

The effect of common carp, *Cyprinus carpio* (L.) and mrigal, *Cirrhinus mrigala* (Hamilton) as bottom feeders in major Indian carp polycultures

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Abstract

A polyculture experiment with the large carp rohu, *Labeo rohita* (Hamilton), catla, *Catla catla* (Hamilton) and either mrigal, *Cirrhinus mrigala* (Hamilton) or common carp, *Cyprinus carpio* (L.) (as cash crop fish), and the small indigenous fish punti, *Puntius sophore* (Hamilton) (as food for the small-scale farmer family) was carried out at the Field Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. The main objective was to compare polycultures of large carp in which the bottom feeder is either the native mrigal or the exotic common carp. Secondary objectives were to assess the effects of adding the small indigenous species punti to polycultures of large carp, and to compare the effects of mrigal and common carp on punti production and reproduction. It was found that (i) common carp damaged embankments, had no effect on catla, improved rohu performance by 50% and total fish production by 20%; (ii) punti addition did not affect rohu, catla and total yield, improved mrigal performance by 50%, and decreased common carp performance by 20%; and (iii) punti was not affected either by common carp or by mrigal. However, its performance was not satisfactory, probably owing to frequent netting, which might have hindered growth and breeding. In spite of the embankment damage caused by common carp, this bottom feeder seems to be more promising than mrigal, because it leads to higher fish production. The addition of punti to the large carp polyculture is a viable proposition, as it does

not reduce cash crop production, and might be a good food source for a small-scale farmer's family.

Keywords: catla, common carp, mrigal, polyculture, punti, rohu

Introduction

Aquaculture in Bangladesh, as elsewhere in the South Asian region, has taken place on an *ad hoc* basis without giving adequate thought to the maintenance of biodiversity of its rich aquatic resources. About six or seven species of large carp, both of Indian and Chinese origin, have been cultured together as a polyculture (or composite) technology. As a first step of pond preparation before stocking, naturally available small self-recruiting fishes are removed from the fish ponds by repeated netting, dewatering and even by using piscicides, such as rotenone. As these small fish are a major source of animal protein and micronutrients in the diet of the rural small-scale farmer's family, this strategy has negative socio-economic and nutritional impacts on the rural households. The farmers often sell all their large carp production in the market as a cash crop, leaving their family deprived of fish. Consequently, there is widespread nutritional deficiency with various diseases such as night blindness among rural children and women (Zafri & Ahmed 1981; Thilsted, Roos & Hasan 1997).

As some of the small indigenous fishes such as punti (*Puntius sophore* Hamilton), mola

Table 1 Stocking characteristics: fish species composition in each treatment, number per pond and mean weight

Treatment:	CC		CM		PC		PM	
Fish species:	No.	weight	No.	weight	No.	weight	No.	weight
	/pond	g	/pond	g	/pond	g	/pond	g
Rohu	33	18.4	33	21.1	33	17.2	33	19.3
Catla	33	67.2	33	68.4	33	67.7	33	67.0
Common carp	34	25.0			34	25.1		
Mrigal			34	25.1			34	23.0
Punti					250	5.3	250	5.2

Treatments: CC = control-common carp, CM = control-mrigal, PC = punti-common carp, PM = punti-mrigal. Pond area = 100 m².

(*Amblypharyngodon mola* Hamilton), and dhela (*Osteobrama cotio cotio* L.) are highly nutritious, even far more than large carp (Ahmed, Hossain, Huda & Abdullah 1977; Ahmed 1981; Zafri & Ahmed 1981; Hossain & Afroze 1991; Thilsted *et al.* 1997), people are becoming interested in culturing large carp and small fish together in their ponds.

In response to this need, a programme to develop a viable fish polyculture technology, under Bangladesh conditions, that allows simultaneous production of small indigenous fish species for small-scale household consumption and of large carp as a cash crop is in progress. The first step within this framework was to test which bottom feeder is the most compatible with the large carp in this new production system, as there is an ongoing debate between two commonly stocked bottom-feeder fish: mrigal (*Cirrhinus mrigala* Hamilton) and common carp (*Cyprinus carpio* L.). While people like the taste and are often sympathetic to mrigal as an indigenous large carp, they often are reluctant to stock it owing to its slow growth rate. Common carp, on the contrary, grow fast but often fetch a lower market price. Moreover, it has a serious reputation for damaging the embankment of earthen ponds. It is also suspected that, as a result of its voracious nature, it may consume the eggs and hatchlings of the self-recruiting small fishes. To resolve these issues, this experiment was carried out to concentrate on the polyculture of large carp rohu (*Labeo rohita* Hamilton), catla (*Catla catla* Hamilton), mrigal and common carp, and the small barb punti. The specific objectives were: (i) to compare polycultures of large carp in which the bottom feeder is either the native mrigal or the exotic common carp;

(ii) to assess the effects of adding the small punti to polycultures of large carp; and (iii) to compare the effects of bottom feeders, mrigal and common carp, on punti.

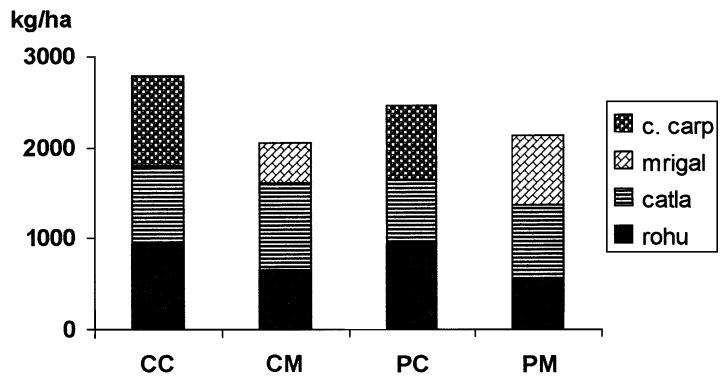
Materials and methods

The experiment was conducted in 12 earthen fish ponds of 100-m² area and 1.5-m depth in the Field Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University (BAU). Before starting the experiment, ponds were drained to eradicate all predatory fishes, embankments and slopes were repaired, and agricultural lime (CaCO₃) at 250 kg ha⁻¹ (= 2.5 kg pond⁻¹) was applied. Ponds were filled up with pumped water and fertilized with urea and triple super phosphate (TSP), each at 100 kg ha⁻¹ (= 1 kg pond⁻¹) to promote algal growth.

The experiment had a factorial design (2 × 2), with three replications per treatment. The treatment name reflects this structure, the first letter indicating whether punti was present (P) or not (C for control), and the second letter whether the bottom feeder was common carp (C) or mrigal (M).

Ponds were stocked in May 1999, at a stocking density of 10 000 large carpha⁻¹ and 25 000 punti ha⁻¹ (Table 1). Supplementary feed consisted of rice bran and soaked oil cake (2:1), given six times per week at a daily rate of 3% of the large carp' body weight. Feeding was adjusted after fish weighing. Fish weighing was performed every 10 days instead of monthly samples usually performed at BAU, to detect when punti reproduction starts. Fertilizer and manure were applied at 10-day intervals, in the

Figure 1 Yield of each large carp species, mean by treatment. Treatments: CC = control (no punti) + common carp. CM = control + mrigal. PC = punti + common carp. PM = punti + mrigal.



middle, between two fish weighing dates. Fertilizers were urea and TSP (1 kg pond⁻¹ each). Fresh manure (6.5 kg pond⁻¹) was applied in the four corners of each pond.

Environmental sampling was carried out at 10-day intervals, the day before fish weighing, always at around the same hour (09.00). The parameters measured were temperature, transparency, pH, dissolved oxygen, total alkalinity, phosphate, nitrogen compounds (NH₃, NO₃, NO₂), chlorophyll-a and plankton composition.

Data were analysed through one- and two-way ANOVA and mean multicomparisons (Duncan test) using the statistical package SAS. A significance level of $P < 0.05$ was used. Survival (percentage) data were normalized using the arcsine of the square root transformation. Feed conversion ratio (FCR) data were transformed to ranks (non-parametric technique appropriate for ratios) before performing further analyses.

Results and discussion

All the environmental parameters showed significant differences with time. No significant differences among treatments were found for water temperature, transparency, alkalinity, pH, dissolved oxygen, nitrite, nitrate, total phytoplankton, and zooplankton groups. Only ammonia, phosphate, chlorophyll-a, diatoms, blue-green algae, euglenoids and green algae were affected by the fish species composition (treatment). Green algae were more abundant in common carp ponds. All the other parameters were significantly higher in the polyculture with mrigal than in that with common carp, and were not affected by the addition of punti. Further analyses of water quality will be published in a separate article.

Results of fish parameters are presented in Tables 2–4, and in Figs 1 and 2. Bottom feeder and punti addition had different effects on the different fish species studied.

Species combinations and fish yield

The major contributors to the pond production were common carp in treatment CC, catla in CM and PM, and rohu in PC (Fig. 1). There was a wide difference in the net yield of fish among different treatments, with higher production in common carp ponds (2800 kg ha⁻¹ in CC and 2500 kg ha⁻¹ in PC) than with mrigal ponds (about 2000 kg ha⁻¹ in CM and PM). These yields were obtained in 6.5 months in a region where the growing period is 8 months (no fish growth from November to February), hence they might be considered a rough estimation of the yearly production. As such, these yields are similar to several production levels obtained in other polycultures in the South Asian region. For example, Shahabuddin, Miah and Alam (1994) obtained yields of 2000–3400 kg ha⁻¹ yr⁻¹, and Mazid, Zaher, Begum, Ali & Nahar (1997) recorded a gross production of 3600 kg ha⁻¹ yr⁻¹ from a composite culture of Indian major and Chinese carp.

Effects on total fish production and feed conversion ratio (FCR)

The two-way ANOVA testing the effects of bottom feeder and punti addition on total fish production explain about 80% of the variability of total fish harvesting biomass and yield (Table 2 and Fig. 1). The significant source of variability was the bottom feeder, whereas punti addition did not have a significant effect. Total biomass and yield were about 25%

Table 2 ANOVA and Duncan mean multicomparisons of total fish harvesting biomass and yield and feed conversion ratio (FCR)

	large carp biomass		total biomass		total yield		FCR*	
	kg/pond		kg/pond		kg/pond			
ANOVA	Sign.	r ²	Sign.	r ²	Sign.	r ²	Sign.	r ²
	**	0.81	**	0.80	**	0.78	***	0.91
Variability source	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS
punti	ns	4	ns	1	ns	5	ns	1
b.feeder	***	84	***	88	**	84	***	86
p * b.f	ns	12	ns	11	ns	11	**	13
Mean multicomparisons by bottom feeder								
c. carp	A	29.5	A	29.9	A	26.3	B	3.8
mrigal	B	23.9	B	24.2	B	20.8	A	4.7
Mean multicomparisons by punti								
present	A	26.0	A	26.7	A	22.8	A	4.1
absent	A	27.4	A	27.4	A	24.2	A	4.4

*Statistical tests based on rank-transformed FCR data. Values of means given untransformed. r² = coefficient of determination, %SS = % of the total sum of squares. Sign = significance level: * = 0.05, ** = 0.01, *** = 0.001, ns = not significant. Mean multicomparisons: same letters in each column indicate no significant differences at the 0.05 level.

higher when the bottom feeder was common carp than when it was mrigal. The two-way ANOVA accounted for 91% of the variability of (rank transformed) FCR as well. Most of the variability accounted for was owing to bottom feeder (86%), with 20% lower FCR when in common carp ponds than in mrigal ponds (percentages based in untransformed data, significance from test on transformed data). The punti main effect was not significant, but a further 13% of the explained variability was because of the bottom feeder–punti cross effect, as punti addition reduced FCR in mrigal ponds and increased it in carp ponds.

Effects on rohu

The two-way ANOVA testing the effects of bottom feeder and punti addition on rohu explained 72–86% of the variability of its harvesting biomass,

weight, growth rate and yield, whereas the model is not significant for survival (Table 3 and Fig. 2). In all models, the significant source of variability was owing to the bottom feeder, whereas punti addition did not have a significant effect on this fish. Rohu presented about 50% higher biomass and growth rate and 60% higher weight and yield when the bottom feeder was common carp than when it was mrigal. This can be explained by common carp stirring up mud bottom while feeding, thus improving nutrient re-circulation. This, in turn, favours phytoplankton development in the water column, on which rohu feeds (Jhingran & Pullin 1985; Das & Moitra 1956; Dewan, Wahab, Beveridge, Rahman & Sarker 1991). The phenomenon of nutrient release as a result of stirring effects of common carp in the pond bottom is well documented (Milstein 1992; Wahab, Ahmed, Aminul Islam, Haq & Rahmatullah 1995).

Table 3 ANOVA and Duncan mean multicomparisons of each large carp species harvesting parameters

variable	number	biomass	weight	Survival*	growth	SGR*	yield
unit	/pond	kg/pond	g	%	g/day	%	kg/pond
ROHU							
ANOVA	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2
	ns 0.21	** 0.85	* 0.72	ns 0.25	* 0.73	** 0.79	*** 0.86
Variability source	Sign. %SS	Sign. %SS	Sign. %SS	Sign. %SS	Sign. %SS	Sign. %SS	Sign. %SS
punti	ns	ns 2	ns 5	ns	ns 4	ns 0	ns 2
b.feeder	ns	** 96	** 95	ns	** 96	*** 100	*** 96
p * b.f	ns	ns 2	ns 0	ns	ns 0	ns 0	ns 2
Mean multicomparisons by bottom feeder							
c. carp	A 29	A 9.92	A 396	A 88	A 1.69	A 0.66	A 9.42
mrigal	A 27	B 6.53	B 241	A 82	B 1.14	B 0.56	B 6.00
Mean multicomparisons by punti							
present	A 28	A 7.98	A 281	A 86	A 1.36	A 0.61	A 7.48
absent	A 27	A 8.47	A 305	A 85	A 1.47	A 0.61	A 7.93
CATLA							
ANOVA	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2
	ns 0.25	ns 0.29	ns 0.35	ns 0.25	ns 0.34	ns 0.30	ns 0.29
Var. source	Sign. %SS	Sign. %SS	Sign. %SS	Sign. %SS	Sign. %SS	Sign. %SS	Sign. %SS
punti	ns	ns	ns	ns	ns	ns	ns
b.feeder	ns	ns	ns	ns	ns	ns	ns
p * b.f	ns	ns	ns	ns	ns	ns	ns
Mean multicomparisons by bottom feeder							
c. carp	A 29	A 9.80	A 390	A 89	A 1.37	A 0.35	A 7.82
mrigal	A 27	A 10.70	A 333	A 83	A 1.66	A 0.39	A 8.81
Mean multicomparisons by punti							
present	A 28	A 9.50	A 337	A 86	A 1.39	A 0.36	A 7.58
absent	A 28	A 10.98	A 386	A 86	A 1.64	A 0.38	A 9.03
MRIGAL							
ANOVA	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2
punti	*** 0.95	** 0.88	ns 0.23	** 0.93	ns 0.26	ns 0.40	** 0.88
Mean multicomparisons by punti							
present	A 33	A 8.27	A 248	A 98	A 1.16	A 0.53	A 7.50
absent	B 22	B 5.01	A 224	B 66	A 1.03	A 0.49	B 4.47
COMMON CARP							
ANOVA	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2
punti	ns 0.34	* 0.78	ns 0.29	ns 0.34	ns 0.30	ns 0.55	* 0.77
Mean multicomparisons by punti							
present	A 28	B 8.72	A 313	A 82	A 1.48	A 0.56	B 8.00
absent	A 31	A 10.79	A 345	A 92	A 1.65	A 0.59	A 10.00

*Statistical tests based on transformed data. Values of means given untransformed.

SGR = specific growth rate, r^2 = coefficient of determination, %SS = % of the total sum of squares, Sign = significance levels: * = 0.05, ** = 0.01, *** = 0.001, ns = not significant. Mean multicomparisons: same letters in each column indicate no significant differences at the 0.05 level.

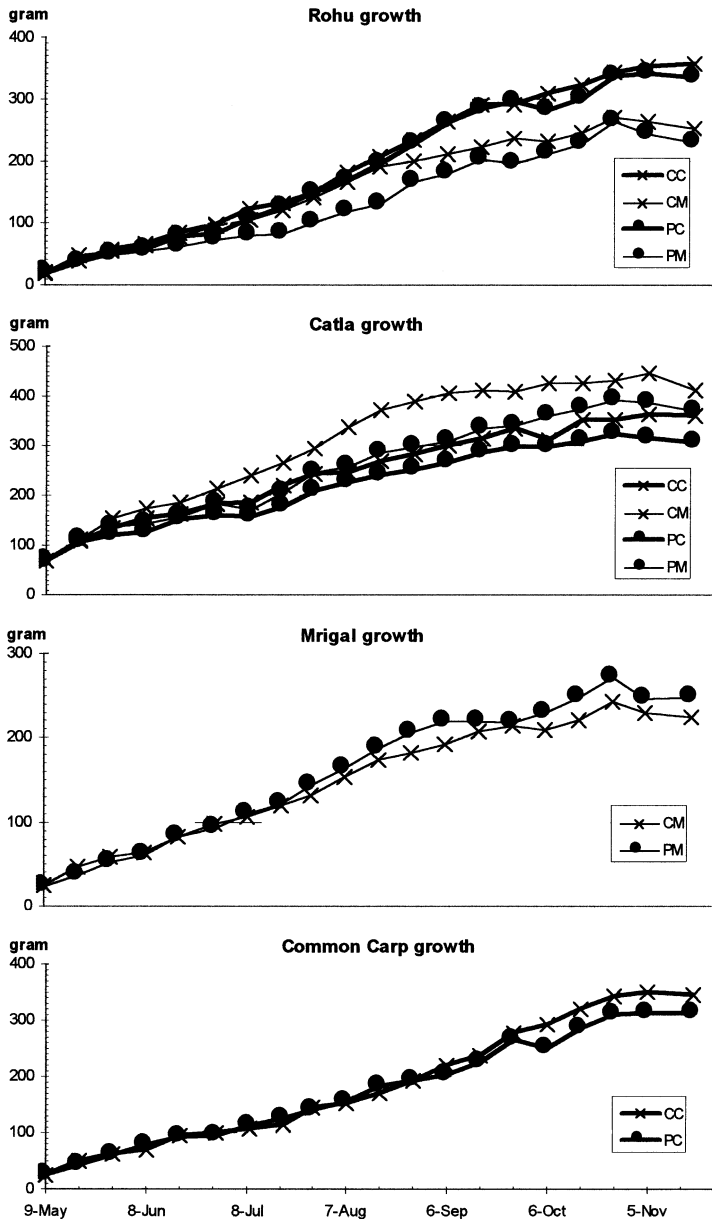


Figure 2 Growth of each large carp species, mean by treatment. Treatments: CC = control (no punti) + common carp. CM = control + mrigal. PC = punti + common carp. PM = pun-punti + mrigal.

Effects on catla

Catla performance presented large variability among ponds that resulted in non-significant treatment effects (Table 3 and Fig. 2). Thus, the apparent better catla growth in mrigal ponds, shown in Fig. 2, should be considered only a trend. The two-way ANOVA indicates that neither bottom-feeder fish nor punti addition significantly affected any catla performance parameter. Catla is a surface feeder mainly capturing zooplankton (Natarajan & Jhingran 1961; Jhingran & Pullin 1985; Rahman 1989).

Zooplankton abundance and composition were similar in common carp and mrigal ponds. Zooplankton, and hence catla, did not benefit from the phytoplankton enhancement produced by common carp activity, which instead was utilized by rohu. The trend of higher catla growth in mrigal ponds, suggested by Fig. 2, might be related to phytoplankton composition, hence of secondary importance to have a significant effect on a fish eating phytoplankton only as complementary food. From the phytoplankton, catla positively selects diatoms (Dewan *et al.* 1991; Wahab, Ahmed,

Table 4 ANOVA and Duncan mean multicomparisons of punti harvesting parameters

variable	number	biomass	weight	Survival*	yield
unit	/pond	kg/pond	g	%	kg/pond
PUNTI					
ANOVA	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2	Sign. r^2
b.feeder	ns 0.57	ns 0.24	ns 0.53	ns 0.57	ns 0.13
Mean multicomparisons by bottom feeder					
c. carp	A 145	A 0.73	A 10.2	A 58	A 0.08
mrigal	A 116	A 0.55	A 11.5	A 46	A -0.02
PUNTI FRY					
ANOVA	Sign. r^2	Sign. r^2	Sign. r^2		
b.feeder	ns 0.33	ns 0.41	ns 0.10		
Mean multicomparisons by bottom feeder					
c. carp	A 43	A 0.12	A 2.99		
mrigal	A 16	A 0.05	A 3.34		

*Statistical tests based on transformed data. Values of means given untransformed.

r^2 = coefficient of determination. Sign = significance levels: * = 0.05, ** = 0.01, *** = 0.001, ns = not significant. Mean multicomparisons: same letters in each column indicate no significant differences at the 0.05 level.

Haq & Miah 1994), which were more abundant in mrigal ponds, in which catla seems to have performed better, and rejects Chlorophyceae (Dewan *et al.* 1991), which were dominant in common carp ponds.

Effects on mrigal

The one-way ANOVA testing the effect of punti addition on mrigal explains 88–95% of the variability of its harvesting biomass, survival and yield, whereas the model was not significant for weight and growth rate (Table 3 and Fig. 2). The addition of punti to polycultures with mrigal improved mrigal survival in almost 50%, and hence its harvesting biomass and yield also improved (65% higher in punti ponds). Punti, however, did not affect the growth rate of mrigal, which indicates that food resources are probably not directly involved in punti–mrigal interactions. The reasons for the positive effect of punti on mrigal survival are unknown and warrant further investigation.

Effects on common carp

The one-way ANOVA testing the effect of punti addition on common carp explains 78% of the variability of its harvesting biomass and yield, whereas the model is not significant for the other parameters (Table 3 and Fig. 2). The addition of punti to polycultures with common carp decreased harvesting biomass and yield of common carp by 20% in comparison with the ponds without punti, whereas the differences in harvesting weight and growth rate were not significant. The lower performance of common carp might be as a result of food competition with punti, which partially feeds on the bottom and on detritus (Kohinoor 2000).

Effects on punti production

No significant differences in punti regarding harvesting biomass, weight, yield, survival, or harvested fry related to bottom feeder occurred (Table 4). Punti, although also a bottom feeder, was indifferent to

what other large carp bottom feeder was present in the polyculture. This might be related to the low punti density present in the ponds.

Effects on reproduction of punti

In nature, punti reproduces in May–June and September–October (Mustafa, Islam, Ali & Ashraf-Alam 1983; Kohinoor 2000). In this experiment, stocking of rather small fish was carried out in May. Thus, their reproduction was delayed and did not occur in May–June. In the common carp ponds, punti fry of about 2–5 g were caught during the second half of August to September and later, again, by the end of October to November. One of the ponds produced much less fry than the other two. In one mrigal pond, punti fry was caught in the second half of August and at harvest in mid-November, with smaller punti production figures than in the carp ponds. In the other two mrigal ponds, recruitment did not occur in August and at harvest, very few fry were recovered. One of these ponds overflowed during the rainy season and punti could have escaped to the adjacent drainage channel. The large variation of fry recruitment among the ponds of each treatment and the superposition of the ranges of fry production between treatments account for the lack of significant differences in punti performance at harvest as a result of the presence of common carp or mrigal in the polycultures. In any case, compared with previous records at BAU ponds (Kohinoor, 2000), punti reproduction was low in all ponds. This low reproduction rate was most probably as a result of the disturbance caused to brooder punti by the fishing nets during the frequent samplings (each 10-day interval), as opposed to monthly samples usually performed at BAU's experimental ponds.

Effects of bottom feeder on pond embankments

Monsoon rains damaged the air-exposed parts of the embankments of all ponds. Besides, the six ponds stoked with common carp also had embankment damage at the water–air interface, which led to larger damage of the air-exposed areas. The six ponds stocked with mrigal were not damaged by fish-digging activity. It seems that common carp damages pond embankments by searching for food or burrowing to build nests. The economic impacts

of these behaviours on the pond owners warrant a thorough investigation.

Punti effects in mrigal ponds

In this experiment, almost no punti effects were significant, probably because of the low punti density resulting from the disturbance caused by the too-frequent netting. In the same ponds, but weighing fish once a month instead of at 10-day intervals, Kohinoor, Wahab & Thisted (1998) found different results. Their control ponds were stocked with rohu, catla and mrigal, and, in the treatment ponds, 500 small fish were added. Compared with the present experiment, the density of the large carp was lower (25 fish of each species in 100 m² ponds) whereas punti density was higher (500 fish per pond). Under these stocking densities, and without strong disturbance through netting, punti exerted a significant negative effect on the three large carps' growth and production, without affecting their survival. Despite that, the large punti production resulted in significantly higher total yield in punti ponds. In the present experiment, the opposite punti effect on mrigal was observed, related to low mrigal survival when punti was absent. As indicated above, punti–mrigal relationships are not clear and require further research. In relation to rohu and catla, in the mrigal ponds of the present experiment, there were slight indications of the negative punti effects described by Kohinoor *et al.* (1998), when only the treatment means are considered (Fig. 2). These trends were not significant but, at higher punti densities, they probably will be.

Conclusions

Polyculture manipulations indicated that just the selection of the bottom-feeding fish species leads to different levels of production of the traditional polyculture in Bangladesh and neighbouring countries, which includes two surface and column dwelling large carp, catla and rohu. Choosing common carp instead of mrigal as the bottom feeder strongly improved rohu performance (over 50% better performance) without affecting catla, which together resulted in 25% higher total yield with 20% lower FCR. However, the damage caused to the pond embankments by common carp cannot be overlooked and demands further work in search of its mitigation. Addition of the small fish species punti to large

carp polycultures almost had no effect on the polyculture system. The lack of negative effects of punti addition on the traditional polyculture supports the viability of the joint culture of large carp as cash crop and small fish as small-scale farmer's family food. However, under higher punti pressure, negative effects might occur and should be tested. Punti addition only affected the bottom-feeding large carp, strongly improving mrigal performance and moderately reducing common carp performance. The differential punti effect on bottom feeders was not reflected in total production because the contribution of common carp to the total pond production remained higher as a result of its own rapid growth compared with that of mrigal, and owing to common carp enhancement of rohu performance.

While the addition of punti to the polyculture with common carp decreased the harvested biomass and yield of common carp by 20%, punti, also being a bottom feeder, was indifferent to other bottom-feeder fish (either common carp or mrigal) present in the polyculture. Punti, a self-recruiting species, usually breeds twice a year and, once stocked, it may be replenished in successive years if the ponds are not dried or poisoned. Punti reproduction was disrupted as a result of repeated seine netting for sampling purposes, so a punti-friendly harvesting technique needs to be devised so that the farmers can partially harvest this small fish for feeding their family without much interference in the breeding activities of this species.

Based on the outcomes of this trial and on information derived from relevant literature, rohu, catla and common carp are appropriate cash crop species for small-scale household pond aquaculture technology. As an additional much-needed crop for small holder family consumption, punti seemed to be appropriate but further experimentation is required without disrupting its reproduction. Besides punti, other small indigenous fish species need to be tested for compatibility in the culture system and sustainability as self-recruiting species in rural household ponds.

Acknowledgments

This research was supported by Grant no. TA-MOU-97-C17-060, US-Israel Cooperative Development Research Program, Economic Growth, US Agency for International Development. Professor Abidur Reza of Bangladesh Agricultural University, Mymensingh, is acknowledged for his co-operation during this study.

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