ISSN 1996-3351

Asian Journal of Biological Sciences

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Asian Journal of Biological Sciences 4 (5): 468-476, 2011
ISSN 1996-3351 / DOI: 10.3923/ajbs.2011.468.476

Spatial Variation and Community Composition of Phytoplankton along the Pahang Estuary, Malaysia

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ABSTRACT

The aim of this study was to examine the phytoplankton patchiness, as expressed by community composition and their diversity during the monsoon and Non-monsoon seasons along the Pahang estuary, Malaysia during 2008. Three zones in the estuary were sampled on both the seasons covering both upstream and downstream of the estuary. Among the identified 42 genera of phytoplankton, the most dominant phytoplankton were *Leptocylindrus* sp. (19.05%), *Lauderia* sp. (11.02%) and *Skeletonema* sp. (10.32%) of total abundance. The least dominant or rare phytoplankton were *Ditylum* sp. (0.05%), *Asterionella* sp. (0.04%), *Gyrosigma* sp. (0.05%), *Gymnodinium* sp. (0.04%) and *Prorocentrum* sp. (0.07%) of total abundance. The statistical analysis showed that there was no significant difference in diversity of phytoplankton between different zones ($p>0.05$). Result indicated that many of the phytoplankton species inhabiting in Pahang estuary were sensitive to salinity fluctuation. The increased diversity during monsoon might be due to the runoff water that probably brought the phytoplankton of other freshwater sources. Physicochemical parameters showed significant variation between different zones ($p<0.05$) except for temperature. Present study clearly showed that phytoplankton community in Pahang estuary was quiet diverse during monsoon and dominant during non monsoon season.

Key words: Phytoplankton patchiness, community composition, pahang estuary, physicohemical parameters, spatial distribution

INTRODUCTION

Diversity, distribution, abundance and variation in the biotic factors provide information of energy turnover in the aquatic systems. In these systems phytoplankton is of great importance as a major source of organic carbon located at the base (Laskar and Gupta, 2009; Agboola *et al.*, 2011). Their sensitivity and large variations in species composition are often a reflection of significant alteration in ambient condition within an ecosystem (Adesalu, 2010). Hence for any scientific utilization of water resources plankton study is of primary interest. Estuaries environment are the harsh ecosystems subject to highly variable environmental conditions like tidal amplitudes and salinity. It is among the most complex bodies of water inhabiting more tolerable organisms that can with stand various environmental conditions. Yet slight fluctuation in the water quality may affect more sensitive organisms like phytoplankton which plays a major role in primary production. Phytoplankton patchiness is usually examined at the level of biomass distributions as determined by chlorophyll concentrations. Much focus in recent years has been directed towards elucidating the response of marine and freshwater phytoplankton to nutrient enrichment by examining changes over time in chlorophyll distributions. Phytoplankton community and size composition are also known to be related to nutrient availability (Kiorboe, 2001). Nutrient enrichment can be predicted to alter phytoplankton community composition (Farahani *et al.*, 2006; Islam and Tanaka, 2004; Tabinda *et al.*, 2003).

The study of physicochemical parameters is also important as these factors determine the distribution and composition of bacterial community (Hahn, 2006), temporarily and spatially within habitat (Lindstrom, 2001; Dominik and Hofle, 2002) as well as between habitats (Yannarell and Triplett, 2004). Phosphate and nitrate are macronutrients used by phytoplankton for growth. Phytoplanktons generally utilize certain concentration of nitrate and phosphate (Rahimibashar *et al.*, 2009). It was also observed that changes in phytoplankton community composition can influence food web structure and energy flow in the pelagic ecosystem (Kiorboe, 2001).

In Malaysia, the rapid changes in the natural environment were mainly driven by the continued eco-social growth and industrialization whereby the coastal area is the most affected region. The coastal zone of Malaysia experiences the most intense human activity, where a large percentage of the population, ports, industries, tourism constructions as well as agriculture, aquaculture, fisheries, mineral and oil and gas exploitation, communication, transportation, recreation and sewage discharge result in many conflicting human activities in that region (Kamaruzzaman *et al.*, 2010; Zaleha *et al.*, 2010).

Based on the above perspective a study was conducted to determine the phytoplanktonic community composition, abundance, seasonal variation in their diversity distribution in Pahang estuary, Malaysia.

MATERIALS AND METHODS

Location of sampling sites: Sampling was carried out in Pahang Estuary (Pekan, Pahang) from April to December 2008 (Fig. 1). Sampling was done by dividing the study area into three zones with the distance of approximately 3 km for each zone to encompass three different habitat of the sampling station. Zone 1 was located at the river mouth of Pahang estuary. The water body of this area characterizes by high saline water especially during non-monsoon season where the freshwater flow from Pahang River was low and the sea water intrusion was high. Zone 2 was characterized by low salinity area and Zone 3 was located at freshwater area of the Pahang estuary since it is located further away from the open ocean. The sampling stations were lies between longitude 103°25'56.48" E to 103°29'10.55" E and latitude 03°33'01.78" N to 03°30'50.38" N, samples were collected using Random Stratified Method from the three zones of the sampling station.

Sampling technique: Phytoplankton samples were collected at each station by towing plankton net with mesh size of 53 μm over the surface water and 0.5 m under surface water at a known distance on each sampling. The plankton was concentrated into a 25 mL container. Samples were stored in an ice chest and 25 mL Lugol's solution added after the plankton was collected from the plankton net. 'Lackey Drop Method' was used for identification of the phytoplankton in the laboratory (Sunita *et al.*, 2007). In Lackey's drop method, the cover slip was placed over a drop of water in the slide and whole of the cover slip was examined by parallel overlapping strips to count all the organisms in the drop. About 20 strips were examined in each drop. Number of subsamples

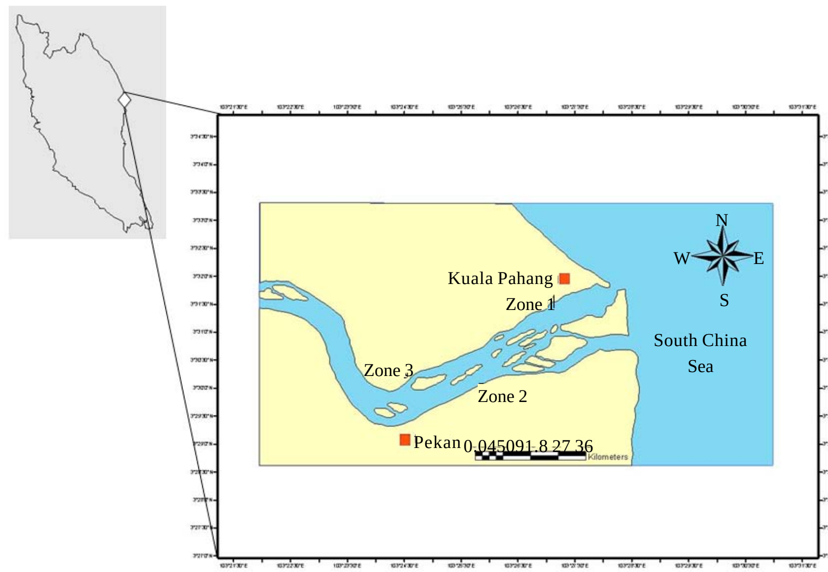

Fig. 1: Map showing location of study area along pahang river-estuary, Malaysia

to be taken was dependent on the examining 2 to 3 successive subsamples without any addition of unencountered species when compared to the already examined subsamples in the same sample (APHA, 1998).

Physico-chemical parameters: Physico-chemical parameters: temperature, salinity, pH and dissolved oxygen of both upstream and downstream of the river water were measured by using 'Hydro lab Datasonde 4a, USA'. All the data were recorded *in-situ* and then analyzed in the laboratory. Standard Method APHA 4500-NO_3-B, 1995 was used to evaluate Nitrogen-Nitrate (NO^{3-}N) at wavelength (λ) of 507 nm. HACH program 2515 (detection range: 0-0.50 mg L^{-1}) was used to measure nitrate in the sample. Standard Method APHA 4500-P-D, 1995 was used to evaluate phosphorus value at wavelength (λ) of 420nm. HACH program 541 (detection range: 0.00-33.00 mg L^{-1}) was used to measure phosphate level in the water column.

Statistical analysis: Shannon (H') and Simpson Diversity (D) indices were used to determine the phytoplankton richness and abundance during monsoon and Non-monsoon seasons (Shannon and Weaver, 1949; Simpson, 1949). Berger-Parker dominance (1 d^{-1}) (Berger and Parker, 1970) was calculated to determine the diversity during different seasonal periods. Bray-Curtis cluster analysis was done to find out the species similarity between different sampling periods at 3 different sampling zones (Pielou, 1984). One-way Analysis of Variance (ANOVA) was used to find the significant variation in physicochemical parameters using SPSS 17v.

RESULTS

A total of 42 genera of phytoplankton were identified from three zones. Among the identified phytoplankton, 34 genera were from 23 families of class diatom, 7 genera were belong to 7 families of dinoflagellates and one species of blue green algae were also observed. The most dominant phytoplankton were *Leptocylindrus* sp. (19.05%), *Lauderia* sp. (11.02%), *Skeletonema* sp. (10.32%), *Rhizosolenia* sp. (9.13%), *Bacillaria* sp. (7.97%), *Chaetoceros* sp. (6.55%), *Bacretiastrum* sp. (6.27%), *Nitzschia* sp. (5.18%) and *Flagilaria* sp. (5.04%) of total abundance were observed. Blue green algae *Trichodesmium* sp. showed 2.74% of total abundance and it was more than the total

Table 1: List of phytoplankton identified from three different zones of pahang estuary

Class	Family	Genus	Percentage of Relative Species Abundance (RSA)
Diatom	Achnanthaceae	*Achnanthes* sp.	0.11
	Bacillariaceae	*Bacillaria* sp.	7.97
	Bacillariaceae	*Nitzschia* sp.	5.18
	Bacillariophyceae	*Ditylum* sp.	0.05
	Bacillariophyceae	*Flagilaria* sp.	5.04
	Bellerocheaceae	*Bellerochea* sp.	0.60
	Biddulphiaceae	*Biddulphia* sp.	0.54
	Catenulaceae	*Amphora* sp.	0.21
	Chaetocerataceae	*Bacteriastrum* sp.	6.27
	Chaetocerataceae	*Chaetoceros* sp.	6.55
	Cocconeidaceae	*Cocconeis* sp.	0.05
	Coscinodiscaceae	*Coscinodiscus* sp.	3.56
	Dictyochaceae	*Distephanus* sp.	0.49
	Flagilariaceae	*Asterionella* sp.	0.04
	Hemiaulaceae	*Cerataulina* sp.	0.21
	Hemiaulaceae	*Eucampia* sp.	0.84
	Hemiaulaceae	*Hemiaulus* sp.	0.25
	Hemidiscaceae	*Hemidiscus* sp.	0.21
	Lauderiaceae	*Lauderia* sp.	11.02
	Leptocylindraceae	*Leptocylindrus* sp.	19.05
	Melosiraceae	*Melosira* sp.	0.74
	Naviculaceae	*Navicula* sp.	0.11
	Pleurosigmataceae	*Gyrosigma* sp.	0.05
	Pleurosigmataceae	*Pleurosigma* sp.	0.25
	Rhabdonemataceae	*Rhabdonema* sp.	1.04
	Rhizosoleniaceae	*Guinardia* sp.	0.12
	Rhizosoleniaceae	*Rhizosolenia* sp.	9.13
	Skeletonemaceae	*Skeletonema* sp.	10.32
	Stephanopyxidaceae	*Stephanopyxis* sp.	2.23
	Thalassionemataceae	*Thalassionema* sp.	0.14
	Thalassionemataceae	*Thalassiothrix* sp.	1.40
	Thallassiosiraceae	*Planktoniella* sp.	0.53
	Thallassiosiraceae	*Thalassiosira* sp.	1.74
	Triceratiaceae	*Triceratium* sp.	0.39
Dinoflagellate	Ceratiaceae	*Ceratium* sp.	0.18
	Dinophyceae	*Peridinium* sp.	0.16
	Dinophysiaceae	*Dinophysis* sp.	0.11
	Gonyaulacaceae	*Gonyaulax* sp.	0.21
	Gymnodiniaceae	*Gymnodinium* sp.	0.04
	Noctilucaceae	*Noctiluca* sp.	0.11
	Prorocentraceae	*Prorocentrum* sp.	0.07
Blue green algae	Phormidiaceae	*Trichodesmium* sp.	2.74
Total			100.00

Table 2: Diversity index values of phytoplankton during monsoon and non monsoon seasons at different zones

Index	Zone 1 non monsoon	Zone 2 non monsoon	Zone 3 non monsoon	Zone 1 monsoon	Zone 2 monsoon	Zone 3 monsoon
Shannon H' log base 10	0.936	1.075	1.013	1.197	1.077	1.164
Simpsons diversity (D)	0.139	0.104	0.125	0.088	0.118	0.093
Simpsons reciprocal index (1/d)	7.201	9.586	7.989	11.335	8.478	10.787
Berger-parker dominance (d)	0.235	0.196	0.214	0.164	0.240	0.199
Berger-parker dominance (1/d)	4.261	5.102	4.672	6.103	4.167	5.036

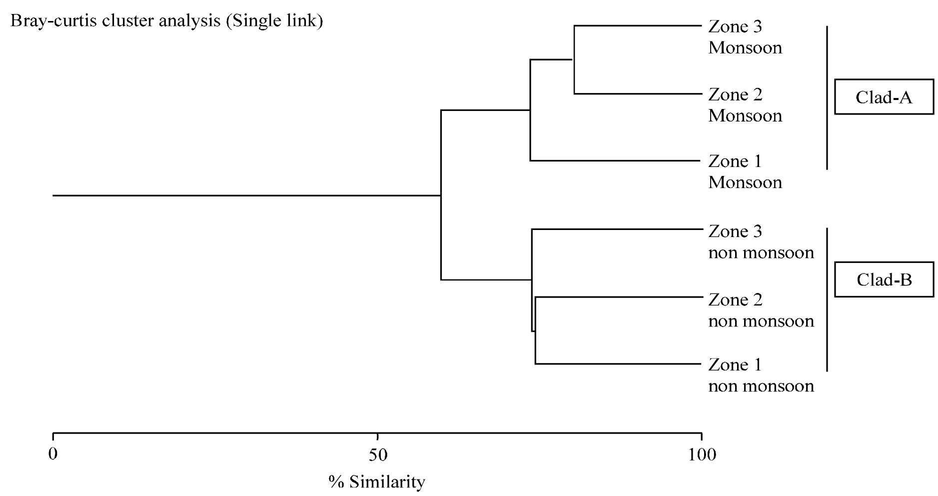

Fig. 2: Dendrogram for hierarchical clustering of phytoplankton community composition and distribution based on different zones during monsoon and non-monsoon season

abundance of all the dinoflagellates (1.27%). The least dominant or rare phytoplankton were *Ditylum* sp. (0.05%), *Asterionella* sp. (0.04%), *Gyrosigma* sp. (0.05%), *Gymnodinium* sp. (0.04%) and *Prorocentrum* sp. (0.07%) of total abundance (Table 1). The overall Shannon diversity index (H') of phytoplankton in the study area was observed to be 2.73, indicates the different zones are quiet diverse in terms of species diversity. The statistical analysis showed that, there was no significant difference in diversity of phytoplankton between different zones ($p>0.05$).

Diversity and seasonal fluctuation of phytoplankton: Higher diversity was observed in zone 1 and 3 during monsoon (H' = 1.197 and 1.164, respectively) followed by zone 2 (H' = 1.077). During non monsoon season zone 2 and 3 showed comparatively higher diversity (H' = 1.075 and 1.013, respectively) than zone 1 (H' = 0.936) (Table 2). This result clearly indicating that many of the phytoplankton species inhabiting in Pahang estuary were sensitive to salinity changes hence the higher diversity was observed during monsoon season.

Higher Berger-Parker dominance value in zone 1 ($1\ d^{-1} = 6.103$) and zone 3 ($1\ d^{-1} = 5.036$) during monsoon season also indicate that the diversity was higher during monsoon season (but lower dominance) and lower diversity was observed in zone 1 ($1\ d^{-1} = 4.261$) during non monsoon season (but higher dominance) (Table 2).

There were two major clads (Clad A and B) observed which differentiated monsoon and non monsoon sampling (Fig. 2). During monsoon season zone 2 showed more similarity in plankton community composition with zone 3 with the percentage value of (80.38%) than with zone 1 (73.44%). During non monsoon season zone 1 showed more similarity in plankton community composition with zone 2 and zone 3 with the percentage value of (~74%) indicating that the there is less fluctuation in community structure of phytoplankton during non monsoon season (Table 3).

Physicochemical parameters: There were no significant difference in temperature was observed in different stations ($p>0.05$) and the highest temperature was recorded in April and lowest was in December in all the three stations and it was ranged between (30.61 -26.76°C). All the other water quality parameters have shown significant difference between stations ($p<0.05$). Salinity (27.01-0.02 ppt), pH (8.31-4.69), Dissolved oxygen (7.44-2.96), Nitrate (1.00-0.09 mg L^{-1}) and Phosphate (0.103-0.015 mg L^{-1}) level in the water column was determined since they influences the diversity of any aquatic biota (Table 4).

Table 3: Bray-Curtis cluster analysis (Single link) indicates percentage of similar phytoplankton community composition between different sampling zones

	Bray-curtis cluster analysis (Single link)					
Zone	Zone 1 non monsoon	Zone 2 non monsoon	Zone 3 non monsoon	Zone 1 monsoon	Zone 2 monsoon	Zone 3 monsoon
Zone 1 non monsoon	-	74.4063	74.0584	50.4228	58.3203	58.5618
Zone 2 non monsoon	-	-	63.9831	56.6755	52.3958	59.8140
Zone 3 non monsoon	-	-	-	52.626	54.0314	53.8941
Zone 1 monsoon	-	-	-	-	73.4481	72.0124
Zone 2 monsoon	-	-	-	-	-	80.3882
Zone 3 monsoon	-	-	-	-	-	-

Data represent the percentage of species similarity between different zones sampled during monsoon and non-monsoon period

Table 4: Physicochemical parameters of pahang estuary in three different zones during the sampling period.

Parameters	Level	Zone 1	Zone 2	Zone 3	Significance
Temperature (°C)	Maximum	30.61	30.58	30.56	NS
	Minimum	26.76	27.05	26.86	
	Average	29.21	29.27	29.27	
Salinity (ppt)	Maximum	27.01	20.64	15.41	*
	Minimum	0.02	0.03	0.02	
	Average	11.65	11.89	11.23	
pH	Maximum	7.81	8.31	7.95	*
	Minimum	6.35	5.36	4.69	
	Average	7.15	6.84	6.75	
Dissolved oxygen (mg L^{-1})	Maximum	7.22	7.43	7.44	*
	Minimum	3.27	3.57	2.96	
	Average	5.38	5.22	5.48	
Nitrate NO_3 (mg L^{-1})	Maximum	0.56	0.72	1.00	*
	Minimum	0.09	0.14	0.18	
	Average	0.33	0.18	0.45	
Phosphate PO_4 (mg L^{-1})	Maximum	0.056	0.071	0.103	*
	Minimum	0.025	0.015	0.023	
	Average	0.032	0.039	0.045	

(*) Significant different ($p<0.05$), NS: No. significant different ($p<0.05$)

DISCUSSION

The identified phytoplankton from the study area can be group into diatom, dinoflagellate and blue-green algae. Present study revealed that the diatom was the dominant group recorded with 96.40% of the total phytoplankton densities and constituted the largest group of phytoplankton in Pahang estuary. This was followed by dinoflagellate and blue-green algae with 2.74 and 1.27%, of total abundance respectively. Similar observation was recorded in previous studies where they observed diatom and dinoflagellate were the most abundant groups of marine phytoplankton (Carter *et al*., 2005; Onyema, 2008). It was also reported that in the pristine marine tropical waters, diatoms normally form more than 80% of the total phytoplanktonic biomass (Casea *et al*., 2008).

From the observed overall diversity indices value, Zone 3 showed highest value of (H' = 2.39) compared to Zone 1 (H' = 2.21) and Zone 2 (H' = 2.12). This observation might probably due to the higher nutrient load in the Zone 3 followed by Zone 2 and 1. Recent studies were also well corresponded with this findings where Shah *et al*. (2008) and Farahani *et al*. (2006) proved the influence of nutrient or light availability towards the estuarine phytoplankton production. The nutrient levels influence total phytoplankton biomass, taxonomic composition and size distribution of the community (Tabinda *et al*., 2003). These parameters might have influence on the phytoplankton due to the availability of conducive environment in Zone 3 probably led to the observed highest diversity index (H') of phytoplankton in this zone.

The most encountered genus of phytoplankton in all the zones was *Leptocylindrus* sp. indicating its adaptability in all the conditions. The second dominant species in zone 1, 2 and 3 were *Skeletonema* sp., *Lauderia* sp. and *Rhizosolenia* sp., respectively and the least dominant species were *Asterionella* sp., *Hemiaulus* sp. and *Prorocentrum* sp., respectively.

Different diversity indices values from the present study clearly demonstrated that monsoon season had higher diversity of phytoplankton compared to the non monsoon season but their abundance was higher during later season. Percentage similarity between monsoon and non-monsoon season was considerably higher (59.43%) indicating that NE monsoon has not significantly affected the distribution of phytoplankton since zone 2 and 3 were of fresh water areas. Throughout non-monsoon season the temperature was higher, this would ultimately led to the increase in salinity value in turn helped very specific tolerable phytoplankton (*Leptocylindrus* sp.) to flourish well in the Pahang estuary. The increased diversity during monsoon might also due to the runoff water that probably brought the phytoplankton of other freshwater sources. Similar finding was observed in studies of Bailey and James (2000) and Nielsen *et al*. (2003) where they observed the influence of salinity changes in the physical environment that would ultimately affect the ecosystem process and distribution of sensitive forms in aquatic water body.

CONCLUSION

Phytoplankton is crucially dependant on minerals and especially to macronutrients such as nitrate, phosphate or silicic acid, whose availability is governed by the balance between the biological pump and upwelling of deep, nutrient-rich waters. Moreover, physicochemical parameters such as water temperature, salinity and pH influence phytoplankton productivity (Ghosal *et al*., 2000). Present study revealed that the phytoplankton community in Pahang estuary is quiet diverse during monsoon and dominant in non monsoon season. It was also established that most of the species of phytoplankton present in the study area were sensitive to the fluctuation in salinity and various nutrient levels. This study found that water quality throughout the study area was at acceptable levels and significantly differ between different zones except for temperature.

This pattern is attributed to limited upstream development, a condition that should be maintained to ensure the integrity of the aquatic ecosystems. High levels of vegetative cover were also thought to mitigate the impacts of local conditions on water bodies and should be preserved to protect these systems from future change.

ACKNOWLEDGMENT

The authors wish to express their gratitude to Oceanography Laboratory teams, Faculty of Science and Technology for their invaluable assistance and hospitality throughout the sampling period.

REFERENCES

APHA., 1998. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, New York.

Adesalu, T.A., 2010. Phytoplankton dynamics of river oli in kainji lake national park, Nigeria during dry season. Int. J. Bot., 6: 112-116.

Agboola, J.I., M.A. Adewolu and E.O. Lawson, 2011. Linking climate change and fisheries: The role of phytoplankton. J. Fish. Aquat. Sci., 6: 225-235.

Bailey, P.C.E. and K. James, 2000. Riverine and wetland salinity impacts: Assessment of R and D Needs. LWRRDC Occasional Paper No. 25/99, Land and Water Research and Development Corporation. Canberra, Australia.

Berger, W.H. and F.L. Parker, 1970. Diversity of planktonic foraminifera in deep-sea sediments. Science, 168: 1345-1347.

Carter, C.M., A.H. Ross, D.R. Schiel, C. Howard-Williams and B. Hayden, 2005. *In situ* microcosm experiments on the influence of nitrate and light on phytoplankton community. J. Exp. Marine Biol. Ecol., 326: 1-13.

Casea, M., E.E. Lecab and S.N. Leitaoc, 2008. Plankton community as an indicator of water quality in tropical shrimp culture ponds. Marine Pollution Bull., 56: 1343-1352.

Dominik, K. and M.G. Hofle, 2002. Changes in bacterioplankton community structure and activity with depth in a eutrophic lake as revealed by 5S rRNA analysis. Applied Environ. Microbiol., 68: 3606-3613.

Farahani, F., H. Korehi, S. Mollakarami, S. Skandari, S.G.G. Zaferani and Z.M.C. Shashm, 2006. Phytoplankton diversity and nutrients at the Jajerood River in Iran. Pak. J. Biol. Sci., 9: 1787-1790.

Ghosal, S., M. Rogers and A. Wray, 2000. The turbulent life of phytoplankton. Proceedings of the Summer Program 2000, Center for Turbulence Research, pp: 31-45. http://www.math.ens.fr/equipes/edp/biomath/references/ghosal.pdf.

Hahn, M.W., 2006. The microbial diversity of inland water. Curr. Opin. Biotechnol., 17: 256-261.

Islam, M.S. and M. Tanaka, 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: A review and synthesis. Mar. Pollut. Bull., 48: 624-649.

Kamaruzzaman, B.Y., A.S. Waznah, M.S.M. Zahir, M.C. Ong and S. Shahbudin *et al*., 2010. Distribution of chromium, manganese and cobalt in the bottom sediment of pahang river-estuary, Pahang, Malaysia. J. Applied Sci., 10: 3122-3126.

Kiorboe, T., 2001. Formation and fate of marine snow: Smallscale processes with large-scale implications. Sci. Marina, 65: 57-71.

Laskar, H.S. and S. Gupta, 2009. Phytoplankton diversity and dynamics of Chatla floodplain lake, Barak Valley, Assam, North East India: A seasonal study. J. Environ. Biol., 30: 1007-1012.

Lindstrom, E.S., 2001. Investigating influential factors on bacterioplankton community composition: Results from a field study of five mesotrophic lakes. Microbiol. Ecol., 42: 598-605.

Nielsen, D.L., M.A. Brock, G.N. Rees and D.S. Baldwin, 2003. Effects of increasing salinity on freshwater ecosystems in Australia. Aust. J. Bot., 51: 655-665.

Onyema, I.C., 2008. A checklist of *Phytoplankton* species of the iyagbe Lagoon, Lagos. J. Fish. Aquatic Sci., 3: 167-175.

Pielou, E.C., 1984. The Interpretation of Ecological Data. Wiley, New York, pp: 263.

Rahimibashar, M.R., A. Esmaeili-Sary, S.A. Nezami, A. Javanshir, S.M. Reza Fatemi and S. Jamili, 2009. The planktonic community structure and fluxes nutrients in the sefid-rood river estuary (South Caspian Sea). Res. J. Environ. Sci., 3: 149-162.

Shah, M.M.R., M.Y. Hossain, M. Begum, Z.F. Ahmed and J. Ohtomi *et al*., 2008. Seasonal variations of phytoplanktonic community structure and production in relation to environmental factors of the Southwest Coastal waters of Bangladesh. J. Fish. Aquatic Sci., 3: 102-113.

Shannon, C.E. and W. Weaver, 1949. The Mathematical Theory of Communication. University of Illinois Press, Urbana, pp: 125.

Simpson, E.H., 1949. Measurement of diversity. Nature, 163: 688-688.

Sunita, K., G. Chirashree and J. Girija, 2007. Phytoplankton composition, community structure and regional climatic variations in two tropical model ponds in India. Asian J. Water Environ. Pollut., 4: 123-128.

Tabinda, A.B., M. Ali Khan, Omm-e-Hany, M. Ayub, M. Hussain, A. Yasar and M. Altaf Khan, 2003. Relative abundance of planktonic life in relation to water quality parameters in non-polluted zone of deg nullah. J. Biological Sci., 3: 635-642.

Yannarell, A.C. and E.W. Triplett, 2004. Within and between lake variability in the composition of bacterioplankton communities: Investigations using multiple spatial scales. Applied Environ. Microbiol., 70: 214-223.

Zaleha, K., B.Y. Kamaruzzaman, B.A. John and M.C. Ong, 2010. Cd, Cu and Pb concentration levels in horseshoe crab nesting grounds of pahang coast, Malaysia. J. Biol. Sci., 10: 790-794.