Journal of Aquatic Biology and Fisheries Vol. 2/2014/ pp. 835 to 842

PHYTOPLANKTON AS POLLUTION INDICATORS: A CASE STUDY FROM WETLAND AREAS OF VEMBANAD LAKE ADJACENT TO SEA FOOD PROCESSING FACILITIES

Vidya, V*., Sumathy, K. and Prasad, G.
Department of Zoology, University of Kerala, Kariavattom Thiruvananthapuram
Kerala, India, 695581,
**Email: vidyaveee@gmail.com*

Received on: 10 October 2013, accepted on: 12 December 2013

Abstract: Kerala is one of the most important maritime states in the country, contributing significantly to the Indian seafood industry. Vembanad Lake has been acclaimed as the 'Inland fish basket' of the state due to its fisheries resources. The coastal belt of Vembanad Lake is bordered by a number of seafood processing units. During the processing of fishes a large bulk of by-products and wastes are produced. The direct discharge of sea food processing effluents to the nearby water bodies may cause eutrophicaton and algal blooms. The present study deals with the role of biological parameter (plankton population) to understand the effects of seafood processing waste discharge on the Cherthala-Aroor-Edakochi coastal belt of Vembanad lake ecosystem. The water samples were collected from the five pre-selected sites namely, Pattanakadu (S1), Parayakadu (S2), Edakochi (S3), Aroormukkam (S4) and Panavally (S5) for a period of one year (October 2011to September 2012) on a monthly basis. The four sites (S1-S4) were near to the the seafood processing discharge outlets and the site S5, was kept as a reference site, which is free from the seafood processing discharge pollution. The phytoplankton populations were identified using research publications, books and standard keys. A total of 137 phytoplankton genus representing the 8 diverse taxonomic classes of Bacillariophyceae (53), Chlorophyceae (55), Cyanophyceae (19), Rhodophyceae (4), Chrysophyceae (2), Haptophyceae (2), Eustigmatophyceae (1) and Cryptophyceae (1) were reported during the study period. The diversity were measured using biological indices and it include Shannon Weiner's diversity index, Simpson's dominance index and Margalef's richness index and Palmer's genus pollution index. The Shannon Weiner's diversity index (H') ranged in between 3.58 to 3.87. The lowest H' value (3.58) was obtained in Pattanakadu (S_1) and that of higher value (3.87) in Panavally (S_5). In S_1 the correlation analysis of plankton revealed that there was a significant positive correlation between Bacillariophyceae and Cyanophyceae ($r = 0.668$, $p < 0.05$). A positive correlation of Bacillariophyceae and Chlorophyceae ($r = 0.914$, $p < 0.01$) was also recorded in S_2 and S_3 ($r = 0.932$, $p<0.01$ The higher dominance of these phytoplankters in varying number in all the four sites (S_1-S_4) when compared to the reference site indicated that they have been exposed to the organic pollution load from the sea food processing industry. The study concluded that the dominant members like *Nitzschia sp, Navicula sp, Coscinodiscus sp, Biddulphia sp, Chaetoceros sp Ankistrodesmus sp, Scenedesmus sp, Chlorella sp, Oscillatoria sp* and *Phormidium sp* can be used as an indicator of sea food processing discharge associated pollution.

Key words: Vembanad Lake, Pollution, Phytoplankon, Indicator, Diversity indices.

INTRODUCTION

Indian foreign exchange earnings from fish exports are expected to cross the 3.5 billion dollar mark with a million tonnes of export during 2012-2013(CMFRI, 2012). Kerala is one of the most maritime states in the country contributing significantly to the Indian sea food Industry. There are about 287 sea food exporters in Kerala with 124 processing plants, 169 cold storages with a total capacity of 23086.50, which are the highest figures in the country (www. ksidc. org/marine-products.php). The Kochi region has a vast majority of export processing plants within the state.81 out of the 91 registered exporters in Kerala are situated within the Kochi and Cherthala taluks (SIFFS, 2002). The fishing industry comprises fish catching, processing and marketing. Effluents from fish and crustacean processing plants are generally characterized by high concentrations of nutrients, high levels of nitrogen content found as ammonia (NH_3-N;

29 to 35 mg L-1), high total suspended solids (0.26 to 125,000 mg L-1), increased biological oxygen demand (10 to 110,000 mg L-1) and chemical oxygen demand (496 to 140,000 mg L-1), and by the presence of sanitizers (AMEC Earth and Environmental Limited, 2003). The direct discharge of waste from the seafood processing industries into the adjacent wetlands affects the aquatic life and thus may affect the whole food chain. Problems occur when the quantity of organic matter discharged exceeds the carrying capacity of the ecosystem and/or when its dispersion is constrained within coastal waters. Excessive discharge of organic nutrients into the marine environment can result in reduction of dissolved oxygen in the water leading to hypoxia or anoxia, increased ammonia concentrations, overloads of nitrogen (N) and phosphate (P) causing excessive plant growth, variation in pH, and increased water turbidity (Tchoukanova *et al*., 2003). The fish processing effluents detrimentally affect the quality of water bodies (Hamid *et al*., 2010). Phytoplankton are characterized by their rapid responses to alterations in environmental conditions (Reynolds, 1984) such as anthropogenically introduced eutrophications of coastal waters (Richardson, 1997). Their presence or absence from the community indicates changes in physico-chemical environment of the estuary (Rissik, 2009). Bonsdorff *et al.* (1997), Blomqvist, Mattila and Norkko, reported the increase in phytoplankton biomass and decrease in species diversity of benthic and fish communities, with respects to the discharge of seafood processing wastes on aquatic bodies. Several studies explained the pollution status of Vembanad lake from various sources including domestic and municipal sewage, fertilizer and pesticide residues, heavy metals, coconut retting, industrial effluents from oil refineries, fertilizer plants and chemical industries (Rai *et al*., 1976; Remani *et al*., 1980; Saraladevi *et al*., 1979; Bijoy Nandan, 2003; Mohan and Omana, 2006). However, a detailed investigation on this perspective of pollution and its impact on the Vembanad lake have not been done earlier. Hence, the present study has been formulated to understand the preliminary effects of seafood processing waste discharge on the phytoplankton population of the Vembanad lake ecosystem.

MATERIALS AND METHODS

Study site

The Vembanad wetlands extending between the latitude 09°00'—10°40'N latitude and 76°00'-7° 30'E longitude, is the most important tropical wetland in Kerala and supporting maximum livelihood activities. This Ramsar site covers an area of 1,513 km^2 and stretching from Alappuzha to Cochin. The Vembanad Lake borders Cherthala, Ambalapuzha and Kuttanad taluks of Alappuzha district (Fig. 1). The present study was conducted in Cherthala - Aroor - Edakochi coastal belt. Samples for the present study were collected from five different stations namely, Pattanakadu (S_1), Parayakadu (S_2), Edakochi (S_3), Aroormukkam (S_4) and Panavally (S_5) (Table: 1) for a period of one year from October 2011to September 2012 on a monthly basis.The sites (S_1-S_4) were closely associates the seafood processing discharge outlets and the site S_5, was kept as a reference site, which is free from the seafood processing discharge.

Phytoplankton analysis

Phytoplankton samples were collected from the surface water using a conical net of mesh size 50 µm, for a period of one year on a monthly basis. A known volume (25 litres) of water is passed through the net and was collected in a 50ml plastic container. The labeled samples were preserved in 4% formalin solution at the site itself, labelled and brought to the laboratory. Taxonomic identification of plankton up to genus level was done using standard keys (Adoni, 1985; Newell and Newell, 1986; Palmer, 1980; Santhanam *et al*., 1987). Quantitative analysis of plankton was done by employing Sedgewick-rafter cell counting chamber, one ml of filtered plankton sample was transferred to the counting chamber and counted using a binocular microscope.

Statistical analysis

Correlation analysis was employed to determine the relationship between phytoplankers. The diversity indices such as Shannon-Weaner species diversity index, Simpson dominance index and Margalef richness index were employed to assess the plankton biodiversity using the software PAST (2005). The pollution

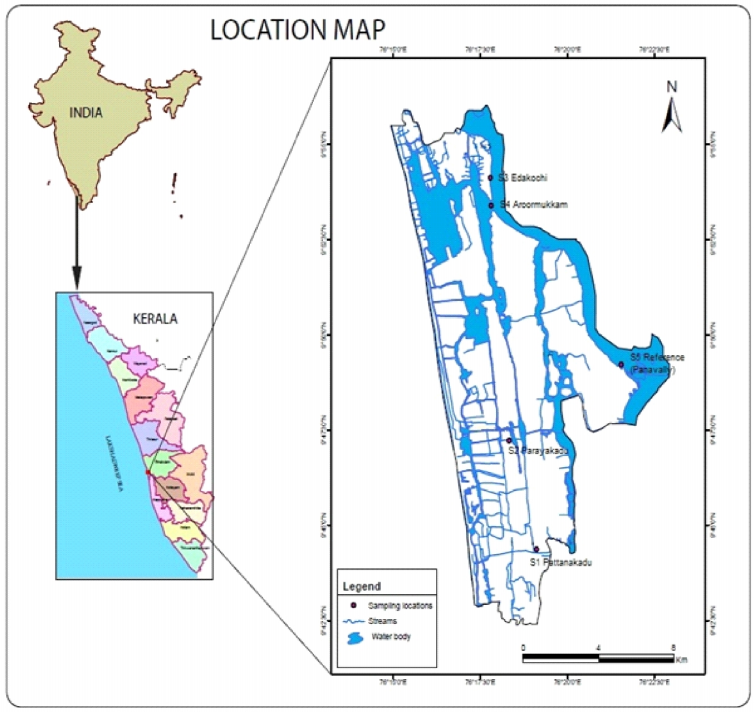

Fig. 1 Study area

Table 1. Detailes of Study area

Sl.No	Name	Geographic Position	Land Utilisation	Remarks
1	Pattanakadu	9°44'22N,76°19'07E	Panchayat area	Interconnected canal
2	Parayakadu	9°47'13N,76°18'20E	Aquaculture farm	Interconnected canal
3	Edakochi	9°54'07N,76°17'42E	Boat building yard	Main water body
4	Aroormukkam	9°53'23N,76°17'49E	Fallow land	Main water body
5	Panavally	9°49'13N,76°21'33E	Agriculture and aquaculture area	Main water body

status was assessed using Palmer's algal genera pollution index (Palmer, 1980).

RESULTS

A total of 137 phytoplankton genera representing 8 diverse taxonomic classes of Bacillariophyceae (53), Chlorophyceae (55), Cyanophyceae (19), Rhodophyceae (4), Chrysophyceae (2), Haptophyceae (2), Eustigmatophyceae (1), and Cryptophyceae (1) were reported during the study period. The total number of individuals quantified from the five stations during the investigation period was 9138, and they were classified upto the genus level. The phytoplankton diversity and their percentage composition were given in Table 2.

The Bacillariophyceae had a higher representation in all stations with maximum individuals of 1374 in S_1 and a minimum of 814

Table 2. Percentage composition of phytoplankton

Class	S_1	S_2	S_3	S_4	S_5	Total	% composition
Bacillariophyceae	1374	1288	1089	1153	814	5718	62.57
Chlorophyceae	340	690	313	234	234	1811	19.82
Cyanophyceae	426	651	208	128	136	1549	16.95
Rhodophyceae	2	0	3	2	9	16	0.18
Chrysophyceae	0	0	11	4	0	15	0.16
Haptophyceae	1	2	2	1	0	6	0.07
Eustigmatophyceae	7	3	3	0	0	13	0.14
Cryptophyceae	4	0	4	2	0	10	0.11
Total	2154	2634	1633	1524	1193	9138	100.00

in S_5. Among them, representatives of 33 genera were present in all stations which includes *Achananthes* sp., *Amphora* sp., *Asterionella* sp., *Biddulphia* sp., *Ceratulina* sp., *Cheatoceros* sp., *Climacosphenia* sp., *Coscinodiscus* sp., *Cyclotella* sp., *Cymbella* sp., *Diatoma* sp., *Diploneis* sp., *Fragellaria* sp., *Frustulia* sp., *Gyrosigma* sp., *Grammatophora* sp., *Ishtmia* sp., *Leptocylindrus* sp., *Licmophora* sp., *Navicula* sp., *Nitzschia* sp., *Pinnularia* sp., *Pleurosigma* sp., *Rhizosolenia* sp., *Skeletonema* sp., *Stauroneis* sp., *Streptotheca* sp., *Synedra* sp., *Tabellaria* sp., *Thalassionema* sp., *Thalassiosira* sp., *Thalassiothrix* sp. and *Triceratium* sp. Of these, *Nitzschia, Navicula, Coscinodiscus* and *Fragellaria* showed higher dominance with varying number of individuals. The class Bacillariophyceae occupied 62.57% of the total individuals reported during the study.

The second dominant class obtained in our study was Chlorophyceae (19.52 %). The highest number of individuals were reported in S_2 (690) and lower in S_4 and S_5 (234). Twenty genera were present in all stations and they were, *Actinastrum* sp., *Ankistrodesmus* , *Characium* sp., *Chlamydomonas* sp., *Chlorella* sp., *Cladophora* sp., *Closteridium* sp., *Closerium* sp., *Cosmarium* sp., *Elakatothrix* sp., *Melosira* sp., *Microspora* sp., *Oedogonium* sp., *Scenedesmus* sp., *Spirogyra* sp., *Spirotaenia* sp., *Staurastrum* sp., *Tetraedon* sp., *Ulothrix* sp. and *Zygnema* sp. The genera *Ankistrodesmus, Scenedesmus, Chlorella* and *Spirogyra* showed dominance.

The class Cyanophyceae represented 16.95 % of total phytoplankton identified during the study period. More number of individuals were

Table 3. Biodiversity Indices

	Pattanakadu (S_1)	Parayakadu (S_2)	Edakochi (S_3)	Aroormukkam (S_4)	Panavally (S_5)
Taxa	98	97	101	101	92
Individuals	2154	2634	1633	1524	1193
Palmer pollution index	30	25	26	27	24
Simpson dominance index (1-D)	0.95	0.96	0.95	0.95	0.97
Shannon Weaner diversity index (H')	3.58	3.66	3.67	3.73	3.87
Margalef richness index (d)	12.64	12.19	13.52	13.64	12.85

reported from S_2 (651) and less from S_4 (128). The genera represented in all stations were *Agmenellum* sp., *Anabaenopsis* sp., *Anabaena* sp., *Lyngbya* sp., *Oscillatoria* sp., *Phormidium* sp., *Spirulina* sp. and *Trichodesmium* sp. Out of these, *Oscillatoria* and *Phormidium* were dominant.

The members of Rhodophyceae (0.18%), Chrysophyceae (0.16%), Eustigmatophyceae (0.14%), Cryptophyceae (0.11%) and Haptophyceae (0.07%) were also obtained. They didn't show any dominance during the study period.

Out of the 8 taxonomic classes of phytoplankton obtained, 7 were present in Pattanakadu (S_1). Among Bacillarophyceae, *Nitzschia* sp. (301), *Navicula* sp. (221), *Fragelleria* sp. (96), and *Coscinodiscus* sp. (92) were dominant. *Ankistrodesmus* sp. (65), *Scendesmus* sp. (47) and *Chlorella* sp. (47) were predominant among Chlorophyceae. *Oscillatoria* sp. (208) and *Phormidium* sp. (95) represented the leading genus among Cyanophyceae.

A total of 97 genera were reported in Parayakadu (S_2). The predominant genera of Bacillariophyceae were, *Nitzschia* sp. (306), *Navicula* sp. (229), and *Fragelleria* sp. (104). *Scendesmus* sp. (182), *Ankistrodesmus* sp. (59) and *Chlorella* sp. (54) were dominant among Chlorophyceae, and *Anabaenopsis* sp. (152), *Phormidium* sp. (130) and *Oscillatoria* sp. (106) were dominant among the Cyanophyceae.

All the 8 phytoplankton groups with 101 genera were present in Edakochi (S_3). Dominant genera among Bacillariophyceae were *Nitzschia* sp. (261), *Navicula* sp. (206), *Coscinodiscus* sp. (76) and *Fragelleria* sp. (52). Among Chlorophyceae, *Ulothrix* sp. (51), *Microspora* sp. (35), *Ankistrodesmus* sp. (28) and in Cyanophyceae, Oscillatoria sp. (80) and *Phormidium* sp. (29) were dominant.

A total of 101 genera belonging to 7 phytoplankton taxonomic classes were reported in Aroormukkam (S_4). Among Bacillariophyceae (1153 members) *Navicula* sp. (214), *Nitzschia* sp. (155) and *Coscinodiscus* sp. (86) were dominant. Chlorophyceae had 37 genus (234 members) with predominance of *Spirogyra* sp. (31), *Uronema* sp. (19), *Microspora* sp. (16) and *Ankistrodesmus* sp. (16). Cyanophyceae with 14 genus (128 members) were dominated by *Phormidium* sp. (39) and *Oscillatoria* sp. (29).

In the reference site Panavally (S_5), 92 genera from 4 classes were reported, which included, Bacillariophyceae (43 genus with 814 individuals), Chlorophyceae (35 genus with 257 individuals), Cyanophyceae (11 genus with 136 individuals) and Rhodophyceae (3 genus with 9 individuals). *Navicula* sp. (214), *Nitzschia* sp. (155), and *Pleurosigma* sp. (75) of Bacillariophyceae, *Gonatozygon* sp. (34) and *Spirogyra* sp. (32) of Chlorophyceae, *Phormidium* sp. (32) and *Oscillatoria* sp. (26) of Cyanophyceae were the dominant genera in S_5.

The values of Simpson dominance index (1-D) were in the range of 0.95 - 0.97. Its minimum value (0.95) was observed in S_1, S_3 and S_4 whereas the maximum in S_5. The Shannon Weaner diversity index (H') ranged in between 3.58 to 3.87. The lowest H' value (3.58) was obtained in Pattanakadu (S_1) and that of higher value (3.87) in Panavally (S_5). Margalef richness index (d) was ranged between12.19–13.64. The lowest and highest values were noticed in S_2 and S_4 respectively (Table 3).

In 1969, a procedure was described for using the 20 genera or species, for each of the algae and a pollution index factor was assigned. In making a microscopic analysis of a sample, all of the 20 algae that are observed are recorded (providing 5 or more individuals, per slide, of a particular general species present). Then total index factors of the algae present are taken. In S1, a high value of 30 was obtained. The next higher value of pollution index, 27 was reported in S4, followed by 26 (S3), and 25 (S2). The lowest value (24) was observed in the reference site (S5) (Table 3).

Correlation study was done between phytoplankters in all the five sites to understand their interrelationship. In S_1, the correlation analysis of plankton with each other revealed that there was a significant positive correlation between Bacillariophyceae and Cyanophyceae ($r = 0.668$, $p < 0.05$). In S_2 and S_4 Chlorophyceae showed a significant positive correlation to Bacillariophyceae. In S_3 and S_5 the plankton groups did not show any significant relationship with each other.

DISCUSSION

Phytoplankton reflects water quality through changes in its community structure, patterns of distribution and the proportion of sensitive species; therefore they may be used as an indicator of water quality (Palmer, 1969; Nandan and Aher, 2005; Zargar and Ghosh, 2006). Bacillariophyceae (diatoms) were the dominant group in all stations, their highest numbers of occurrence were reported in the study sites S_1 - S_4. The reference site Panavally, had only a limited number of individuals as compared to other sites. Bellinger and Siegee, (2010) reported that abundance of Bacillariophyceae is a characteristic feature of a eutrophic environment. Nandan and Aher, (2005) showed that the diatoms like *Nitzschia* sp., *Navicula* sp. etc. are the species found in organically polluted water. Our results enumerated a higher number of this genus from S_1-S_4, as compared to that of reference site, S_5. In this study, the epiphytic algae *Gomphonema* sp. were present in S_1 and S_4, as an indication of water pollution (Round 1965; Shekhar *et al*., 2008). The second dominant class of phytoplankton obtained in the study was Chlorophyceae, The presence of genus *Ankistrodesmus* and *Scenedesmus*, was considered as the eutrophicated environment (Jose and Kumar, 2011). More number of this genus was reported from S_1 and S_2. The presence of Cyanophyceae indicated that the water is not potable. Cyanophyceae dominance and its blooms are the most visible symptom of accelerated eutrophication of lakes and reservoirs (Moss *et al*., 1997). According to Round (1965), epilethic algae such as *Oscillatoria* sp. and *Phormidium* sp. are excellent indicators of water pollution. They were reported in higher number in S_1, S_2 and S_3, which indicate the presence of pollutants of biological origin. Not only there was abundance of phytoplankton in the study sites, but also there was a greater diversity of taxa also. High mean value of Shannon Weaner diversity index (H') was observed in Panavally (S_5), as compared to other sites. According to Dash (1996), higher the value of Shannon index, greater the planktonic diversity, hence a healthier ecosystem. The result was supported by observation of Bode *et al*. (2002). Species diversity decrease to minimum levels when one or a few species are dominant (Ignatiades 1969). This value is a suitable index for water quality assessment (Wilhm 1975; Junshum *et al*., 2008; Rajagopal *et al*., 2010). Lower value of H' index is an indication of pollution load in environment. In the present study, the pollution tolerant genus shown dominance in S_1 - S_4. Thus we can substantiate that Panavally supported greater diversity and have lesser pollution with respect to other sites. The values of Simpson dominance index (1-D) were in the range of 0.95 - 0.97. Its minimum value (0.95) was observed in S_1, S_3 and S_4 whereas the maximum in S_5. Margalef richness index (d) was ranged between12.19 – 13.64. The lowest and highest values were noticed in S_2 and S_4 respectively.

Algal genera pollution index ranged from 24-30 in S5 - S1 and clearly indicated the water bodies were progressing towards eutrophic nature at an alarming rate (Palmer, 1969; Palmer and Adams, 1977; Parvateesam and Mishra, 1993; Junshum *et al*., 2008). In S1, a high value of 30 was obtained. The lowest value (24) was observed in the reference site (S5). The high index value in all four study sites, as compared to the reference site indicated that they have been exposed to different sources of organic pollution, including seafood processing effluents.

The study on pollution using phytoplankton showed that the water qualities of the four sites (Pattanakadu, Parayakadu, Edakochi and Aroormukkam) are deteriorating when compared to the reference site (Panavally). The waste discharge from the sea food processing industry is one of the factors contributing to the alarming rate of water pollution. The deteriorated water quality will negatively affect the sea food production, its export and our foreign exchange reserve. Hence, appropriate measures should be taken by the legal bodies before the complete destruction and loss of this national treasure otherwise the Vembanad wetland becomes a waste land for ever.

CONCLUSIONS

In addition to many anthropogenic stressors, the functioning of seafood processing plants along the Coast of Vembanad Lake is causing a serious ecological issue. The present study has been conducted for assessing the influence of seafood waste on Vembanad Lake ecosystem. The pollution status of the lake was determined by phytoplankton enumeration. Primary change of an aquatic system from oligotrophy to eutrophy involves a great increase in the phytoplankton biomass and subsequent productivity. These are the general response of phytoplankton to eutrophication.

About 137 phytoplankton genera were obtained in the present study. The dominant class Bacillariophyceae was followed by Chlorophyceae, and Cyanophyceae. The results showed that the presence of *Nitzschia sp., Navicula sp., Coscinodiscus sp., Biddulphia sp., Chaetoceros sp., Ankistrodesmus sp., Scenedesmus sp., Chlorella sp., Oscillatoria sp.* and *Phormidium sp.* is an indication of organic pollution load. The high values of Shannon Wiener diversity index and Palmer's algal genera pollution index in all four effluent discharge sites, as compared to the reference site also supported the fact that they have been exposed to various sources of organic pollution, mainly seafood processing effluents. The study concluded that the dominant members like *Nitzschia sp., Navicula sp., Coscinodiscus sp., Biddulphia sp., Chaetoceros sp., Ankistrodesmus sp., Scenedesmus sp., Chlorella sp., Oscillatoria sp* and *Phormidium sp* can be used as an indicator of sea food processing discharge associated pollution.

ACKNOWLEDGMENTS

The financial aid for the study has been obtained from the Directorate of Environment and Climate Change, Govt. of Kerala which is greatly acknowledged.

REFERENCES

Adoni, A.D. 1985. WorkBook on Limnology. Pratibha Publications, India 126 pp.

AMEC Earth and Environmental Limited. 2003. Management of wastes from Atlantic seafood processing operations. Submitted to National Programme of Action Atlantic Regional Team, Dartmouth. Report number: TE-23016.

Bellinger, G.E and Siegee, D.C. 2010. Fresh water algae: identification and use as bio-indicators. 1st Edition, John Wiley and Sons, Ltd. 271 pp.

Bijoy Nandan, S. 2003. Coconut husk retting and its impact in the Vembanad wetland. Abstracts of Regional Seminar on Ramsar Sites of Kerala. Centre for Water Resources Development and Management, Calicut, Kerala 38-39.

Bode, R.W., Novate, M.A., Abele, L.E., Heitzman, D.L. and Smith, A.J. 2002. Quality assurance work plan for biological stream monitoring in New York State. Department of Environmental Conservation, Albany, New York 122 pp.

Bonsdorff, E., Blomqvist, E.M., Mattila, J. and Norkko, A. 1997. Coastal eutrophication: causes, consequences and perspectives in the Archipelago areas of the northern Baltic Sea. Estuarine, Coastal and Shelf Science 44: 63-72.

CMFRI, Annual Report 2011-12. 2012. Central Marine Fisheries Research Institute, Cochin 186pp

Dash, M. C. 1996. Fundamentals of ecology. Tata Mac Graw Hill Publishing company Ltd., New Delhi 229 pp.

Hamid, M., Masoud, A., Masoud, H. and Fardin, B. 2010. An assessment of Fish Processing plant Discharge Effluent on The Tizab River World Academy of Science, Engineering and Technology. 70pp.

Ignatiades, L. 1969, Annual cycle, species diversity and succession of phytoplankton lower Saronicus Bay, Aegean Sea, Marine Biology 3(3): 196-200.

Jose, L. and Kumar, C. 2011. Evaluation of Pollution by Palmer's Algal pollution index and physico chemical analysis of water in Four Temple ponds of Mattanchery, Ernakulam, Kerala. : Nature Environment and Pollution Technology 10(3): 471-472.

Junshum, P., Menasveta, P and Traichaiyaporn, S. 2007. Water quality assessment in reservoirs and wastewater treatment system of the Mae Moh Power Plant, Thailand. Journal of Agriculture & Social Sciences 3(3): 1813–2235.

KSIDC, Marine products, Major Exports, Kerala. Accessed on 16 October 2013, 13:35:04.

Mohan, M. and Omana, P.K. 2006. Distribution of mercury and the threat to Vembanad Ecosystem, Ramsar site, Kerala. Proceedings of the 18th Kerala Science Congress, Kerala State Council for Science, Technology and Environment, Thiruvananthapuram, 392-394.

Moss, B., Madgwick, J. and Philips, G. 1997. A guide to the restoration of nutrient enriched shallow lakes, W.W. Hawes, U. K, 179 pp.

Nandan, S.N. and Aher, N.H. 2005. Algal community used for assessment of water quality of Haranbaree dam and Mosam river of Maharashta. *Journal of Environmental Biology,* 26:223-227.

Newell, G.E. and Newell, R.C. 1986. Marine Plankton A Practical Gide. Hutchinson and Co. Publishers Ltd, London, 206 pp.

Palmer, C.M. and Adams, S. 1977 Algae and water pollution. Office of Research and Development Ohio.

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

Palmer, C.M. 1980. Significance of algae. In "Algae and water pollution" castle Home publications London.

Parvateesam, M. and Mishra, M. 1993. Algae of Pushkar Lake including pollution indicating forms. J. Phyco. Soc. 32(1 & 2): 27 – 39.

PAST. 2005. PAST - PAlaeontological STatistics, ver. 1.34 Øyvind Hammer, D.A.T. Harper and P.D. Ryan. http://folk.uio.no/ohammer/past.

Rai, L.C. and Kumar, H.D. 1976. Studies on the seasonal variation in the algal communities of pond polluted with fertilizer factory effluent. *Ind. Jour. Eco.* 4(2): 124-131.

Rajagopal, T., Thangamani, A., Sevarkodiyone, S.P., Sekar, M. and Archunan, G. 2010. Zooplankton diversity and physic chemical conditions in three perennial ponds of Virudhunagar district, Tamilnadu. *J. Environ. Biol.* 31: 265-272.

Remani, K.N., Venugopal, P., Saraladevi, K., Lalitha, S. and Unnithan, R.V. 1980. Sediments of Cochin backwaters in relation to pollution. *In. J. Mar. Sci.* 9: 111- 113.

Reynolds, C.S. 1984. The ecology of freshwater phytoplankton. Cambridge University Press, Cambridge, New York. 384 pp.

Richardson K. 1997. Harmful or exceptional phytoplankton blooms in the marine ecosystem. *Advances in Marine Biology*.31: 301-385.

Rissik, D. 2009. Plankton: A Guide to their Ecology and Monitoring for Water Quality. Suthers IM, Rissik D (eds.) . CSIRO Publishing, Collingwood, Australia.ISBN: 9780643090583.

Round, F.E. 1965. The biology of the algae. Edward Arnold Publications. London 269 pp.

Santhanam, R., Ramanathan, N., Venkataramanujam, K and Jegatheesan, G. 1987. Phytoplankton of the Indian Seas. Daya publishing House, Delhi. 134 pp.

Shekhar, T.R.S., Kiran, B.R., Puttaiah, E.T., Shivaraj, Y. and Mahadevan, K.M. 2008. Phytoplankton as an index of water quality with reference to industrial pollution. Journal of Environmental Biology 29(2): 233-236.

SIFFS. 2002. A review of export supply chains in kerala. globalisation and international sea food legislation: the impact on poverty in india Dfid. Poject, July. 32pp.

Tchoukanova, N., Gonzalez, M. and Poirier, S. 2003. Best Management Practices: Marine Products Processing. Fisheries and Marine Products Division of the Coastal Zones Research Institute Inc., Shippagan, New Brunswick, Canada. Available on-line at: http://www.umcs.ca/Institut/BMP.pdf

Wilhm, J.L., 1975, Biological indicators of pollution. In:. River Ecology, B.A Whitton (ed.), Studies in Ecology, Vol. 2, Blackwell Science publications, London, 375 –402.

Zargar, S. and Gosh, T.K. 2006. Influence of cooling water discharges from Kaiga nuclear power plant on selected indices applied to plankton population of Kadra reservoirs. *J. Envi. Biol.* 27: 91-198.