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The effects of partially substituting Indian carps or adding silver carp on polycultures including small indigenous fish species (SIS)

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ABSTRACT

A sustainable semi-intensive pond aquaculture technology including major carp species (Indian, Chinese and common carp) as cash-crop and small indigenous fish species (SIS) as food for the farmers' families is being optimized in Bangladesh. Silver carp inclusion in the polyculture is now being considered, because this very efficient filter feeder has a strong impact on pond ecology and also on the farmers' family nutrition because it is a cheap fish that the family can afford to eat instead of selling. The present paper is centered on the reduction of silver carp negative effects on other species while keeping the advantages of increased total yield and income due to silver carp stocking. It presents the results of two experiments, one on-station and one on-farm, in which 3–5 silver carp/100 m^2 were added or partially substituted major carp filter feeders. The basic stocking density was 100 carps (rohu, catla and a bottom feeder, either mrigal or common carp, at a 1:1:1 ratio) and 250 SIS (punti and mola) per 100 m^2. In the on-station experiment silver carp density was 3 and 5 fish/100 m^2 and the large carp bottom feeder was common carp. In the on-farm experiment silver carp density was 5 fish/100 m^2 and the bottom feeder was either common carp or mrigal.

Most of the water quality and fish performance parameters tested were not affected by the polyculture composition. Adding 3–5% silver carp or substituting 3–5% of the herbivorous fish species by this highly efficient filter feeder increased grazing pressure on the phytoplankton, which led to a 25–40% reduction of the chlorophyll concentration in the water column. The increased grazing pressure was not enough to affect other water quality parameters and fewer effects on the availability of food for the other fish species occurred than when the silver carp addition was 10% of the polyculture, as reported in a previous work. The strong negative effects of silver carp on the other species of the polyculture and the higher total yields and income recorded in previous experiments with the addition of 10 silver carp/100 m^2 were much weaker and their expression depended on other pond conditions when 3 or 5 silver carp/100 m^2 were added or substituted the same number of rohu or catla, either when the bottom feeder was mrigal or common carp. It was concluded that stocking 3 silver carp/100 m^2 over the usual 100 large carp and 250 SIS /100 m^2 can be considered a 'no effect' stocking density in relation to the control without silver carp, while stocking 10 silver carp/100 m^2 should be preferred by farmers to keep the option of selling or consuming the silver carp.

1. Introduction

A sustainable semi-intensive pond aquaculture technology including major carp species as cash-crop and small indigenous fish species (SIS) as food for the farmers' families is being optimized in Bangladesh. Initially, the optimization of the cash-SIS technology was directed to interfere on the pond bottom through the bottom feeding fish (Wahab et al., 2002; Milstein et al., 2002; Wahab et al., 2003; Alim et al., 2004, 2005). The polyculture combinations studied included rohu (*Labeo rohita*) and catla (*Catla catla*) that are filter feeders (Jhingran and Pullin, 1985), the bottom feeders mrigal (*Cirrhinus cirrhosus*) and common carp (*Cyprinus carpio*), and the SIS punti (*Puntius sophore*) and mola (*Amblypharyngodon mola*) that are respectively a bottom feeder and a filter feeder (Miah and Siddique, 1992; Kohinoor, 2000). Currently the research concentrates on the intervention in the water column through the addition of silver carp (*Hypophthalmichthys molitrix*). This fish has ecological and socio-economic potential advantages: it is expected to have a strong impact on the pond ecology because it is a very efficient filter feeder (Milstein et al., 1985a, b; Milstein, 1992), and also on the farmers' family nutrition because it is a cheap fish that the family can afford to eat instead of selling. Both types of impacts were recorded in previous studies when 10–20 silver carp /100 m^2 were added to cash-SIS polycultures with either common carp or mrigal as bottom feeders (Kadir et al., 2006, 2007; Milstein et al., 2006). Through its impact on the natural food web silver carp had several negative effects on the growth of the other fish, while the total yield and income increased.

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Table 1
On-station experiment: overall mean and standard deviation of variables that did not present significant differences among treatments

Fish species	Variable	Unit	Mean	Standard deviation
Rohu	Survival	%	97	3
Catla	Harvesting weight	g	181	96
	Growth rate	g/day	0.89	0.54
Common carp	Harvesting weight	g	184	30
	Harvesting biomass	kg/100 m^2	5.9	0.9
	Survival	%	95	4
	Growth rate	g/day	0.90	0.18
	Yield	kg/100 m^2	5.8	0.9
Punti	Total yield	kg/100 m^2	2.41	1.07
	Total harvesting biomass	kg/100 m^2	2.81	1.09
	Biomass of small (3 g) punti	kg/100 m^2	0.80	0.36
	Biomass of medium (8.5 g) punti	kg/100 m^2	1.10	0.41
	Biomass of large (18.5 g) punti	kg/100 m^2	0.90	0.32
Mola	Total yield	kg/100 m^2	2.52	1.22
	Total harvesting biomass	kg/100 m^2	2.78	1.22
	Biomass of small (3 g) mola	kg/100 m^2	1.17	0.76
	Biomass of medium (8.5 g) mola	kg/100 m^2	1.14	0.44
	Biomass of large (18.5 g) mola	kg/100 m^2	0.48	0.23
Large carp	Harvesting biomass	kg/100 m^2	22.3	4.5
	FCR		3.2	0.35
Total fish	Harvesting biomass	kg/100 m^2	27.9	3.5
	Yield	kg/100 m^2	25.9	3.5

The next step in the optimization of the cash-SIS technology was centered on the reduction of silver carp negative effects on other species while keeping the advantages of increased total yield and income. This was tried reducing silver carp stocking density to decrease interspecific competition, combined with a reduction of each filter feeder density to decrease intraspecific competition and with the presence of two different bottom feeders. SIS stocking rate was kept constant. The present paper presents the results of two such experiments, one on-station and one on-farm, in which silver carp was added or partially substituted major carp filter feeders. In the on-station experiment, silver carp density was reduced to 3 and 5 fish/100 m^2 and the bottom feeder was common carp. In the on-farm experiment, silver carp density was reduced only to 5 fish/100 m^2 and the bottom feeder was either common carp or mrigal.

2. Methods

The experiments were performed simultaneously at the Fisheries Field Laboratory, Bangladesh Agricultural University, Mymensingh (BAU) and in farmers' ponds in the Tarakanda village of Fulpur Upazila in the Mymensingh district. Before starting the experiments agricultural lime ($CaCO_3$) at 2.5 kg/100 m^2 and fresh cattle manure (6.5 kg/100 m^2) were applied. Manuring was repeated fortnightly throughout the culture season.

The on-station experiment was carried out in 18 ponds of 100 m^2 area and 1 m mean depth each. The experiment had 6 treatments, 3 replicates per treatment. In the control treatment (Control) stocking was 33 rohu (mean stocking weight 27 g), 33 catla (23 g), 34 common carp (5 g), 125 mola (2.1 g) and 125 punti (3.2 g) per 100 m^2, and no silver carp was present. In the other treatments 3 or 5 silver carp/100 m^2 (35 g) were added (SC_add) or substituted either rohu (R_subst) or catla (Ct_subst). Stocking was on 1-Apr-06 and harvesting on 1–4 October-06. Fish were weighed monthly to adjust feeding amounts. Supplementary feed consisted of rice bran and soaked oil cake (2:1), given daily at a rate of 3% of the large carps body weight.

The on-farm experiment was carried out in 40 farmers' fish ponds. The pond area ranged from 220 to 680 m^2 and had 1 m mean depth. The experiment had 8 treatments in a 2×4 factorial design, 5 replicates per treatment. The basic stocking density was the same as in the on-station experiment. The 2-level factor was bottom feeder, either common carp (C) or mrigal (M). The 4-level factor was large carp composition: no silver carp present (Control), addition of 5 silver carp/100 m^2 (SC_add), substitution of 5 rohu/100 m^2 (R_subst) or of 5 catla/100 m^2 (Ct_subst) by silver carp. Fish were stocked on 6-Jun-06, and were harvested on 10–20 Dec-06. Weighing, manuring and feeding practices were the same as in the on-station experiment. Inorganic fertilization was not planned to be performed, but some farmers applied urea and triple super phosphate in some occasions, and extra liming when a surface scum developed.

Pond water sampling was performed always at around the same hour (9:00 AM). When a surface scum was present, in-situ measurements were done under the scum and samples for laboratory analyses were taken agitating the water to remove it. At 7 day intervals on-station and 15 days intervals on-farm data were collected on temperature, dissolved oxygen (YSI, model 58), pH (Jenway, model 3020), and water depth. At 15 and 30 day intervals respectively on-station and on-farm, samples for phosphate and nitrogen compounds ($P–PO_4$, $N–NH_4$, $N–NO_2$, $N–NO_3$, HACH Kit DR/2010), total alkalinity and chlorophyll-*a* (standard procedures, APHA, 1992) were collected and transparency (Secchi disk) was measured.

On-station fish data were analyzed with one-way-ANOVA and water quality data with repeated measurements ANOVA with treatment as the main effect. In the on-farm data ANCOVA instead of ANOVA was used with pond size as covariate, and some runs with bottom feeder (presence of common carp or of mrigal) instead of treatment (8 different fish combinations) were also performed. Differences between treatments (or bottom feeder) were tested with

Table 2
On-station experiment: significant ANOVA and Duncan mean multicomparisons of rohu and catla harvesting parameters

ANOVA	Rohu weight (g)	Rohu biomass (kg/100 m^2)	Rohu growth (g/day)	Rohu yield (kg/100 m^2)	Catla biomass (kg/100 m^2)	Catla survival* (%)	Catla yield (kg/100 m^2)
Significance	(+)	*	(+)	*	(+)	*	(+)
r^2	0.48	0.55	0.48	0.54	0.50	0.65	0.49
Mean multicomparisons by treatment (n=3 per treatment)							
Control	338 a_	10.5 a_	1.76 a_	9.6 a_	8.2 a_	91 _b	8.0 a_
3_SC-add	298 ab	9.5 ab	1.55 ab	8.7 ab	7.8 ab	92 _b	7.7 ab
3_Ct-subst	236 ab	7.4 ab	1.18 ab	6.6 ab	3.9 ab	98 a_	4.7 ab
5_SC-add	221 _b	7.1 _b	1.11 ab	6.2 _b	3.4 _b	91 _b	3.2 _b
5_Ct-subst	208 _b	6.7 _b	1.02 _b	5.8 _b	4.6 ab	98 a_	4.4 ab
5_R-subst	236 ab	6.4 _b	1.17 ab	5.6 _b	4.1 ab	91 _b	4.0 ab

*Statistical tests based on transformed data. Values of means given untransformed.
r^2=coefficient of determination. ANOVA significance levels: *=0.05, (+)=0.1. Mean multicomparisons: different letters in each column indicate significant differences at the 0.05 level.