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Impacts of fish sanctuaries on the production and diversity of plankton in *beels* of haor region in Bangladesh

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Abstract
The experiment was carried out to study the impacts of fish sanctuaries on the production and diversity of plankton in *beels* of haor region at Mithamain Upazila of Kishoreganj district in Bangladesh during July 2004 to June 2005. A total of 75 (60 phyto and 15 zooplankton) and 74 (59 phyto and 15 zooplankton) genera of plankton were recorded in T-1 and T-2 (with sanctuary) respectively while only 50 (39 phyto and 11 zooplankton) genera were obtained in T-3 (control). Chlorophyceae and Copepoda were the most dominant group of phytoplankton and zooplankton respectively in all the treatments. The total phytoplankton numbers were found to range from 5472 to 35,833 cells/l and 5250 to 40,472 cells/l and total zooplankton from 667 to 1722 cells/l and 611 to 1667 cells/l in T-1 and T-2 respectively in sanctuary sites whereas the ranges of phytoplankton and zooplankton in the control site were 1778 to 29,333 cells/l and 56 to 1056 cells/l respectively. The maximum phytoplankton and zooplankton were recorded during winter season in all the treatments. The ranges of total plankton were 6194 to 37,500 cells/l, 6028 to 41,806 cells/l and 1889 to 29,444 cells/l in T-1, T-2 and T-3 respectively. The phytoplankton, zooplankton and total plankton recorded in treatments with sanctuary were significantly higher ($p<0.5$) than the treatment without sanctuary (control) indicating positive impacts of sanctuaries on the production of plankton. Between two treatments of fish sanctuaries the total plankton populations were comparatively higher in T-2 than T-1.

Key words: Fish sanctuary, Impacts, Beel, Plankton

Introduction

Nature is the nourisher of all kinds of life system on earth by providing proper environment to the living beings. Diverse environment is the base for diversity of lives both plants and animals. The divers environment includes land, air and water. Bangladesh has the widest spectrum of inland open water resources and marine resources. The inland open waters have been the major source of fish production in Bangladesh from time immemorial. But due to different environmental and destructive activities wild fishes are declining day by day. Water is harmed profusely everywhere in

all over the country by the insane intrusion of human beings. Therefore, conservation of biodiversity should get priority for the greater interest of future generations.

Sanctuary is an adaptive approach for fish conservation in open waterbodies. In simple sense, "Fish sanctuary" is that type of habitat where fishes congregate for shelter; protection and peaceful life without any disturbance and from where they can move independently towards feeding and breeding ground. So establishment of 'Fish Sanctuary' is the way by which we can provide such facilities and create opportunities for protection, conservation and breeding of open water fishes in easiest way.

A satisfactory understanding of aquatic lives requires knowledge on the organisms and external influences, which clerically or indirectly affect them. So the physico-chemical and the biological parameters of water are needed to be determined for better production of the biota there in. Several works have been done in different waterbodies to know the impacts of sanctuaries on fish production and biodiversity. No research has yet been carried out to study impacts of sanctuaries on the plankton population. But plankton is the base of productivity in aquatic ecosystems, which ultimately determine the productivity of fish. For this reason the present study has been undertaken to know the impacts of sanctuaries on the production and diversity of plankton in *beel.*

Materials and methods

The experiment was conducted for a period of 12 months from July 2004 to June 2005 in two *beels* situated at Mithamain Upazila of Kishoreganj district to study the impacts of sanctuaries on the production and diversity of plankton population. For this purpose, the quantitative and qualitative study on plankton in the study area were introduced. The status of physico-chemical parameters of water was also recorded during the study period.

Two types of sites had been included in this study. Dopi *beel* was selected for establishing sanctuaries (for 2 years duration) through Fisheries Community and CBFM (Community Based Fisheries Management) project of DoF (Department of Fisheries) and Chotadigha-boradigha *beel* was used as control. i.e. without sanctuary (T-3). The results of the study on control site were used to compare the results of the study of sanctuary sites.

Two treatments of separate design of sanctuaries having 3 replications for each were established in Dopi *beel.* The sanctuaries were established during December in 2003. The area of each sanctuary was 15 to 20 decimal. he designs of sanctuaries are given below:

- In treatment-1 (T-1) sanctuary was established in each replication by using brush park, bamboo and bamboo pole, bamboo pipe, betel nut tree – by making them like pipe, fish friendly structure like '*Chai*', leaf of coconut tree, etc. and water hyacinth, only in winter season.
- In treatment-2 (T-2) sanctuary was designed by using brush park with bamboo and bamboo pole, old broken country boat, water hyacinth (only in winter season) and triangular fish friendly bamboo device, locally known as "*Hogra*".

Recording of air and surface water temperature, transparency, water depth, dissolved oxygen, carbon dioxide, total hardness and pH were done monthly in the morning between 8.00-12.00 AM on the spot by standard method (Clesseri *et al.*).

Plankton samples were collected monthly from three specific locations of each site that is from each replication of every treatment of Dopi *beel* and Chotadigha-boradigha *beel* (control). Ten liters of water were taken from each locations of every replication of *beel* using a tube sampler made of flexible uniform plastic tube (PVC pipe sampler). The plankton population present in 30 liter (10 liter from each location) and made 50 ml for preservation after adding buffered formalin and distilled water in small plastic bottle for subsequent examination in the laboratory. The preserved samples were studied using a Sedgwick-Rafter cell (S-R cell) and a compound microscope (NOVA 950 ES). One ml stored sample was transferred to the counting cell. Plankton was expressed numerically as cells/l. The procedure of Pennak (1953), Ward and Whipple (1954), Needham and Needham (1962) and Prescott (1964) were followed as the keys for the identification of plankton.

$$N = \frac{A \times C \times 1000}{V \times F \times L}$$

Where,

N = No. of plankton cells or units per liter of original water
A = Total number of plankton cells counted
C = Volume of final concentrate of the sample in ml
V = Volume of a field in cubic mm
F = No. of fields counted

Results

The results of physico-chemical parameters of water of Dopi *beel* and Chotadigha-boradigha *beel* are shown in Table 1.

Table 1. Monthly variations in the water quality parameters in different treatments of Dopi *beel* and Chotadigha-boradigha *beel* from July 2004 to June 2005

Month	Treatment	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
Air	T-1	30.83	29.67	31.17	29.25	26.17	21.17	23.5	28.42	29.17	27	27	31.42
Temperature	T-2	30.17	29.67	31.25	29.58	25	21.58	23.5	27.83	29.83	27.17	27.17	30.92
(°C)	T-3	30.33	30.5	30	28.5	24.25	20	19.75	27.75	26.92	29.5	29.5	29.57
Water	T-1	30.5	29.33	31.33	28.25	24.17	19.58	22.67	27.42	27.83	25.25	25.25	29.42
Temperature	T-2	31	29.42	31.17	28.67	23.17	19.67	22.5	26.83	27.83	25.17	25.17	29.17
(°C)	T-3	29.42	29	30.5	28	23.25	19.5	20.75	27.17	25.5	27.5	27.5	29.17
Water	T-1	9.08	9.51	5.28	7.25	3.77	2.22	1.6	1.43	1.29	2.87	2.87	5.04
depth	T-2	9.08	9.51	5.28	7.25	3.74	2.05	1.37	1.51	1.42	2.87	2.87	4.93
(m)	T-3	7.68	8.11	3.87	5.8	2.79	1.94	0.24	0.37	0.64	1.06	1.06	4.93
Transparenc	T-1	90.58	54.8	64.94	70.5	43.5	32.9	32	23	28.7	49.92	49.92	84.33
(cm)	T-2	93.43	54.63	66.8	65.75	41.17	33.5	25.73	23.73	25.87	50.53	50.53	82.43
	T-3	63	54.8	62.25	67.35	30.5	10.5	18.75	12	56.9	31.92	31.92	82.43

Dissolved	T-1	8	8.33	9.33	8.33	8.33	8	7.67	8.67	8.33	5.67	5.67	6.5
Oxygen	T-2	8.67	7	8.33	8.67	8.67	9	8	8.33	8	5.67	5.67	6.5
(mg/l)	T-3	8.5	8	8	8	6.5	4	9	7.33	7.33	7.33	7.33	7.33
	T-1	7.75	7.5	7.58	7.83	7.83	7.56	7.83	8	8	7	6.5	7.17
pH	T-2	7.75	7.5	7.58	7.58	7.83	7.56	7.25	7.67	8.17	7.17	6.75	6.83
	T-3	7	7.5	7	7	7.5	7	7.67	7.33	6.5	7.5	6.5	7
Free	T-1	11.67	8.33	6.67	6.67	8.33	11.67	5	6.67	8.33	10	11.67	15
CO_2	T-2	6.67	5.00	5.00	6.67	10.00	11.67	6.67	8.33	10	10	10	15
(mg/l)	T-3	8.33	6.67	6.67	10.00	11.67	15.00	5	7.5	8.33	10	11.67	15
Total	T-1	17.10	22.80	28.50	34.20	51.30	68.40	51.3	85.35	102.6	68.4	51.3	34.2
Hardness	T-2	22.80	28.50	28.50	34.20	51.30	68.40	51.3	85.5	102.6	68.4	51.3	28.5
(mg/l)	T-3	17.10	28.80	34.20	34.20	51.30	85.50	68.4	85.5	85.5	68.4	51.3	34.2

Plankton population

Plankton populations in the experimental *beels* were enumerated and identified up to genus level. It composed of 75 (60 phyto and 15 zooplankton) and 74 (59 phyto and 15 zooplankton) genera respectively in T-1 and T-2 belonged to ten major groups, such as Chlorophyceae, Cyanophyceae, Bacillariophyceae, Euglenophyceae, Dinophyceae, Xanthophyceae and Chrysophyceae of phytoplankton and Cladocera, Copepoda and Rotifera of zooplankton. In T-3 the planktonic population was composed of 50 (39 phyto and 11 zooplankton) genera belonged to seven major groups mentioned above except Dinophyceae, Xanthophyceae and Chrysophyceae. The generic statuses of plankton with different groups are shown in Table 2. Mean abundances (cells/l) and percent composition of planktonic groups in three treatments of Dopi *beel* and Chotadigha-boradigha *beel* during July 2004 to June 2005 are shown in Table3.

Table 2. Generic statuses of planktonic groups as recorded from three treatments of Dopi *beel* and Chotadigha-boradigha *beel* during July 2004 to June 2005

Plankton	Group	Dopi *beel* (T-1 and T-2)	Chotadigha-barodigha *beel* (T-3)
Phytoplankton	Chlorophyceae	*Actinastrum, Ankistrodesmus, Botryococcus, Bulbochaete, Chlorella, Cladophora, Closterium, *Coelastrum, Cosmarium, Crucigenia, Dactyloccopsis, Gonatozygon, Microspora, Mougeotia, Oocystis, Palmella, Pediastrum, Scenedesmus, Sphaerocystis, Spirogyra, Staurastrum, Tetraedron, Ulothrix, Volvox, Zygnema.*	*Botryococcus, Bulbochaete, Chlorella, Cladophora, Closterium, Crucigenia, Dactyloccopsis, Microspora, Mougeotia, Oocystis, Pediastrum, Scenedesmus, Sphaerocystis, Spirogyra, Staurastrum, Tetraedron, Ulothrix.*

	Bacillariophyceae	*Bidulphia, Cocconeis, Coscinodiscus, Cymbella, Cyclotella, Diatoma, Epithemia, Fragillaria, Gomphonema, Gyrosigma, Melosira, Navicula, Nitzschia, Pinnularia, Rhizosolenia, Surirella, Synedra, Tabellaria.*	*Bidulphia, Diatoma, Fragillaria, Gomphonema, Gyrosigma, Melosira, Navicula, Nitzschia, Pinnularia, Surirella, Synedra, Tabellaria.*
	Cyanophyceae	*Anabaena, Anacystis, Chroococcus, Gloecapsa, Gomphosphaeria, Lyngbya, Merismopedia, Microcystis, Oscillatoria, Spirulina.*	*Chroococcus, Gomphosphaeria, Merismopedia, Microcystis, Oscillatoria, Lyngbea, Spirulina.*
	Euglenophyceae	*Euglena, Phacus, Trachaelomonus.*	*Euglena, Phacus, Trachaelomonus*
	Dinophyceae	*Ceratium.*	-
	Xanthophyceae	*Botrydium, Ophiocytium.*	-
	Chrysophyceae	*Dinobryon.*	-
Zooplankton	Cladocera	*Daphnia, Ceriodaphnia, Diaphanosoma, Bosmina, Moina.*	*Daphnia, Diaphanosoma, Bosmina, Moina.*
	Copepoda	*Cyclops and Diaptomus.*	*Cyclops and Diaptomus*
	Rotifera	*Brachionus, Keratella, Trichocera, Filinia, Lecane, Polyarthra, Asplanchna, Monostyla.*	*Brachionus, Keratella, Filinia, Lecane, Monostyla.*

* Not found in T-2

Phytoplankton population

Chlorophyceae with its 25, 24 and 17 genera respectively in T-1, T-2 and T-3, was found to be most dominant group of phytoplankton. Among these, *Chlorella* was the genus, which constituted the major portion of total population in all the treatments. Other important genera were *Ulothrix, Pediastrum, Closterium, Microspora, Spirogyra, Scenedesmus, Oocystis,* etc. The ranges of Chlorophyceae numbers were 1972 to23944 cells/l, 1917 to 25639 cells/l and 778 to 22667 cells/l respectively in T-1, T-2 and T-3. The highest numbers of Chlorophyceae were recorded during January in T-1 and T- 2, and in December in T-3. The lowest numbers of Chlorophyceae was obtained in October in all the treatments.

Cyanophyceae with its 10, 10 and 7 genera were found to be the second dominant group of phytoplankton in T-1, T-2 and T-3 respectively. The ranges of Cyanophyceae numbers were 722 to 7000 cells/l, 889 to 11111 cells/l and 444 to 6000 cells/l respectively in T-1, T-2 and T-3. The highest numbers of Cyanophyceae was recorded in March in T-1 and T-2 and during January in T-3. The lowest of the same were recorded during October in T-1 and T-2, and during September in T-3.

Table 3. Mean abundances (±SE), ranges and percent composition of planktonic groups as recorded from T-1, T-2 and T-3 during July 2004 to June 2005

Plankton group	Mean Value			%			F
	T-1	T-2	T-3	T-1	T-2	T-3	Value
Chlorophyceae	14752±2076[a] (1972 - 23944)	14604±2217[a] (1917 - 25639)	7842±1709[b] (778 - 22667)	66.3	64.8	67	3.85
Cyanophyceae	3995±668[a] (722 - 7000)	4764±1022[a] (889 - 11111)	2648±521[a] (444 - 6000)	17.9	21.1	23	1.95
Bacillariophyceae	2509±247[a] (1000 - 4167)	2361±249[a] (889 - 4111)	1070±162[b] (111 - 1667)	11.3	10.5	9	12.62
Euglenophyceae	940±280[a] (111 - 2944)	745±151[a] (222 - 1444)	204±61[b] (0 - 722)	4.2	3.3	2	*4.14
Dinophyceae	28±14[a] (0 - 111)	28±14[a] (0 - 111)	-	0.1	0.1	0.1	1.83
Xanthophyceae	23±16[a] (0 - 167)	23±16[a] (0 - 167)	-	0.1	0.1	0	1.05
Chrysophyceae	19±12[a] (0 - 111)	28±19[a] (0 - 167)	-	0.1	0.1	0	1.19
Total Phytoplankton	22266±2804[a] (5472 - 35833)	22553±3316[a] (5250 - 40472)	11764±2219[b] (1778 - 29333)	100	100	100	4.77
Copepoda	454±63[a] (222 - 778)	417±59[a] (167 - 778)	171±47[b] (0 - 444)	43	40	47	7.27
Cladocera	264±46[a] (56 - 611)	264±39[a] (111 - 556)	97±28[b] (0 - 333)	25	26	27	6.23
Rotifera	333±49[a] (111 - 611)	352±48[a] (111 - 722)	93±35[b] (0 - 389)	32	34	26	10.5
Total Zooplankton	1051±104[a] (667 - 1722)	1032±85[a] (611 - 1667)	361±86[b] (56 - 1056)	100	100	100	18.27
Total Plankton	23317±2868[a] (6194 - 37500)	23586±3364[a] (6028 - 41806)	12125±2253[b] (1889 - 29444)				5.21

A total of 18, 18 and 12 genera of Bacillariophyceae were observed in T-1, T-2 and T-3 respectively. Among these, *Synedra, Gomphonema, Bidulphia, Diatoma, Melosira, Tabellaria, Navicula, Gyrosigma* etc. were predominant. The ranges of Bacillariophyceae numbers were 1000 to 4167 cells/l, 889 to 4111 cells/l and 111 to 1667 cells/l respectively in T-1, T-2 and T-3. The highest numbers of Bacillariophyceae were recorded during February in all the treatments. The lowest numbers of the same were recorded during September in T-1 and T-2, and during July in T-3.

Of Euglenophyceae *Euglena, Trachaelomonus* and *Phacus* were recorded in all the treatments and in all the months during the study period except in May in T-3. The ranges of Euglenophyceae numbers were 111 to 2944 cells/l, 222 to 1444 cells/l and 0 to

722 cells/l respectively in T-1, T-2 and T-3. The highest numbers of Euglenophyceae were recorded in November in T-1, in July and February in treatment-2 and in July in T-3. The lowest numbers of Euglenophyceae were recorded during October and May in T-1 and T-2 respectively. In T-3 Euglenophyceae was completely absent in May.

Only one genus *(Ceratium)* of Dinophyceae was observed in the month of May, June and July only in T-1 and T-2. The ranges of Dinophyceae numbers were 0 to 111 cells/l both in T-1 and T-2 of Dopi *beel.*

Similarly one genus of Chrysophyceae (*Dinobryon*) was observed only in May and June in T-1 and T-2. Chrysophyceae were found to range from 0 to 111 cells/l and 0 to 167 cells/l respectively in T-1 and T-2 of Dopi *beel.*

The genera *Botrydium* and *Ophiocyticum* of Xanthophyceae were recorded in T-1 and T-2 during the month of May and June only. Xanthophyceae were found to range from 0 to 167 cells/l in T-1 and T-2. But Dinophyceae, Chrysophyceae and Xanthophyceae were not observed in T-3.

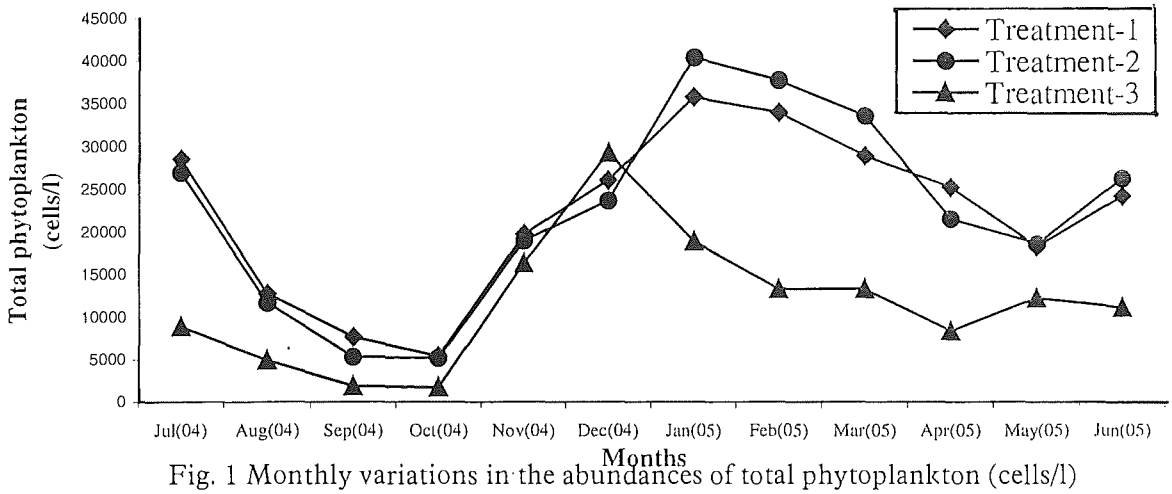

Fig. 1 Monthly variations in the abundances of total phytoplankton (cells/l) in three treatments of beels during July 2004 to June 2005.

The total phytoplankton numbers were found to range from 5472 to 35833 cells/l, 5250 to 40472 cells/l and 1778 to 29333 cells/l with mean values 22266±2804 cells/l, 22553±3316 cells/l and 11764±2219 cells/l respectively in T-1, T-2 and T-3.

The highest crops of phytoplankton were found during January in T-1 and T-2, and in December in T-3. Whereas the lowest abundance of phytoplankton was recorded in October in all the treatments.

Zooplankton population

The zooplankton populations of T-1, T-2 and T-3 were composed of three major groups, viz. Cladocera, Copepoda and Rotifera.

Copepods mainly represented by common genera like *Diaptomus* and *Cyclops,* and dominated over other groups in three treatments. The average abundance of Copepods

were ranged from 222 to 778 cells/l, 167 to 778 cells/l and 0 to 444 cells/l / respectively in T-1, T-2 and T-3. Copepods attained the highest peak in January and March in T-1, February and January in T-2 and T-3 respectively. The lowest number of Copepoda was found in August, September and December in T-1, August and December in T-2 and it was not obtained in September and October in T-3.

Cladocera with its 5, 5 and 4 genera in T-1, T-2 and T-3 respectively, was found to be important group of zooplankton. The average abundances of Cladocera were ranged from 56 to 611 cells/l, 111 to 556 cells/l and 0 to 333 cells/l respectively in T-1, T-2 and T-3. The highest numbers of Cladocera were recorded in February in T-1 and T-2 and in January in T-3. The lowest number of Cladocera was recorded during October in T-1 and July and October in T-2. Whereas it was not recorded in September and October in T-3.

Rotifera with its 8 genera in T-1 and T-2, and 5 genera in T-3 were found to range from 111 to 611 cells/l, 111 to 722 cells/l and 0 to 389 cells/l respectively. The highest number of rotifers was recorded during August in T-1and T-2, and in June in T-3.

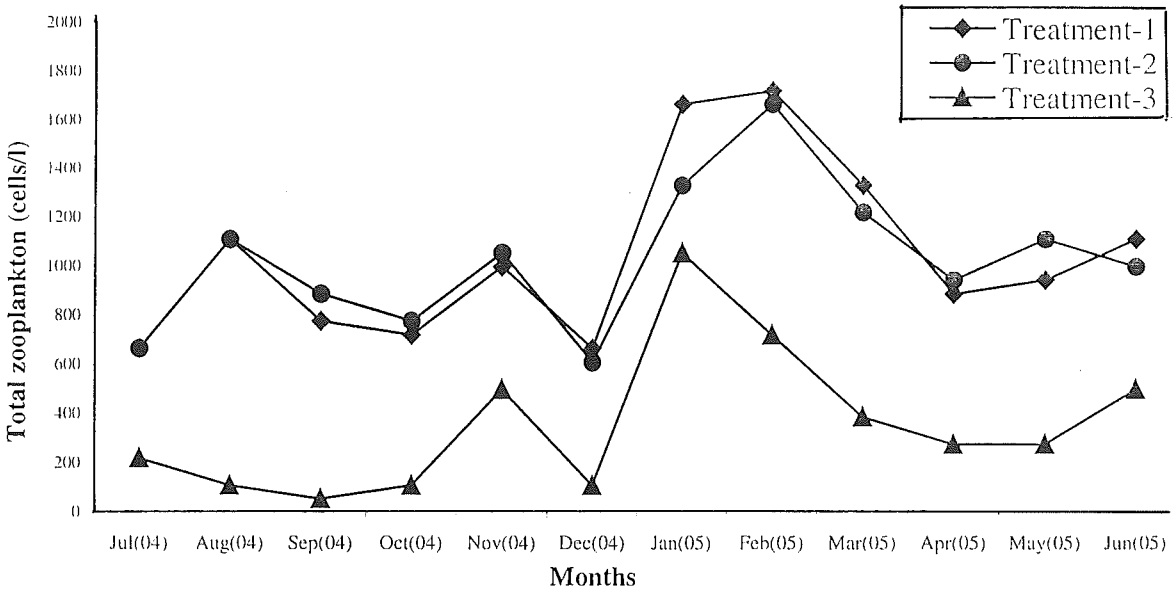

Fig. 2 Monthly variations in the abundances of total zooplankton (cells/l) in three treatments of beels during July 2004 to June 2005.

The ranges of total zooplankton numbers were 667 to 1722 cells/l, 611 to 1667 cells/l and 56 to 1056 cells/l with mean values 1051±104 cells/l, 1032±85 cells/l and 361±86 cells/l respectively in T-1, T-2 and T-3. The total zooplankton population showed almost similar trend of monthly fluctuations with few exceptions in all the treatments with a higher peak during winter season.

The maximum abundance of total zooplankton was recorded in the month of February in T-1 and T-2, and January in T-3. The lowest number of zooplankton was recorded during July in T-1, December in T-2 and September in T-3

Total plankton

In T-1, T-2 and T-3 the ranges of total plankton were 6194 to 37500 cells/l, 6028 to 41806 cells/l and 1889 to 29444 cells/l with mean values 23317± 2868 cells/l, 23586±3364 cells/l and 12125±2253 cells/l respectively.

Total plankton population showed two peaks, the major one were observed during January and minor one in July in T-1 and T-2. But in T-3 only one peak was observed during December.

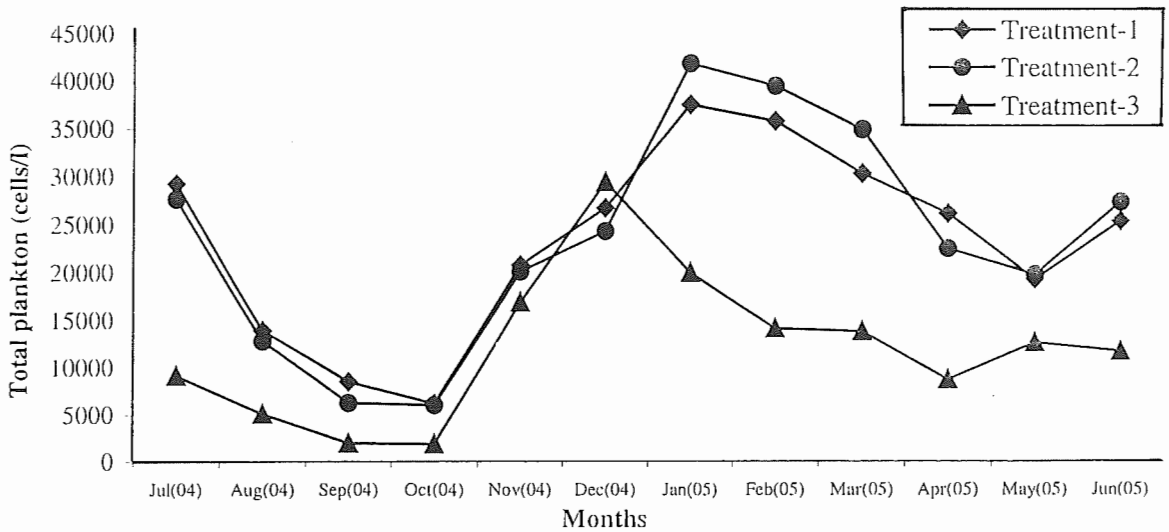

Fig. 3 Monthly variations in the abundances of total plankton (cells/l) in three treatments of beels during July 2004 to June 2005.

The minimum plankton was recorded during October in all the treatments. Phytoplankton contributed about 95% 96% and 97%, and zooplankton about 5%, 4% and 3% to total plankton in T-1, T-2 and T-3 respectively.

Discussion

The physico-chemical factors did not show any significant difference among the treatments except water depth in the present study and they were within productive levels.

In the present study 60, 59 and 39 genera of phytoplankton were recorded from T-1, T-2 and T-3 respectively. These findings were more or less similar to findings reported by Yousuf and Parveen (1990), Razzaque *et al.* (1995), Ehshan *et al.* (1997) and Saha and Hossain (2002).

The total abundance of phytoplankton ranged between 5472 to 35833 cells/l, 5250 to 40472 cells/l and 1778 to 29333 cells/l respectively in T-1, T-2 and T-3. Similar abundance of phytoplankton was also recorded by Ahmed *et al.* (2004), Ehsan (1996) and Razzaque *et al.* (1995) in their study.

The phytoplankton population had two peaks in T-1 and T-2 with major peak in January and minor peak in July. Whereas in T-1 (control) only one peak was recorded in December. Ahmed *et al.* (2004) and Hasan (2004) also found the maxima of phytoplankton during July in Shakla and Shapla *beel* and during January in Hurul *beel*. In the present study the minima of phytoplankton was obtained in the month of October in three treatments. Similarly Baten (2003) recorded the minima of phytoplankton during October. In the present research, phytoplankton populations were found to decrease from August extending upto October when they reached to the lowest value.

Chlorophyceae formed the main bulk of phytoplankton in three treatments. The percentage of Chlorophyceae in T-1, T-2 and T-3 were 66.3%, 64.8% and 67% respectively. This group of phytoplankton also dominated qualitatively with highest number of genera compared to other groups. The blue green algae Cyanophyceae was the second dominant group in order of abundance but in order of genus richness the Bacillariophyceae was the second dominant group in three treatments. Similarly Khan *et al.* (1990), Ahmed *et al.* (2004) also recorded Chlorophyceae as the most dominant group. Chowdhury (2004), Hasan (2004), Rahman (2004), Yousuf and Parveen (1990) and, Saha and Hossain (2002) observed almost similar phenomenon in different *beels*.

The mean values of Chlorophyceae, Bacillariophyceae and Euglenophyceae, obtained in T-1 and T-2 (with sanctuary) were significantly higher from the mean value of these in T-3 (control) ($p>0.5$). But no such difference was recorded between the T-1 and T-2.

In present study 15 genera of zooplankton were recorded from T-1 and T-2, and 11 genera from T-3. Hasan (2004) and Rahman (2004) recorded 11 and 15 genera of zooplankton in different waterbodies in Bangladesh respectively.

The ranges of total zooplankton populations recorded were 667 to 1722 cells/l, 611 to 1667 cells/l and 56 to 1056 cells/l respectively in T-1, T-2 and T-3. The present findings were more or less close to the ranges reported by Chowdhury (2004) in Burulia *beel*, Hasan (2004) in Hurul *beel*, Rahman (2004) in Boro *beel* and Razzaque *et al.* (1995) in Halti *beel*.

Zooplankton population showed a well defined peak in the month of January to February in three treatments. Whereas Patra and Azadi (1987) found two peaks of zooplankton, one in August and another in February. Razzaque *et al.* (1995) reported two peaks of zooplankton, one in May and another in October.

Copepods mainly dominated over other groups in three treatments contributing about 43%, 40% and 47% respectively in T-1, T-2 and T-3. The second dominant group in T-1 and T-2 was Rotifera, but in T-3 it was Cladocera. Similarly Patra and Azadi (1987), and Khan *et al.* (1990) reported that Copepods dominated over other groups in Halda river and Bachhra reservoir respectively. Khan *et al.* (1990) also reported Rotifera as the second dominant group. The mean values of Cladocera, Copepoda and Rotifera in T-1 and T-2 (with sanctuary) were significantly different from the mean value of T-3 (control).

In the present study ranges of total plankton obtained were 6194 to 37500 cells/l, 6028 to 41806 cells/l and 1889 to 29444 cells/l respectively in T-1, T-2 and T-3. Hasan (2004) recorded the range of total plankton as 1400 to 42500 cells/l with mean value

24200 cells/l which are almost similar to the findings of present study. Total plankton population showed more or less similar trend of monthly variations with two peaks, major one during winter and minor one during early monsoon in all the treatments.

In the present study it was found that the phytoplankton, zooplankton and total plankton populations in sanctuary sites (T-1 and T-2) were significantly higher (almost double) than control site (T-3) both qualitatively and quantitatively in all the months except in December when phytoplankton population was greater in T-3 than the rest two treatments. It is known that the feeding of phytoplankton by fish contributes to the depletion of the floral elements. This phenomenon might be the cause of lower phytoplankton in the sanctuaries (T-1 and T-2) in December when large number of fish aggregated in sanctuaries and decreased to a great extant in T-3 due to intensive fishing by the fishers.

From the above findings of present study it may be concluded that the establishment of sanctuaries have profound positive impacts on the phytoplankton, zooplankton and total plankton production and diversity in *beels*. Between the two treatments of sanctuary establishments, the sanctuary of T-2 was found better than that of T-1 in respect of the production and diversity of plankton. Therefore establishment of sanctuary in open waterbodies may be recommended for obtaining sustainable fish production. However further research should be carried out with different sanctuary materials for obtaining better results.

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