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Sustentation of the wetland ecosystem by an analysis of its Primary production status

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Abstract
Wetlands under extreme threats are more in Kerala than any other state. The present study focuses on the four selected stations of Thekkumbhagam creek for the analysis of its primary productivity. The assessment of primary production of this creek is necessary to make out whether the productivity recorded is enough to sustain its biodiversity. The stations recorded a productivity range from 0.15 mg C/l/day to 8.8mgC/l/day. Station 2 recorded the maximum rate of gross primary production. Maximum production was noticed in the post-monsoon period and minimum during the monsoon period. Gross primary production and net primary production below detectable levels were also noticed. The depletion of dissolved oxygen in the surface water and bottom water caused the total failure of production especially in polluted areas. Thus a "scientific knowledge" about the water quality of the "Thekkumbhagam creek" will help in the understanding of the economic, cultural, social, aesthetic, spiritual values and all other benefits thereby focusing the mitigation of pollution affecting the creek.

Keywords: Gross productivity, net production, dark and light bottle, Winkler's method, NEP

1. Introduction

Primary productivity of an ecological system, community or any part is defined as the rate at which radiant energy is stored by photosynthetic or chemosynthetic activity of producer organisms in the form of organic substances which can be used as food materials (Odum, 1971) [24]. Primary production and respiration are the major metabolic pathways by which organic matter is produced and destroyed. Gross primary productivity is the total rate of photosynthesis including the organic matter used up in respiration during the measurement period while Net Primary Productivity (NPP) indicates the amount of organic matter that is stored in the plant tissues after meeting the demand of respiration (Chattopadhyay, 1998) [6]. The primary production of an estuarine environment depends upon several factors such as light, temperature, salinity, dissolved nutrients and phytoplankton abundance. One of the most obvious ecological factors influencing primary production is the amount of solar energy reaching the surface of the aquatic ecosystem (Nair and Thampy, 1980; Govindasamy *et al*., 2000) [23, 11]. The efficiency of an aquatic system generally depends upon the production rates and the primary producers. Primary productivity values have been used in estimating the productivity of an aquatic environment.

The abundance of phytoplankton will reflect the primary production of the particular ecosystem. The primary productivity of the estuaries of Kerala is comparatively high. High fertility due to nutrient enrichment and large standing crop derived from marine, estuarine and fresh water masses suspended in a widely fluctuating ambient medium. Biological productivity in aquatic ecosystem is highly influenced by the cycling of essential nutrients, especially nitrogen and phosphorous (Vitousek, *et al.*, 1997; Carpenter *et al.*, 1998) [29, 5]. Productivity in estuarine and coastal systems is typically limited by nitrogen availability whereas productivity in freshwater systems is typically phosphorous limited (Jordan *et al.*, 2008) [17].

Some of the important works on the primary production of inshore, offshore and estuarine environment by various researches in temperate and tropical are those of Gaader and Gran (1927) [10]; Michael *et al*.,(1991) [20]; Reddi *et al*.,(1993) [26]; Krishna Kumari *et al.*, (2002) [18]; Desmit *et al*., (2005) [8]. Hence, considering the extreme importance of measurement of primary productivity as a vital tool for assessing water quality and productivity of an ecosystem, the present study deals with estimation of the productivity or fertility of a water body. Thus its monitoring will thereby help to take remedial measures for the conservation and sustainable development of the Thekkumbhagam creek of Ashtamudi estuary

2. Materials and methods
Primary productivity of the creek was studied for a period of two years from June 2008 to May 2010.Light and dark bottle method of Gaader and Gran (1927) [10] was adopted for estimating the primary productivity of the creek. Primary productivity of a water body is usually determined from the differences in dissolved oxygen values of water samples incubated in bottles under light and dark condition thus allowing photosynthetic activity to take place in one bottle and the same to be restricted under the other. Oxygen in the initial bottle was estimated immediately and the light and dark bottles were incubated for three hours and after that, oxygen was determined by Winkler's method (Adoni, 1985) [1]. The decrease in dissolved oxygen content in the dark bottle as compared to initial value represents the amount of dissolved oxygen consumed by respiration by all the biomass in the bottle. The increase in dissolved oxygen in light bottle indicates the amount of dissolved oxygen in water which exceeded oxygen consumption by respiration. Both GPP and NPP can be calculated from the differences in their dissolved oxygen values.

3. Results
Gross primary productivity
The gross primary productivity of station 1, ranged from 0.65 mgC/l/ day to 6 mgC/l/ day in 2008-2009 and 0.2 mgC/l/ day to 7 mgC/l/ day in 2009-2010. The mean ± SE of gross primary productivity in monsoon, post-monsoon, pre-monsoon were 1.21 ± 0.42, 2.55 ± 1.2 and 1.41 ± 0.33 in 2008-2009 and 1.36 ± 0.6, 4.1 ± 1.07, 2.01 ± 0.49 (2009-2010) respectively. The annual mean ± SE of gross primary productivity was 1.73 ± 0.44 (2008-2009) and 2.4 ± 0.53 (2009-2010). (Table 1.1&1.2, fig 1.1a &1.1b).
In station 2, the gross primary productivity ranged from 0.2 mgC/l/ day to 8.8 mgC/l/ day in the first year and 0.4 mgC/l/ day to 8.8 mgC/l/ day in the second year. The mean ± SE of gross primary productivity in monsoon, post- monsoon were 2.2 ± 1.53, 2.88 ± 1.09 and 2.65 ± 2.06 in 2008-2009 and 2.41 ± 1.47, 2.9 ± 1.2, 2.65 ± 2.06 (2009-2010) respectively. The annual mean ± SE of gross primary productivity was 2.65 ± 2.06 (2008-2009) and 2.65 ± 0.85 (2009-2010).(Table 1.1&1.2, fig 1.1a &1.1b).
In station3, the gross primary productivity ranged from 0.28 mgC/l/ day to 3.2 mgC/l/ day in 2008-2009 and 0.3 mgC/l/ day to 6.2 mgC/l/ day in the second year. The mean ± SE of gross primary productivity in monsoon, post monsoon and pre monsoon were 0.7 ± 0.26, 0.47 ± 0.38 and 1.2 ± 0.67 in 2008-2009 and 1.45 ± 0.77, 1.99 ± 1.41, 1.89 ± 0.91 in (2009-2010) respectively. The annual mean ± SE of gross primary productivity was 0.79 ± 0.26 (2008-2009) and 1.78 ± 0.56 (2009-2010).(Table 1.1&1.2, fig 1.1a &1.1b).
In station 4, the gross primary productivity ranged from 0.4 mgC/l/ day to 6.4 mgC/l/ day in 2008-2009 and 0.2 mgC/l/ day to 5.2 mgC/l/ day in 2009-2010. The mean ± SE of gross primary productivity in monsoon, post-monsoon were 1.5 ± 0.66, 3.11 ± 1.22 and 0.4 ± 0.28 in 2008-2009 and 1.34 ± 0.6, 2.44 ± 0.93, 0.25 ± 0.19 in (2009-2010) respectively. The annual mean ± SE of gross primary productivity was 1.67 ± 0.54 (2008-2009) and 1.34 ± 0.43 (2009-2010). (Table 1.1&1.2, fig 1.1a &1.1b).
ANOVA comparing gross primary productivity between stations for the year 2008-2009 showed significant variations (at 5% level) between seasons and for periods within seasons .ANOVA comparing gross primary productivity between years of study showed variations between years significant (at 1% level) between seasons and for periods within seasons for station 1.Station2, 3 and 4 showed variations between years significant at (1% level). Tukey test revealed that station 1 and 4 showed significant variations between seasons (Table 1.2,1.3&1.4).

Net primary productivity
The net primary productivity of station 1, ranged from -4.8 to 2.4 mgC/l/ day to 2.4 mgC/l/ day in 2008-2009 and -6 mgC/l/ day to 3 mgC/l/ day in 2009-2010. The mean ± SE of net primary productivity in monsoon, post-monsoon and pre-monsoon were -0.31 ± 2.24, 0.05 ± 0.84 and -0.97 ± 1.07 in 2008-2009 and -0.55 ± 2.29, -0.1 ± 1.04,-0.73 ± 1.08 in (2009-2010) respectively. The annual mean ± SE of net primary productivity was -0.41 ± 0.79 in 2008-2009 and -0.46 in 2009-2010 (Table 1.1 & 1.2, fig 1.2a &1.2b).
The net primary productivity of station 2 ranged from -5.2 mgC/l/ day to 6.2 mgC/l/ day in 2008-2009 and -5.2 mgC/l/ day to 7 mgC/l/ day in 2009-2010. The mean ± SE of net primary productivity in monsoon, post monsoon and pre monsoon were -2.85 ± 0.93, 0.55 ± 1.54 and 0.39 ± 1.94 in 2008-2009 and -0.199 ± 1.1, 1.09 ± 1.62, 0.7 ± 2.12 in (2009-2010) respectively. The annual mean ± SE of net primary productivity was -0.64 ± 0.93 in 2008-2009 and -0.07 ± 0.96 in 2009-2010(Table 1.1 & 1.2, fig 1.2a &1.2b).
The net primary productivity of station 3, ranged from -2 mgC/l/ day to 0.6 mgC/l/ day in 2008-2009 and -5.4mgC/l/ day to 6mgC/l/ day in 2009-2010. The mean ± SE of net primary productivity in monsoon, post- monsoon and pre-monsoon were -1.88 ± 0.72, -0.38 ± 1.82 and -0.35 ± 9.62 in 2008-2009 and -0.83 ± 0.73, 0.9 ± 1.72,-1.8 ± 1.24 in 2009-2010 respectively. The annual mean ± SE of net primary productivity was -0.29 ± 0.73 in 2008-2009 and -0.58 ± 0.76 in 2009-2010(Table 1.1 & 1.2, fig 1.2a &1.2b).
The net primary productivity of station 4, ranged from -1.8 mgC/l/ day to 4.05 mgC/l/ day in 2008-2009 and -1.2mgC/l/ day to 2.6 mgC/l/ day in 2009-2010. The mean ± SE of net primary productivity in monsoon, post- monsoon and pre-monsoon were 0.45 ± 0.8, 0.95 ± 1.12 and 0.15 ± 0.3 in 2008-2009 and 0.2 ± 0.72, 0.68 ± 0.86, 0.05 ± 0.13 in 2009-2010 respectively. The annual mean ± SE of net primary productivity was 0.52 ± 0.44 in 2008-2009 and 0.31 ± 0.35 in 2009-2010(Table 1.1 & 1.2, fig 1.2a &1.2b).
ANOVA comparing net primary productivity between stations showed variation at 5% level for periods within seasons during 2009-2010. ANOVA comparing net primary productivity between years showed significant variation between years (at 1% level) in station 2 and station 4. But station 1 showed variation between seasons significant (at 5% level) and for periods within seasons significant at (1% level). Tukey test revealed that station 1 and 4 showed significant variations between seasons (Table 1.2, 1.3 & 1.4).

Table 1.1: Gross primary productivity and net primary productivity (mgC/ l/day) of stations (2008-2010)

Year	Season	Month	Primary productivity							
			Station 1		Station 2		Station 3		Station 4	
			Gross production	Net production	Gross production	Net production	Gross production	Net production	Gross production	Net production
2008-2009	Monsoon	JUN	2.1	1.4	0.6	-3.4	1.2	-3	3	2.8
		JUL	1.8	1.4	6.8	-1	1	-3	0	0
		AUG	0.15	-4.8	0.6	-5.2	0	0	0.2	-0.8
		SEP	0.8	0.775	0.8	-1.8	0.6	-1.5	2.8	-0.2
	Post-Monsoon	OCT	2.4	-1.6	3.5	2.3	1.6	-0.4	3.4	0.044
		NOV	0.8	-0.2	3.6	3.1	0	0	1.6	-1.2
		DEC	3	2.4	1.8	-3.8	0.2	-1	1	0.9
		JAN	4	-0.4	2.6	0.6	0.08	0.05	6.45	4.05
	Pre-Monsoon	FEB	2.4	2.2	8.8	6.2	0.4	-2	1.2	1
		MAR	1.05	-2.5	1.2	-1.8	3.2	-0.6	0.4	-0.4
		APR	1	-1.8	0.2	-1.46	0.6	0.6	0	0
		MAY	1.2	-1.8	0.4	-1.4	0.6	0.6	0	0
2009-2010	Monsoon	JUN	3.15	3	1.25	-0.75	1.4	-3	2.75	2.2
		JUL	1.8	1.6	6.8	-1.6	3.6	0	0	0
		AUG	0.2	-6	0.8	-5.2	0	0	0	-1.2
		SEP	0.3	-0.8	0.8	-0.4	0.8	-0.31	2.6	-0.2
	Post-Monsoon	OCT	2.4	-1.2	3.6	2.75	0.355	-0.4	1.75	-0.4
		NOV	3.4	-1.4	0	-3.6	0.2	-1.6	1	-1.08
		DEC	3.6	3	4	3.6	1	-0.4	1.8	1.6
		JAN	7	-0.8	4	1.6	6.4	6	5.2	2.6
	Pre-Monsoon	FEB	3.4	2.4	8.8	7	1.2	-1.4	0.8	0.4
		MAR	2	-2.4	1.2	-2.2	4.6	-0.4	0.2	-0.2
		APR	1.27	-1.92	0.2	-1.2	0.95	0	0	0
		MAY	1.4	-1	0.4	-0.8	0.8	-5.4	0	0

Table 1.2: Mean and SE values of primary productivity at stations 1-4 (2008-2010)

Stations	Year 2008-09	Season	Gross Productivity Mean & SE Values	Net Productivity Mean & SE Values
			t	u
	u) -.41u1	1	1.21 a	-0.31 a
	0.79		0.42	2.24
1		2	2.55 b	0.05 b
	v) 44.91		1.2	0.84
	4.34	3	1.41 a	-0.97 c
			0.33	1.07
	u) -.64u2	1	2.2 a	-2.85 a
	0.93		1.53	0.93
2		2	2.88 a	0.55 b
	v) 56.19		1.09	1.54
	5.47	3	2.65 a	0.39 c
			2.06	1.94
	u) -.29u1	1	0.7 a	-1.88 a
	0.73		0.26	0.72
3		2	0.47 a	1.34 b
	v) 47.89		0.38	1.82
	5.53	3	1.2 b	-0.35 c
			0.67	0.62
	u) .52u2	1	1.5 a	0.45 a
	0.44		0.66	0.8
4		2	3.11 b	0.95 a
	v) 59.04		1.22	1.12
	7.2	3	0.4 c	0.15 a
			0.28	0.3
Stations	2009-2010	Season		
	u) -.46u1	1	1.36 a	-0.55 a
	0.83		0.6	2.29
1		2	4.1 b	-0.1 b
	v) 44.16		1.07	1.04
	3.96	3	2.01 c	-0.73 a
			0.49	1.08
	u) -.07u2	1	2.41 a	-0.199 a

	0.96		1.47	1.1
2		2	2.9 a	1.09 b
	v) 55.24		1.2	1.62
	5.69	3	2.65 a	0.7 c
			2.06	2.12
	u) -.58u1	1	1.45 a	-0.83 a
	0.76		0.77	0.73
3		2	1.99 a	0.9 b
	v) 49.13		1.41	1.72
	5.46	3	1.89 a	-1.8 c
			0.91	1.24
	u) .31u1	1	1.34 a	0.2 a
	0.35		0.6	0.72
4		2	2.44 b	0.68 b
	v) 59.73		0.93	0.86
	7.07	3	0.25 c	0.05 c
			0.19	0.13
Results of Tukey Test presented using Subscripts a, b, c etc for Seasons				
Results of Tukey Test presented using Subscripts a1 etc, b 1 etc, c1 etcetc for Stations				
Subscripts with same alphabets do not differ significantly				

Table 1.3: ANOVA testing Gross primary productivity between stations (2008-2010)

	Gross Primary Productivity 2008-2009			**Gross Primary Productivity 2009-2010**		
Source	**Sum of squares**	**Mean Sum of squares**	**F Ratio**	**Sum of squares**	**Mean Sum of squares**	**F Ratio**
Total	186.60			211.90		
Between stations	19.10	6.40	2.20	13.70	4.60	1.20
Between seasons	7.60	3.80	1.28	15.00	7.50	1.98
Periods within seasons	62.35	6.93	2.34*	57.98	6.44	1.70
Error	97.50	2.95		125.22	3.79	

Table 1.4: ANOVA testing Net primary productivity between stations (2008-2010)

	Net Primary Productivity 2008-2009			**Net Primary Productivity 2009-2010**		
Source	**Sum of squares**	**Mean Sum of squares**	**F Ratio**	**Sum of squares**	**Mean Sum of squares**	**F Ratio**
Total	303.10			309.90		
Between stations	9.10	3.00	0.50	5.80	1.90	0.40
Between seasons	27.90	13.90	2.35	17.90	8.90	1.75
Periods within seasons	70.31	7.81	1.32	117.76	13.08	2.56*
Error	195.80	5.93		168.46	5.10	

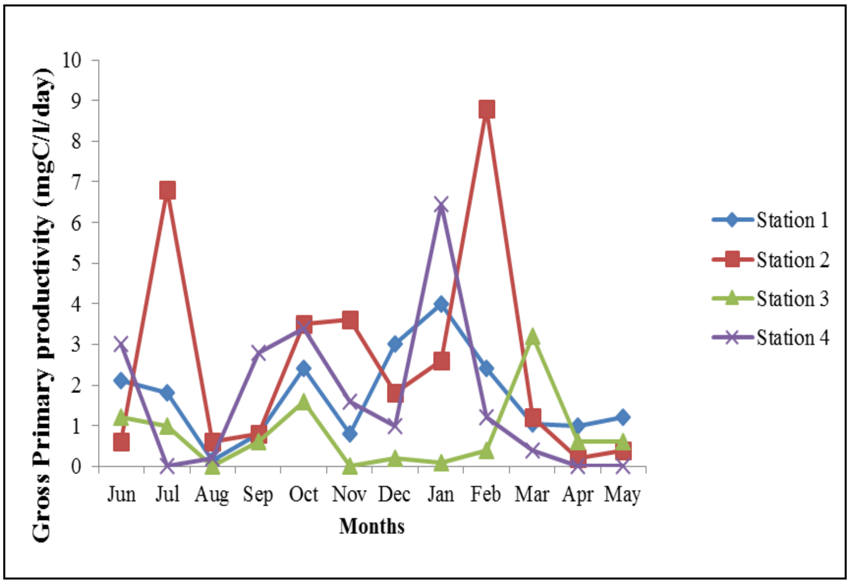

Fig 1.1a: Monthly variations of Gross primary productivity (2008-2009)

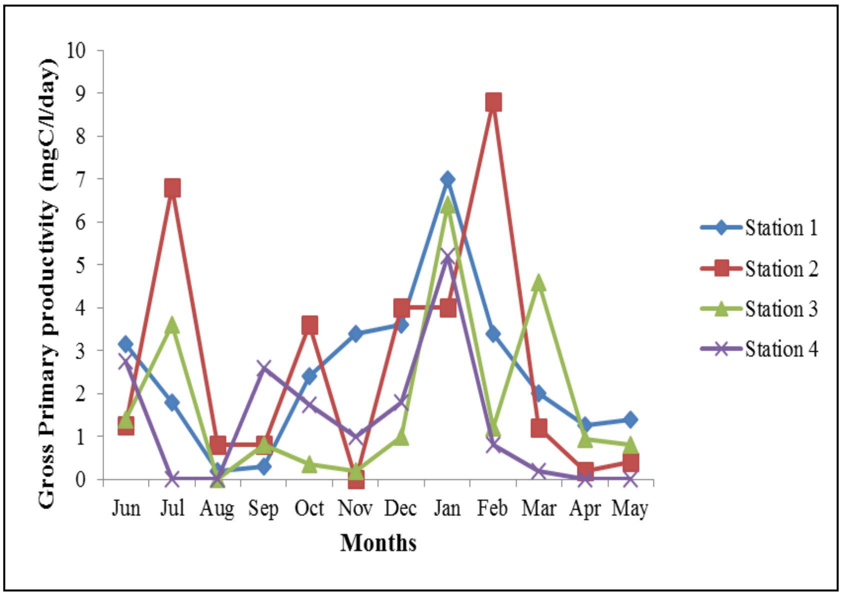

Fig 1.1b: Monthly variations of Gross primary productivity (2009-2010)

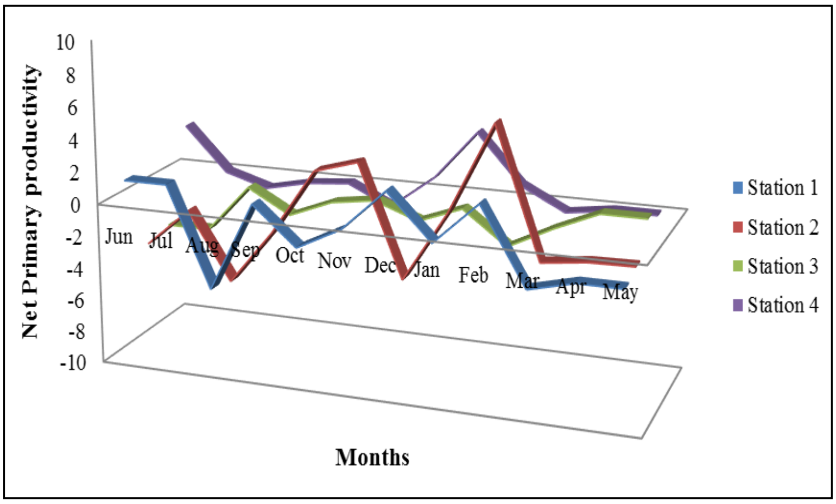

Fig 1 .2a: Monthly variations of Net primary productivity (2008-2009)

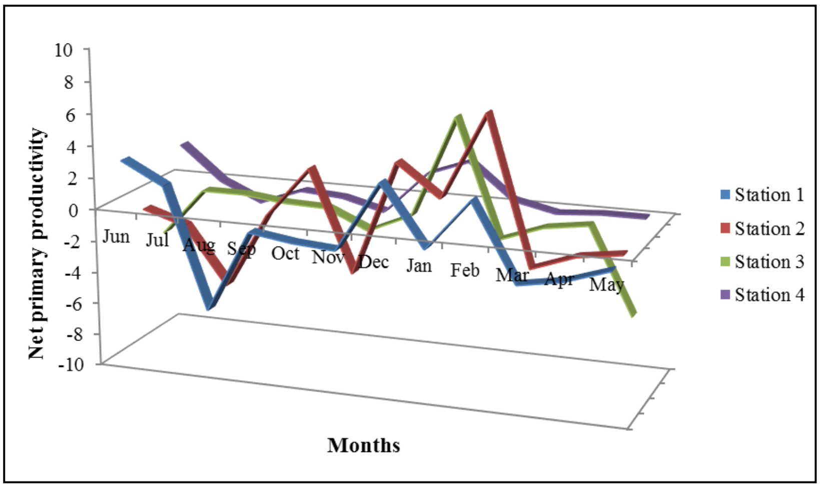

Fig 1.2b: Monthly variations of Net primary productivity (2009-2010)

4. Discussion

Studies on the primary productivity of aquatic ecosystems are essential for the proper assessment of the biological potential of that habitat. Primary production and respiration are the major metabolic pathways by which organic matter is produced and destroyed. The basis for nearly all life in the aquatic ecosystem is the photosynthetic activity of the aquatic plants and phytoplankton. The abundance of phytoplankton will reflect the primary production of a particular ecosystem. They nourish the other microorganisms present in the aquatic system. This will increase the fish production of the water body directly or indirectly the primary productivity of the environment (Vijayaraghavan, 1971) [30]. In an aquatic ecosystem, fishes entirely depend on natural foods. Thus there is a close dependence of fish production upon the levels of primary productivity (Boyd and Lichtkoppler, 1979) [3].

The stations recorded productivity range from 0.15 mgC/l/day to 8mgC/l/day. Station 2 showed maximum rate of gross primary production. Productivity values showed maximum during the post monsoon period and a minimum during the monsoon period. Gross primary productivity was higher than that of net primary productivity and lower values of net primary productivity below detectable levels was also noticed in certain periods. Similar observations were made by Shibu (1991) [28] in Paravur Lake. Gross primary productivity touched zero values and in case of net primary productivity zero values observed mostly during pre-monsoon followed by monsoon. Gross primary productivity and net primary productivity maximum values obtained during post-monsoon and minimum values in monsoon season. This may be due to the high level of dissolved oxygen during post-monsoon. The seasonal variation in the primary production seems to be controlled by the interaction of light, temperature and phytoplankton population.

Transparency was maximum during the post-monsoon where gross production and net production was maximum. This is because there is a significant positive relationship between gross production and net production. The rate of primary production within the estuary itself is determined partly by the availability of light (Jonathan &Rammohan, 2003) [16].

High temperature during pre-monsoon seems to coincide with high gross productivity and low temperature in monsoon coincides with low gross primary productivity. An inverse relationship between dissolved oxygen and gross primary productivity was noticed in the present study. The relation between dissolved oxygen and gross primary productivity increased and decreased along with fluctuation in the oxygen concentration (Nair and Abdul Aziz, 1987) [21]. In Ashtamudi estuary it has been found that the depletion of dissolved oxygen in the surface water and bottom water caused total failure of primary productivity especially in polluted areas (Nair *et al.,* 1984) [22]. The high dissolved oxygen concentration in Paravur back water coincided with high net primary productivity.

Salinity showed an inverse relationship with gross primary productivity in all stations, while it also showed a positive relationship with net primary productivity in station 4. Ragothaman and Reddy (1982) [25] observed that less salinity leads to less production in Tapi estuary.

pH surface also expressed an inverse relationship with gross primary productivity in almost all stations except station 3.Seasonal variation in hydrogen ion concentration seemed to have an inverse effect on the productivity as reported by the studies of Anuradha *et al*., (2011) [2].

A significant positive relationship between nitrite surface and nitrate surface and gross primary productivity was observed in station 2. The variation in nutrient concentration was recognized as one of the major factors controlling primary production (Fee *et al.*, 1988) [9]. Previous researches indicated that primary productivity was strongly correlated with nitrate of surface water concentration and negatively correlated with salinity (Malten *et al.*, 1991) [19]. Also periods of increased river flow were associated with an increase in nitrate, phosphate loads that have become a major environmental concern for these aquatic ecosystems which experience eutrophication and hypoxic condition (Bowen and Valiela, 2004) [4]. There was also the effect of effluents of prawn culture fields that enters in to the Thekkumbhagam creek.

Net primary productivity showed negative values for certain periods. As this creek is often subjected to high nutrient loads, which may lead to eutrophication of this water mass. Hence phytoplankton respiration can exceed biomass production because of low light penetration in to the water column. This results in a negative depth integrated net primary production (Grobbelar, 1985; Reid *et al*., 1990; Cole *et al.*,1992, Heip *et al.*,1995) [12, 27, 7, 13]. Net Ecosystem Production (NEP) is the difference between gross primary production and ecosystem respiration .NEP, which can be positive or negative, represents the overall metabolic balance of an ecosystem (Howarth *et al.*, 1988) [14]. When NEP is negative, respiration exceeds the gross primary productivity and the system respires more organic carbon than was produced by primary production within the system’s boundaries (Jonathan *et al.*,2000) [16]. Sustained negative values of NEP or GPP/R ratios less than one imply that a system’s respiration is subsidized by organic matter that was imported from outside of its boundaries.

Thus the assessment of primary production in aquatic systems and determination of the physical and chemical characteristics of water serves as an important tool in water quality monitoring.

5. Conclusion

Productivity of an aquatic biotope can be defined as the capacity to produce and is commonly used as a qualitative term for indicating the fertility of any water body. Since all the organic matter available in a water body is primarily synthesized by the primary producers and the products are transferred to consumers through different trophic levels, the amount of primary production is the most significant factor which determines whether or not a particular water body is important from the fisheries angle.

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7. References

1. Adoni AD. Work book on Limnology. Indian MAB Committee, Department of Environment, Government of India, New Delhi (India). 1985, 216.
2. Anuradha V, Nair SM, Kumar NC. Humic acids from the sediments of three ecologically different estuarine systems, a comparison. International Journal of Environmental sciences. 2011; 2:174-184.
3. Boyd CE, Lichtkoppler F. Water quality in warm fresh water fishpond. Agricultural Experimental stations Auburn University, 1979, 45-54.
4. Bowen JL, Valiela I. Nitrogen loads to estuaries using loading models to assess the effectiveness of management options to restore estuarine water quality. Estuaries. 2004; 27:482-500.
5. Carpenter SR, Caraco NF, Correll DL, Howrath RW, Sharpley AN, Smith VH. Non-point pollution of surface waters with phosphorous and nitrogen. Ecological applications. 1998, 559-568.
6. Chattopadhyay GN. Chemical Analysis of fish pond water and soil. Daya Publishing House, New Delhi. India. 1998, 130.

7. Cole JJ, Caraco NF, Peierls BL. Can phytoplankton maintain a positive carbon balance in a turbid, fresh water, tidal estuary. Limnology and Oceanography, 1992; 37:1608-1617.
8. Desmit X, Vanderborght JP, Regnier P, Wollast R. Control of phytoplankton production by physical forcing in a strongly tidal, well mixed estuary. Biogeosciences Discussions. 2005; 2:37-75.
9. Fee EJ, Hecky RE, Guildford SJ, Anema C, Mathew D, Hellard K. Phytoplankton, primary production and related limnological data for lakes and channels in the Mackenzie Delta and lakes on the Tuktoyaktuk Peninsula, N.W.T. Canadian Technical Report of Fisheries and Aquatic Sciences. 1988; 1614:67.
10. Gaader T, Gran HH. Investigation on the production of plankton in the Oslofjord. Rappots Et Process Verbaux Des Reunions. 1927; 144:56-60.
11. Govindasamy C, Kannan L, Azariah J. Seasonal variation in physico-chemical properties and primary production in the coastal water biotopes of Coromandel, India. Journal of Environmental Biology. 2000; 21:1-7.
12. Grobbelar JU. Phytoplankton productivity in turbid waters, Journals of Plankton Research. 1985; 7:653-663.
13. Heip CHR, Gossen N, Herman PMJ, Kromkamp J, Middleberg JJ, Soetaert K. Production and consumption of biological particles in temperate tidal estuaries, Oceanography and Marine Biology. An Annual Review. 1995; 33:1-149.
14. Howarth R, Merino R, Lane J, Cole J. Nitrogen fixation in fresh water estuarine and marine ecosystems. Rates and importance. Limnology and Oceanography. 1988; 33:688-701.
15. Jonathan J Cole, Michael L Pace, Stephen R Carpente, James F Ketchell. Persistence of net heterotrophy in lakes during nutrient addition and food web Manipulation, Limnology and Oceanography. 2000; 45(8):1718-1730.
16. Jonathan MP, Rammohan V. Heavy metals in sediments of the inner shelf of Gulf of Mannar, east coast, India, Pollution Bulletin. 2003; 46:258-268.
17. Jordan F, Jelks HL, Bortone SA, Dorazio RM. Comparison of visual survey for estimating abundance of endangered benthic stream fish. Environmental Biology of Fishes. 2008; 81:313-319.
18. Krishnakumari L, Bhattathiri PMA, Matondkar SGP, Julie John. Primary productivity in Mandovi - Zuari estuaries in Goa. Journal of Marine Biological Association India. 2002; 44(1, 2):1-13.
19. Malten MA, Paeel HW, Rudek J. Seasonal phytoplankton composition, productivity and biomass in the Neuse River Estuary, North Carolina. Estuarine Coast Shelf Science. 1991; 32:609-623.
20. Michael A Mallin, Hans W, Paerl. Commentary on primary productivity and nutrient limitation in the Neuse River Estuary, North Carolina, USA. Marine Ecology Progress Series. 1991; 3:311-312.
21. Nair NB, Abdul Azis PK. Hydrobiology of the Ashtamudi estuary, A tropical back water system in Kerala Proceedings Natural Sem Estuarine Management. 1987, 268-280.
22. Nair NB, Abdul Azis PK, Balasubramanian NK. Ecology of Indian Estuaries.Primary productivity of the Ashtamudi Estuary South West coast of India. Proceedings of Indian Academy Science. 1984; 93(1):9-23.
23. Nair NB, Thampy. A text book of marine Ecology (India: The Macmillan Company Tropical Estuarine Biology, 1980, 1-72.
24. Odum EP. Fundamentals of Ecology, Toppan Company Ltd, 1971.
25. Ragothaman G, Reddy RV. Hydrobiology of Tapi estuary Surat, Indian Journal of Marine Sciences. 1982; 11:256-258.
26. Reddi KR, Jayaraju N, Suriyakumar I, Sreenivas K. Tidal fluctuation in relation to certain physico-chemical parameters in Swarnamukhi river Estuary, East coast of India. Indian Journal of Marine Science. 1993; 22:232-234.
27. Reid PC, Lancelot C, Gieskes WWC, Hagmeier E, Wrichart G. Phytoplankton of the North sea and its dynamics,a review, Netherlands. Journal of Sea Research. 1990, 295-331.
28. Shibu S. Ecology of the Paravur Lake. Ph.D Thesis, University of Kerala, Trivandrum, 1991.
29. Vitousek PM, Aber J, Howarth GE, Likens PH, Matson DW, Schindler *et al*. Human alteration of the global nitrogen cycle; sources and consequences. Ecological applications. 1997; 7:737-750.
30. Vijayaraghavan S. Seasonal variation in primary production in the tropical ponds. Hydrobiologia. 1971; 38:395-407.