Asian Fisheries Science 11(1998):121-132
Asian Fisheries Society, Manila, Philippines

https://doi.org/10.33997/j.afs.1998.11.2.003

A Trial to Test the Suitability of a Low-Input Cost, Silver Barb (*Puntius gonionotus*)-Based, Polyculture Model for Seasonal Ponds in Northwest Bangladesh

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Abstract

An affordable polyculture system was developed and found appropriate for seasonal ponds with a mean culture season of <220 days and situated in poor soil types. The three main species used were silver barb, *Puntius gonionotus*, silver carp, *Hypophthalmichthys molitrix* and common carp, *Carpio carpio*. Pond preparation and management was dependent upon the use of lime, cow manure, triple super phosphate (TSP) and urea. Duck weed, *Lemna* sp., green vegetable leaves and rice bran were the principle supplementary feeds. This system raised production levels from a baseline of 740 kg*ha^{-1} to 2,195 kg*ha^{-1} with a cost benefit ratio of 1:3.8.

Introduction

The northwest region of Bangladesh (Fig. 1) is typified by cool winters averaging 17.0°C (range 8.8 - 24.7) in the month of January, with a drier (2,321 mm of rain) summer than the average for the whole country (2,884 mm). Soil is characterized by non-calcareous alluvium with a wide variation of sand in slightly elevated areas to silty loams in old depressions.

The total number of ponds over 0.032 ha in 1989 in northwest Bangladesh was 88,940 and covered a total of 13,322 ha (BBS 1992). Of these, 54% were classified as derelict or culturable, yielding only wild fish and 46% cultured by traditional methods. The resulting production from all these pond types is correspondingly low at 740 $kg \cdot ha^{-1}$ (BBS 1992). This compares with an average for similar ponds throughout the country of 771 $kg \cdot ha^{-1}$ according to Gupta & Rab (1994) and 913 $kg \cdot ha^{-1}$ reported by Zaher & Mazid (1992).

Traditional aquaculture is extensive and consists of one of the following operations: allowing wild fish from rice fields to enter the pond during flooding, stocking fingerlings of the Indian major carp, or both. Little or no pond management or supplementary feeding is practiced. The main constraints to aquaculture development in this region are listed below:

i) Overstocking, often at very high densities (>7 $\cdot m^{-2}$) in ponds with little or no additional feed or fertilizer;

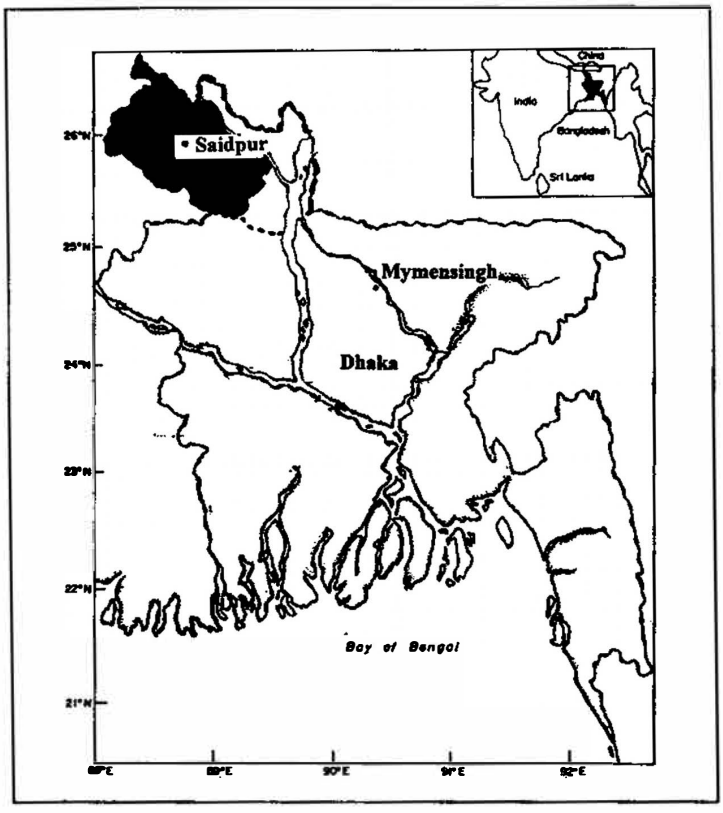

Fig. 1. A map of Bangladesh showing the boundary (dotted line) of the northwest region and the area (shaded) covered by this work.

ii) the type of species stocked. With the possible exception of catla, *Catla catla*, the traditionally favored species, catla, rui, *Labeo rohita* and mrigal, *Cirrhinus mrigala*, do not grow well in seasonal ponds (Nandeesha *et al* 1994);

iii) "Aquaculture is for the rich." Many pond owners believe they have to be wealthy to practice proper aquaculture management. This is because many aquaculture extension agencies (including the Department of Fisheries as well as Asian Development Bank- and FAO-sponsored programs) tend to target owners of large ponds who are usually both wealthy and well-educated.

From baseline surveys conducted by the Northwest Fisheries Extension Project (NFEP) in 1993, 80% of pond owners could not afford to save. Of these, 25% had an average annual income of less than Tk 7,300 (One US$ = Taka 40) earned mainly through daily labor.

In response to the above constraints, the NFEP designed a polyculture package of fast-growing exotic fish combined with low-cost pond inputs. This strategy aimed to provide a production system that is affordable to all, suitable to local pond conditions, consistent with the local market demands and would generate a high financial return to the farmer.

The polyculture model

Silver carp, *Hypophthalmichthys molitrix*, is a readily available species and is recognized locally for its rapid growth rate. However, it is not a popular table fish and has the lowest market price of all hatchery-produced fish (Table

1). Common carp, *Carpio carpio*, were used as detritivores because of locally common reports of their better growth rates over mrigal. The silver barb, *Puntius gonionotus*, is variously known in Bangladesh as *Thai shorputi*, *sharputi* or *rajputi* and was introduced into the country from Thailand in 1977 (Rahman 1989). It is well adapted to culture in seasonal ponds and can reach a market size of about 100g in three or four months (Gupta & Rab 1994). Silver barb is also morphologically very similar to the highly-prized local species *P. sarana* and consequently commands the highest market price of all farmed fish for its size in the area. It is primarily a macrophyte feeder and was introduced into this model because of the large quantities of duck weed, *Lemna* sp., freely available in rice fields during the monsoon season.

At 14,800 $kg \cdot ha^{-1}$, the stocking density was more than double than that recommended by the Department of Fisheries (Kumar *et al.* 1992) for Indian major carp. The increase was mainly taken up by silver barb, but these were harvested in October or November when supplies of duckweed diminished. The strategy of partial harvesting was essential to reduce stocking densities over the cool winter months and prevent disease, particularly epizootic ulcerative syndrome (EUS), which is prevalent at that time of the year.

The model was field-tested in 1992 and, following observations on farmer implementation, small numbers of catla and rui were included to allow farmers to compare the production of two traditional species with the exotic combination (Table 2). In 1993, the system was introduced more widely to poverty-selected farmers in the region. Apart from being a poverty-focused Project, the NFEP wished to test the model on the poorest sector of the pond-owning community to evaluate its suitability for low-income farmers. It was also evaluated against other on-farm activities in terms of total income return against time.

Materials and Method

Trial procedure

In the 1993 trial, 174 pond owners from the operational area of the NFEP (Fig. 1) were selected through wealth ranking by their neighboring peer

Table 1. Mean first-sale price for market-size fish cultured by NFEP farmers with the average weight of fish harvested from the trial.

Fish species	Mean Weight (kg)	First-sale price (Tk. 1*kg)
Silver carp	0.357 (0.176)	26.4 (4.3)
Silver barb	0.085 (0.030)	40.2 (7.1)
Common carp	0.220 (0.255)	32.6 (4.3)
Catla	0.261 (0.124)	32.4 (5.5)
Rui	0.190 (0.080)	34.2 (5.3)
Grass carp	0.400 (0.186)	28.9 (4.9)

Note: Figures in parenthesis are standard deviations of the respective means.

Table 2. Composition and density of fish, fertilization and supplementary feeding rates[1].

Fish Species	(Number·ha^{-1})	Pond Preparation kg·ha^{-1}		Pond management kg·ha^{-1}·day^{-1}	
Silver carp	3,952	Lime	247	Cow dung	3.7
Silver barb	7,410	Urea	50	Urea	2.5
Common carp	1,482	TSP	25	TSP	1.2
Catla	988				
Rui	988				
Total	14,820				

Note: Duck weed and/or soft leaves were given at a wet weight rate of 12 kg·ha^{-1}·day^{-1} at stocking rising by an increment of 2.5 kg·ha^{-1}·day^{-1} until the harvesting of the silver barb.

[1]Rice bran was given at the rate of 5 kg·ha^{-1}·day-1 on the first month, rising by increments of 1 until the third month. The rate increased to 10 kg·ha^{-1}·day-1on the fourth month, 12 kg·ha^{-1}·day^{-1} on the fifth and 15 kg·ha^{-1}·day^{-1} from the six month until harvest time.

group following the method described by Grandin (1988), with an additional criteria being that they and their family members could not afford to eat rice more than once a day for part of the year. Also considered essential was that the farmer was sufficiently interested to provide pond management as dictated in the production model (Table 2). Experience had shown that, where a pond is under joint ownership, there are invariably disputes over its management even if all parties are given training. Therefore, no ponds with multiple owners were included. Security was also considered and ponds that were out of sight of the owner's homestead were not selected. Mean pond size was 0.06 ha ranging from 0.016 to 0.134 ha with a mean maximum depth of 2.3 m (range 1.5 - 4.6 m). All ponds were seasonal.

Each farmer received three one-day training sessions, one each in May (pond preparation), July (pond management) and October (disease control and marketing) from the local *thana* fisheries officer and NFEP extension staff. One or both of these extension agents also visited the farmers on a weekly basis throughout the season to discuss the appearance of the pond water and the condition of the fish. Advice with regards to any adjustment of the food and fertilizer application rates was given. No water testing apparata were used since these were not available to the farmer. Fingerlings, fertilizers and rice bran were provided by the Project on the basis of interest-free credit. The pond owners were expected to supply fresh vegetable feeds themselves.

Every farmer kept a record book of all pond inputs and harvesting data , including home consumption by weight and species and first sale price. Fish were either sold to passersby at the time of harvesting or, more commonly, to wholesalers called *bapari* who retailed the fish through established markets. Quantities consumed were priced as though sold to assess the value of the total crop. The record book was checked at each visit by the extension officer who also kept a log book of all activities for each pond under his or her supervision. A sample of all species was weighed at the time of stocking and on four other occasions, including partial and final harvesting. Sampling was done using a cast net while both cast and seine nets were used for partial harvesting. The final harvest was usually conducted over a week when pond water depth had dropped to about one meter.

The numbers and weight of all fish taken from the ponds throughout the season were recorded and biomass calculated by species and total. Chi-squared was used in tests for significance.

Pond preparation

Pond banks were repaired where necessary to prevent flooding and the casual introduction of wild species. Shade plants on the banks and floating macrophytes in the water were removed. Ponds were treated with rotenone, where there was a residue of water, to kill any wild fish or old stock. Lime was added to kill pathogenic organisms and increase water hardness and alkalinity. Hardness was demonstrated to be low at 18.2 (mg·l as $CaCO_3$) in a sample of 32 ponds in the area (R. Gregory, 1991, unpublished) and alkalinity low at 31 (mg·l as $CaCO_3$) (BAFRU 1990).

Pond management

Cow dung, triple super phosphate (TSP) and urea were added to promote and maintain phytoplankton production. Lime was again added in October or November to raise pH, which has been shown to prevent EUS (Barua 1994).

Feeding

Fertilizers were introduced to promote naturally occurring food items. However, allochthonous material was vital for silver barb. Duckweed was the principle component with soft green leaves from vegetables, banana trees and military grass (*Cominilla* sp.) being included according to availability. The harvest of silver barb coincided with the natural die-back of duckweed. If grass carp were present (see below), or a few silver barb left, other green vegetable matter was applied on a casual basis after this time. Rice bran was supplied throughout the culture period and visibly consumed mainly by silver barb. Farmers were encouraged to use feeding rings but, in the absence of rings, food was broadcast from set points on the bank.

Economic analysis

To obtain a socioeconomic profile, 67 of the selected farmers were interviewed in April 1993, before the start of the aquaculture season, using a closed format questionnaire. Respondents were also asked to express an opinion on the species commonly cultured in their area with regard to price, growth performance and taste.

Results

For reasons such as local availability of fingerlings and farmer preference, only 100 (coincidentally) completely followed the model. The results from these farmers are used here for analysis.

Fish production

Fig. 2 shows the growth rates for all species over the season. The mean stocking date was 8 July 1993 (23 June - 30 July) and the mean final harvesting time 24 January 1994 (6 November 1993 - 1 March 1994). A few grass carp, *Ctenopharyngodon idella* were accidentally introduced with silver barb fingerlings in 41 ponds at a mean stocking density of 345 kg·ha^{-1}. The number of silver barb stocked was recalculated from their mean survival rate (Table 3) in non-affected ponds. The net production between ponds with grass carp and those without was found not to be significant and consequently data from all ponds were grouped together. Production data and income are summarized in Table 4. Mean net daily production was calculated at 11.0 kg·ha^{-1}*day^{-1}. There was no significant difference between pond size and production.

An attempt was made to estimate standing crop by the mark and recapture method at the time of partial harvest. However, the identification of fin clips given to a sample of fish in each pond a month before proved too difficult to be reliably recognizable.

The contribution that each species made to total biomass and gross income was assessed by dividing stocking density into their respective percentages of biomass and income. The result is given in Table 5.

Average operational costs, income from production and cost-benefit ratios are given in Table 6. Some farmers ate a proportion of their fish but the amount was low with 7.6% of the total biomass for silver carp, 4.6% for silver barb and 2.8% for common carp. For all other species, the amount was <2.1%. Items such as cow dung and duck weed were usually collected by unemployed members of the family at no financial cost to the farmer. However, cow dung does have a market value, principally as a fuel, and was priced accordingly at Tk. 0.25 per kg. Duckweed at the time of this work had no commercial value and was estimated at Tk.0.25 per kg for labor costs.

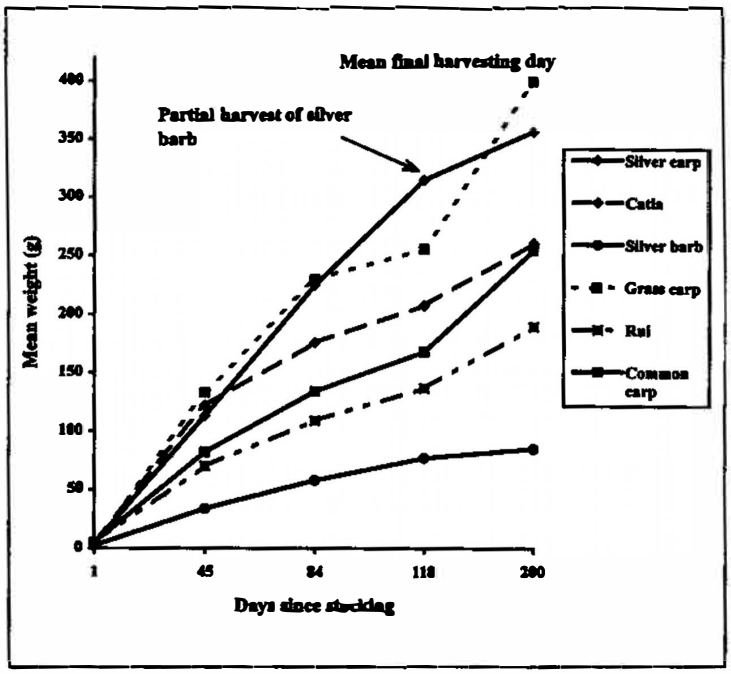

Fig. 2. The growth rates for all fish species in the trial. Day 1 was 8 July 1993 and Day 200, 24 January 1994.

Table 3. Survival rates of stocked fish species in all ponds with variability and standard deviation.

Fish species	Survival rate(%)	Variability	Standard deviation
Silver carp	75	14 - 98	18.9
Silver barb	78	13 - 100	17.3
Common carp	73	19 - 100	16.8
Catla	79	9 - 100	17.8
Rui	77	25 - 100	15.5
Grass carp	81	30 - 100	18.1

Table 4. Net fish production with the contribution by each species as a whole and as a percentage of the total biomass and total gross income.

Fish species	Net production ($kg^{*}ha^{-1}$)	% of total biomass	% of total gross income
Silver carp	995 (420)	45 (10.5)	38 (11.1)
Silver barb	469 (198)	22 (6.8)	10 (5.2)
Common carp	264 (124)	12 (4.2)	28 (9.1)
Catla	227 (124)	10 (4.8)	13 (4.6)
Rui	151 (74)	7 (3.3)	4 (3.3)
Grass carp	89 (96)	4 (3.5)	7 (3.8)
Total	2,195 (692)		

Note: Figures in parentheses are standard deviations of the respective means.

Table 5. Percentage contribution by species to total biomass and total gross income according to their respective stocking densities.

Fish species	% Stocking density	Biomass	Income
Silver carp	26.7	1.69	1.46
Silver barb	50.0	0.44	0.56
Common carp	10.0	1.2	1.3
Catla	6.7	1.05	1.05
Rui	6.7	1.05	1.05
Grass carp	2.3	1.74	1.74

Table 6. Average cost of production ($Tk.^{*}ha^{-1}$), net income (total and daily over the season) and cost benefit ratio. Figures in parentheses are standard deviations of means.

Total cost	Tk.18,426 *ha (4,125)	92 $Tk.^{*}ha^{-1}day^{-1}$ (20.6)
Net income	Tk.49,771 *ha (24,280)	249 $Tk.^{*}ha^{-1}day^{-1}$ (124)
Cost : benefit	1 : 3.8 (1 : 1.4)	

Socioeconomic survey

Typically, the pond owner was male (98%) with a mean total land holding of 0.68 ha (range 0.4 - 3.5 ha). However, 18% of Project-trained pond managers were female. The average family size was 6.0 members (range 2 - 14). Nearly 85% of the household heads derived their income from agriculture, either through working their own land and/or that of other farmers on a daily paid basis. Table 7 gives the mean amount of land available to Project farmers and how it was apportioned according to use, together with the average annual value of each farming activity. Bananas and mangos were considered to

Table 7. On-farm agriculture activities by household, the mean amount of land involved and the net value of the crop from rice, fruit plantations, vegetables and aquaculture. The mean number of livestock by species and their first-sale value are also included.

	Number of households	Mean amount of land (ha)	Mean number	Net value of crop ($Tk^{*}ha^{-1*}year^{-1}$)
Rice	51	0.715		10,545*
Plantation (bananas and mangos)	27	0.063		113,136
Vegetables	24	0.05		65,949
Aquaculture	67	0.064		
: pre intervention				20,600
: post intervention				49,771
Chickens	56	free range	8.5	60 - 70 $Tk^{*}kg^{-1*}$
Ducks	23	free range	5.8	55 - 65 $Tk^{*}kg^{-1*}$
Goats	43	free range	2.7	100 $Tk^{*}kg^{-1*}$
Cows	47	tethered	2.8	4,200

* Source: Department of Agriculture Extension, Dinajpur.

be typical plantation crops for the area and their value was obtained from the Bangladesh Bureau of Statistics (1992). The mean income from vegetables was provided by Rangpur Dinajpur Rural Services (1996), which is a nongovernmental organization working in 15 of the 37 *thanas* of the NFEP area. Also included in Table 7 are the number of households owning livestock. Poultry were usually kept for routine commercial purposes while the bovids were generally regarded as an investment to be realized in an emergency. Cattle were also used for ploughing.

Fig. 3 illustrates the reasons given by pond owners for culturing fish used in the model. The data only refers to those farmers who expressed an opinion.

Climate

The mean monthly air temperature, rainfall and total bright sunshine from July 1993 to January 1994, recorded at Saidpur Airport, are presented in Fig. 4.

Discussion

The biological suitability of this model for the seasonal ponds of northwest Bangladesh appears to be justified with a three-fold increase in normal production at 2,195 $kg \cdot ha^{-1}$. This compares favorably with other systems in the country. Gupta & Rab (1994) recorded production of 1480 $kg \cdot ha^{-1}$ over an average of 215 days from 181 ponds in central and western Bangladesh. Their culture model was more species-variable and included silver barb at an average stocking rate of 26%, catla at 19%, rui at 20%, silver carp at 17%, with other species at 18%. W. Collis (pers. comm.) reported similar production in the NFEP model of 2,082 $kg \cdot ha^{-1}$ (11.9 $kg \cdot ha^{-1} \cdot day^{-1}$) for seasonal ponds in the area around Mymensingh (Fig. 1). In this case, stocking density was 14,326 $\cdot ha^{-1}$ with silver barb represented at 69%, silver carp at 21% and grass carp and mirror carp, *Cyprinus carpio*, at 5% each. There was no partial harvesting of silver barb.

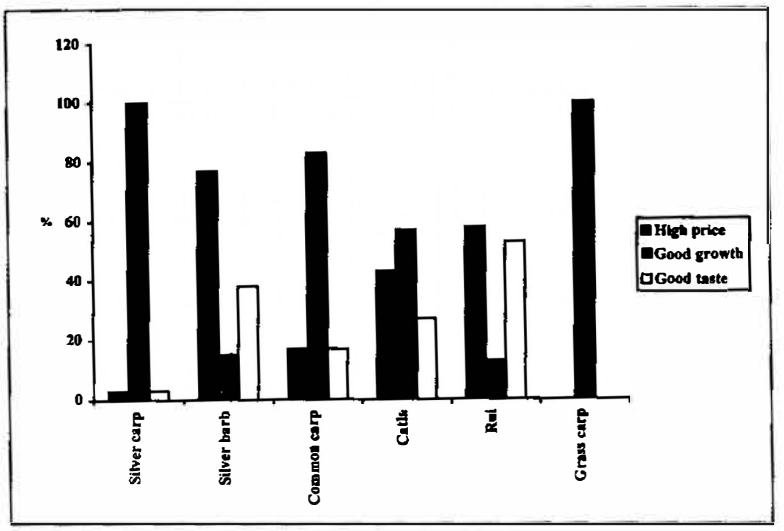

Fig. 3. The reason given by pond owners for culturing selected fish species expressed as a percentage of the respondents.

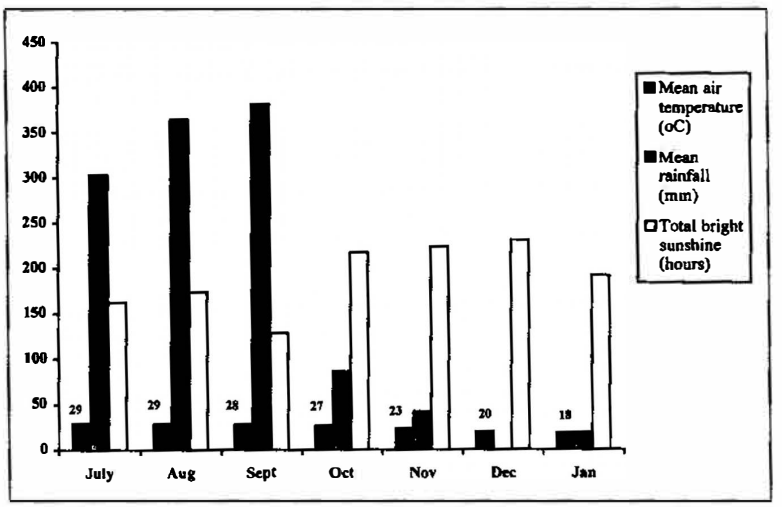

Fig. 4. The mean monthly air temperature, rainfall and total bright sunshine from July 1993 to January 1994 at Saidpur airport.

The cost-benefit ratio was good particularly when compared to the ponds in Mymensingh. Here a CBR of 1:1.68 was recorded which may reflect local prices but is also depressed by the high daily input level of cow dung at 13 times that of the NFEP model. Mustard oil cake is often recommended in other fish production models both as feed and fertilizer (Gupta & Rab 1994). However, it is expensive (7-10 Tk·kg^{-1}) compared with rice bran (1-2 Tk·kg^{-1}). Since the spread of silver barb as a cultured fish in the area, a market for duckweed has been created and duckweed is sold, coincidentally, at the estimated rate of 0.25 Tk·kg^{-1}. For a family dependent upon the earnings of a day laborer (approx 7,300 Tk·year^{-1}), the extra 3,000 Tk realized from a properly-managed average-size pond of 0.06 ha is a considerable bonus.

Compared to other on-farm activities, aquaculture performed favorably with the main, and traditional, crop, rice, particularly following enhanced pond management practices (Table 7). The high cash value of plantation crops such as mangos should be balanced against the five-year minimum growing period before first fruiting of mangos, although the one-year turnaround for bananas

would appear to make them a more attractive proposition. However, both mangos and bananas require well-drained soils, with bananas favoring loamy and clay loam soils; such conditions are uncommon in the area (Source: Department of Agriculture Extension, Dinajpur). Vegetables also gave a high return and their inclusion on pond banks is being actively promoted by the NFEP.

At 26% of the stocking density, silver carp yielded 45% of the harvest and 38% of the total gross income compared with silver barb, which, at a stocking density of 50%, only contributed to 22% of the biomass and 28% of the gross return (Table 4). Silver barb performed the worst when its contribution to biomass and income is ranked against the other species in the system (Table 5). But, with its comparative intrinsic low overall size, this is to be expected. However, it is favored by fish farmers for its high price and was ranked second to rui for taste (Fig. 3). Gupta *et al* (1992) also cite farmers in the Mymensingh area as favoring silver barb for its high market value. The inclusion of silver barb in the polyculture system is designed to take advantage of the abundance of duckweed for three months of the season. Provided that it is not economically antagonistic to the other species, this alone should merit its inclusion. Additionally, silver barb is likely to contribute nutrients to the aquatic system through feed waste conversion from low-grade feeds such as duckweed (Gouthman 1990).

The growth rate of grass carp noticeably slowed between the third and fourth sampling occasions (Fig. 2), which was reversed after the harvest of many of the silver barb. This is possibly related to competition for food. The minimal growth increase of the remaining silver barb would support this, with the larger grass carp possibly competing more successfully for the limited vegetable feed available over the winter months. It might also indicate that silver barb growth rates are more readily depressed by reduced temperatures (Fig. 4). The marked decrease in silver carp growth over the winter months also suggests this, though the increased amount of sunlight (Fig. 4) would not be a limiting factor for phytoplankton production. Catla growth rates were better than expected, particularly when compared to silver carp, over the winter months between the third sampling and final harvest (Fig. 2). Sukumaran *et al.* (1968) reported that catla grows faster than silver carp during winter, with the latter reversing the situation as temperatures rise and plankton production increases. This suggests that silver carp should also be harvested at the same time as silver barb. Considering the higher market price of catla compared to silver carp (Table 2), their proportional stocking densities should also be reviewed. Milstein *et al.* (1988) and Hepher *et al* (1989) clearly demonstrated the relationship between stocking densities of particular species on the production of other species within a polyculture system. The relationships between all the species used need further investigation for the possible improvement of the NFEP polvculture model. The presence and absence of silver barb within the system is currently under investigation, with particular attention being paid to the nutrient loading of duckweed, through silver barb, into the food web.

Published data on such polyculture systems in Bangladesh is scarce and a more detailed and varied comparison is, therefore, difficult. It is hoped, though, that once pond owners have recognized the potential for increased

production in their ponds, they will use their newly acquired knowledge to develop the system to suit their personal requirements, should this be necessary. Probably the best indication of whether a particular production system is right for local conditions is the adoption level by farmers after the extension team has left the area. This is currently being monitored by the NFEP for the northwest of Bangladesh. The results of such monitoring will be published in due course.

Acknowledgements

This work was carried out as part of the NFEP, which is jointly funded by the Government of Bangladesh and the Overseas Development Administration (UK).

The author acknowledges the cooperation of the District Fisheries Officers and *Thana* Fisheries Officers of Greater Dinajpur and the Districts of Nilphamari and Rangpur and extension staff of the NFEP. He further acknowledges the contribution made by Mr. R. Gregory, Technical Cooperation Officer (1988 - 1992), and Mr. M. Islam of the Department of Fisheries, who proposed the original three-species polyculture model of silver carp, silver barb and common carp.

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Manuscript received 30 October 1995; Accepted 23 February 1998.