measured in Korangi creek and Phitti creek areas during pre-monsoon season (January to April 1998). In the present study higher air temperature (32°C) and water temperature (30°C) was measured in April at station ≠ 1. However, at station ≠ 2 highest salinity (43 $^{ppt}$) was measured in February, dissolved oxygen (7.0mg/L) in April, and transparency (90cm) in January (Table 1 Fig. 2a to 2f). The range of air temperature (21-32 °C), water temperature (19-30°C), salinity (39-43 $^{ppt}$), dissolved oxygen (5.7-7.00 mg/L), PH (7.9-8.00) and transparency (20-90cm) were recorded at station ≠ 1 and 2 (Table 2). Highest mean of air temperature (26±4.18 °C) and transparency (55±12.90 cm) were recorded at station # 1 and highest mean of water temperature (24±5.27 °C), salinity (41.5±1.29 $^{ppt}$), and dissolved oxygen (6.4±0.49 mg/L) were measured at station # 2 (Table 2, Fig. 3).

**Table 1. Variation in physico-chemical parameters recorded at two permanent stations, (station # 1 Korangi creek and station # 2 Phitti creek) during January to April 1998 (pre-monsoon season).**

| Locality | Air Temperature ($^0C$) | Water Temperature ($^0C$) | Salinity (ppt) | Dissolved oxygen (mg/L) | pH | Transparency (cm) |
|---|---|---|---|---|---|---|
| **Station # 1 Korangi creek** | | | | | | |
| January | 24.0 | 19.0 | 40 | 5.7 | 8.0 | 50 |
| February | 22.5 | 20.0 | 41 | 6.8 | 8.0 | 60 |
| March | 25.5 | 26.5 | 40 | 6.0 | 8.0 | 70 |
| April | 32.0 | 30.0 | 39 | 6.9 | 8.0 | 40 |
| **Station # 2 Phitti creek** | | | | | | |
| January | 23.0 | 19.0 | 42 | 6.1 | 8.0 | 90 |
| February | 21.0 | 20.0 | 43 | 5.9 | 7.9 | 50 |
| March | 26.0 | 27.5 | 41 | 6.6 | 8.0 | 20 |
| April | 31.5 | 29.5 | 40 | 7.0 | 8.0 | 30 |

**Table 2. Mean and standard deviation (mean ±SD, min-max) of physico-chemical parameters from station # 1 (Korangi creek) and station # 2 (Phitti creek) during January to April 1998 (pre-monsoon season).**

| Station # 1 (Korangi creek) | Air temperature ($^0C$) | Water temperature ($^0C$) | Salinity (ppt) | Dissolved oxygen (mg/L) | pH | Transparency (cm) |
|---|---|---|---|---|---|---|
| Mean | 26 | 23.87 | 40 | 6.35 | 8 | 55 |
| Std. Deviation | 4.18 | 5.26 | 0.81 | 0.59 | 0 | 12.90 |
| Minimum | 22.5 | 19 | 39 | 5.7 | 8 | 40 |
| Maximum | 32 | 30 | 41 | 6.9 | 8 | 70 |
| **Station # 2 (Phitti creek)** | **Air temperature ($^0C$)** | **Water temperature ($^0C$)** | **Salinity (ppt)** | **Dissolved oxygen (mg/L)** | **pH** | **Transparency (cm)** |
| Mean | 25.37 | 24 | 41.5 | 6.4 | 7.97 | 47.5 |
| Std. Deviation | 04.57 | 5.27 | 1.29 | 0.49 | 0.05 | 30.95 |
| Minimum | 21 | 19 | 40 | 5.9 | 7.9 | 20 |
| Maximum | 31.5 | 29.5 | 43 | 7 | 8 | 90 |

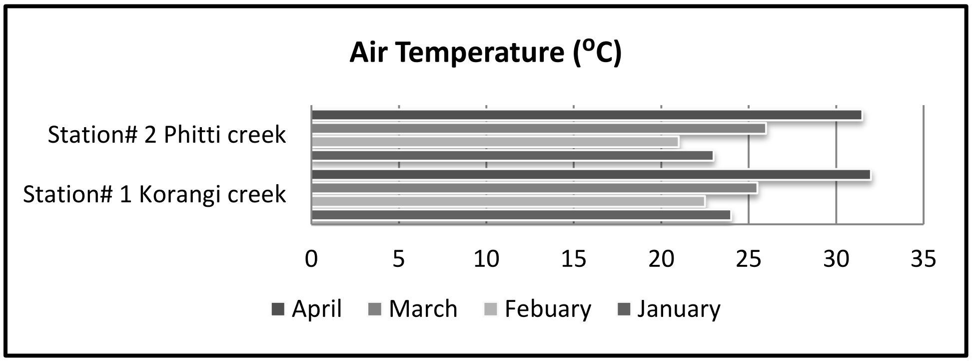



Fig. 2(a). Monthly variation in Air temperature (°C) collected from two permanent stations, station # 1 (Korangi creek) and station # 2 (Phitti creek) during January to April 1998.

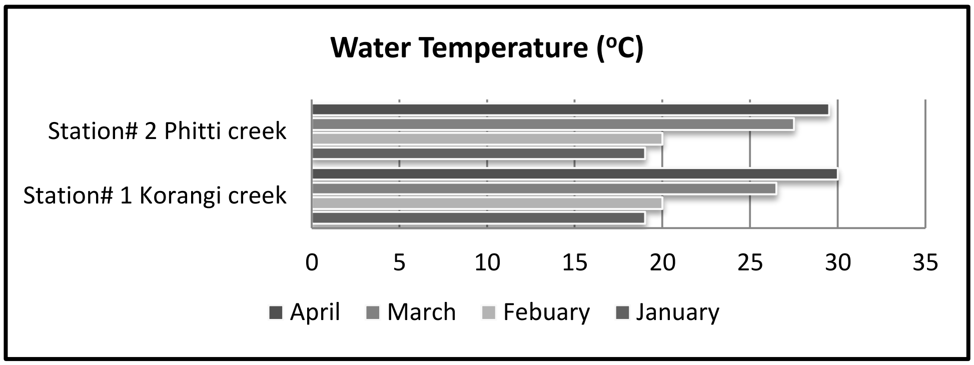



Fig. 2(b). Monthly variation in Water temperature (°C) collected from two permanent stations, station # 1 (Korangi creek) and station # 2 (Phitti creek) during January to April 1998.

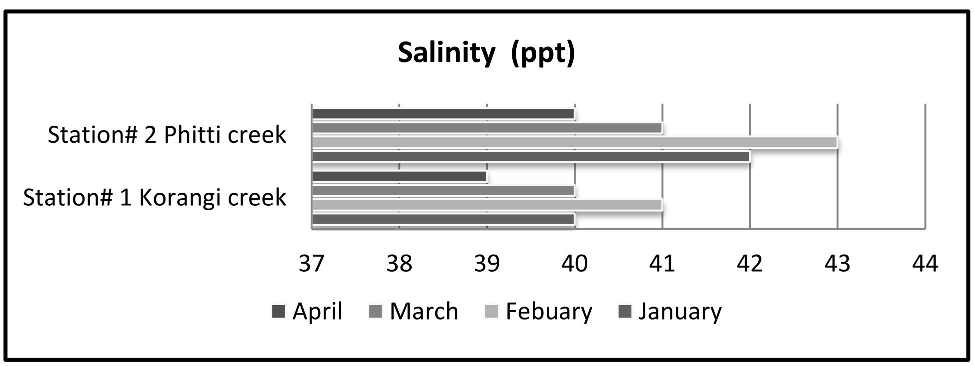



Fig. 2(c). Monthly variation in Salinity (ppt) collected from two permanent stations, station # 1 (Korangi creek) and station # 2 (Phitti creek) during January to April 1998.

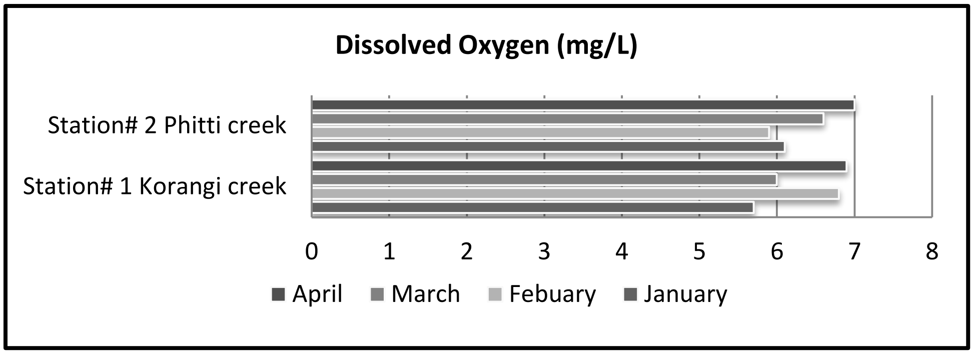



Fig. 2(d). Monthly variation in Dissolved oxygen (mg/L) collected from two permanent stations, station # 1 (Korangi creek) and station # 2 (Phitti creek) during January to April 1998.

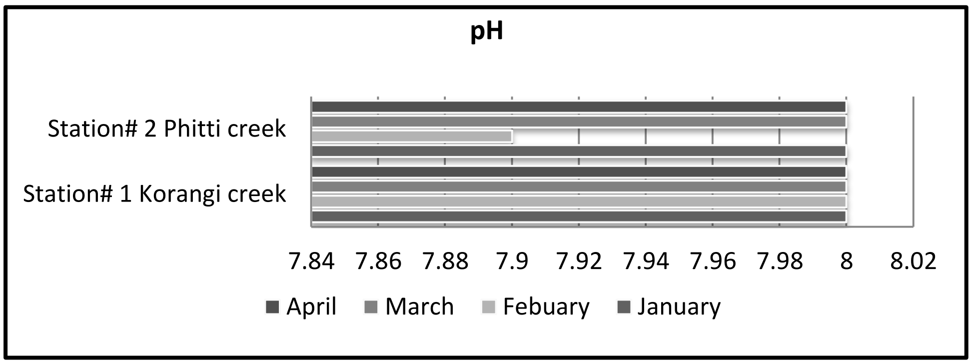



Fig. 2(e). Monthly variation in pH value collected from two permanent stations, station # 1 (Korangi creek) and station # 2 (Phitti creek) during January to April 1998.

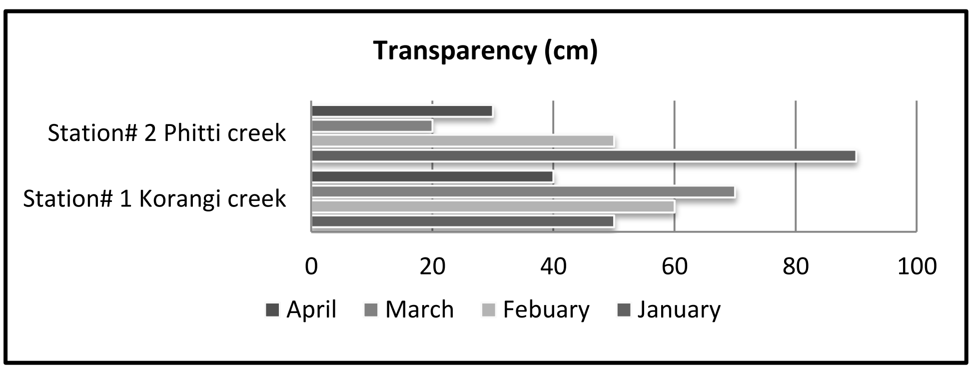



Fig. 2(f). Monthly variation in Transparency (cm) collected from two permanent stations, station # 1 (Korangi creek) and station # 2 (Phitti creek) during January to April 1998.

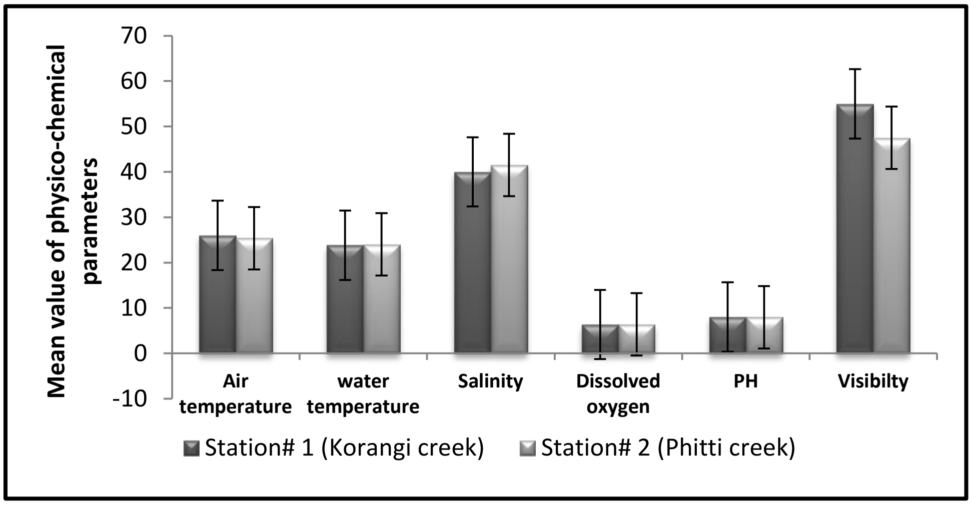


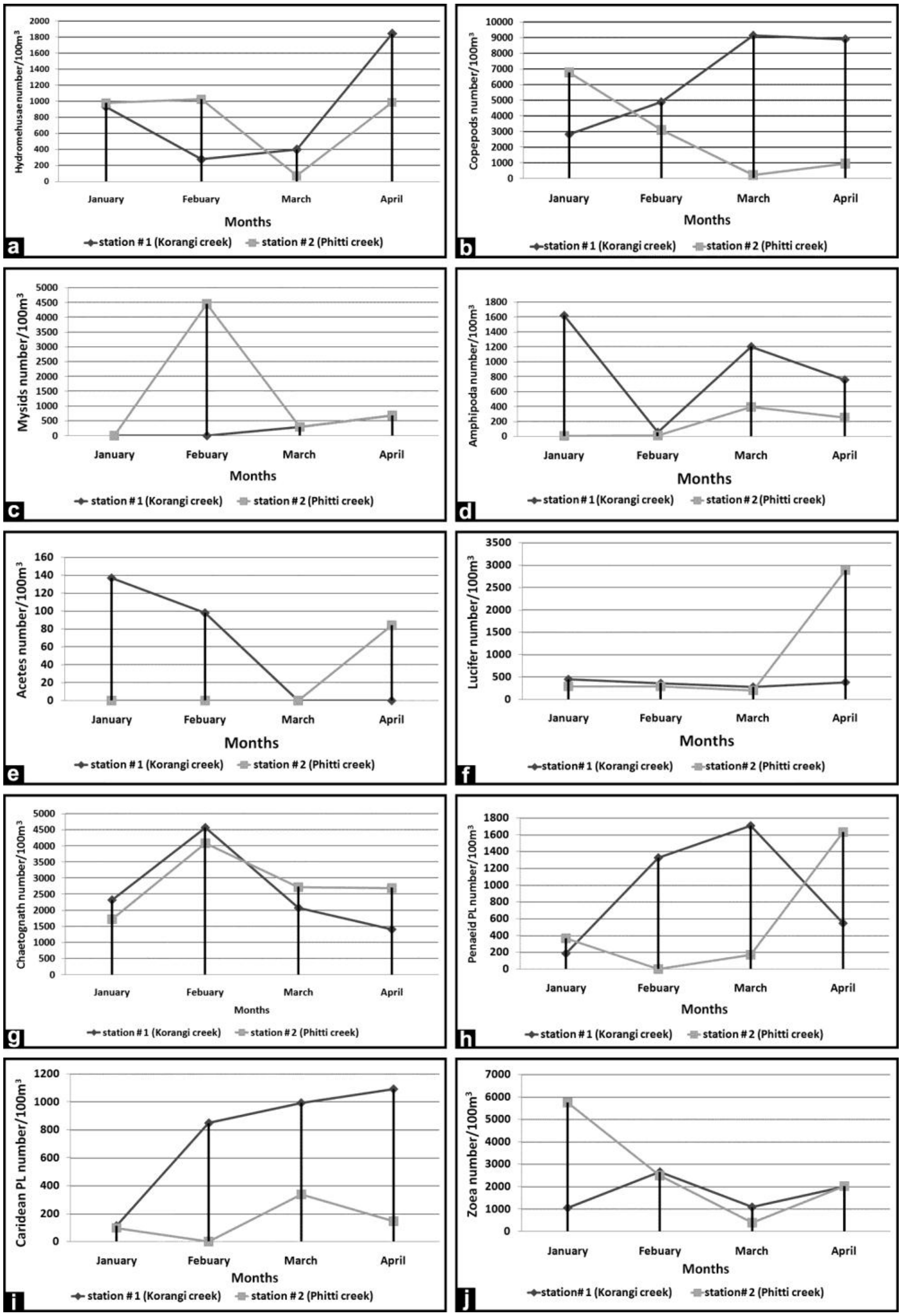

Fig. 3. Mean value of air temperature (°C), water temperature(°C), salinity (ppt), dissolved oxygen (mg/L), pH and transparency (cm) collected from (Korangi creek) and (Phitti creek) during January to April 1998.

Table. 3 shows the numerical data of zooplankton number/100m$^3$ collected from two permanent stations, Korangi creek and Phitti creek during pre-monsoon season from January to April 1998. The abundance of zooplanktonic group occurs at station # 1 as hydromedusae (3454 number/100m$^3$ ), copepoda (25735 number/100m$^3$), mysids (978 number/100m$^3$), amphipoda (3643 number/100m$^3$), acetes (235 number/100m$^3$), lucifer (1497 number/100m$^3$), chaetognath (10361 number/100m$^3$), penaeid PL (3769 number/100m$^3$), caridean PL (3046 number/100m$^3$), zoea (6789 number/100m$^3$), megalopa (1251 number/100m$^3$), squilla larvae (106 number/100m$^3$), fish larvae (1897 number/100m$^3$), fish eggs (1091 number/100m$^3$), others (363 number/100m$^3$). From station#2 as hydromedusae (3069 number/100m$^3$ ), copepoda (11061 number/100m$^3$), mysids (5438 number/100m$^3$), amphipoda (663 number/100m$^3$), acetes (84 number/100m$^3$), lucifer (3681 number /100m$^3$), chaetognath (11248 number / 100m$^3$), penaeid PL (2166 number/100m$^3$), caridean PL (584 number/100m$^3$), zoea (10668 number/100m$^3$), megalopa (2281 number/100m$^3$), squilla larvae (14 number/100m$^3$), fish larvae (1757 number/100m$^3$), fish eggs (1380 number/100m$^3$), others (220 number/100m$^3$). The highest (18794/100m$^3$) and lowest (6439/100m$^3$) number of zooplankton were collected in April from station#1 and in March from station # 2 (Table 3, Fig. 4 a to 4 o).

Highest mean (%) composition of copepods (38.96) was recorded at station # 1 (Table 4, Fig. 5). The effect of air temperature, water temperature, salinity, pH, dissolved oxygen and transparency on the seasonal abundance of zooplankton is shown in (Figure 6). Analysis of variance (ANOVA $P < 0.05$) were performed between zooplankton with locality, months and physico-chemical parameters and no significant difference was observed between locality, months and physico-chemical parameters shown in (Table 5).

**Table 3. Monthly variation numerical value (number/100m$^3$) of major zooplankton groups collected from two permanent stations, station # 1 Korangi creek and station # 2 Phitti creek during January to April 1998 (pre-monsoon season).**

| MAJOR TAXA | January | February | March | April |
|---|---|---|---|---|
| **Station # 1 Korangi creek** | | | | |
| **Total Zooplankton number/100m$^3$** | **10849** | **15797** | **18775** | **18794** |
| **HOLOPLANKTON** | | | | |
| **Hydromedusae** | 932 | 279 | 401 | 1842 |
| **Copepoda** | 2819 | 4876 | 9137 | 8903 |
| **Mysids** | - | - | 294 | 684 |
| **Amphipoda** | 1623 | 56 | 1205 | 759 |
| **Acetes** | 137 | 98 | - | - |
| **Lucifer** | 456 | 367 | 285 | 389 |
| **Chaetognath** | 2319 | 4565 | 2072 | 1405 |
| **MEROPLANKTON** | | | | |
| **Penaeid PL** | 186 | 1327 | 1709 | 547 |
| **Caridean PL** | 112 | 849 | 993 | 1092 |
| **Zoea** | 1049 | 2653 | 1084 | 2003 |
| **Megalopa** | 306 | 263 | 465 | 217 |
| **Squilla larvae** | - | - | 106 | - |
| **Fish larvae** | 574 | 316 | 745 | 262 |
| **Fish eggs** | 239 | 75 | 193 | 584 |
| **Others** | 97 | 73 | 86 | 107 |
| **Station#2 Phitti creek** | | | | |
| **Total Zooplankton number/100m$^3$** | **16397** | **16264** | **6439** | **15214** |
| **HOLOPLANKTON** | | | | |
| **Hydromedusae** | 980 | 1027 | 73 | 989 |
| **Copepoda** | 6786 | 3114 | 210 | 951 |
| **Mysids** | --- | 4459 | 297 | 682 |
| **Amphipoda** | 7 | 11 | 392 | 253 |
| **Acetes** | --- | --- | --- | 84 |
| **Lucifer** | 294 | 290 | 204 | 2893 |
| **Chaetognath** | 1729 | 4091 | 2730 | 2698 |
| **MEROPLANKTON** | | | | |
| **Penaeid PL** | 367 | --- | 168 | 1631 |
| **Caridean PL** | 98 | --- | 339 | 147 |
| **Zoea** | 5743 | 2506 | 403 | 2016 |
| **Megalopa** | 45 | 101 | 219 | 1916 |
| **Squilla larvae** | --- | --- | 14 | --- |
| **Fish larvae** | 115 | 584 | 289 | 769 |
| **Fish eggs** | 224 | 81 | 1022 | 53 |
| **Others** | 9 | --- | 79 | 132 |


a
Hydromehusae number/100m³
January
Febuary
March
April
Months
station # 1 (Korangi creek)
station # 2 (Phitti creek)
b
Copepods number/100m³
Months
c
Mysids number/100m³
Months
d
Amphipoda number/100m³
Months
e
Acetes number/100m³
Months
f
Lucifer number/100m³
Months
g
Chaetognath number/100m³
Months
h
Penaeid PL number/100m³
Months
i
Caridean PL number/100m³
Months
j
Zoea number/100m³
Months

Continued......

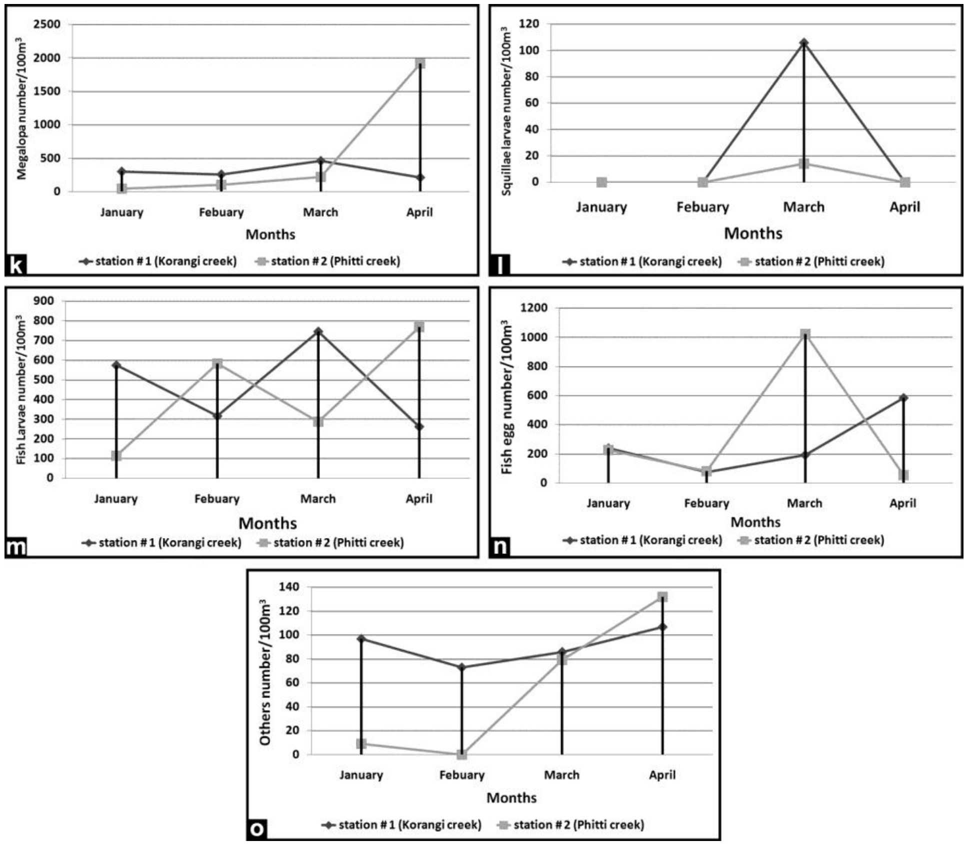



Fig. 4. Monthly variations of major zooplankton groups in numbers/100m$^3$ from (Korangi creek) and (Phitti creek) during January to April 1998.

Present study showed that copepoda is the dominant group at station # 1. Similar trend was highlighted by Ali and Ahmed, 2013, copepod was the major group, constituting 50.50% and 46.12% in Shahbunder creek system during post-monsoon period. Lower numbers of copepoda was observed at station # 2, similar as Qureshi and Sultana, (2000) reported that the copepod densities in the mangrove area were lower in pre-monsoon. Copepods are known to be influenced by hydrographic condition and they have been suggested as good biological indicator species for water masses (Lan *et al.*, 2004; Boucher *et al*, 1978; Hsieh *et al.*, 2004). Huda and Ahmad (1988) studied trends in zooplankton production in inshore waters along the Karachi coast in the three different stations of Korangi creek channel during Jan. 1983 to Dec. 1985. Seasonal variation in species and abundance of zooplankton in relation to hydrological parameters are discussed.

The present study showed no significance correlation between zooplankton with physico-chemical parameters, air temperature, water temperature, salinity, dissolved oxygen, pH, and transparency. Also no significant correlation was observed between zooplankton with locality and months. The study has shown that during premonsoon

**Table 4. Percentage (%) distribution of major zooplankton groups collected from two permanent stations, station # 1 Korangi creek and station # 2 Phitti creek during January to April 1998 (pre-monsoon season).**

| MAJOR TAXA | January | February | March | April | Mean (%) |
|---|---|---|---|---|---|
| **Station # 1 Korangi creek** | | | | | |
| HOLOPLANKTON | | | | | |
| **Hydromedusae** | 8.59 | 1.76 | 2.13 | 9.80 | 5.57 |
| **Copepoda** | 25.98 | 30.86 | 48.66 | 47.37 | 38.96 |
| **Mysids** | --- | --- | 1.56 | 3.63 | 1.29 |
| **Amphipoda** | 14.95 | 0.35 | 6.41 | 4.03 | 6.43 |
| **Acetes** | 1.26 | 0.62 | --- | --- | 0.47 |
| **Lucifer** | 4.20 | 2.32 | 1.51 | 2.06 | 2.52 |
| **Chaetognath** | 21.37 | 28.89 | 11.03 | 7.47 | 17.19 |
| MEROPLANKTON | | | | | |
| **Penaeid PL** | 1.71 | 8.40 | 9.10 | 2.91 | 5.53 |
| **Caridean PL** | 1.03 | 5.45 | 5.28 | 5.81 | 4.39 |
| **Zoea** | 9.66 | 16.79 | 5.77 | 10.65 | 10.71 |
| **Megalopa** | 2.82 | 1.66 | 2.47 | 1.15 | 2.02 |
| **Squilla larvae** | --- | --- | 0.56 | --- | 0.14 |
| **Fish larvae** | 5.29 | 2.00 | 3.96 | 1.39 | 3.16 |
| **Fish eggs** | 2.20 | 0.47 | 1.02 | 3.10 | 1.69 |
| **Others** | 0.89 | 0.46 | 0.45 | 0.56 | 0.59 |
| MAJOR TAXA | **January** | **February** | **March** | **April** | **Mean (%)** |
| **Station # 2 Phitti creek** | | | | | |
| HOLOPLANKTON | | | | | |
| **Hydromedusae** | 5.97 | 6.31 | 1.13 | 6.50 | 4.97 |
| **Copepoda** | 41.38 | 19.14 | 3.26 | 6.25 | 17.50 |
| **Mysids** | --- | 27.41 | 4.61 | 4.50 | 9.13 |
| **Amphipoda** | 0.04 | 0.06 | 6.08 | 1.67 | 1.96 |
| **Acetes** | --- | --- | --- | 0.55 | 0.13 |
| **Lucifer** | 1.79 | 1.78 | 3.16 | 19.01 | 6.43 |
| **Chaetognath** | 10.54 | 25.15 | 42.39 | 17.73 | 23.95 |
| MEROPLANKTON | | | | | |
| **Penaeid PL** | 2.23 | --- | 2.60 | 10.72 | 3.88 |
| **Caridean PL** | 0.59 | --- | 5.26 | 0.96 | 1.70 |
| **Zoea** | 35.02 | 15.40 | 6.25 | 13.25 | 17.48 |
| **Megalopa** | 0.27 | 0.62 | 3.40 | 12.59 | 4.22 |
| **Squilla larvae** | --- | --- | 0.21 | --- | 0.05 |
| **Fish larvae** | 0.70 | 3.59 | 4.48 | 5.05 | 3.45 |
| **Fish eggs** | 1.36 | 0.49 | 15.87 | 0.34 | 4.51 |
| **Others** | 0.05 | --- | 1.22 | 0.86 | 0.53 |

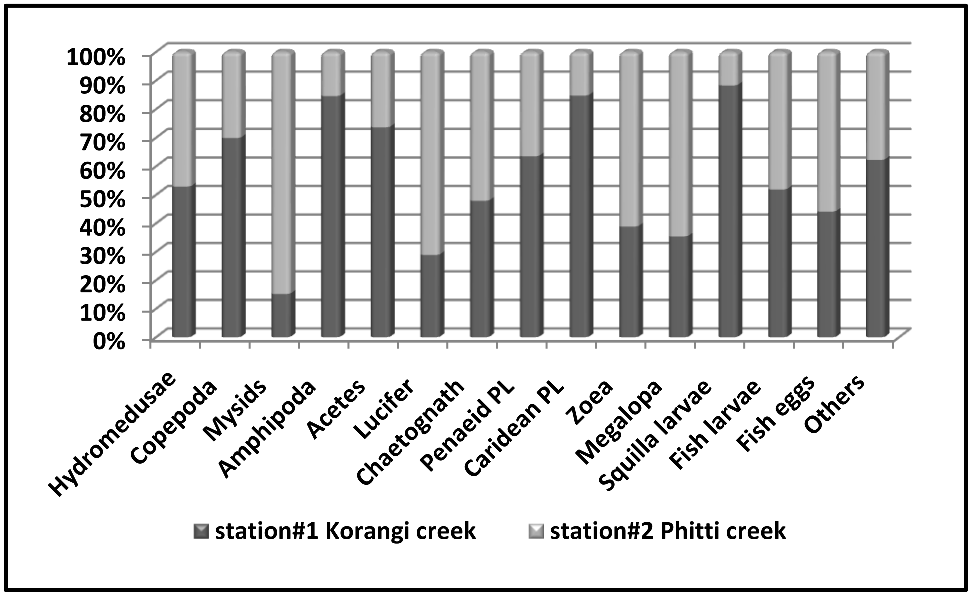



Fig. 5. Composition of zooplanktonic groups collected from two permanent stations, station # 1 Korangi creek and station # 2 Phitti creek during January to April 1998 (pre-monsoon season).

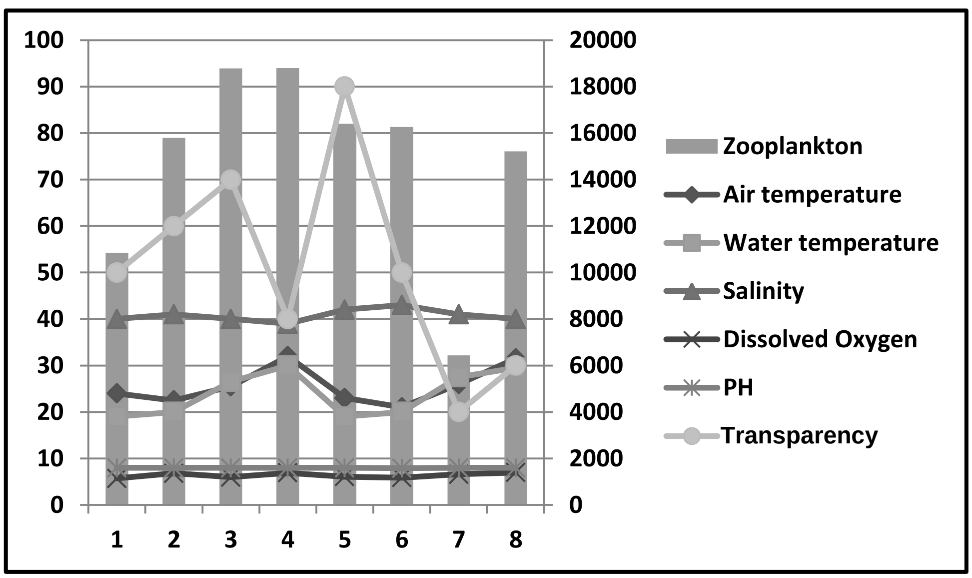



Fig. 6. Correlation between the physico-chemical parameters (air temperature ($^{o}$C), water temperature ($^{o}$C), salinity (ppt), PH, dissolved oxygen (mg/L) and transparency (cm) and the abundance of zooplankton (no/100m$^3$) at station # 1 Korangi creek and station # 2 Phitti creek during January to April 1998 (pre-monsoon season).

**Table 5. Summary of variance (ANOVA) for testing the effect of locality, months and physico-chemical parameters on zooplankton abudance.**

| | | | Sum of Squares | df | Mean Square | F | *P* |
|---|---|---|---|---|---|---|---|
| **Zooplanktons * Locality** | Between Groups | (Combined) | 816915.008 | 1 | 816915.008 | 0.303 | 0.583 |
| | Within Groups | | 318343686 | 118 | 2697827.847 | | |
| | Total | | 319160601 | 119 | | | |
| **Zooplanktons * Months** | Between Groups | (Combined) | 1675371.225 | 3 | 558457.075 | 0.204 | 0.893 |
| | Within Groups | | 317485229.8 | 116 | 2736941.636 | | |
| | Total | | 319160601 | 119 | | | |
| **Zooplankton * Water temperature** | Between Groups | (Combined) | 107627216.4 | 5 | 21525443.28 | 2.778 | 0.286 |
| | Within Groups | | 15499196.5 | 2 | 7749598.25 | | |
| | Total | | 123126412.9 | 7 | | | |
| **Zooplankton * Salinity** | Between Groups | (Combined) | 47821856.88 | 4 | 11955464.22 | 0.476 | 0.757 |
| | Within Groups | | 75304556 | 3 | 25101518.67 | | |
| | Total | | 123126412.9 | 7 | | | |
| **Zooplankton * dissolved oxygen** | Between Groups | (Combined) | 384673.274 | 4 | 265271.34 | 0.347 | 0.628 |
| | Within Groups | | 43647298 | 3 | 2187543.543 | | |
| | Total | | 27365102.7 | 7 | | | |
| **Zooplankton * PH** | Between Groups | (Combined) | 2395819.446 | 1 | 2395819.446 | 0.119 | 0.742 |
| | Within Groups | | 120730593.4 | 6 | 20121765.57 | | |
| | Total | | 123126412.9 | 7 | | | |
| **Zooplankton * transparency** | Between Groups | (Combined) | 108465300.4 | 6 | 18077550.06 | 1.233 | 0.597 |
| | Within Groups | | 14661112.5 | 1 | 14661112.5 | | |
| | Total | | 123126412.9 | 7 | | | |

season fourteen (14) major zooplankton groups were observed at two stations, concluding that copepod and chaetognath were the major components. The number of zooplankton /$100^3$ at station # 1: as copepod > chaetognath > zoea > penaeid PL > amphipoda > hydromedusae > caridean PL > fish larvae > lucifer > megalopa > fish eggs > mysids > acetes > squilla larvae. At station # 2: chaetognath > copepod > zoea > mysids > Lucifer > hydromedusae > megalopa > penaeid PL > fish larvae > fish eggs > amphipoda > caridean PL > others > acetes > squilla larvae. Copepods, chaetognath and zoea constituted the major component of the zooplankton population at both the stations.

## REFERENCES


Ali, Q.M and Q. Ahmed. 2013. Composition of major zooplanktonic groups in shahbunder creek system - indus deltaic area, *Pak. J. Mar. Sci.* 22(1&2): 43-59.

Boucher, M., F. Ibanez and L. Prieur. 1978. Daily and seasonal variations in the spatial distribution of zooplankton population in relation to the physical structure in the Ligurian Sea front, *J. Mar. Res*, 45: 133-173.

Day J.W., C.A.S. Hall, W.M. Kemp and A. Yanez-Arancibia. 1989. Estuarine Ecology. John Wiley and Sons, New York, USA.

Gannon, J.E. and R.S. Stemberger. 1978. Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Trans. Am. Microsc. Soc.* 97: 16-35.

Harris, E., 1959. The nitrogen cycle in Long Island Sound. *Bull. Bingham Oceanogr. Collect.* 17: 31-42.

Hsieh C.H., T.S. Chiu and C.T. Shih. 2004. Copepod diversity and composition as indicators of intrusion of the Kuroshio Branch Current in to the northern Taiwan Strait in spring 2000, *Zool. Stud.* 43: 393-403.

Huda, I.A. and J. Ahmad. 1988. Zooplankton Production Trends in the Inshore waters of a Mangrove Ecosystem along the Karachi Coast. Marine Science of The Arabian Sea, Proceedings of an International Conference, pp. 407-416.

Lan Y.C., C.T. Shih, M.A. Lee and H.Z. Shieh. 2004. Special distribution of copepods in relation to water mass in the Taiwan Strait, *Zool. Stud*. 43: 332-343.

Newell, G.E. and R.C. Newell. 1977. Marine Plankton a Practical guide. 5th Ed. Hutchinson & Co. (Publishers) Ltd. 244 p

Perumal P., P. Sampathkumar, P.K. Karuppasamy. 1999. Studies on the bloom forming species of phytoplankton in the Vellar estuary, southeast coast of India. *Ind. J. Mar. Sci.* 28: 400-403.

Qureshi, N.A. and R. Sultana. 2000. "Distribution and Abundance of Meiobenthos in Sandspit Backwaters Mangrove Area, Karachi," Proc. of the Nat. ONR Symposium on Arabian Sea as Resource of Biological Diversity, pp. 90-103.

Rajasegar M, M. Srinivasan and R. Rajaram. 2000. Phytoplankton diversity associated with the shrimp farm development in Vellar estuary, south India. *Seaweed Res. Utiln.* 22: 125-131.