A COMMUNITY-BASED STOCK ENHANCEMENT PROJECT OF *Macrobrachium rosenbergii* (GIANT FRESHWATER PRAWN): SPECIES ABUNDANCE AND DIVERSITY OF PHYTOPLANKTON IN PETAGAS RIVER

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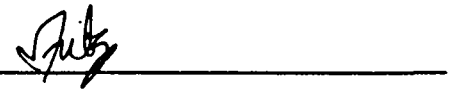

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ABSTRACT

The Borneo marine Research Institute (BMRI) UMS embarked on a stock enhancement programme of the *Macrobrachium rosenbergii* (giant freshwater prawn) in an attempt to replenish stocks in Petagas River, Sabah. In rivers, phytoplankton is crucial for biogeochemical cycles and forms the base of food chains and food webs in every aquatic ecosystem. The purpose of this study was to investigate the species abundance and diversity of phytoplankton in Petagas River and their relationships with the postlarvae (PL) of the giant freshwater prawn, *Macrobrachium* sp., salinity, and water quality of Petagas River. A phytoplankton net and Van Dorn Water Sampler were used to collect qualitative and quantitative phytoplankton samples, respectively, from five sampling stations. Samples collected were preserved with Lugol's solution, stored and labelled. The samples were examined, counted and identified using the Sedgwick-Rafter counting cell under a compound. The Pollution Index method by Palmer (1969) was used to determine the level of organic pollution of the Petagas River within the study area. Results obtained showed that a total of 48 species of phytoplankton belonging to 34 genera from 5 Division were recorded. The species identified were from the divisions Bacillariophyta (21), Chlorophyta (16), Cyanophyta (5), Dinophyta (2) and Euglenophyta (4). *Chlorella* sp., *Scenedesmus quadricauda*, *Coelastrum microsporum*, *Crucigenia lauterbonii* and *Oscillatoria* sp. were the dominant species. Diversity based on Shannon-Wiener diversity index (H') showed a higher value during the wet season compared to dry season, although total phytoplankton abundance were higher during the dry season, due to prevalence of red tide season. The results also showed that the presence of PL is negatively correlated to the total cell abundance of phytoplankton, while salinity showed positive correlation to species diversity and abundance of phytoplankton in Petagas River. The study revealed that Petagas River is contaminated with high organic pollution, which may be due to increasing population and human-interaction activities. The outcome of this study suggests that phytoplankton can be used as bio-indicator species to monitor the river water quality in terms of organic pollution in Petagas River.

ABSTRAK

Institut Penyelidikan Marin Borneo (IPMB) UMS telah memulakan projek penambahbaikan stok udang galah *Macrobrachium rosenbergii* sebagai usaha dalam meningkatkan sumber perikanan di Sungai Petagas, Sabah. Di sungai-sungai, fitoplankton sangat penting dalam kitaran biogeokimia dan pengeluar dalam rantaian makanan ekosistem akuatik. Tujuan kajian ini dijalankan adalah untuk mengkaji kepadatan dan kepelbagaian spesies fitoplankton di Sungai Petagas, serta hubungkait mereka dengan kehadiran pasca larva (PL) Udang Galah, *Macrobrachium* sp., kemasinan dan juga kualiti air. *Phytoplankton net* dan *Van Dorn Water Sampler* telah digunakan dalam proses pengsampelan fitoplankton daripada lima stesen. Sampel yang diperoleh telah dikaji, dikira, serta dikenalpastikan dengan menggunakan *Sedgwick-Rafter counting cell* dan mikroskop kompaun. Indeks Pencemaran Palmer (1969) telah digunakan bagi mengklasifikasikan tahap pencemaran organik di Sungai Petagas. Keputusan yang diperolehi menunjukkan sejumlah 48 spesies fitoplankton daripada 34 genus dari 5 divisi telah direkod di Sungai Petagas, iaitu divisi Bacillariophyta (21), Chlotophyta (16), Cyanophyta (5), Dinophyta (2) dan Euglenophyta (4). *Chlorella* sp., *Scenedesmus quadricauda*, *Coelastrum microsporum*, *Crucigenia lauterbonii* dan *Oscillatoria* sp. adalah spesies dominan. Indeks kepelbagaian Shannon-Wiener (H') menunjukkan nilai yang lebih tinggi pada musim hujan berbanding dengan H' pada musim kering, walaupun kepadatan keseluruhan adalah lebih tinggi pada musim panas, yang mungkin disebabkan oleh pengaruh fenomena laut merah. Keputusan juga menunjukkan bahawa tidak ada hubungkait positif antara kehadiran PL dan kepadatan sel fitoplankton, manakala faktor kemasinan air pula menunjukkan hubungkait positif dengan kepadatan dan kepelbagaian spesies fitoplankton di Sungai Petagas. Kajian ini mendedahkan bahawa terdapat pencemaran organik yang tinggi di Sungai Petagas, yang mungkin disebabkan oleh populasi dan aktiviti-aktiviti yang kian meningkat di sungai tersebut. Hasil kajian ini boleh digunakan dalam menentukan kawasan yang sesuai untuk pelepasan PL *Macrobrachium* sp. yang seterusnya. Hasil kajian ini turut mencadangkan bahawa fitoplankton di Sungai Petagas boleh digunakan sebagai spesies penunjuk untuk memantau kualiti air sungai dari segi pencemaran organik.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

LIST OF SYMBOLS

%	Percentage
°	Degrees
=	Equal to
≤	Less than or equal to
×	Multiplied by
H'	Shannon-Wiener's Diversity Index
Σ	Sigma
P_i	Ration of individual in species *i*
Ln	Natural log
S	Total number of species
N	Cell density per litre

LIST OF UNITS

µm	Micrometre
mm	Millimetre
mL	Millilitre
ppt	Parts per thousand
psu	Practical salinity unit
C	Celsius
mg/L	Milligram per litre
Cells/L	Cells per litre

LIST OF ABREVIATIONS

DO	Dissolved oxygen
ANOVA	Analysis of Variance
SPSS	Statistical Package for Social Sciences

LIST OF FORMULA

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Historically, the Petagas River in Putatan, Sabah, was an economic source to the fishermen and the main water supply to the Petagas community. However, decades of being exposed to pollutants and overfishing have caused the depletion of fishery resources and deterioration of water quality in the river (New Straits Times, 2012a; New Straits Times, 2012b). Currently, a fisheries stock enhancement program is being organised by the Borneo Marine Research Institute (BMRI) of Universiti Malaysia Sabah (UMS) in collaboration with the Putatan District Office. The program is conducted through *sea ranching* by releasing the postlarvae (PL) *Macrobrachium rosenbergii* (*M.rosenbergii*), commonly known as the giant freshwater prawn or giant river prawn (Nandlal and Pickering, 2005), obtained and produced from UMS hatchery, into the Petagas River. The project aims to reimburse the decline of fishery stock in Petagas River as well as to sustain supplementation of the residents.

To date, there have been three phases of the stock enhancement program coinciding with 3 releases of prawn PL into the river. The program was first launched by the Minister of Agriculture and Food Industry and Deputy Chief Minister of Sabah, YB Datuk Seri Panglima Yahya Hussin on 23rd of April 2012.Phase one was held on 23rd of April, 2012, with 2000 PL released, the second phase on December 6th, 2012, with 6000 PL and the third phase on September 22nd, 2013, with 10,000 PL released. In addition, on the 18th of January, 2014, the *tagal* system was introduced in the Petagas River. *Tagal* refers to the conservation of certain sections of a river where

they would be off-limits to fishing activities in order to allow fish and other riverine creatures to flourish. The *tagal* system was also initiated with the hope that the fishery resources can be conserved and waterways can be prevented from being used as garbage dump. Various studies and research are carried out to monitor and evaluate the progress as well as the effectiveness of the program.

Phytoplankton is crucial for biogeochemical cycles and forms the base of food chains and food webs in every aquatic ecosystem. At its larval stages, the giant freshwater prawn, *M.rosenbergii*, feeds on zooplankton (Nandlal and Pickering, 2005), while zooplankton feeds on phytoplankton. Hence, phytoplankton has an indirect relationship with the prawn. The freshwater prawn *M.rosenbergii* was originally discovered in the Indo-West Pacific region (Holthuis, 1980) but today it can be found in almost every continent. There are four distinct phases in the prawn life cycle and they are egg, larva (zoea), PL and adult. Most *Macrobrachium* species require brackish water to survive in the initial stages of their life cycle (Banerjee, 2003) and move towards less saline water as they grow up. *Macrobrachium* sp. PL can be found from estuary to freshwater regions. Adult *M.rosenbergii* is only available in freshwater areas and is more active at night (Nandlal and Pickering, 2005). They can be found in most inland freshwater regions, such as swamps, lakes, river and estuaries (Arumugam, 2012). High densities of phytoplankton in certain regions may be both beneficial and harmful for the prawns. When phytoplankton exists in large numbers, it turns the water turbid, allowing the prawns to hide and seek refuge, thus providing "shelter" for them (Nandlal and Pickering, 2006). In addition, phytoplankton adds oxygen to the water during the daytime and this activity aids in the respiration process of *M.rosenbergii*. However, at night, phytoplankton stops producing oxygen and instead uses it for respiration.

The amount, types, and ecological impacts of pollutants released into estuarine and coastal waters are closely related to population growth in their watersheds (Nixon, 1995). With the rapidly growing population in Putatan, which now has more than 50,000 residents (New Straits Times, 2012b), housing and building projects are increasing fast. However, in the absence of proper sewerage and water treatment system, discharge of untreated wastes released into the river contributes to river pollution (The Borneo Post, 2012). Algal communities provide an

integrated measure of water quality and possess biological characteristics that make them an ideal and important aspect for biological monitoring (Barinova et al., 2010). The species composition and densities of phytoplankton in a particular area can help in evaluating the water quality and the degree of eutrophication of that area.

Water quality of water bodies can be defined based on their physico-chemical and plankton characteristics (Edward and Ugwumba, 2010). As such, the relationship between the physico-chemical parameters and plankton production in water bodies play an important role in management strategies of aquatic ecosystems. According to Zebek (2004), most phytoplankton have short life spans and they promptly respond to environmental factors. In other words, most of them are sensitive to changes in their surroundings. Water salinity has a positive correlation with phytoplankton diversity (Senapati et al., 2011). In regions of higher salinity, freshwater phytoplankton is normally replaced by marine species and vice versa. Normally, during high tide, salinity is often higher due to the intrusion of saltwater from downstream. Salinity usually decreases with increasing distance from the sea, as well.

1.2 Significance of Study

River water is more buoyant than ocean water and as river water flows seaward, seawater flows landward. Mixing of seawater and river water tend to occur as a result of these activities, especially during high tide. As the freshwater of Petagas River mixes with saltwater, several marine phytoplankton species are found among the freshwater species, thus increasing the species diversity. No study on phytoplankton composition and density has been conducted in the Petagas River before. Therefore, the species diversity and abundance of phytoplankton is not known and needs to be investigated, along with the influence of salinity value, as it is one of the important factors in determining the distribution of phytoplankton. Phytoplankton forms the basis of aquatic food webs and even though the giant freshwater prawns do not directly feed on phytoplankton, their larvae and PL feed on zooplankton, while zooplankton feeds on phytoplankton. Hence, the phytoplankton composition or abundance will indirectly influence the presence or absence of PL of

Macrobrahium sp. and this finding can aid in determining the possible location of the next sea ranching session in Petagas River. Although it is known that the water of Petagas River is polluted, the level of its organic pollution is still unknown. The Pollution Index (Palmer, 1969) will be used by studying the phytoplankton present in the water sample.

1.3 Objectives

The objectives of this research are to investigate the phytoplankton species diversity and abundance in Petagas River. This study has four specific objectives:

i. To provide a checklist of phytoplankton species found in Petagas River.

ii. To study the influence of river salinity on the phytoplankton in Petagas River.

iii. To correlate phytoplankton with the presence PL of *Macrobrachium* sp. along Petagas River.

iv. To determine the water quality of Petagas River by using phytoplankton as an indicator-species.

1.4 Hypotheses

Based on the above objectives, two hypotheses were tested in this study:

- When salinity decreases, the species diversity of phytoplankton will increase.
- When the cell density of phytoplankton is high, there will be presence of PL of *Macrobrachium* sp.

CHAPTER 2

LITERATURE REVIEW

2.1 Stock Enhancement of Inland Waters in Asia

Stock enhancement is a fundamental component of many inland fisheries. In Asian rivers, fishery stock enhancement for fishery developments is relatively rare compared to developed countries (Welcomme, 1997). Stocking programmes for the Mekong giant fish species, such as the giant barb (*Catlocarpio siamensis*) and the giant catfish (*Pangasianodon gigas*) are examples of riverine stock enhancement in Asia (De Silva and Funge-Smith, 2005).

Stock enhancement of the giant freshwater prawn, *M.rosenbergii*, was attempted in several rivers in Thailand since 1998 (De Silva and Funge-Smith, 2005). From the year 1998 to the year 2003, 15 rivers were stocked with nearly 70 million PL. The most intensely stocked river was Pak Nanang in southern Thailand, with 26 million PL in 1999 and Songkhla Lake, with 32 million PL in 2002 (Choonhapran *et al.*, 2003). Increase in river production was reported, as a result of the stocking activities. The most successful stock enhancements in Asia are in floodplain beels and oxbow lakes in Bangladesh (De Silva and Funge-Smith, 2005), where the use of small water bodies that are not capable of supporting natural fisheries had led to culture-based fisheries that have very high rates of recapture and stock.

REFERENCES

Admiraal, W. 1977. Salinity tolerance of benthic estuarine diatoms as tested with a rapid polarographic measurement of photosynthesis. *Marine Biology*, **39**: 11-18.

Akpan, E.R. 1997. Spatial and seasonal distribution of phytoplankton in the Cross River estuary, Nigeria. A paper delivered at the 6th Annual Conference of the Nigerian Society for Biological Conservation 26th – 28th November, 1977, Calabar, Nigeria.

Al-Saadi, H.A., Kassim, T.I., Al-Lami, A.A. & Salman, S.K. 2000. Spatial and seasonal variation of phytoplankton in the upper region of the Euphrates river, Iraq. *Limnologica*, **30**: 83-90

Arumugam, S. 2012. Distribution and seasonal availability of freshwater prawn *Macrobrachium* spp. in Kodayer River in Tamil Nadu, India. *Universal Journal of Environmental Research and Technology*, **2**(4): 247-253

Banerjee, T.K. 2003.*Culture of Freshwater Prawns.*Applied Zoology, Banaras Hindu University, Varanasi, pp.1-21.

Barinova, S., Tavassi, M., Glassman, H. & Nevo, E. Algal indication of pollution in the lower Jordan River, Israel.*Applied Ecology and Environmental Research*, **8**(1): 19-38.

Belcher, H. & Swale, E. 1979.*An illustrated guide to River Phytoplankton.*Institute of Terrestrial Ecology, Cambridge, pp.6-56.

Bellinger, E.G. & Sigee, D.C. 2010.A key to the more frequently occurring freshwater algae. *Freshwater Algae: Identification and Use as Bioindicator*, pp.137-240.

Bisson, M.A. & Kirst, G.O. 1995. Osmotic acclimation and turgor pressure regulation in algae. *Naturwissenschaften*, **82:** 461-471.

Chakraborty.P., Acharrya, T., Babu, R. & Bandhyopadhyay, D. 2011. Impact of salinity and pH on phytoplankton community in a tropical freshwater

system: An investigation with pigment analysis by HLPC. *Journal of Environmental Monitoring*, **13**(3):614-620.

Choonapran, A., Assava-Aree, A., Sritakon, T. & Predalumpaburt,Y. 2003. *Status of fisheries resources after Songkhla Lake Fisheries Enhancement Preoject.* Department of Fisheries, Coastal Aquaculture Research Institute, Songkhla, Thailand.Technical Paper No. 2/2003, 22 pp.

Cook, P.A. & De Baissac, P. 1994. Does phytoplanktonplay a role in the nutrition of the larvae of the prawn, *Macrobrachium rosenbergii* (De Man).*Water SA*, **20**(1).

Daily Express. 2012. Need to monitor river quality. *Daily Express*, 7 December: 2

Das, S.K., Biswas, D. & Roy, S. 2007.Phytoplanktonic community of organically polluted tropical reservoirs in Eastern India.*Chinese Journal of Applied Environmental Biology*, **13**(4): 449-453

De Silva, S.S. & Funge-Smith, S.J. 2005.*A review of stock enhancement practices in the inland water fisheries of Asia.* Asia-Pacific Fishery Commission, Bangkok, Thailand.RAP Publication No. 2005/12, 93 pp.

Dorgelo, J. 1976. Salt tolerance in Crustacea and the influence of temperature upon it.*Biology Rev., Cambridge Philosophy Society*, **51**:255-290.

Edward, J.B. & Ugwumba, A.A.A. 2010.Physico-chemical parameters and plankton community of Egbe Reservoir, Ekiti State, Nigeria.*Research Journal of Biological Sciences*, **5**(5): 356-367.

Ekwu, A.O. & Sikoki, F.D. 2006.Phytoplankton diversity in the Cross River Estuary of Nigeria.*Journal of Application Science in Environmental Management*,**10**(1): 89-95.

Emerson, W.D. 1980. Ingestion, growth and development of Penaeus indicus larvae as a function of *Thalassiora weissflogii* cell concentration. *Marine Biology*, **58**: 65-73.

Farianah E. Molusin. 2014. A community-based stock enhancement project of *Macrobrachium rosenbergii* (Giant freshwater prawn): Water quality of Petagas River and its effect on the abundance of *Macrobrachium* sp. *Degree of Bachelor Science Thesis, Universiti Malaysia Sabah*, Sabah, pp. 16.

Flameling, I.A. & Kromkamp, J. 1994. Responses of respiration and photosynthesis of Scenedesmus protuberans Fritsch to gradual and steep salinity increases. *Journal of Plankton research*, **16**: 1781-1791

Fujimura, T. 1966. Notes on the development of a practical mass culture technique of the giant prawn *Macrobrachium rosenbergii. Proc. Indo-Pacific Fish Council*, **12**:3.

Fujimura, T. & Okamoto, H. 1972.Notes on progress made in developing a mass culture technique for *Macrobrahium rosenbergii* in Hawaii. In: Pillay, TVR (ed.). *Coastal Aquaculture in the Indo-Pacific Region*. Fishing New Books, London, pp. 313-327.

George, M.J. 1969. Genus *Macrobrachium* (Bates, 1968).*Center of Marine Fish Research Institute, India Bulletin*, **14**:179-204.

Hassan, F.M., Taylor, W.D., Al-Taee, M.M.S. & Al-Fatlawi, H.J.J. 2010.Phytoplankton composition of Euphrates River in Al-Hindiya barrage and Kifil City region of Iraq.*Journal of Environmental Biology*, **31**: 343-350.

Hickman, C.P., Roberts, L.S. & Larson, A. 2001.*Integrated Principles of Zoology 11th Edition*.McGraw Hill, Library Congress:New York, 899 pp.

Holthuis, S.A. 1980. Shrimp and prawns of the world.*FAO Fisheries Synopsis*, **1**(125).United Nations Food and Agriculturel Organization, Rome, Italy.

Huang, L., Jian, W., Song, X., Huang, X., Liu, S., Qian, P., Yin, K. & Wu, M. 2004. Species diversity and distribution for phytoplankton of the Pearl River estuary during rainy and dry seasons.*Marine Pollution Bulletin*, **49**: 588-596

Hötzel, G., & Croome, R. 1999. *A Phytoplankton Methods Manual for Australian Freshwaters*. La Trobe University Albury, Wodonga.

John, C.M. 1957. Bionomics and life history of of Macrobrachium rosenbergii (de Man). *Bulletin Centre of Research Institute, University Kerala, India*, **15**:93-102.

John, D.M. 1994. Biodiversity and conservation: an algal perspective. *The Phycologist*, **38**: 3-15

Johnson, V.L. 2005. Primary productivity by phytoplankton: Temporal, spatial and tidal variability in two North Carolina tidal creeks. *Master of Science Thesis, University of North Carolina Wilmington*, North Carolina, pp.1-66.

Jomas, C.R. 1997. *Identifying Marine Phytoplankton.*Academic Press, Harcourt Brace & Company, California.

Jost, L. 2010. The relation between evenness and diversity.*Diversity*, **2**:207-232; doi:10.3390/d2020207.

Kamal M.M., Khan, M.S.R., Galib, S.M., Nahar, M.D.G. & Haque, M.R. 2010. Comparison of plankton communities among freshwater prawn post larvae rearing ponds.*Int. J. BioRes.*, **1**(5): 21-26.

Khan, I.A. & Khan, A.A. 1985.Physical and Chemical conditions in Seikha Jheel at Aligarh, *Ecology*, pp. 269-274.

Kshirsagar, A.D. 2013. Use of algae as a Bioindicator to determine water quality of River Mula from Pune City, Maharashtra (India).*Universal Journal of Environmental Research and Technology*, **3**(1): 79-85

Lancelot, C. & Muylaert, K. 2011.*Trends in Estuarine Phytoplankton Ecology*. Elsevier Inc., Belgium.

Madariaga, I. 1995. Photosynthetic characteristics of phytoplankton during the development of a summer bloom in the Urdaibai Estuary, Bay of Biscay. *Est. Coast. Shelf Sci*, **40**: 559-575

Manzi, J.J., Maddox, M.B. & Sandifer, P.A. 1977.Algal supplement enhancement of *Macrobrachium rosenbergii* (de Man) larviulture.Proc. World Maricult. Soc., 8: 207-223

Maulood, B.K., Al-Saadi, H.A. & Hadi, R.A.M. 1993.A limnological studies on Tigris, Euphrates and Shatt Al-Arab, Iraq. *Mutah. J. Res. Studies*, 8: 53-67

Meyers, S.P. 1971. Crustacea ration formula research. *Feedstuffs*, **43**(28): 27

Miller, R.L. & Kamykowski, D.L. 1986. Effects of temperature, salinity, irradiance and diurnal periodicity on growth and photosynthesis in the diatom *Nitzschia americana*: light-saturated growth. *Journal of Phycology*, **22**: 339-348.

Mizuno, T. 1978. *Illustrations of the freshwater plankton of Japan.* Hoikusha Publishing Co., LTD., Osaka, Japan.

Mock, C.R. & Murphy, M.A. Techniques for raising penaeid shrimp from egg to postlarvae. *Proc. World Mariculture Society*, **1**: 143-158.

Muylaert, K., Sabbe, K. & Vyverman, W. 2000.Spatial and temporal dynamics of phytoplankton communities in a freshwater tidal estuary (Schelde, Belgium). *Estuarine, Coastal and Shelf Science*, **50**: 673-687.

Nandlal, S., and Pickering, T. 2005.*Freshwater prawn Macrobrachium rosenbergii farming in Pacific Island countries.Hatchery operation. Noumea, New Caledonia: Secretariat of the Pacific Community*, **1**: 5-19.

Nandlal, S. & Pickering, T. 2006.*Freshwater Prawn Macrobrachium rosenbergii farming in Pacific Island countries: Grow-out in ponds.* Nournea, New Caledonia: Secretariat of the Pacific Community, **2**: 4-32.

New, M.B. 1990. Freshwater prawn culture: A review. *Aquaculture,* **88**: 99-143.

New Straits Times. 2012a. Overfishing contributes to diminishing fishery resources. *New Straits Times*, 24 April: 12

New Straits Times. 2012b. Yahya wants committee to monitor Petagas River. *New Straits Times*, 7 December: 12

Nixon SW. 1995.Coastal marine eutrophication: A definition, social causes, and future concerns. *Ophelia*, **41**: 199–219.

Palmer, C.M. 1969. Composite rating of algae tolerating organic pollution.*Journal of Phycology*, **5**: 78-82.

Palmer, C.M. 1980. *Algae and water pollution.* Castle House Publishers Ltd., England.

Parago, M. 2008. Feeding of tropical cladocerans (*Moina micrura, Diaphanosoma excisum*) and rotifer (*Brachionus calyciflorus*) on natural phytoplankton: effect of phytoplankton size–structure. *Journal of Plankton Research*, **30**: 401-414.

Perdue, J.A. & Nakamura. 1976. The effect of salinity on the growth of *Macrobrachium rosenbergii. Proc. 7th Annual Meeting Worl Mariculture Society*, pp. 647-654.

Person, J.L. 1989.*Environmental Science Investigations*. J.M. LeBel Enterprises, Ltd., Ronkonkoma, New York, pp 131.

Plafkin, J.L.M.T., Barbour, K.D. Porter, S.K., Gross, R.M. & Hughes. 1989. *Rapid assessment protocols for use in streams and rivers*. EPA: Washington.

Rai, U.N., Dubey, S., Shukla, O.P., Dwivedi, S. & Tripathi, R.D. 2008. Screening and identification of early warning algal species for metal contamination in freshwater bodies polluted from poin and non-point sources. *Environmental Monitoring Assessment*, **144**: 469-481.

Remane, A. & Schlieper, C. 1958.*Die Biologie des Brackwassers*. E. Schwiezerbart'sche Verlagsbuchnändlung. Stuttgart, pp. 348.

Reynolds, C.S. 1993. *The Ecology of Freshwater Plankton* (Cambridge Studies in Ecology). Cambridge University Press, New York, pp 384.

Rice, T.R., & Ferguson, R.L. 1975. Response of estuarine phytoplankton to environmental conditions. In: F.J.VERNBERG. Physiological ecology of estuarine organisms. The Belle Baruch Library in Marine Science, Univ. South Carolina Press, Columbia, S.C.**3:** 1-43.

Rijstenbil, J.W. 1988. Netherlands Journal of Sea Research, **22**: 291–300.

Rijstenbil, J.W., Mur, L.R., Wijnholds, J.A. & Sinke, J.J. 1989.Impact of a temporal salinity decrease on growth and nitrogen metabolism of the marine diatom *Skeletonema costatum* in continuous culture.*Marine Biology*, **101***:* 121- 129.

Senapati, T., Ghosh, S. & Mandal, T. 2011. Variation in phytoplankton diversity and its relation with physic chemical parameters of a semi lentic water body of Golapbag West Bengal, India. *International Journal of Current Research*, **3**(7):53-55.

Shekhar, R.T., Kiran B.R., Puttaiah E.T., Shivaraj Y, &. Mahadevan.K.M. 2008. Phytoplankton as index of water quality with reference to industrial pollution. *Journal of Environmental Biology*, **29**: 233-240.

Snoejis, P. 1995. Effects of salinity on epiphytic diatom communities on Pilayella littoralis (Phaeophyceae) in the Baltic Sea.*Ecoscience*, **2**: 382-394.

Stephenson, M.J. & Knight, A.W. 1982.Temperature and acclimation effects on salinity preferences of post-larvae of the Giant Malaysian Prawn, Macrobrachium rosenbergii (de Man).*Journal of Experimental Mariculture, Biology and Ecology*, **60**:253-260.

Stirling, H.P. 1985. *Chemical and biological methods of water analysis for aquaculturists*.Institute of Aquaculture. University of Stirling, Scotland.

Stoermer, E.F. & Julius, M.L. 2003.Centric diatoms.*In*: Freshwater algae of North America Ecology and classification (Eds.: Wehr J.D. and Sheath R.G.). *Academic Press, USA*, pp. 559-594.

Szelag-Wasielewska, E. 2003.Phytoplankton community structure in Non-stratified Lakes of Pomerania (NW Poland).*Hydrobiologia*, **506-509**: 229-236

Tas, B.I., Gonulol, A. & Tas, E. 2002. A study on the seasonal variation of the phytoplankton of lake Cernek (Samsun-Turkey). *Turkish J. Fish.Aquat. Sci.*, **2**: 121-128.

Temponeras, M., Kristiansen, J. & Moustaka-Gouni, M. 2000.Seasonal variation of the phytoplankton composition and physical-chemical features of the shallow lakeDoraini, Macedonia, Greece.*Hydrobiologia*, **424**: 109-122.

The Borneo Post. 2012. Putatan needs water treatment and sewerage systems - Yahya. *The Borneo Post*, 24 April: A2

Welcomme, R.L. 1997. Stocking as a technique for enhancement of fisheries.*FAO Aquaculture Newsletter*, 14: 8-12.

Willen, E., Hajdu, S. & Pejler, Y. 1990.Summer phytoplankton in 73 nutrient-poor Swedish lakes.Classification, ordination and choice of long-term monitoring objects.*Limnologica*, **21**: 217-227

Zebek, E. 2004. Species biodiversrity of net phytoplankton as an indicator of trophic changes in the urban lake Jeziorak Maly. *Teka Kom. Ochr.Kszt. Srod.Przyr.*, **1**: 316-321.