Bangladesh J. Bot. **41**(2): 135-142, 2012

PLANKTONIC PRIMARY PRODUCTIVITY OF A EUTROPHIC WATER BODY OF DHAKA METROPOLIS, BANGLADESH

MD. SHAFIQUL ISLAM[1], MD. ALMUJADDADE ALFASANE AND MONIRUZZAMAN KHONDKER*

Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh

Key words: Phytoplankton, Primary productivity, Eutrophication, Assimilation numbers, Water quality

Abstract

Dynamics of phytoplankton primary productivity were determined in a eutrophic water body of Dhaka Metropolis fortnightly for one year. The mean value of daily rate of primary productivity was 10.05 $gC/m^2/d$ and annual sum of primary productivity was estimated 3669.5 $gC/m^2/y$. The yearly mean value of conductivity, pH, alkalinity, SRP and SRS were 486.66 µS/cm, 7.21, 4.02 meq/l, 0.75 mg/l and 49.75 mg/l, respectively which indicated the intensity of contamination from the catchment. Significant correlations were obtained among the variables (day length, irradiance, water temperature and DO) relating to primary productivity. "Green soup" like algal bloom was found to occur on most occasions. The productivity was confined to the upper few centimeter depth of the water indicating a typical eutrophic nature of the water body.

Introduction

Uptake of available nutrients by the population of phytoplankton and its subsequent release into the water via decomposition is one of the fundamental causes of surface water eutrophication. So, planktonic primary productivity which culminates in pelagic food cycle as well as contributing surface water eutrophication serves as a good indicator for the fertility of water. Dhaka Metropolis, though supports a number of closed water bodies yet water quality in most of them are not acceptable because of the enhanced rate of eutrophication. Assessment on the rate of planktonic primary productivity in the water bodies of Dhaka Metropolis is limited (Khondker *et al*. 1988, Khondker and Parveen 1993, Khondker and Kabir 1995, Sultana and Khondker 2009). Mirpur Jheel has already been designated as a eutrophic water body and information on its biological and physicochemical water quality has already been published (Afroze and Khondker 1995, 1996, Khondker *et al*. 2011). The present paper deals with the dynamics and status of planktonic primary productivity of the same water body.

Materials and Methods

Present investigation was carried out in Mirpur Jheel which is subjected to a dense human settlement in its catchment. The location map and morphometirc feature of the *Jheel* have been presented by Khondker *et al.* (2011). Samples were collected at 15 days interval from August 19, 1993 to July 14, 1994 (except in August 1993 and July 1994, when a single sample was collected in each month). A Schindler sampler of 5 liter capacity was used to collect samples from 0.5 m depth. The samples were covered with black cloth to avoid light shock to the phytoplankton. Eight triplicate clear borosilicate BOD bottles (120 ml, Jena Schott, Germany) were filled and kept in a

---

[1]Present address: Graduate School of Science, Kobe University, Japan.
*Author for correspondence: <mkhondker@yahoo.com>.

light proof wooden box. Duplicate bottles were vertically suspended along a rope at a desired depth of incubation. Two dark bottles were incubated at the bottom of the rope. Third bottle was used for the determination of initial oxygen concentration. Processing took *ca*. 40 minutes; incubation time was two hours, usually between 10:00 and 12:00 a.m. After incubation, samples were fixed immediately by adding 1 ml manganous sulfate and 1 ml Winklers reagent and kept immersed under water in a container until further analysis. Rest of the collected 5 litre sample was transported to the Hydrobiology and Limnology Laboratory, Department of Botany, University of Dhaka and was analyzed for eight other limnological parameters (Afroze and Khondker 1995). *In situ* measurement of Secchi depth, photosynthetically active radiation and water temperature were also carried out (Afroze and Khondker 1995, Khondker and Kabir 1995). All the other measurements related to the components of the productivity and day length were made following the methods described in Khondker and Parveen (1993) and Khondker and Kabir (1995). There are altogether 22 measurements during the period of investigation for all the variables.

Results and Discussion

Data on aerial daily total assimilation rate (ΣΣA $gO_2/m^2/day$), assimilation number (P/B $mgO_2/l/h$•mg chl *a*/l), phytoplankton biomass (chl *a* μg/l) and phaeopigment concentration (μg/l) have been plotted in Figs 1 and 2 (n = 22). However, monthly mean values (n = 12) for rest of the other parameters have been shown in Table 1. Table 2 shows their seasonal fluctuations. Annual sum of gross primary productivity and the results of correlation analyses have been presented in Tables 3 and 4, respectively.

Phytoplankton biomass (chl *a*) showed a total of three peaks. The first one occurred in between November and December and the second one in mid-February whilst the third one in late May (Fig. 1). Similar observation of three peaks were also reported by Khondker and Parveen

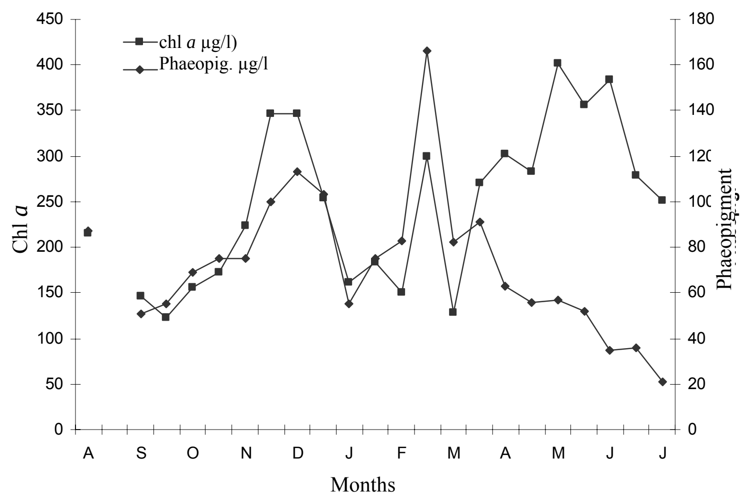

Fig. 1. Annual fluctuation of phytoplankton biomass as chl *a* and phaeopigment concentration in Mirpur Jheel.

(1993) in Dhanmondi lake. The concentration of phaeopigment showed a similar trend as that of chl *a*, except late March to onwards when the concentration of the former fell down (Fig. 1). The biomass of phytoplankton (chl *a*) showed a high concentration in summer and a low in autumn

Table 1. Monthly and annual mean values of different limnological parameters in Mirpur Jheel.

Parameter	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Mean (n = 22)	SD
Z_{max} (m)	4	4.2	4.05	4.3	4.55	4.35	3.65	4.05	4.25	3.4	4.2	4.4	4.11	0.32
Z_s (m)	0.31	0.3	0.29	0.26	0.22	0.21	0.155	0.19	0.125	0.16	0.27	0.19	0.22	0.06
I_o ($\mu E/m^2/sec$)	452.1	806.55	861.6	649.55	680.95	673.9	615.05	920.15	788.05	1063.55	1055.65	1085.7	804.4	200.58
I_k ($\mu E/m^2/sec$)	100	150	144	169	138	88	162.5	162.5	149.5	113	81.5	175	136.08	32.41
k (ln unit/m)	5.9	5.2	5.75	7.2	8.7	8.2	10.6	10.3	10.45	13.45	11.3	7.8	8.73	2.53
Z_{eu} (m)	0.8	0.8	0.75	0.65	0.55	0.5	0.45	0.45	0.45	0.35	0.4	0.6	0.56	0.15
ΔT (h)	12.9	12.255	12.53	12.47	12.675	11	12.255	12.2	12.74	13.225	13.565	13.66	12.62	0.70
Water t°C	31.1	30.25	31.15	27.4	24	21.65	22.1	26.75	28.5	30.35	30.6	30.7	27.87	3.53
pH	7.2	7.3	7.65	7.6	7.55	7.4	6.45	7.1	7.15	7.2	6.65	7.3	7.21	0.35
Cond. µS/cm)	340	300	360	415	480	535	595	665	665	525	540	420	486.66	122.10
Alkal. meq/l)	2.2	2	2.85	3.7	4.25	5	5.5	5.2	5.2	4.55	4.25	3.6	4.02	1.18
DO (mg/l)	6	4.35	4.7	1.7	0.3	0	2.4	3.25	4.55	4	3.9	4.3	3.28	1.83
SRP (mg/l)	0.2	0.1665	0.343	0.316	0.218	0.369	1.064	1.506	1.564	1.1475	1.314	0.843	0.75	0.54
SRS (mg/l)	35	27	29.5	44.5	48.5	59.5	59.5	65	64	61.5	58	45	49.75	13.58
NO_3-N (mg/l)	0.085	0.046	0.029	0.022	0.018	0.017	0.031	0.047	0.029	0.053	0.112	0.02	0.042	0.02
Phytopl. ×1000 ind/l	832	63	112	54.5	80.5	311.5	290	338	956	1303	1595	954	574.12	532.9
P mg O_2/l/h	6.5	6.38	6.88	6.63	2.00	1.88	2.75	3.63	11.5	10.5	9.00	9.75	6.45	3.32
B chl *a* mg/l	0.216	0.135	0.164	0.289	0.301	0.173	0.225	0.200	0.293	0.379	0.332	0.251	0.246	0.073
P/B	30.09	48.01	42.13	24.63	11.37	21.72	18.33	15.95	38.75	27.49	38.34	38.84	29.63	11.59

SD = standard deviation.

(Table 2). However, its monthly mean value ranged from 135 - 379 µg/l (Fig 1). Phytoplankton biomass was relatively lower in autumn but yielded high productivity. In winter and summer the water body remains heavily eutrophicated, which however, starts recovering from rainy to autumn seasons (Table 2). From Table 2 it is evident that in summer the biomass was higher (290.33 µg/l) and the productivity was low in winter (11.57 $gC/m^2/d$). On the contrary despite 21% reduction in the biomass in autumn, from the productional stand point autumn was the best (Table 2). Increase Z_{eu} and decrease in conductivity might be responsible for this.

Table 2. Seasonal mean values of different limnological parameters in Mirpur Jheel.

Parameter	Winter			Summer			Rainy			Autumn		
	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Z_{max} (m)	4.18	0.48	7	4.06	0.54	6	4.2	0.18	6	4.16	0.58	3
Z_s (m)	0.19	0.03	7	0.15	0.03	6	0.24	0.06	6	0.3	0.02	3
Io ($\mu E/m^2$/ sec)	657.65	105.63	7	923.91	200.02	6	877.0	303.78	6	786.1	165.84	3
I_k ($\mu E/m^2$/ sec)	136	50.58	7	141.66	39.74	6	123	44.87	6	146	6.92	3
k (ln unit/m)	9.08	1.90	7	11.4	1.81	6	7.78	2.93	6	5.76	0.35	3
Z_{eu} (m)	0.5	0.1	7	0.41	0.07	6	0.63	0.20	6	0.76	0.05	3
ΔT (h)	10.95	0.25	7	12.72	0.56	6	13.03	0.66	6	11.37	0.33	3
Water t°C	23.12	2.16	7	28.53	2.65	6	30.58	0.43	6	30.23	1.85	3
pH	7.37	0.34	7	7.15	0.17	6	7.06	0.34	6	7.56	0.15	3
Cond. (µS/cm)	521.42	63.35	7	618.33	75.21	6	406.66	113.07	6	373.33	23.09	3
Alkal. (meq/l)	4.77	0.65	7	4.98	0.37	6	3.05	1.10	6	3.06	0.40	3
DO (mg/l)	0.85	1.75	7	3.93	0.80	6	4.13	1.07	6	4.06	1.20	3
SRP (mg/l)	0.51	0.40	7	1.39	0.22	6	0.66	0.56	6	0.34	0.008	3
SRS (mg/l)	54.71	6.67	7	63.5	1.97	6	41.66	14.40	6	33.33	10.01	3
NO_3-N (mg/l)	0.021	0.008	7	0.039	0.021	6	0.070	0.044	6	0.028	0.097	3
Phytopl. ×1000 ind/l	202	156.78	7	540.66	353.46	6	850.33	925.08	6	94.33	32.86	3
Chl *a* µg/l	248.85	85.10	7	290.33	93.48	6	233.33	94.89	6	184	35.55	3
Phaeo. µg/l	92.14	22.13	7	66.83	15.89	6	47.5	22.88	6	73	3.46	3
$\Sigma\Sigma A\ gO_2/m^2$/day	11.57	7.11	7	27.5	21.98	6	35.66	7.65	6	37	2	3
P mgO_2/l/h	3.25	2.18	7	8.54	5.61	6	7.83	1.74	6	6.91	0.38	3
B mgChl *a*/l	0.248	0.085	7	0.290	0.093	6	0.233	0.094	6	0.184	0.035	3
P/B	14.16	8.96	7	27.39	15.88	6	36.93	11.95	6	38.50	7.63	3

Phaeopigment showed higher concentration in winter and lower in rainy season (Table 2). Sultana and Khondker (2009) reported lowest biomass of phytoplankton (chl *a*) during September. This observation is similar to the present investigation (Fig. 1). Annual mean chl *a* was 240.26 µg/l that is near closer to Dhanmondi lake (264.83 µg/l, Khondker and Parveen 1993, Table 5) but almost 18 times higher than a mesotrophic pond in Dhaka (Khondker and Kabir 1995).

The monthly average light attenuation coefficient varied from 5.2 - 13.45 ln unit/m (Table 1). This indicates high turbid condition of the water body. Similar turbid condition was reported by Khondker and Parveen (1993) in Dhanmondi lake.

Daily mean productivity recorded for the present water body was 10.05 $gC/m^2/d$ (Table 3) which is almost similar to the values reported by Khondker and Parveen (1992a) in Dhanmondi lake and Rab *et al*. (1978) in a fish pond at Boyra, Mymensingh. In Shahidullah Hall pond this value was comparatively low (Table 5). The total assimilation (ΣΣA) and the assimilation number (P/B) showed an almost bimodal pattern annually (Fig. 2). The highest assimilation was obtained in early September and late April (Fig. 2). Highest assimilation number also lied closer to these two assimilation peaks. A peak of assimilation number of relatively lower range compared to the others occurred in late February (Fig. 2). Both of these parameters showed their seasonal highest occurrence in autumn and lowest in winter (Table 2).

Table 3. Monthly average gross primary productivity of Mirpur Jheel.

Months	Number of incubation per month	Productivity $gC/m^2/day^*$
		Arithmetic mean
August'03	1	12.7
September	2	14.6
October	2	14.2
November	2	10.0
December	2	4.2
January'04	2	3.0
February	2	2.6
March	2	4.0
April	2	16.0
May	2	11.0
June	2	11.5
July'04	1	16.7
Daily Mean		10.05
Annual sum	**22**	**3669.5**

*Oxygen values × 0.375.

Annual mean values of Z_{max}, Z_s, I_k, k and Z_{eu} suggest that the studied water body is perennial but shallow and having a poor light climate (Table 1). A value of yearly mean conductivity 486.66 µS/cm indicates strong ionic load in its water. This value is higher than that reported for Shahidullah Hall pond (340.10 µS/cm, Khondker and Kabir 1995). Khondker and Parveen (1992b) reported higher conductivity value (579.32 µS/cm) in Dhanmondi lake. High conductivity, alkalinity, SRP and SRS also indicate the intensity of contamination from the catchment (Table 1). The annual pH value ranged from 6.45 - 7.65 (Table 1). During December to January the whole water body was almost anoxic (Table 1). In Dhanmondi lake, Khondker and Parveen (1993) reported very low (0.18 mg/l) DO concentration at few stations. The bottom remain always anoxic. Annual average concentration of DO (3.28 mg/l) recorded in the present investigation is almost similar to another hypertrophic lake of Dhaka Metropolis (Table 5). The total density of phytoplankton ranged from 54.5 - 1595 × 10^3 ind/l (Table 1).

Seasonal changes in the water depth of the Jheel were found to be negligible because it has an inlet and outlet via which the water level is well balanced (Table 2). The Jheel suffers with a low light penetration and a high turbidity in almost all the seasons except a slight improvement in its light climate in autumn (Table 2).

Monthly average gross primary productivity showed a range of 2.6 - 16.7 mgC/m^2/day, where the lowest was in February and highest record was in July (Table 3). The annual sum yielded 3669.5 mgC/m^2/y. This value is about 62.3 and 11.81% higher than Shahidullah pond and Dhanmondi lake, respectively (Table 5). Nasar (1980) also obtained 1543 mgC/m^2/y in a fish pond of Bhagalpur, India. Takamura *et al.* (1989) recorded 2020.46 mgC/m^2/y from hypertrophic Lake Teganuma. Tempertature has been considered a major contributor to the higher rates of photosynthesis observed in the tropics (Talling 1965). In the present study a good positive correlation (r = 0.69, n = 22) is found between ΣΣA and temperature (Table 4).

Table 4. Result of correlation analysis between planktonic primary productivity (mg O_2/m^2/day) and other related parameters in Mirpur Jheel (n = 22).

Parameters	r	Level of significance
Z_{max} (m)	0.23032	ns
Z_s (cm)	0.07759	ns
Io (μS/m^2/sec)	0.44239	5%
I_k (μS/ m^2/sec)	0.28242	ns
K (ln unit/m)	–0.27117	ns
Z_{eu} (m)	0.31442	ns
ΔT (h)	0.62465	0.1%
Water temp. (°C)	0.69819	0.1%
pH	0.19967	ns
Cond (μS/cm)	–0.39167	ns
Alkal (meq/l)	–0.44533	5%
DO (mg/l)	0.58072	1%
SRP (μg/l)	0.01408	ns
SRS (mg/l)	–0.37264	ns
NO3-N (μg/l)	–0.01085	ns
Phytopl. (× 10^3 ind/l)	0.35821	ns

ns = not significant.

Chl *a* and P/B showed almost three peaks throughout the period of the present investigation (Figs 1, 2). Primary productivity also showed similar trend except the chl *a* and P/B peaks occurred during February (Fig. 2). In this month, the productivity, instead of showing a clear peak, showed a gradual increasing trend culminating in the peak values of chl *a* and P/B of April (Fig. 2). This trend of primary productivity might be the cause of incident radiation (Io) which also took a gradual increasing trend from February onward (Table 1). Khondker and Kabir (1995) had obtained a unimodal peak of biomass in a mesotrophic pond of Dhaka metropolis. In the present study the biomass peaks were observed in mid December, February and May, whereas the unimodal peak of biomass observed by Khondker and Kabir (1995) occurred in March. In the later study, the maximum areal primary productivity occurred just in one month (i.e., in February) earlier than the peak phytoplankton biomass. Same relationship between peak biomass and productivity has also been observed in the present investigation but only at the second peak development, out of the two peaks of the primary productivity (Fig. 2). Integrated productivity showed a minimum value in early February and a maximum value in late April (Fig. 2). The decreasing phase started in November and continued until early March showing a short rise in mid-February (Fig. 2). In the present study, the dynamics of planktonic primary productivity and its controlling components unveils several interesting facts which have not been so far reported from this unique geoclimatic area, Bangladesh.

Table 5. Comparison of different major factors relating to primary productivity among three water bodies in Dhaka Metropolis.

Parameter	MJ	SHP	DL
Chl *a* µg/l	240.26	13.07	264.8l
Phaeo. µg/l	74.86	5.63	131.31
DO mg/l	3.28	4.37	3.78
ΣΣA gC/m^2/day	10.05	3.85	9.82
Annual primary productivity gC/m^2/y	3669.5	1383.35	3236

MJ = Mirpur Jheel (Present study); SHP = Shahidullah Hall pond (Khondker and Kabir 1995); DL = Dhanmondi Lake (Khondker and Parveen 1993).

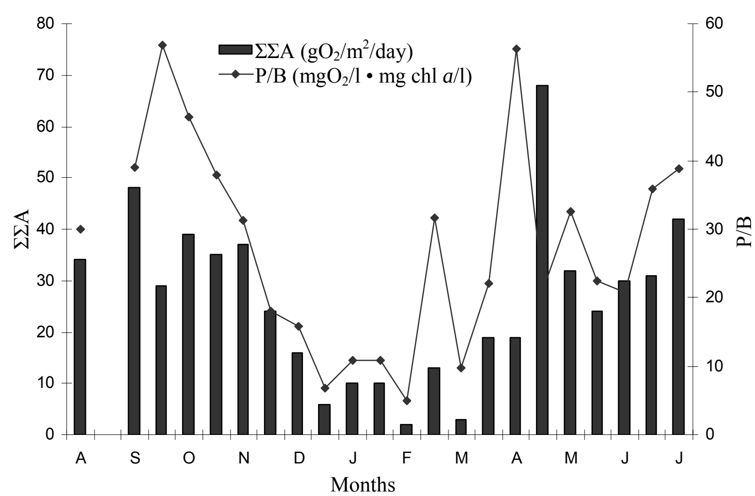

Fig. 2. Annual fluctuation of total assimilation rate (ΣΣA) and photosynthetic efficiency of phytoplankton (P/B) from Mirpur Jheel.

Plankton growth, biomass and productivity are influenced by a myriad of related and unrelated factors. Nutrients, light and water temperature are often of prime importance. The later are important because it affects photosynthetic rates. High light attenuation occurred due to both high algal standing crops and suspended non-algal material. However, nutrients in this aquatic ecosystem could not be considered as limiting factors because concentrations always remained more than enough.

Surface irradiation (I_o), light period in hours (ΔT), water temperature and dissolved oxygen (DO) were found to correlate the productivity positively (Table 4). However, alkalinity showed a negative correlation with the productivity. Biomass did not correlate with productivity. It is clearly evident that the key governing factors limiting productivity in this aquatic system are both physical and chemical in nature means the controlling components are other than the biomass.

The present water body is strongly influenced by direct input of waste water and organic matter discharged from the nearby huts, sewerages and garbages from the residential colonies and markets. The yearly mean values of conductivity, pH, alkalinity, SRP and SRS were 486.66 µS/cm, 7.21, 4.02 meq/l, 0.75 mg/l and 49.75 mg/l, respectively. These values indicated the intensity of contamination from the catchment. As a whole, the present aquatic system having an average SRP > 600 µg/l, the algal zone becomes restricted only in the upper meter, productivity proliferates just at 10 cm depth, allows trophogenic zone to be confined only upper few centimeter, poor DO as well as anoxic bottom, swift light attenuation caused by high biomass deprived the possibility to improve underwater light climate reveals sufficient prove to label this aquatic ecosystem an eutrophic one. Day length, irradiance, water temperature and DO showed positive significant correlations with primary productivity (Table 4). "Green soup" like algal bloom was found to occur most occasions. The productivity was confined to the upper few centimeter depth of the water indicating a typical eutrophic nature of the water body.

References

Afroze SH and Khondker M 1995. On eutrophication of small water body: A case study in Bangladesh. Bangladesh J. Bot. **24**(2): 213-215.

Afroze SH and Khondker M 1996. Status of coliform bacteria and heavy metal concentration in a eutrophicated water body. Dhaka Univ. J. Biol. Sci. **5**(1): 109-112.

Khondker M and Parveen L 1992a. Species composition, standing crop and seasonality of phytoplankton in a hypertrophic artificial lake. Dhaka Univ. Stud. **7**(1): 49-55.

Khondker M and Parveen L 1992b. Study on the physical and chemical limnology of a shallow, hypertrophic artificial lake. Bangladesh J. Sci. Res. **10**(1): 9-16.

Khondker M and Parveen L 1993. Daily rate of primary productivity in hypertrophic Dhanmondi lake, *In:* Tilzer MM, Khondker M, Eckman R, Gibson CE, Marchand H, Martinez R and Mertens J (Eds), Hypertrophic and Polluted Freshwater Ecosystems: Ecological Bases for Water Resources Management. Proc. Int. Symp. Limnol., Bot. Dept., Dhaka Univ., Dhaka. pp. 181-191.

Khondker M and Kabir MA 1995. Phytoplankton primary production in a mesotrophic pond in sub-tropical Bangladesh. Hydrobiol. **304**: 39-47.

Khondker M, Nurul Islam AKM and Islam R 1988. Studies on the primary productivity of Dhanmondi lake. Dhaka Univ. Stud. Pt. E **3**(1): 15-21.

Khondker M, Islam MS and Afroze SH 2011. Vertical distribution of phytoplankton in a hypertrophic jheel, Mirpur, Dhaka. Dhaka Univ. J. Biol. Sci. **20**(1): 7-13.

Nasar SAK 1980. Primary productivity studies on freshwater fish-ponds of Bhagalpur, India. Acta Hydrochium. Hydrobiol. **8**: 569-581.

Rab MA, Islam MA, Eaqub M and Idris M 1978. Studies on soil, primary productivity and growth rate of major carps (*Catla catla*, *Labeo rohita* and *Cirrhina mrigala*) in an artificial pond of village Boyra, Mymensingh. Bangladesh J. Aq. Cult. **1**(1): 52-63.

Sultana M and Khondker M 2009. Assesment of Phytoplankton primary productivity of two urban pond ecosytems of Bangladesh. Dhaka Univ. J. Biol. Sci. **18**(2): 127-135.

Takamura K, Sugaya Y, Takamura N, Hanazato T, Yasuno M and Iwakuma T 1989. Primary production of phytoplankton and standing crops of zooplankton and zoobenthos in hypertrophic Lake Teganuma. Hydrobiol. **173**: 173-184.

Talling JF 1965. The photosynthetic activity of phytoplankton in East African lakes. Int. Revue ges. Hydrobiol. **50**: 1-32.

(Manuscript received on 16 July, 2012; revised on 1 October, 2012)