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Growth and Production of Planktivorous Fish Species in Cages Stocked as Monoculture and Polyculture at Khapuadi in Phewa Lake, Nepal

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Abstract

Growth and production of planktivorous fish species were conducted from 6 November 2009 to 6 August 2010 in 15 outdoor experimental cages of 50 m^3 with nylon netting of 25 mm mesh size. These cages were located at Khapaudi, Phewa Lake, Nepal. The growth rate of silver carp ($0.32\pm0.01 g\cdot day^{-1}$) in the monoculture system was found to be significantly higher ($P<0.05$) than that in the polyculture system in different stocking ratios at 7:3, 1:1 and 3:7 of silver carp, *Hypophthalmichthys molitrix* (Valenciennes, 1844) and bighead carp, *Aristichthys nobilis* (Richardson, 1845) in cage culture at Khapaudi. But the growth rate of bighead carp ($0.48\pm0.02 g\cdot day^{-1}$) in monoculture was found significantly lower than that in the polyculture with silver carp. The extrapolated net production was 1.55 $kg\cdot m^{-3}\cdot yr^{-1}$ and was best at 3:7 stocking ratio of silver carp to bighead carp. The farmers of Phewa Lake can stock fish seed at 3:7 stocking ratio of silver carp to bighead carp to obtain maximum yield per unit area of cage volume.

Introduction

The subsistence cage fish farming in Nepal depending on natural productivity of the water bodies is often cited as an environment friendly livelihood approach (Gurung and Bista 2003). The livelihoods of the Jalari community (a deprived ethnic and traditional community), living around the Phewa Lake of Pokhara is entirely dependent on cage aquaculture and fishery in Phewa Lake (Gurung and Bista 2003; Gurung 2003; Gurung et al. 2005; Wagle et al. 2007; Nepal 2008). Extensive cage fish culture is an appropriate enterprise for small-scale farmer and is one of the cheaper ways of fish production. Farming of plankton feeding fish is eco-friendly as it helps to remove the nutrient and organic load entering the lake (Pradhan and Pantha 1995). Extensive cage fish farming is considered sustainable farming in Phewa Lake as it mitigates eutrophication.

Cage fish culture was introduced in Nepal in 1972 at Lake Phewa, Pokhara Valley (Swar and Pradhan 1992). Total cage culture in Nepal occupied 80,000 m^3 volume of water with fish production of 480 tonnes and productivity at 6.0 $kg\cdot m^{-3}$ in 2007/08(DOFD 2007/08).

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There are 75 lakes in Nepal (Shrestha and Jha 1993) with an estimated area of 5,000 ha occupying 0.6% of water resource of the country (DOFD 2007/08), and in Pokhara Valley the extent of lakes is 1,000 ha which is utilised for aquaculture (Wagle et al. 2007). It is estimated that 92,400 ha of reservoir will be available for cage fish farming in the near future (Pradhan 2009).

Pokhara has eight lakes of varying sizes. Among them, Phewa, Begnas and Rupa are utilised for cage fish culture using planktivorous fish species. Phewa Lake (523 ha) is the biggest lake in Pokhara Valley and is located at the southwestern edge of Pokhara Valley (28º 1’ N, 82º 5’ E, alt. 742 m) (Ferro and Swar 1978). The total number of fish cages in 2010 was 636 with a volume of 26,074.0 m^3 in Phewa Lake.

Approximately 200 households of Jalari live around the Pokhara Valley and about 80 families live around the Phewa Lake (Nepal 2008). These 80 families still have no farming land and are continuing their traditional occupations of fishing and cage aquaculture. Farmers were getting low yields per unit area of cage due to the lack of proper stocking composition of fish species in Phewa Lake. In the present study, an attempt was made to find out the best stocking composition of planktivorous fish species for getting maximum yield per unit volume of cage at Khapaudi.

Materials and Methods

Experimental Location

This experiment was conducted at Khapaudi which is located in the northern part of Phewa Lake. The lake is situated at the southwestern edge of Pokhara Valley with a watershed area of approximately 110 km^2 (Ferro and Swar 1978). The total surface area of the lake was estimated at 500 ha by Ferro and Swar (1978), while Rai et al. (1995) reported 523 ha.

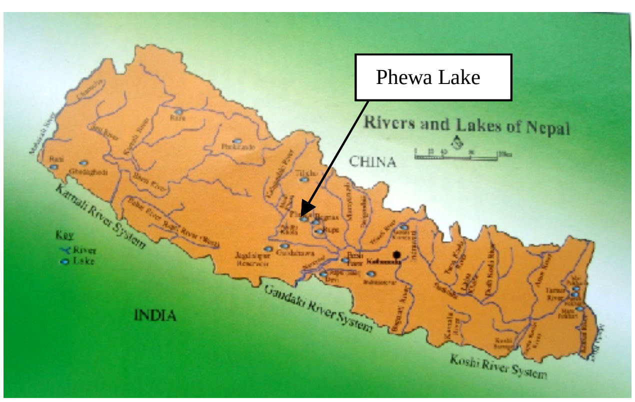

Fig.1A. Rivers and lakes of Nepal.

Fig.1B. Experimental cages at Khapaudi in Phewa Lake.

Site selection and experimental setup

The experiment was conducted from 6 November 2009 to 6 August 2010 in 15 outdoor experimental cages of 50 m^3 (5 m×5 m×2 m). The cages were made of nylon threads of 25 mm mesh size and fixed to galvanised angle iron frame with styrofoam drums (Fig.1B). The planktivorous fish species, silver carp *Hypophthalmichthys molitrix* (Valenciennes, 1844) and bighead carp *Aristichthys nobilis* (Richardson, 1845) were selected for the study.

A completely randomised design (CRD) was used with five treatments and three replicates to each treatment. The five treatments were: 1 (silver carp 100%), 2 (bighead carp 100%), 3 (bighead carp 50% and silver carp 50%), 4 (silver carp 30% and bighead carp 70%) and 5 (silver carp 70% and bighead carp 30%). All these fish were of the same stock and were obtained from Fisheries Research Center, Pokhara.

The cages were removed from the water and were cleaned with water by brushing manually and dried in sunlight. All 15 cages were installed again as per the experimental design.

Stocking was done at the density of 10 fish·m^{-3}. The individual and batch weight, and length of fish were determined on the day of stocking. Stocking weight of silver carp ranged from 5.8 g to 31.0 g (mean±SD, 15.02±6.24 g) and bighead carp ranged from 5.4 g to 32.0 g (mean±SD, 12.5±6.8 g). Cages were inspected weekly for fouling. The manual cage cleaning with plastic brush was done fortnightly whenever needed. Fish health was also checked weekly for diseases and parasites.

Water quality

Water samples were collected at depths of 0.5 m (at surface) and 2.5 m from three spots within the frame of experimental cages and one spot from just 3m outside the frame of the cage for water quality measurements. Water samples were collected with a 2 L capacity Van Dorn water sampler. The water quality parameters determined weekly were temperature, pH, dissolved oxygen (DO) and Secchi-disc depth. Monthly water sampling was done for the determinations of total ammonium-nitrogen, nitrite- and nitrate-nitrogen, soluble reactive phosphorus (SRP), total phosphorus (TP), chlorophyll-a, zooplankton, phytoplankton and primary productivity. The DO concentration was measured by using Winkler’s method. The water temperature was measured with a mercury thermometer, the pH with a digital pH meter and transparency measured with 20 cm secchi-disc. Lake water was passed through pre-combusted GF⁄C filters (at 450 °C for 2 hr) for SRP, ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen and TP analysis. The standard methods involved in the nutrient analysis of water were ammonium-nitrogen (NH_4-N) by Bower and Hansen (1980), nitrite-nitrogen (NO_2-N) and nitrate-nitrogen (NO_3-N) by Downes (1978), and phosphate–phosphorous (PO_4-P) by Murphy and Riley (1962). Chlorophyll-a samples were obtained by filtering the lake water through Whatman GF⁄C glass fibre filters (≈1.2 µm pore size). Before extraction, chlorophyll-a samples were refrigerated in a sealed plastic container with silica gel.

Chlorophyll-a was determined using a spectrophotometer (SSI UV2101, China) according to the method of Lorenzen (1967). Primary production was measured in situ once a month using the light and dark bottle method and Winkler oxygen analysis. The collected phytoplankton samples were fixed with acid Lugal's solution, and subsequently enumerated quantitatively with a haemocytometer after concentrating 200 mL water samples to 0.2-0.4 mL overnight by sedimentation (Rai 2000a). Zooplankton samples were obtained by passing 10 L water through the plankton net (<75 µm) in each depth. Zooplankton samples were anaesthetised with 3% procaine and preserved in 5% formalin. Zooplanktons were identified and enumerated under a compound microscope (Nikon Optiphot-2, Japan) following the methods described by Masuda and Pradhan (1988).

Fish growth measurement

Monthly fish growth was monitored using at least 15% population of fish in each treatment and replicate. Individual and batch weight of experimental fishes were measured.

Data analysis

One-way analysis of variance (ANOVA) using SPSS (version 12) statistical software package (SPSS Inc., Chicago) was employed to investigate whether growth rates and survival rates of fish in the treatments were significantly different. Differences among treatment means were determined by using LSD test. The differences were considered significant at the level of 5% ($P<0.05$). All means were provided with ±1 S.E.

Results

Fish growth and survival

Mean stocking weight and harvesting weight, growth rate ($g \cdot day^{-1}$) of silver carp and their survival rate during the experimental period in different treatments are shown in Table 1. The trend of monthly weight gain (g) in silver carp is presented in Fig. 2. Mean stocking weight was not significantly different ($P>0.05$) among treatments. However, mean harvesting weight and growth rate were significantly higher ($P<0.05$) in treatments T_1 than T_3, T_4 and T_5. Mean harvesting weight was not significantly different ($P>0.05$) among T_3, T_4 and T_5. Growth rate of silver carp was not significantly ($P>0.05$) different between treatments T_3 and T_4. Similarly, growth rates in treatments T_3 and T_5 were also not significantly different ($P>0.05$) but that in T_4 was significantly different ($p<0.05$) from T_5. Survival was significantly higher ($P<0.05$) in T_3 than T_1, T_4 and T_5. Survival was not significantly different ($P>0.05$) between treatments T_4 and T_5 and treatments T_4 and T_1. Treatment T_5 showed the lowest fish survival among treatments (Table 1).

Table. 1. Mean stocking weight, harvesting weight, growth rate and survival of silver carp (Mean±S.E.) in different treatments.

Parameters	Treatments			
	T_1(Monoculture)	T_3 (1SC: 1BC)	T_4(3SC:7BC)	T_5 (7SC: 3BC)
Mean stocking weight (g)	14.7 ± 0.5^a	14.9 ± 0.2^a	15.1 ± 0.2^a	15.6 ± 0.2^a
Mean harvesting weight (g)	102 ± 2.2^a	88.6 ± 2.2^b	90.6 ± 2.2^b	83.9 ± 2.2^b
Growth rate(g·day^{-1})	0.32 ± 0.01^a	0.27 ± 0.01^{bc}	0.28 ± 0.01^b	0.25 ± 0.01^c
Survival (%)	90.1 ± 0.7^b	94.3 ± 0.7^a	88 ± 0.7^{bc}	86.1 ± 0.7^c

Mean values with same superscript in the same row are not significantly different (P>0.05)
SC=silver carp; BC=Bighead carp

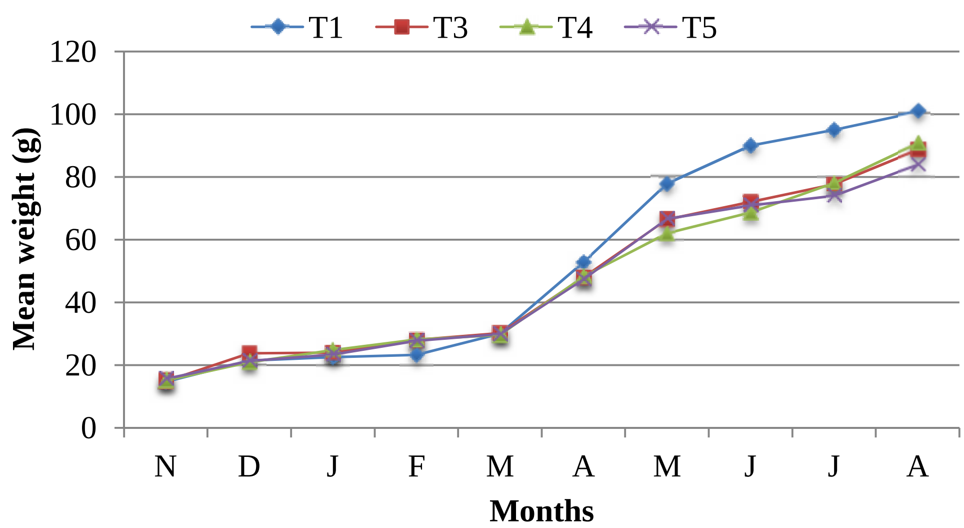

Fig. 2. Monthly mean weight gain (g) of silver carp in different treatments.

Mean stocking weight and harvesting weight, survival rate and growth rate of bighead carp in different treatments are shown in Table 2. The trend of monthly weight gain (g) of bighead carp during the experimental period is presented in Fig. 3. The mean stocking weight was not significantly (P>0.05) different among treatments. Mean harvesting weight and growth rate of bighead carp were significantly higher (P<0.05) in treatment T_5 than in treatment T_2 but not significantly different (P>0.05) from treatments T_3 and T_4 (Table 2). Mean survival rate of bighead carp was significantly higher (P<0.05) in T_3 than T_2, T_4 and T_5. The lowest survival was found in T_2 among treatments (Table 2). The mean weight of bighead carp at harvest was highest in treatment T_5, followed by treatment T_3, T_4, and T_2. The mean weight of bighead carp at harvest in treatments T_3, T_4 and T_5 were not significantly different (P>0.05). The result showed that mean weight at harvest increased with decreased stocking density of bighead carp but treatment T_2 was significantly diffrent (p<0.05) from treatments T_3,T_4 and T_5.

Table. 2. Mean stocking and harvesting weights, growth and survival of bighead carp (Mean ± S.E.) in treatments.

Parameters	Treatments			
	T_2(Monoculture)	T_3 (1SC: 1BC)	T_4(3SC:7BC)	T_5 (7SC: 3BC)
Stocking mean weight (g)	12.4 ± 0.6^a	12.3 ± 0.6^a	12.7 ± 0.6^a	12.4 ± 0.6^a
Harvest mean weight (g)	142.9 ± 3.9^b	173.1 ± 3.9^a	171.1 ± 3.9^a	176.2 ± 3.9^a
Growth (g day^{-1})	0.48 ± 0.02^b	0.59 ± 0.02^a	0.59 ± 0.02^a	0.60 ± 0.02^a
Survival (%)	89.6 ± 1.1^b	95.1 ± 1.1^a	92.6 ± 1.1^{ab}	91.3 ± 1.1^b

Mean values with same superscript in the same row are not significantly different (P>0.05).
SC=silver carp; BC=Bighead carp.

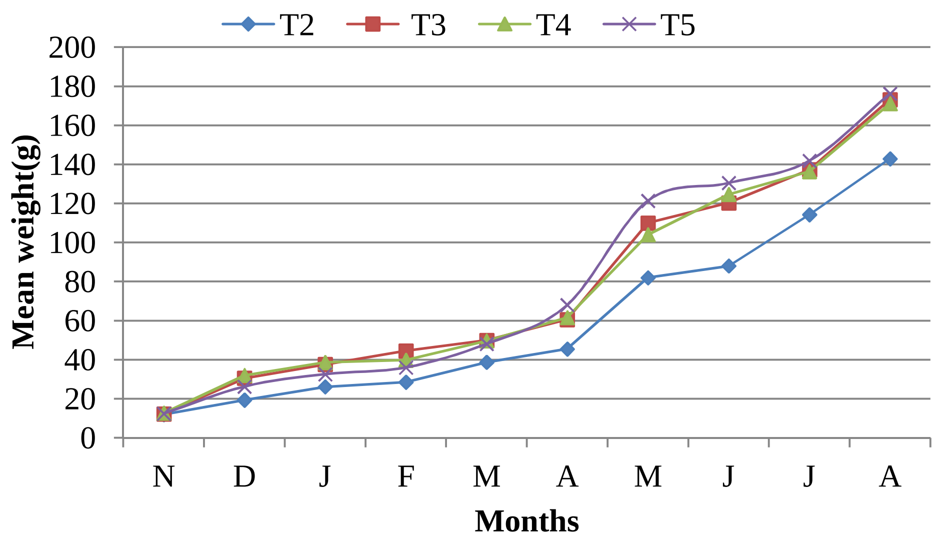

Fig. 3. Monthly mean weight gain (g) of bighead carp in different treatments.

Fish production

Total stocking weight, total harvesting weight and net fish yields (NFY) of treatments are shown in Table 3. Total stocking weight of experimental fish was significantly higher (P<0.05) in treatments T_1 and T_5 than in treatments T_2, T_3 and T_4. Total harvesting weight, net fish yield (kg), extrapolated net fish yield (kg·m^{-3}·yr^{-1}) were significantly higher (P<0.05) in T_4 than in T_3, T_2, T_5 and T_1. However, total harvesting weight, net fish yield (kg), extrapolated net fish yield (kg·m^{-3}·yr^{-1}) were not significantly different (P>0.05) between treatment T_1 and T_5 and treatment T_2 and T_3. These values in treatment T_2 and T_3 were higher and significantly different (P<0.05) than treatment T_1 and T_5. Survival rate was significantly higher (P<0.05) in treatments T_3 than T_4, T_2, T_1 and T_5 while T_1, T_2 and T_4 were not significantly different (P>0.05) .Treatment T_5 showed the least survival percentage (87.7±0.7%) among all the treatments with significant difference (P<0.05) from the rest of the treatments.

Table 3. Total stocking and harvesting weight (kg), survival (%) and NFY, extrapolated NFY of experimental fish in different treatments (Mean±S.E.). SC=silver carp; BC=Bighead carp

Parameter	Treatment				
	T_1 (SC)	T_2 (BC)	T_3 (1SC:1BC)	T_4 (3SC:7BC)	T_5 (7SC:3BC)
(Kg·cage^{-1})					
Total stocking weight	7.3 ± 0.2^{a}	6.23 ± 0.2^{c}	7.1 ± 0.2^{ab}	6.7 ± 0.2^{bc}	7.3 ± 0.2^{a}
Total harvesting weight	45.2 ± 1.3^{c}	59.0 ± 1.3^{b}	60.0 ± 1.3^{b}	64.7 ± 1.3^{a}	48.1 ± 1.3^{c}
NFY	37.9 ± 1.2^{c}	52.8 ± 1.2^{b}	53.2 ± 1.2^{b}	58.0 ± 1.2^{a}	40.8 ± 1.2^{c}
Survival (%)	90.1 ± 0.7^{b}	89.6 ± 0.7^{bc}	94.7 ± 0.7^{a}	91.2 ± 0.7^{b}	87.7 ± 0.7^{c}
Extrapolated NFY (kg·m^{-3}·yr^{-1})	1.01 ± 0.03^{c}	1.41 ± 0.03^{b}	1.42 ± 0.03^{b}	1.55 ± 0.03^{a}	1.09 ± 0.03^{c}

Mean values with same superscript in the same row are not significantly different (P>0.0)

Fish growth and seasonal effect

Silver carp growth rate was the highest in April-May 2010 (0.64±0.06 g·day^{-1}) followed by August 2010 (0.34±0.06 g·day^{-1}). The growth rate of silver carp was the lowest in January-March 2010 (0.09±0.06 g·day^{-1}) and growth rate was also slow (0.22±0.06 g·day^{-1}) from June–July 2010 and December 2009. Maximum growth rate of bighead carp was found in the month of May 2010 (1.5±0.08 g·day^{-1}) followed by August 2010 (1.11±0.08 g·day^{-1}). The growth rate of bighead carp from January-March 2010 was slow (0.22±0.05 g·day^{-1}). The growth rate of bighead carp in April, June, July in 2010 and December in 2009 was 0.46±0.06 g·day^{-1}.

Temperature played a positive role on the growth of both fish species. Fish growth rate was very slow in winter months (January-February) when temperature was below 20 °C. General growth trends in both species showed that growth was faster in early summer (April to May), relatively slower in early rainy season (June to July) and slowest in winter season (January to February) (Fig. 4.)

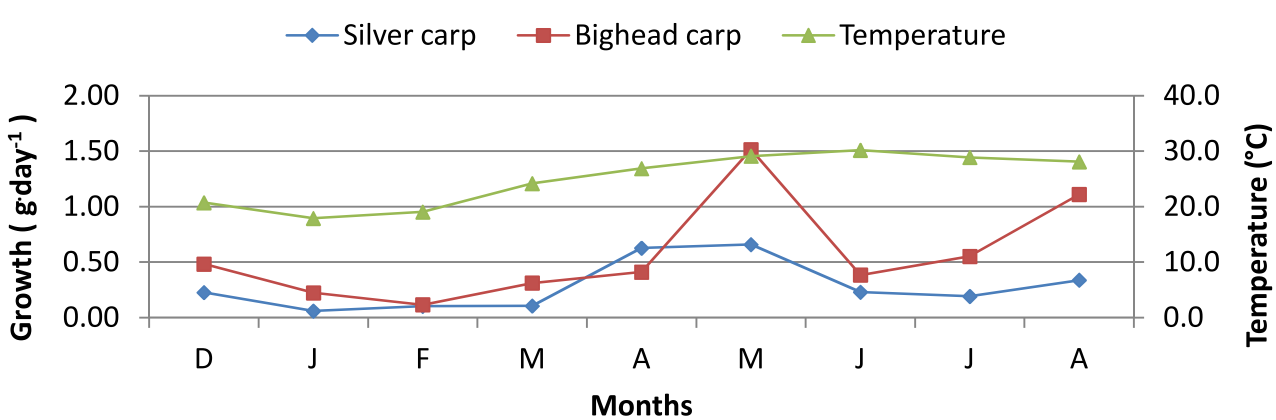

Fig.4. Monthly mean fish growth rate of silver and bighead carp with relation to temperature.

Water quality analysis

Mean (±SE) and range values of water quality parameters are presented in Table 4. The lowest temperature (17.0 $^{\circ}$C) was recorded during the experimental period in January 2010 at 2.5 m while highest (31.5 $^{\circ}$C) in June 2010 at the surface. The temperature began to increase from March, with increasing photoperiod.

Table 4. Mean and range values of water quality parameters during the experiment.

Parameters	Mean±SE	Range
Physical parameters		
Water temperature ($^{\circ}$C)	24.8 ± 0.06	17.0-31.5
Transparency (m)	2.5 ± 0.13	1.5 - 4.0
Chemical parameters		
Dissolved oxygen ($mg\cdot L^{-1}$)	6.6 ± 0.2	3.8 - 9.2
pH	6.8	6.0 - 8.5
Nutrient parameters		
Ammonium (NH_4^+) nitrogen ($mg\cdot L^{-1}$)	0.002 ± 0.000	0.0 - 0.009
Nitrate(NO_3^-) + nitrite(NO_2^-) nitrogen ($mg\cdot L^{-1}$)	0.006 ± 0.001	0.0 - 0.027
Soluble reactive phosphorus($mg\cdot L^{-1}$)	0.002 ± 0.000	0.0 - 0.005
Total Phosphorus ($mg\cdot L^{-1}$)	0.004 ± 0.001	0.0 - 0.016
Biological parameter		
Chlorophyll a ($mg\cdot m^{-3}$)	10.8 ± 1.5	2.3 - 29.8
Gross primary productivity ($gC\cdot m^{-2}\cdot day^{-1}$)	1.65 ± 0.28	0.57 - 3.21
Net primary productivity ($gC\cdot m^{-2}\cdot day^{-1}$)	1.05 ± 0.22	0.21 - 2.28
Zooplankton($No\cdot L^{-1}$)	155.0	40.0 -285.0
Phytoplankton($Cells\cdot mL^{-1}$)	1348.0	523.0 -3607.0

Chlorophyll- a concentration in lake water was not consistant and changed seasonally. It was above 20.0 $mg\cdot m^{-3}$ in December and March with maximum (29.8 $mg\cdot m^{-3}$) at 2.5 m in March 2010 and minimum (2.3 $mg\cdot m^{-3}$) at surface in June 2010. Chlorophyll-a concentration was found below 10 $mg\cdot m^{-3}$ during Januray-February and April to June in 2010.

Five phyla and 21 species of phytoplankton were recorded in Phewa Lake during the study period. The highest total phytoplankton (3.6×10^3 $cells\cdot mL^{-1}$) was observed in March 2010 with species *Microcystis aeruginosa* (1.97×10^3 $cells\cdot mL^{-1}$) being dominant. From April to July, phytoplankton abundance was above 1.0×10^3 $cells\cdot mL^{-1}$. Cyanophyceae occupying 38% of the total phytoplankton community, dominated in Phewa Lake, and this was followed by Chlorophyceae (31%), Bacillarophyceae (17%) and Dinophyceae (14%).

Twenty seven species of zooplankton were recorded during the study period. The composition of zooplankton varied seasonally and zooplankton mass comprised of 71% copepods, 24% rotifers, and 5% cladocerans. The total zooplankton density increased in the lake from November 2009 to January 2010 with maximum ($285 \cdot L^{-1}$) in January 2010 and declined from February and reached lowest density ($40 \cdot L^{-1}$) in March 2010.

Discussion

Fish growth and survival

The growth rate of silver carp ($0.32 \pm 0.01 g \cdot day^{-1}$) in the monoculture system was found significantly higher ($P<0.05$) than that in the polyculture with bighead carp in different stocking ratios like 7:3, 1:1 and 3:7 of silver carp and bighead carp in cages at Khapaudi (Table 1). But the growth rate of bighead carp ($0.48 \pm 0.02 g \cdot day^{-1}$) in monoculture was found significantly lower than that in the polyculture with silver carp (Table 2). Much contradictory information exists on the food habits of silver and bighead carp (Lazareva et al. 1977; Opuszynski 1981; Burke et al. 1986). Growth of silver carp is influenced primarily by food availability (Tripathi 1989). Silver carp feeds primarily on phytoplankton, and also feeds on zooplankton, invertebrates, detritus, and bacteria, especially when phytoplankton abundance is low (Kolar et al. 2007). Bighead carp feeds on both phytoplankton and zooplankton, and phytoplankton constitutes a substantial part of its food (Burke et al. 1986; Opuszynski and Shireman 1993). The present authors believe that in polyculture systems, bighead carp may impact on growth of silver carp as the former may compete for food. Filter feeding by bighead carp affects the composition and size structure of the plankton community by reducing densities of zooplankton and large phytoplankton (Stone et al. 2000). Silver carp may not be able to meet energy requirements consuming phytoplankton alone (Bitterlich 1985). Consumption rate of bighead carp which feeds voraciously, is high, but food consumption rate of silver carp is inconsistent (Kolar et al. 2005). A number of research results revealed that bighead carp consumes phytoplankton as a major portion of its diet (Xie 1999; Rai 2000b). Gut content analyses of silver carp and bighead carp revealed that both species consumed phyto- and zooplankton, which were abundant in the lakes (Rai 2000b).

Fish Production

The mean harvested weight of silver carp ranged from 83.9±2.2 g to 102.0±2.2 g and that of the bighead carp ranged from 142.9±3.9 g to 176.2±3.9 g (Tables1 and 2). The fish did not reach marketable (>500 g) size in the present experiment due to the short culture period (9 months) including the winter months. The culture period to grow fingerlings to harvestable size is 12-24 months depending on the stocking size of the fish (Rai 2000b; Gurung 2003; Wagle et al. 2007; Nepal 2008). Extrapolated net fish yield was significantly higher ($1.55 \ kg \cdot m^{-3} \cdot yr^{-1}$) in stocking composition of 3:7 ratio of silver carp to bighead carp than monoculture of silver carp ($1.01 \ kg \cdot m^{-3} \cdot yr^{-1}$), monoculture of bighead carp ($1.41 \ kg \cdot m^{-3} \cdot yr^{-1}$), in the polyculture stocking ratio of 1:1 (1.42

$kg \cdot m^{-3} \cdot yr^{-1}$) and 7:3 ratio (1.09 $kg \cdot m^{-3} \cdot yr^{-1}$) of silver carp to bighead carp (Table 3). However, extrapolated net fish yield ($kg \cdot m^{-3} \cdot yr^{-1}$) was not significantly different ($P>0.05$) between treatments of monoculture of silver carp (T_1) and 7:3 polyculture stocking ratio of silver carp to bighead carp (T_5), monoculture of bighead carp (T_2) and 1:1 polyculture of stocking ratio of silver carp to bighead carp. Monoculture of bighead carp (T_2) and 1:1 polyculture ratio of silver carp to bighead carp (T_3) were significantly higher ($P<0.05$) than monoculture of silver carp and 7:3 stocking ratio of silver carp to bighead carp (T_4). In culture system, bighead carp shows a high potential and better performance than silver carp in terms of net production (Opuszynski 1981).

Some studies reported net fish production from lakes of Pokhara Valley which differ from the finding of the present study. Sharma (1990) as cited in Wagle et al. (2007) reported 1.33 $kg \cdot m^{-3} \cdot yr^{-1}$ net fish production from cage culture in the lakes of Pokhara Valley which is lower than the present study. The net production in cages with stocking size of >80.0 g was 11.72 $kg \cdot m^{-3}$ for silver carp and 7.34 $kg \cdot m^{-3}$ for bighead carp in Lake Phewa during the 16-month culture periods (Rai 2000b). The net fish production in the present study was lower than those reported by Rai (2000b) in Phewa Lake possibly due to smaller stocking size and shorter culture period of fish in the present experiment. Gurung (2003) reported that the productivity of cage fish culture ranged from 3.0-5.0 $kg \cdot m^{-3} \cdot yr^{-1}$ based on results obtained from farmers' survey. According to Wagle et al. (2007), fish production ranged from 1.3-5.0 $kg \cdot m^{-3}$ in 12-18 months from cage culture in the Pokhara Valley Lake. Nepal (2008) reported that the average yield in cage fish culture of Phewa Lake was 1.41 $kg \cdot m^{-3} \cdot yr^{-1}$. The latter is similar to present findings of monoculture of bighead carp (1.41 $kg \cdot m^{-3} \cdot yr^{-1}$), and in the polyculture stocking ratio of 1:1 (1.42 $kg \cdot m^{-3} \cdot yr^{-1}$) but lower than present finding in stocking composition of 3:7 ratio of silver carp to bighead carp (1.55 $kg \cdot m^{-3} \cdot yr^{-1}$).

Fish growth and seasonal effect

The growth rate of both fish species showed seasonal variation in cages of Phewa Lake at Khapaudi. Faster growth rate was found in summer when temperature was above 20 ˚C (27-29 ˚C) while growth rate was slow in winter months when temperature was below 20 ˚C (17.0-19.0 ˚C) (Fig. 4). Silver carp and bighead carp required higher temperature for optimum growth (Rai, 2000b; Berday et al. 2005; Afzal et al. 2007). Maximum mean growth rate of silver carp was recorded in April-May 2010 (0.64±0.06 $g \cdot day^{-1}$) when temperature ranged from 27.0 to 29.1 ˚C. Mahboob and Sheri (1997) reported that water temperature for maximum growth of silver carp has to be 24-31 ˚C.

Maximum growth rate of bighead carp was found in May 2010 (1.5±0.08 $g \cdot day^{-1}$) when mean temperature was 29.1 °C. The zooplankton density of 198 L^{-1} and phytoplankton density of 1,477 $cells \cdot mL^{-1}$ were found during April to May 2010 which may have enhanced fish growth during this period. Afzal et al. (2007) reported that in pond experiment, higher monthly weight gain of bighead carp was found when temperature ranged between 26-32 °C. Best optimum temperature ranged between 26-32 °C for the bighead carp growth (Bettoli et al. 1985).

The growth rate of bighead carp ranged from 0.48±0.02 $g^{.}day^{-1}$ to 0.60±0.02 $g^{.}day^{-1}$ and that of silver carp ranged from 0.25±0.01 $g^{.}day^{-1}$ to 0.32±0.01 $g^{.}day^{-1}$ (Table 1and 2). These values were much lower as compared to those reported by Rai (2000b), who reported the average growth rates of silver carp as 2.41 $g^{.}day^{-1}$ and bighead carp as 1.52 $g^{.}day^{-1}$ in Lake Phewa. This may be due to smaller stocking size in this study and also different culture period. The present study revealed that bighead carp performed better than silver carp in cage culture in Phewa Lake. In polyculture pond systems, average monthly weight gain of bighead carp (84.28 g) was reported to be higher from the rest of major and Chinese carps (Afzal et al. 2007). Also in terms of net production, bighead carp was reported to show a better performance than silver carp in culture systems (Opuszynki 1981).

Water quality

Water quality of Phewa Lake fluctuated seasonally and influenced the growth of cultured fish species in cages at Khapaudi of Phewa Lake during the study period. Water temperature (17-19 °C) from January 2010 to February 2010 was not suitable for fish growth. Increased water temperature after March 2010 influenced fish growth. The dissolved oxygen was optimum (mean 6.6) throughout the study period. The pH value remained mostly within the range of 6.0–8.5 during the study period (Table 4) that is suitable for aquaculture (Boyd 1984).

Conclusion

The net production and net profit were the best at 3:7 stocking ratio of silver carp to bighead carp. The bighead carp in all stocking combinations showed better performance than silver carp. Growth was affected due to stocking combination in both species. Growth of both species cultured in cages was found retarded during the winter period and increased during the summer season. On the basis of our findings, the best stocking combination of silver carp to bighead carp is 3:7, and this ratio can be recommended to the farmers of Khapaudi in Phewa Lake to get maximum yield per unit volume of cage. There are great prospects of expansion of cage fish farming in Nepal as the reservoir areas occupy up to 92,400 ha.

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