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Inclusion of Pangasiid Catfish in Polycultures of Major Indian Carps (Catla, Rohu and Mrigal) Increases Yield and Economic Gain

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An experiment was conducted in twelve 0.02-ha rain-fed earthen ponds for 18 weeks to evaluate the effects of including pangasiid catfish (*Pangasius hypophthalmus*) in polycultures of major Indian carps, catla (*Catla catla*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus cirrhosus*), on yield and economic gain. Treatment 1 (T_1) consisted of 5,000 catla+2,500 rohu+2,500 mrigal per ha, treatment 2 (T_2) consisted of 5,000 catla+2,500 rohu+2,500 mrigal+2,500 pangasiid catfish per ha, treatment 3 (T_3) consisted of 5,000 catla+2,500 rohu+2,500 mrigal + 5,000 pangasiid catfish per ha, and treatment 4 (T_4) consisted of 5,000 catla+2,500 rohu+2,500 mrigal+7,500 pangasiid catfish per ha. The growth performance of fishes was evaluated by calculating specific growth rate, daily weight gain, and percent weight gain. Inclusion of pangasiid catfish in the carp polyculture resulted in significant increases in the growth and yield of catla and rohu. Catla and rohu grew most in T_4, with 7,500/ha of pangasiid catfish. The presence of pangasiid catfish did not influence the growth of mrigal. The growth of pangasiid catfish varied with stocking density, and they grew best at 5,000/ha (T_3). The carp and the combined fish yields were significantly higher in the carp polycultures with pangasiid catfish than with carps alone. The total carp and the combined fish yields were highest in T_4, in which the density of pangasiid catfish was greatest. However, the total carp and the combined fish yields in T_3 and T_4 were not significantly different. Profit differed significantly among treatments. Economic gain was highest in T_3, with 5,000/ha of pangasiid catfish, and lowest in T_1. The inclusion of pangasiid catfish in major carp polycultures results in higher fish yields and greater economic gain.

Key words: Catla, Major carp, Mrigal, Pangasiid catfish, Polyculture, Rohu

Introduction

Polyculture of major carp species, both native and exotic, is widely practiced in Bangladesh. About 73% of rural households are involved in this type of aquaculture (Mazid, 1999). Polyculture is mostly used to grow carps in ponds by applying animal wastes and chemical fertilizers. However, the yield in carp polyculture ponds is about 3-4 tons/ha/yr (Dewan et al., 1988; Ahmed, 1993; Miah et al., 1993; Uddin et al., 1994; Hossain et al., 1994; Mazid et al., 1997) and is not sufficient to meet the growing demands of the country. The slow growth rate of native carp species is one of the main reasons for the low fish biomass production. Additionally, fish production from inland fisheries is declining due to over-fishing, pollution, and fish diseases. The domestic demand for fish to feed the 130 million people in Bangladesh is increasing. Therefore, enhancement of aquaculture production to meet the growing demands of the country is urgent.

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Inclusion of exotic fish species in polycultures of native fish results in considerably higher yields and better aquatic environments in many Asian countries. Halver (1984) reported that stocking fish that require different habitats in the proper ratios, densities, and combinations can increase the production of fish in polyculture ponds. Thus, fish production in carp polyculture ponds in Bangladesh could be increased by including more compatible species after a closer study of their food niches and energy flow in pond ecosystems. The pangasiid catfish *Pangasius hypophthalmus* is a species with high potential for aquaculture and is the most commonly cultured species in Thailand, Cambodia, and Vietnam in all types of confinements, including cages, pens, and ponds (Bardach et al., 1972). This species was imported into Bangladesh from Thailand in 1990 to enhance aquaculture production. Originally, farmers cultured *P. hypophthalmus* according to their own ideas because they received no guidance regarding the best methods of catfish culture. Intensive monoculture of pangasiid catfish is mostly practiced in Bangladesh. In this culture method, farmers stock pangasiid catfish at high densities and use large quantities of both commercial pellet and homemade food to obtain high profits within a short time, which results in high accumulation of metabolic and food wastes in the pond. Subsequently, decomposition of these wastes enriches the nutrients that favor excessive growth of phytoplankton. Boyd (1973, 1985) reported that ponds that receive fish feed have abundant phytoplankton growth because roughly 75% of the nutrients in fish feed reach the water as excretory products. Thus, in intensive monoculture, pangasiid catfish do not use phytoplankton, which remains unused and eventually deteriorates the water quality through algal pollution. The most serious problem resulting from excessive algal blooms in pangasiid catfish ponds is an off flavor in fish. Because the off flavor lowers the demand and the market price of these fish, pangasiid catfish farming is becoming less profitable. Consequently, the importance of pangasiid catfish is gradually declining in Bangladesh.

As an alternative to pangasiid catfish monoculture, this exotic species could be included in polycultures of native Indian carps to obtain higher yields in rural fish ponds. Merkowsky and Avault (1976), Henderson (1979), and Torrans and Clemens (1981) polycultured channel catfish (*Ictalurus punctatus*) with various carp species and found increased fish production. Thus, omnivorous pangasiid catfish could be a good candidate for polyculture with major Indian carp species. Inclusion of pangasiid catfish in polycultures of major Indian carps could have several advantages for fish farmers. Additional crops of pangasiid catfish can be produced in carp polyculture ponds. Moreover, the growth of carps will increase because they consume the excess algae that grow on the nutrients from leftover feed and metabolic wastes. Good water quality will be maintained in the aquaculture ponds because the carp will reduce algal biomass. Thus, successful polyculture of pangasiid catfish with major carps would provide higher fish yield and increased economic gain for rural fish farmers and could be an attractive alternative to major Indian carp polyculture and pangasiid catfish monoculture in Bangladesh.

This study was conducted to evaluate and compare fish yield and economic gain in polycultures of major Indian carp species (catla *Catla catla,* rohu *Labeo rohita* and mrigal *Cirrhinus cirrhosus*) with and without pangasiid catfish.

Materials and Methods

Experimental design and culture conditions

The experiment was conducted in twelve 0.02-ha rain-fed earthen ponds at the Field Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, Bangladesh, for 18 weeks from June to October 2004. All experimental ponds were fertilized 7 days before the initial stocking of fingerlings, and then regularly at 10-day intervals, with triple super phosphate (TSP), urea, and cow waste at rates of 24.7 kg/ha (=0.5 kg/pond), 24.7 kg/ha (=0.5 kg/pond), and 617.5 kg/ha (=12.5 kg/pond), respectively. Thirteen fertilizer applications were made during the experimental period. Fertilizers were mixed with pond water, and the resulting slurry was sprayed over the pond surface. The experiment was conducted in a randomized complete block design with four treatments, each with three replicates. Treatment 1 (T_1) consisted of 5,000 catla+2,500 rohu +2,500 mrigal per ha, treatment 2 (T_2) consisted of 5,000 catla+2,500 rohu+2,500 mrigal+2,500 pangasiid catfish per ha, treatment 3 (T_3) consisted of consisted of 5,000 catla+2,500 rohu+2,500 mrigal+5,000 pangasiid catfish per ha, and treatment 4 (T_4) consisted of 5,000 catla+2,500 rohu+2,500 mrigal+7,500 pangasiid catfish per ha.

A commercial pelleted feed containing 28% crude protein and 6% lipid was fed only to pangasiid catfish twice daily (09:00-09:30 and 17:00-17:30). The feeding rate was 8% of fish biomass/day during the first 6 weeks, 6% in the second 6 weeks, and 4% thereafter. The feeding rate for the first 2 weeks was based on the average weight of fish in all ponds on day 0 and then adjusted biweekly based on sampled mean weight of fish.

Water quality measurements and phytoplankton determination

Physical, chemical, and biological water quality variables (surface temperature, water depth, transparency, dissolved oxygen, pH, nitrate-nitrogen [NO_3-N], phosphate-phosphorus [PO_4-P], and chlorophyll-*a*) were measured at regular intervals. Measurement of water quality variables started on the first day of the experiment and was carried out between 09:00 and 10:00. Temperature, water depth, transparency, dissolved oxygen, and pH were measured weekly using a thermometer, a graduated pole, a Secchi-disk, a portable waterproof dissolved oxygen meter (HI 9142, Hanna Instruments, Portugal), and a portable pH meter (HI 8424, Hanna Instruments, Portugal), respectively. NO_3-N and PO_4-P were measured biweekly using an Odyssey DR/2500 spectrophotometer (Hach, USA) following procedures described in the manual. Chlorophyll-*a* and plankton composition were measured biweekly. Chlorophyll-*a* was determined with a spectrophotometer after acetone extraction (Greenberg et al., 1992). In analyses of chlorophyll-*a*, 100 mL of water were filtered through Whatman GF/C filter paper (Whatman International Ltd., England). After filtration, the filter paper was put into a 15-mL centrifuge tube (Corning, USA), 5 mL of 90% acetone were added, and then the filter paper was ground with a tissue grinder. When the filter paper was crushed, 5 mL of 90% acetone were added and stirred, and the tube was transferred to a refrigerator for 24 hr. The tubes were centrifuged for 10 min at 3,000 rpm in a centrifuge (Denley BS 400, England), the supernatant was decanted into a 4-mL glass cuvette, and the chlorophyll-*a* concentration was measured with a direct-reading spectrophotometer (Milton Roy Spectronic 1001 Plus, USA) at 664 and 750 nm. For identification and quantification of plankton, samples were collected by passing a known volume of pond water through a 15-µm mesh plankton net. Concentrated samples were preserved in 5% buffered formalin. Quantitative analysis of plankton was done using a Sedgwick-Rafter counting cell (S-R cell; Graticules Ltd., U.K.). The plankton on 20 randomly selected fields of the Sedgwick-Rafter counting chamber was counted under a compound microscope. Plankton density (cells/L) was calculated according to Beveridge (1985). Taxonomic identification of plankton to genus was done in the laboratory using the keys of Edmondson (1959), Prescott (1962), Pontin (1978), and Bellinger (1992).

The growth performance of fishes was evaluated by calculating specific growth rate (SGR), daily weight gain (DWG), and percent weight gain. The feed utilization efficiency of pangasiid catfish was evaluated using the feed conversion ratio (FCR) and protein efficiency ratio (PER). A simple economic analysis was done to estimate and compare the profitability of native major carp polycultures with and without pangasiid catfish. Comparisons of fish growth, yield, water quality, and profits were made using a factorial analysis. When a significant difference ($p<0.05$) between means was detected, a standard deviation range test was used to compare mean values (Gomez and Gomez, 1984).

Table 1. Growth performance of fishes (mean ± SE) in different treatments. Figures having the same superscripts in the same columns are not significantly ($p<0.05$) different

Treatment	Fish species	Mean weight (g)		DWG (g)	SGR	Percent weight gain (%)	Survival %
		Initial	Final				
T_1	Catla	13.44 ± 0.29	204.31 ± 2.23^c	1.52 ± 0.02^d	2.16 ± 0.02^c	1,422.03 ± 35.26^d	95
	Rohu	10.63 ± 0.16	208.21 ± 3.51^c	1.57±0.02^c	2.36 ± 0.0^b	1,858.74 ± 10.52^d	95
	Mrigal	10.38 ± 0.19	131.76 ± 6.06	0.96 ± 0.02	2.02 ± 0.03	1,170.20 ± 41.73	94
T_2	Catla	13.39 ± 0.44	224.60 ± 3.73^b	1.68 ± 0.03^c	2.24 ± 0.02^b	1,580.15 ± 48.76^c	94
	Rohu	10.37 ± 0.59	224.43 ± 0.06^b	1.70 ± 0.04^b	2.44 ± 0.05^{ab}	2,084.56 ± 146.80^c	96
	Mrigal	10.27 ± 0.17	134.73 ± 1.65	0.99 ± 0.02	2.04 ± 0.01	1,212.24 ± 10.18	94
	Pangasiid catfish	12.37 ± 0.07	491.63 ± 2.64^b	3.80 ± 0.02^{ab}	2.92 ± 0.01^b	3,875.91 ± 41.55^b	93
T_3	Catla	13.33 ± 0.52	236.06 ± 5.93^{ab}	1.73 ± 0.05^b	2.27 ± 0.01^{ab}	1,639.91 ± 25.80^b	94
	Rohu	10.76 ± 0.61	235.76 ± 3.29^a	1.79 ± 0.02^b	2.45 ± 0.04^{ab}	2,107.72 ± 120.08^{ab}	95
	Mrigal	10.47 ± 0.11	137.53 ± 2.52	1.01 ± 0.02	2.04 ± 0.02	1,214.62 ± 28.69	94
	Pangasiid catfish	12.26 ± 1.10	525.88 ± 5.03^a	4.08 ± 0.04^a	2.98 ± 0.01^a	4,188.32 ± 27.17^a	94
T_4	Catla	13.22 ± 0.36	243.40 ± 5.24^a	1.83 ± 0.04^a	2.31 ± 0.02^a	1,743.26 ± 54.52^a	94
	Rohu	10.20 ± 0.08	239.43 ± 4.55^a	1.82 ± 0.04^a	2.51 ± 0.03^a	2,262.30 ± 93.13^a	95
	Mrigal	10.08 ± 0.11	135.06 ± 2.95	0.99 ± 0.02	2.05 ± 0.01	1,226.74 ± 20.54	92
	Pangasiid catfish	12.36 ± 1.16	466.59 ± 2.53^c	3.61 ± 0.02^c	2.88 ± 0.01^c	3,676.54 ± 61.57^c	92

Results

Growth performance and survival of fishes

The final weight and length, DWG, SGR, percent weight gain, and survival of catla, rohu, mrigal, and pangasiid catfish in different treatments are presented in Table 1. The final weight reached at harvest of catla, rohu, and pangasiid catfish differed significantly ($p<0.05$) among treatments. The final weight of catla and rohu was highest in T_4 and lowest in T_1. The final weight of pangasiid catfish was highest in T_3, where its density was moderate, and lowest in T_4, where its density was greatest. The final weight of mrigal did not differ significantly ($p<0.05$) among treatments. The SGR, DWG, and percent weight gain of catla, rohu, and pangasiid catfish differed significantly ($p<0.05$) among the treatments. The growth of catla and rohu was highest in T_4, followed by T_3, T_2, and T_1. The growth of pangasiid catfish was highest in T_3, followed by T_1 and T_4. The growth of mrigal was not significantly different among treatments. However, the growth of mrigal was lowest in T_1. The trends in growth in all treatments began immediately after stocking and then continued in an almost linear manner throughout the experiment (Fig. 1). The survival rate was high in all treatments, ranging from 94-95% for catla, 95-96% for rohu, 92-94% for mrigal, and 93-94% for pangasiid catfish, with no significant differences among treatments (Table 1).

Fish yield

The yield of catla, rohu, mrigal, and pangasiid catfish in the different treatments is presented in Table 2. The trends in growth were reflected in yield, with similar results and significant differences (Tables 2 and 3). The yield of mrigal differed significantly ($p<0.05$) among treatments. The yield of catla and rohu was highest in T_4 and lowest in T_1. The yield of pangasiid catfish was highest in T_4 and lowest in T_2. Total yield of carps was lowest in T_1, without pangasiid catfish, and highest in T_4, with the highest density of pangasiid catfish. Likewise, the combined yield of all fishes was lowest in T_1 and highest in T_4 (Table 2). However, there was no significant difference in the combined yield between T_3 and T_4 (Table 3).

Cost and economic gain

The cost and economic gain in the different treatments are presented in Table 3. The production cost and economic gain were calculated according to local prices of the inputs used in the experiment. In the cost and economic gains analysis, the operational cost was considered to be 7.5% of total cost (ADCP, 1983). The economic gain was significantly ($p<0.05$) different among treatments. The net econo-mic gain was highest in T_3 and lowest T_1.

Feed utilization efficiency

FCR was calculated as the total dry weight of feed added divided by the total wet weight of pangasiid catfish at harvest. PER was calculated as the total wet weight of pangasiid catfish at harvest divided by the total protein added. Both FCR and PER differed significantly ($p<0.05$) among treatments and were significantly higher in T_3.

Water quality

The ranges and mean values of the water quality variables are presented in Table 4. The treatments significantly affected some chemical conditions. NO_3-N and PO_4-P were significantly higher ($p<0.05$) in ponds with pangasiid catfish than in carp-only ponds. Both NO_3-N and PO_4-P increased with time in all treatments. The rate of increase was highest in T_4 (Fig. 2). However, surface water temperature, water depth, pH, and dissolved oxygen were not significantly different among treatments. These water quality variables ranged from 28.90-32.73°C, 109.33-143.81 cm, 7.02-8.20, and 4.10-10.83 mg/L, respectively, during the study period. Dissolved oxygen and pH decreased with time in treatments with pangasiid catfish. The mean total phytoplankton density varied significantly ($p<0.05$) among treatments and ranged from 9.06×10^4 to 60.95×10^4 cells/L. The growth of phytoplankton increased with the increase of NO_3-N and PO_4-P. Higher growth of phytoplankton was observed in T_4, followed by T_3, T_2, and T_1 (Fig. 2).

The sampled phytoplankton population comprised four major groups: Cyanophyceae (nine genera) Chlorophyceae (15 genera), Bacillariophyceae (seven genera), and Euglenophyceae (three genera). Chlorophyceae represented the largest portion of phytoplankton, with a mean density of $8.07\pm0.04\times10^4$ cells/L (48.06% of total phytoplankton) in T_1, followed by T_2 (44.73%), T_3 (39.16%), and T_4 (33.80%; Fig. 3). The highest mean density of Cyanophyceae was $13.43\pm0.04\times10^4$ cells/L (40.89% of total phytoplankton) in T_4 (Fig. 3). Only a few Bacillariophyceae and Euglenophyceae were observed. An inverse relationship between chlorophyll-*a* and Secchi transparency was observed. Chlorophyll-*a* was highest and Secchi transparency was lowest in T_4, followed by T_3, T_2, and T_1.

Discussion

The growth of catla and rohu was positively influenced by the inclusion of pangasiid catfish in the

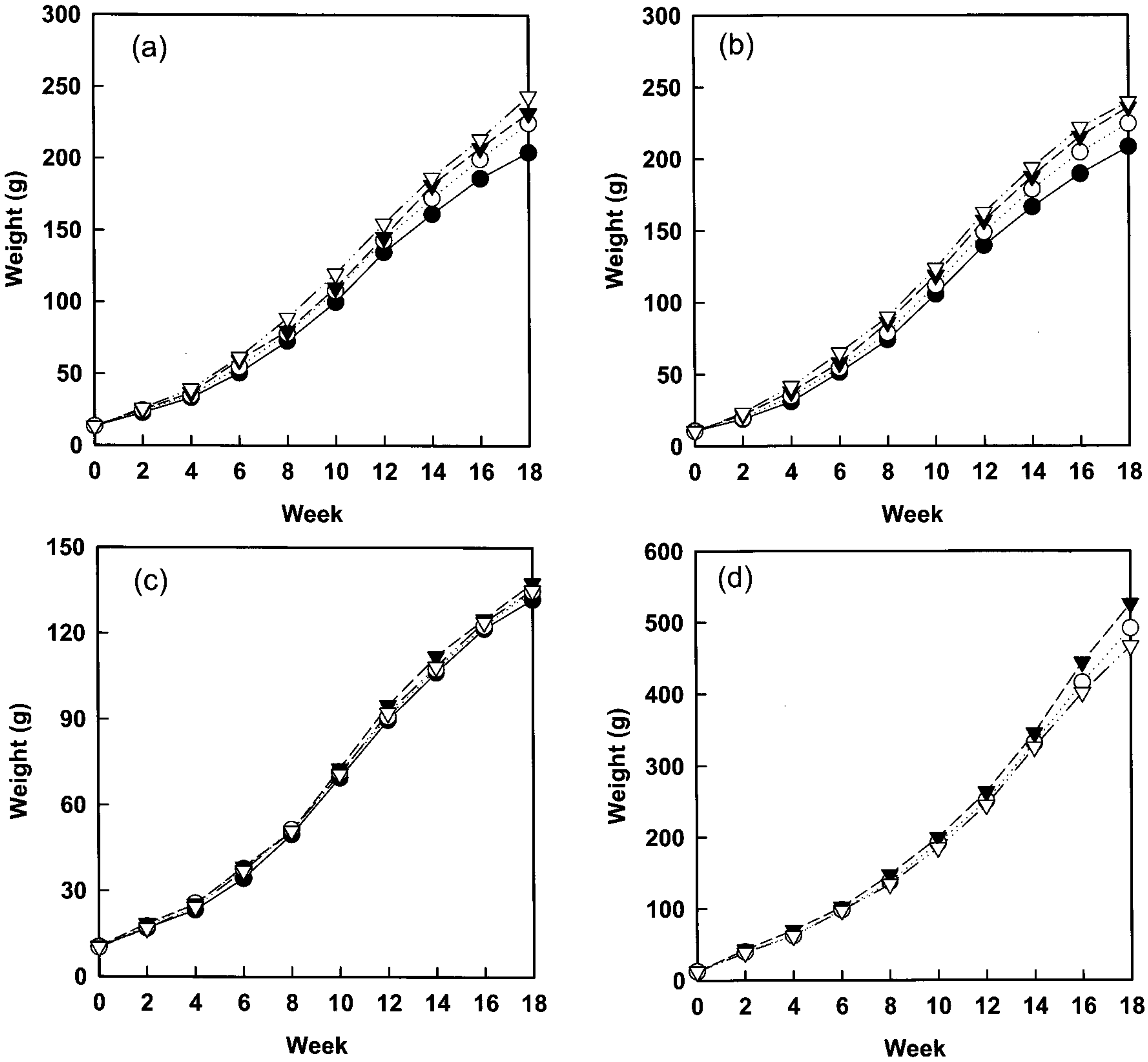

Fig. 1. Growth of catla (a), rohu (b), mrigal (c) and pangasiid catfish (d) in different treatments (T1, ●; T2, ○; T3, ▼; and T4, ▽) during 18 wks of culture period from 15 June to 18 October 2004.

Table 2. Yield (kg/ha) (mean ± SE) of catla, rohu, mrigal and pangasiid catfish in different treatments. Figures having the same superscripts in the same columns are not significantly ($p<0.05$) different

Treatment	Species	Species-wise yield (kg/ha)	Total carps yield (kg/ha)	Total fish yield (kg/ha)
T_1	Catla	$958.69^c \pm 13.71$	$1{,}752.93^c \pm 7.98$	$1{,}752.93^c \pm 7.98$
	Rohu	$488.50^c \pm 5.65$		
	Mrigal	305.74 ± 4.95		
T_2	Catla	$1{,}042.95^b \pm 17.30$	$1{,}888.00^b \pm 30.92$	$3{,}017.31^b \pm 32.66$
	Rohu	$532.27^b \pm 14.13$		
	Mrigal	312.78 ± 5.92		
	Pangasiid catfish	$1{,}129.31^c \pm 7.81$		
T_3	Catla	$1{,}076.10^{ab} \pm 37.03$	$1{,}948.67^{ab} \pm 36.05$	$4{,}390.37^a \pm 32.77$
	Rohu	$553.23^a \pm 8.99$		
	Mrigal	319.34 ± 6.97		
	Pangasiid catfish	$2{,}441.71^b \pm 8.82$		
T_4	Catla	$1{,}129.96^a \pm 17.39$	$1{,}998.44^a \pm 17.37$	$5{,}179.12^a \pm 51.34$
	Rohu	$561.63^a \pm 6.00$		
	Mrigal	306.86 ± 6.36		
	Pangasiid catfish	$3{,}180.67^a \pm 7.81$		

Table 3. Costs and profits after 18-wk culture in pond of 0.02 ha areas in different treatments. 70.00 Tk = US$ 1

Inputs	Unit price (Tk/kg/no.)	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
		Quantity (Kg/no.)	Cost (Tk)	Quantity (Kg/no.)	Cost (Tk)	Quantity Kg/no.)	Cost (Tk)	Quantity (Kg/no.)	Cost (Tk)
Lime	7.00	5.00	35.00	5	35.00	5	35.00	5.00	35.00
Fertilizer									
TSP	14.50	6.50	91.00	6.50	91.00	6.50	91.00	6.50	91.00
Urea	7.00	6.50	45.50	6.50	45.50	6.50	45.50	6.50	45.50
Cow wastes	0.35	162.50	56.87	162.50	56.87	162.50	56.87	162.50	56.87
Fingerling									
Pangasiid catfish	1.00	-	-	50	50.00	100	100.00	150	150.0
Catla	2.00	100	200.00	100	200.00	100	200.00	100	200.00
Rohu	1.75	50	87.50	50	87.50	50	87.50	50	87.50
Mrigal	1.75	50	87.50	50	87.50	50	87.50	50	87.50
Pellet feed	14.60	-	-	52.03	759.64	110.38	1,611.55	152.35	2,224.31
Cost		603.37		1,413.01		2,314.92		2,977.68	
Operational cost		45.25		105.97		173.62		223.33	
Total cost		648.62		1,418.98		2,488.54		3,201.01	
Benefit from fish sale:									
Pangasiid catfish	45.00	-	-	22.86	1,028.70	49.43	2,224.35	64.39	2,897.55
Catla	50.00	19.78	989.00	21.11	1,055.50	21.78	1,089.00	22.87	1,143.50
Rohu	50.00	9.89	494.50	10.77	538.50	11.20	560.00	11.37	568.50
Mrigal	50.00	6.19	309.50	6.33	316.50	6.46	323.00	6.21	310.50
Total return		1,783.00		2,939.20		4,196.35		4,620.05	
Net profit (Tk) (B-A)/0.02 ha/18 wks culture		1,134.38		1,520.22		1,707.81		1,419.04	
Net profit (Tk)/ha/18 wks culture		56,038.37		75,098.87		84,365.81		70,100.57	

Table 4. Values (mean ± SE) of different water quality variables in different treatments. Each value is the mean of three replication ponds collected on eighteen sampling dates (n=54). The range of observed values is given in parenthesis. Figures having the same superscripts in the same row are not significantly different ($p<0.05$)

Parameters	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Temperature (°C)	31.29 ± 0.01 (29.02 - 32.60)	31.30 ± 0.03 (28.95 - 32.63)	31.31 ± 0.02 (28.99 - 32.67)	31.32 ± 0.03 (28.90 - 32.73)
Water depth (cm)	120.89 ± 2.23 (111.27 - 132.33)	123.06 ± 2.09 (113.20 - 140.81)	124.67 ± 1.85 (109.33 - 143.81)	123.97^{a} ± 0.83 (113.01 - 139.14)
Transparency (cm)	36.72^{a} ± 1.97 (29.67 - 54.33)	30.28^{ab} ± 1.74 (25.00-44.33)	27.95^{b} ± 1.21 (21.07 - 46.00)	26.05^{b} ± 0.61 (17.67 - 43.67)
pH	7.60^{a} ± 0.02 (7.20 - 8.14)	7.46^{ab} ± 0.02 (7.07 - 8.11)	7.44^{b} ± 0.03 (7.07 - 7.88)	7.41^{b} ± 0.05 (7.02 - 8.20)
DO (mg/L)	7.37 ± 0.19 (4.30 - 10.83)	6.87 ± 0.17 (5.30 - 8.20)	6.64 ± 0.29 (4.27 - 8.60)	6.41 ± 0.16 (4.10 - 8.43)
NO_3-N (mg/L)	0.81^{c} ± 0.02 (0.46 - 1.05)	0.85^{c} ±0.02 (0.52 - 1.11)	0.98^{b} ± 0.03 (0.67 - 1.22)	1.15^{a} ± 0.02 (0.70 - 1.38)
PO_4-P (mg/L)	1.12^{b} ± 0.02 (0.85 - 1.39)	1.17^{bc} ± 0.02 (0.91-1.48)	1.22^{b} ± 0.02 (0.89 - 1.63)	1.33^{a} ± 0.02 (0.86 - 1.73)
Chlorophyll-*a* (μg/L)	101.64^{b} ± 3.39 (17.55 - 160.86)	119.44^{b} ± 6.27 (25.53 - 183.53)	152.97^{a} ± 9.28 (25.56 - 251.35)	167.07^{a} ± 6.27 (34.12 - 284.66)

native carp polyculture. The growth of catla and rohu was significantly higher in treatments with pangasiid catfish than in the treatment without pangasiid catfish. The growth of catla and rohu increased with an increase in phytoplankton abundance. The highest growth of catla and rohu occurred in T_4, where the abundance of phytoplankton was highest. The growth of mrigal was not influenced by the inclusion of pangasiid catfish in the polyculture of catla, rohu, and mrigal. The growth of pangasiid catfish was in agree-

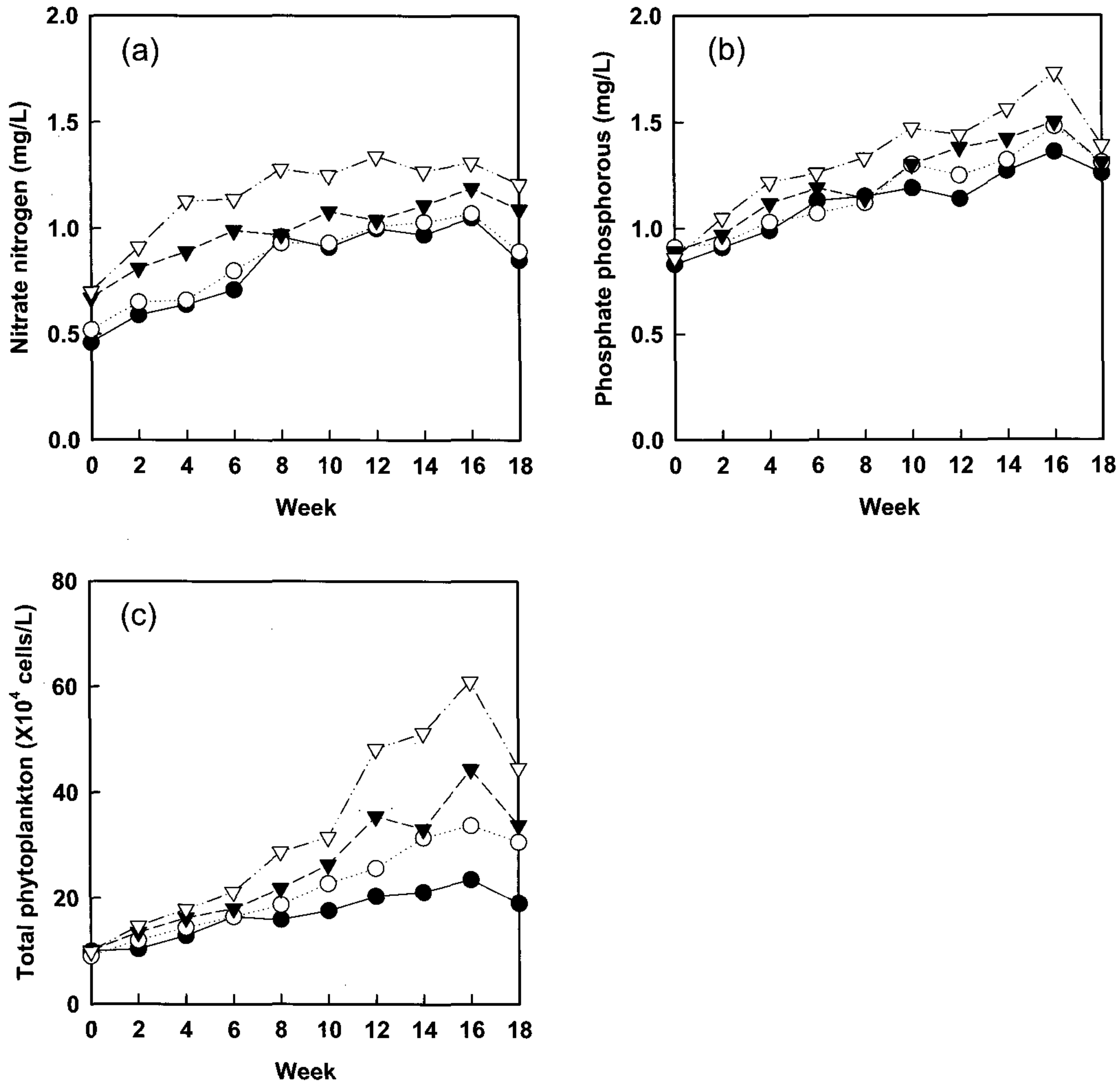

Fig. 2. Nitrate nitrogen (a), phosphate phosphorous (b) and total phytoplankton (c) in ponds of different treatments (T1, ●; T2, ○; T3, ▼; and T4, ▽) during the study period of 18 wks from15 June to 18 October.

ment with the findings of previous experiments (Bardach et al., 1972) and was related to stocking density. The growth of pangasiid catfish was lowest in T_4, where its density was highest. This result agrees with many other studies that found lower fish growth at higher stocking densities (Allen, 1974; Refstie and Kittelsen, 1976; Refstie, 1977; Vijayan and Leatherland, 1988). Significantly higher carp production occurred in carp polycultures with pangasiid catfish than in polycultures with carps only. The combined production of the three major species of Indian carps was highest in T_4, where the density of pangasiid catfish was highest. In this study, carp production in different treatments was higher than the production of carps previously found in carp polyculture ponds in Bangladesh (3,119-4,067 kg/ha/yr; Miah et al., 1993; Uddin et al., 1994; Hossain et al., 1994; Mazid et al., 1997). In our study, total fish production increased by 72-195% and net economic gain increased by 25-51% when pangasiid catfish were included in polycultures of catla, rohu, and mrigal. This was mainly due to the extra production of pangasiid catfish. Total fish production was highest in T_4, whereas net economic gain was highest in T_3. This difference was mainly due to the higher growth rate and better feed utilization efficiency of pangasiid catfish at moderate density. Inclusion of pangasiid catfish in polycultures of native carps altered the water quality, with the exceptions of mean temperature, water depth, and pH, which were similar in all treatments and within the range suitable for fish production. NO_3-N, PO_4-P, chlorophyll-*a*, and phytoplankton density were significantly higher in treatments with pangasiid catfish. NO_3-N, PO_4-P, chlorophyll-*a*, and phytoplankton density increased with the increased feeding rate of pangasiid catfish. In this

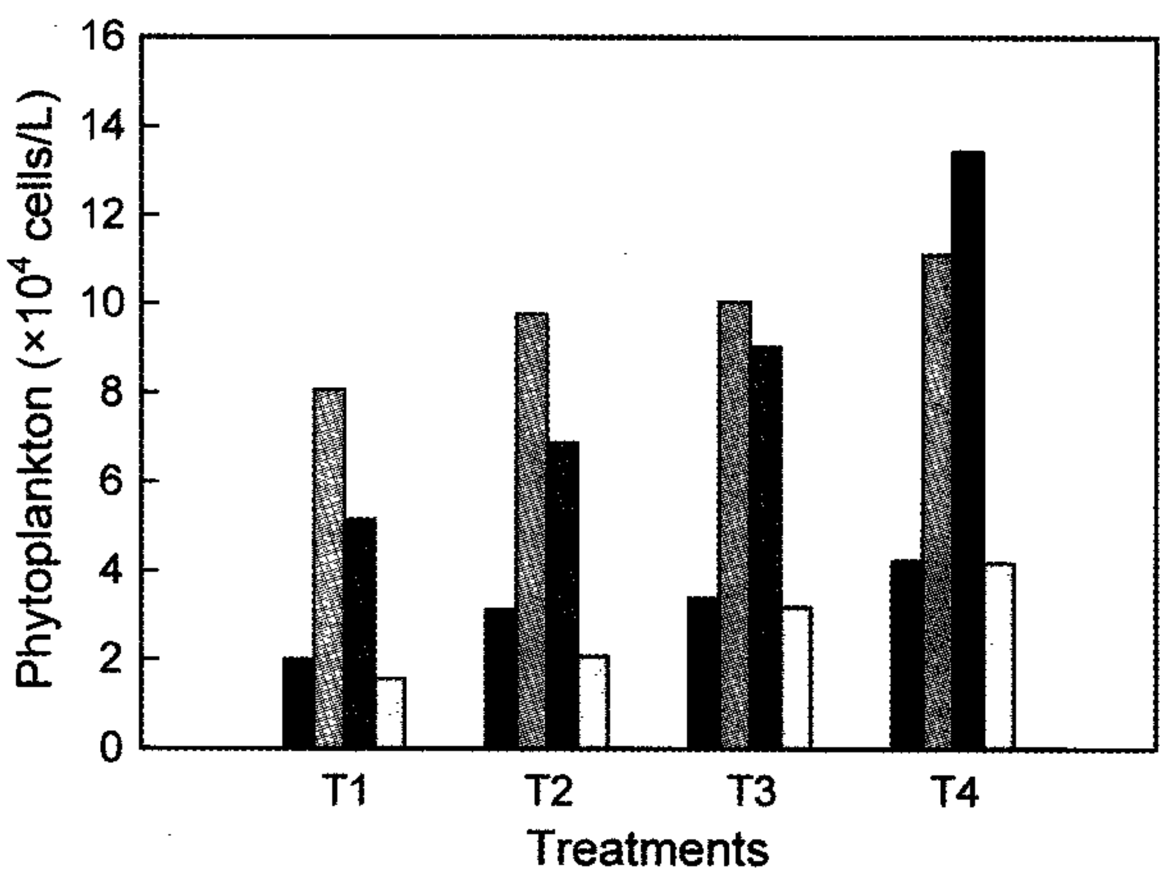

Fig. 3. The phytoplankton density of different groups (Bacillariophyceae, ■; Chlorophyceae, ■; Cyanophyceae, ■; Euglenophyceae, ■) in ponds of different treatments. These data are the mean value of the total study period.

study, pangasiid catfish were fed commercial pelleted feed, and the daily load of feed differed among treatments because of differences in pangasiid catfish density. Increases in plankton productivity, NO_3-N, and PO_4-P with time were perhaps due to the increased feeding rate of pangasiid catfish. Cole and Boyd (1986) found increased concentrations of NO_3-N with increased feeding rates in aquaculture ponds. NO_3-N, PO_4-P, chlorophyll-*a,* and phytoplankton density were highest in T_4 and lowest in T_1. The daily feed loading was highest in T_4 because it had the highest number of pangasiid catfish. Thus, fish feed waste is assumed to be highest in T_4, which could have supplied more NO_3-N and PO_4-P to pond water through microbial decomposition and could have increased algal proliferation. Ponds that receive fish feed have abundant phytoplankton growth because roughly 75% of the nutrients in the feed eventually reach the water as excretory products (Boyd 1973, 1985). The dissolved oxygen concentration declined gradually with time in all treatment ponds. This decline might be due to the higher consumption of dissolved oxygen with higher fish biomass at the end of the study. Phytoplankton density was markedly higher in treatments with pangasiid catfish; this result could explain why catla and rohu grew faster in those treatments. The higher growth rate of catla and rohu resulted in higher total carp production. Increased carp growth and the extra production of pangasiid catfish increased total fish production and economic gain in polycultures of catla, rohu, and mrigal with pangasiid catfish. The results of this study indicate that inclusion of 5,000 pangasiid catfish per ha in polycultures of catla, rohu, and mrigal, keeping their density and ratio the same, can increase fish production and economic gain in Bangladesh.

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