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Integrated cage-cum-pond culture systems with high-valued climbing perch (*Anabas testudineus*) in cages and low-valued carps in open ponds

M. Asaduzzaman*, M.K. Shah, A. Begum[1], M.A. Wahab and Yang Yi[2]
Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
[1] Caritas Fisheries Program, Prokalpa Bhaban, Mirpur 12, Dhaka, Bangladesh
[2]Aquaculture and Aquatic Resources Management, Asian Institute of Technology, Pathumthani, Thailand
*Corresponding author: e. mail: a_zamanbau@yahoo.com

Abstract

An on-farm trial was conducted over 150 days to determine appropriate stocking ratio, growth and production of climbing perch (*Anabas testudineus*) in cages and carps in open water of ponds in eighteen farmers' ponds from Haluaghat *Upazila* at Mymensingh district of Bangladesh. One or two 1 m^3 cage was suspended in each of 12 earthen ponds and other 6 ponds served as control without cages. Climbing perch of 2-3 g in size were stocked in cages while fingerlings of silver carp (*Hypophthalmicthys molitrix)*, catla (*Catla catla*), rohu (*Labeo rohita*), mirgal (*Cirhinus cirrhosus*), rajputi (*Puntius sarana*) and common carp (*Cyprinus carpio*) were stocked at 1 fish/m^2 with a species ratio of 5:4:4:4:2:1 in open water of all ponds to give cage to open-pond fish ratios of 1:1 ($T_{1:1}$) and 2:1 ($T_{2:1}$) and 0:1 ($T_{0:1}$) as three treatments with six replicates each. Survival of climbing perch was higher in $T_{1:1}$ (61.67%) than that of $T_{2:1}$ (29.5%) and was significantly different ($p>0.05$) between the treatments. Stocking of small size climbing perch fry increased the mortality rate in cages. The net yields of Thai koi were 0.13 ± 0.01 (t/ha) and 0.10 ± 0.01 (t/ha) in treatments $T_{1:1}$ and $T_{2:1}$, respectively and both were significantly different ($p>0.05$). Survival of open-pond carps was high, ranging from 50 to 91.67% with significantly lower in $T_{0:1}$ than that of $T_{1:1}$ and $T_{2:1}$ treatment. Net and gross yield of each carp species were significantly higher in the $T_{1:1}$ and $T_{2:1}$ treatment than that in $T_{0:1}$ treatment. Net revenues were positive but low in all treatments. Therefore, bigger size climbing perch with lower stocking ratio ($T_{1:1}$) is suitable for integrated cage-pond culture of Climbing perch and carps. However, more on-farm trials in different ecosystem with scientific interventions are necessary to develop the technology for further dissemination among the rural farmers.

Key words: Integrated culture, Cage, Pond, Climbing perch, Carps

Introduction

The present rate of increase in fish production in Bangladesh is lesser than that of population boom. So, it is strongly felt that all sorts of efforts need to be employed to increase the fish production in all available inland waterbodies to fulfill the protein demand of the people. But, it is true that the vast waterbodies has yet not been properly utilized for fish culture due to lack of adequate knowledge and proper technology. Therefore, culture system development is one of the most important factors to increase fish production. Among the various culture systems, integrated aquaculture is more suitable in context of Bangladesh. The integrated aquaculture systems may be of various types. The integrated cage-cum-pond fish culture technique is one of them. This is comparatively a new method of aquaculture, which has gained much popularity throughout the world due to a number of advantages over the conventional method of fish farming.

The integrated cage-cum-pond culture system is a system in which high-valued fish species are fed with artificial diets in cages, where filter-feeding fish species are stocked to utilize natural foods derived from cage wastes. This integrated system has been developed and practiced using combinations of catfish-tilapia (Lin 1990, Lin and Diana 1995) and tilapia-tilapia (Yi *et al.* 1996, Yi 1997, Yi and Lin 2000 & 2001) at AIT, Thailand and carp-stinging catfish (Wahab *et al.* 2005) at BAU. Although cages were set up in Nile tilapia monoculture ponds in all previous work mentioned above, this integrated system can be applied in polyculture systems. In polyculture, ponds are stocked with several carp species of different feeding habits. It is impossible to target feeding to only high-valued species, because low- valued species consume the feed resulting in economic inefficiency unless an integrated system is adopted. Compared to the nutrient utilization efficiency of about 30% in most intensive culture system (Beverage and Phillips 1993, Acosta-Nassar *et al.* 1994), the nutrient utilization efficiency could reach more than 50% in integrated cage-cum-pond system, resulting in the release of much less nutrients to the surrounding environment (Yi 1997).

Rural pond aquaculture in Bangladesh is mainly the semi-intensive carp polyculture of both Indian major and Chinese carps with low production (for example, 2.8 t/ha. DOF 2001). Pond production systems in many countries are becoming increasingly reliant on external resources (feed and/or fertilizer) to supplement or autochthonous food production for fish. Such a system often discourages small-scale poor farmers because of low on investment. On the other hand, such poor farmers have limited financial resources to turn their whole ponds to culture high-valued species using expensive artificial feeds. However, the integrated cage-cum-pond system may provide an opportunity for small-scale farmers to use their limited resources, to include small amount of high-valued species in their ponds, to generate more income and improve their livelihood. This is achieved through improved nutrient utilization efficiency, marketing high-valued species and saving fertilizer cost, because fish in open pond can efficiently utilize cage wastes and there is no fertilization required. Also this integrated cage-cum-pond system is environmentally friendly due to less waste nutrients released to the environment. In view of the above, the present study has been undertaken to adapt integrated cage-cum-pond systems to local farm conditions in Bangladesh, to determine appropriate stocking ratio of climbing perch (*Anabas testudineus*) in cages and carps in open water of ponds, to assess growth and production of fishes in both cages and open ponds, and to assess the economic benefits of this integrated system.

Materials and methods

This experiment was conducted in 18 earthen rural farmers ponds with average 200 m^2 surface area and average depth of 2 m at the two sites (eastern & western) of Haluaghat Upazila under Mymensingh, Bangladesh from 01 September 2005 to 31 January 2006. One or two 1 m^3 cage was suspended in each of 12 earthen ponds and other 6 ponds served as control without cages. Climbing perch of 2-3 g in size were stocked in cages while fingerlings of silver carp (*Hypophthalmicthys molitrix*), catla (*Catla catla*), rohu (*Labeo rohita*), mirgal (*Cirhinus cirrhosus*), rajputi (*Puntius sarana*) and common carp (*Cyprinus carpio*) were stocked at1 fish/m^2 with a species ratio of 5:4:4:4:2:1 in open water of all ponds to give cage to open-pond fish ratios of 1:1 and 2:1 and control (0:1) as three treatments with six replicates each. Cages were made with iron rods covered by net, and were supported by two vertical and one horizontal bamboo poles for each cage. Fingerlings of all carps species and climbing perch were collected from Brahmaputra hatchery, Shambhoogang, Mymensingh, Bangladesh and were stocked on 01 September 2005 in pond and cages. All fishes were kept into hapa for conditioning and initial length and weight of fingerlings were measured before releasing into the pond.

Climbing perch cages were fed on commercial pelleted feed (32.38% crude protein) twice daily at a rate of 10% body weight per day in the first month and reduced up to 5% body weight in rest of the culture period. Commercial pelleted feed was supplied on a feeding tray (42×26×4 cm), which was hung in each cage. Feed ration was adjusted fortnightly based on sampling weight. No feed and fertilizer was added into the open water of the ponds.

Throughout the experimental period, the water quality parameters were recorded monthly. Temperature (^{0}C), transparency (cm) and dissolve oxygen (mg/l) were measured between 9.00 and 10.00 am at the pond site. Alkalinity (mg/l), pH and ammonia-nitrogen (mg/l) were measured at Water Quality and Pond Dynamics Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. Temperature and dissolved O_2 were measured by a digital DO meter (YSI model 58). Transparency was measured by using a secchi disc and pH with a pH electrode (Jenway, model 3020). Total alkalinity was determined titrimatrically. Ammonia-nitrogen (NH_3-N) was determined by HACH Kit (DR/2010, a direct reading spectrometer).

A good number of fishes (10-20% of the stock) were sampled fortnightly by using cast net from open pond and scoop net from cage and then length and weight of each species was taken separately to assess the growth rate of fish. At the end of the experiment, water was pumped out of the ponds and all fishes were collected, counted and weighed individually for each pond to assess the survival rate and production. Experimental data was collected and analyzed as follows:

Weight gain (g) = Mean final weight (g) – Mean initial weight (g)
Food conversion ratio (FCR) = Dry food fed/live weight gain
Survival rate = (No of fish harvested ×100)/No of fishes stocked

An analysis was conducted to determine economic return of the integrated cage-cum-pond culture system for each treatment (Shang, 1990). The analysis was based on market prices in Bangladesh for harvested fish and all other items, which was expressed in Bangladesh Tk. (US $1= 68 Tk.). Market prices of harvested carps were 50 Tk/kg and 250 Tk/kg for climbing perch. Market price of carp fingerlings (2 Tk/piece), climbing perch fingerlings (3 Tk/piece) and pelleted feed (20 Tk/kg) were applied to the analysis.

Data were analyzed statistically by one-way analysis of variance and linear regression (Steele and Torrie 1980) using SPSS (version 10.0) statistical software (SPSS Inc., Chicago, USA). Differences were considered significant at an alpha of 0.05. Means were given with ± standard error (S.E)

Results

Water quality parameters

The results of water quality parameters in different ponds are shown in Table 1. The recorded dissolved oxygen concentration at 10.00 h fluctuated between 2.3 mg/l to 8.00 mg/l with significant variation ($p<0.05$), while temperature in the experimental ponds was found to vary from 19.10°C to 26.10°C. Overall mean and final values of pH were found to be approximately neutral or slightly alkaline ranging from 6.3 to 8.3 and were significantly higher in $T_{1:1}$ than $T_{0:1}$ and $T_{2:1}$. The mean values of total alkalinity and NH_3-N were significantly different ($p<0.05$) among the treatments.

Table 1. Overall mean values of water quality parameters for each treatments

Parameters	Ratio of caged fish to open pond carps			ANOVA
	$T_{0:1}$	$T_{1:1}$	$T_{2:1}$	
Temperature (°C)	22.89±1.76	23.15±1.86	23.74±2.08	NS
Dissolved O_2 (mg/l)	5.19±1.31^{b}	4.63±0.86^{ab}	4.39±1.24^{a}	*
pH	7.24^{b}	7.44^{a}	7.2^{b}	*
Alkalinity (mg/l)	92.67±13.62^{b}	84.6±19.57^{b}	110.7±42.78^{a}	*
Ammonia-nitrogen (mg/l)	0.64±0.43^{ab}	0.51±0.33^{b}	0.76±0.56^{a}	*

* $p< 0.05$, NS - not significant. Means with the different superscripts are significantly different ($p< 0.05$)

Performance of cage fishes

The performance of cage fishes has been summarized in Table 2. The average individual weight of climbing perch at stocking was same (2.5 g/fish) in both treatment and total initial weight (kg/pond) of climbing perch was significantly different ($p<0.05$) between the treatments due to different stocking ratio. The net yields of Thai koi were 0.13±0.01 (t/ha) and 0.10±0.01 (t/ha) in $T_{1:1}$ and $T_{2:1}$, respectively and both were significantly different ($p<0.05$).The higher survival was obtained in $T_{1:1}$ followed by $T_{2:1}$ with significant variation between two treatments ($p<0.05$). Survival of climbing perch (Thai koi) in cages was low, ranging from 30% to 61.67%. FCR was very high in both $T_{1:1}$

and $T_{2:1}$ (11.3 and 25.1, respectively) and were significantly different ($p<0.05$) between two treatments.

Table 2. Performance of climbing perch stocked in each treatment

	Ratio of caged fish to open pond carps	
	$T_{1:1}$	$T_{2:1}$
Total initial weight (kg/cage)	0.50±0.00[a]	1.0±0.00[b]
Total final weight (kg/cage)	3.04±1.28[a]	2.49±2.24[b]
Total weight gain (kg/cage)	2.55±0.12[a]	2.07±0.17[b]
Total net yield (t/ha/crop)	0.13±0.01[a]	0.10±0.01[b]
Total gross yield (t/ha/crop)	0.14±0.01[a]	0.12±0.01[b]
Survival (%)	61.67±1.86[a]	30.0±4.73[b]
FCR	11.31±0.44[a]	25.13±3.43[b]

Means with the different superscripts are significantly different ($p< 0.05$)

Performance of pond fishes

The performance of pond fishes has been summarized in Table 3. Survival of carps was high ranging from 50 to 91.67%. The lowest survival rate was found in control pond that was significantly different ($p<0.05$) from treatment $T_{1:1}$ and $T_{2:2}$. Total gross and net yields of silver carp, catla and raj punti in all treatments were significantly different ($p<0.05$). In case of rohu, mrigal and common carp, total gross and net yields in control ponds were significantly lower ($p<0.05$) from treatments $T_{1:1}$ and $T_{2:1}$.

Table 3. Performance of carps stocked in each treatment

Performance	Ratio of caged fish to open pond carps		
	$T_{0:1}$	$T_{1:1}$	$T_{2:1}$
Silver carp			
Total initial weight (kg/pond)	0.53±0.03	0.54±0.04	0.55±0.05
Total final weight (kg/pond)	7.08±0.77[a]	15.92±1.09[c]	12.18±1.09[b]
Total weight gain (kg/pond)	6.78±0.77[a]	15.44±1.07[c]	11.72±1.07[b]
Total net yield (t/ha/crop)	0.34±0.04[a]	0.77±0.05[c]	0.59±0.05[b]
Total gross yield (t/ha/crop)	0.36±0.04[a]	0.80±0.05[c]	0.61±0.05[b]
Survival (%)	57.0±3.74[a]	87.33±3.50[b]	85.0±3.74[b]
Catla			
Total initial weight (kg/pond)	0.42±0.02	0.39±0.02	0.40±0.04
Total final weight (kg/pond)	5.04±1.54[a]	11.80±1.24[c]	11.32±1.26[b]
Total weight gain (kg/pond)	4.77±1.53[a]	11.46±1.24[c]	10.95±1.23[b]
Total net yield (t/ha/crop)	0.24±0.07[a]	0.57±0.06[c]	0.55±0.06[b]
Total gross yield (t/ha/crop)	0.25±0.08[a]	0.59±0.06[c]	0.57±0.06[b]
Survival (%)	62.92±4.85[a]	88.33±4.38[b]	91.67±2.58[b]

Rohu			
Total initial weight (kg/pond)	0.43±0.02	0.43±0.03	0.43±0.03
Total final weight (kg/pond)	3.83±0.35^a	8.98±0.25^b	10.28±3.53^b
Total weight gain (kg/pond)	3.57±0.35^a	8.61±0.26^b	9.84±3.60^b
Total net yield (t/ha/crop)	0.18±0.02^a	0.43±0.01^b	0.44±0.17^b
Total gross yield (t/ha/crop)	0.19±0.02^a	0.45±0.01^b	0.45±0.08^b
Survival (%)	60.0±6.12^a	88.75±2.09^b	89.17±3.76^b
Mrigal			
Total initial weight (kg/pond)	0.42±0.02	0.43±0.03	0.43±0.02
Total final weight (kg/pond)	4.17±0.53^a	9.65±1.04^b	8.98±1.36^b
Total weight gain (kg/pond)	3.92±0.52^a	9.25±1.06^b	8.59±1.35^b
Total net yield (t/ha/crop)	0.23±0.10^a	0.47±0.05^b	0.43±0.07^b
Total gross yield (t/ha/crop)	0.21±0.03^a	0.49±0.05^b	0.45±0.07^b
Survival (%)	59.17±4.65^a	91.17±3.03^b	90.83±2.58^b
Common carp			
Total initial weight (kg/pond)	0.10±0.01	0.09±0.01	0.10±0.02
Total final weight (kg/pond)	1.19±0.15^a	3.07±0.41^b	3.22±0.40^b
Total weight gain (kg/pond)	1.13±0.14^a	2.99±0.40^b	3.14±0.39^b
Total net yield (t/ha/crop)	0.06±0.01^a	0.15±0.02^b	0.16±0.02^b
Total gross yield (t/ha/crop)	0.07±0.01^a	0.16±0.02^b	0.16±0.02^b
Survival (%)	61.67±7.53^a	90.0±6.32^b	86.67±5.16^b
Raj punti			
Total initial weight (kg/pond)	0.18±0.01	0.19±0.01	0.18±0.02
Total final weight (kg/pond)	0.94±0.14^a	2.99±0.35^c	2.47±0.34^b
Total weight gain (kg/pond)	0.85±0.13^a	2.83±0.63^c	2.32±0.34^b
Total net yield (t/ha/crop)	0.04±0.01^a	0.14±0.02^c	0.12±0.02^b
Total gross yield (t/ha/crop)	0.05±0.01^a	0.15±0.02^c	0.12±0.02^b
Survival (%)	50.0±6.32^a	87.50±2.74^b	84.17±3.76^b

Means with the different superscripts are significantly different ($p<0.05$)

Combined performance of caged fish and carps

Combined initial weight of Thai climbing perch and carps were 2.57±0.07 (kg/pond) and 3.08±0.07 (kg/pond) in $T_{1:1}$ and $T_{2:1}$, respectively and were significantly different ($p<0.05$) between two treatments (Table 4). Combined net and gross yields were significantly different ($p<0.05$) between two treatments. Overall FCR was better in $T_{1:1}$ treatment (0.54) and poorer in $T_{2:1}$ treatment (1:07) and were significantly different ($p<0.05$) between two treatments.

Table 4. Combined performance of climbing perch and carps in each treatments

Performance	Ratio of cage fish to open pond carps	
	$T_{1:1}$	$T_{2:1}$
Total initial weight (kg/pond)	2.57 ± 0.07^a	3.08 ± 0.07^b
Total final weight (kg/pond)	55.26 ± 0.95^a	50.82 ± 4.74^b
Total weight gain (kg/pond)	53.12 ± 0.98^a	48.69 ± 4.70^b
Total net yield (t/ha/crop)	2.66 ± 0.05^a	2.44 ± 0.23^b
Total gross yield (t/ha/crop)	2.76 ± 0.05^a	2.54 ± 0.23^b
Overall FCR	0.54 ± 0.03^a	1.07 ± 0.14^b

Means with the different superscripts are significantly different ($P < 0.05$)

Partial budget analysis

The partial budget analysis has been summarized in Table 5. Gross income was higher in $T_{1:1}$ followed by $T_{0:1}$ and $T_{2:1}$ and was significantly different ($p<0.05$) from $T_{0:1}$ and $T_{2:1}$. Gross income from carps in $T_{0:1}$ was significantly lower than those in other treatments ($p<0.05$). Gross income from harvested Thai climbing perch in $T_{2:1}$ did not exceed the cost for koi fingerlings. Costs related to the Thai koi increased significantly with stocking density ($p<0.05$). Net income was 1,458.22 Tk/pond in $T_{1:1}$, which was significantly higher than those in other treatments ($p<0.05$).

Table 5. Partial budget analysis

Parameter (Tk Pond^{-1})	Ratio of caged fish to open pond carps		
	$T_{0:1}$	$T_{1:1}$	$T_{2:1}$
Gross income			
Carps	$1,112.08\pm128.19^a$	$2,620.42\pm39.33^c$	$2,422.42\pm218.92^b$
Thai koi		713.75 ± 28.27^b	592.92 ± 47.84^a
Total	$1,112.08\pm128.19^a$	$3,334.17\pm62.5^c$	$3,015.33\pm210.25^b$
Operational cost			
Carps fingerlings	400 ± 0	400 ± 0	400 ± 0
Thai koi fingerlings	-	600 ± 0^a	1200 ± 0^b
Cage	-	300 ± 0	300 ± 0
Pelleted feed	-	575.95 ± 33.66^a	$1,032.7\pm73.55^b$
Total	400 ± 0^a	$1,875.95\pm33.66^b$	$2,932.7\pm73.55^c$
Net income	712.08 ± 128.19^a	$1,458.22\pm44.25^c$	82.63 ± 253.41^b

Means with the different superscripts are significantly different ($p< 0.05$)

Discussion

Some of the measured water quality parameters varied significantly and some were not, which indicates that apart from natural factors the stocking density of climbing perch along with carp and ration of feed might have influence on the pond water. In the past, it was observed that, as caged fish are generally fed with high protein diets, wastes derived from feed are either directly or indirectly released to the surrounding environment, causing accelerated eutrophication in those waters (Beveridge 1984, Ackefors 1986, Lin 1990). Water temperature ranged from 19.10°C to 26.70°C during the investigation period. Dissolved oxygen content of water was found to be within 2.3 to 8.0 mg/l respect to the productivity. A little higher level of DO was observed in treatment $T_{1:1}$, where the stocking density of climbing perch was the lower. Although the climbing perch can tolerate low dissolved O_2 due to their ability to breathe air, water quality does appear to influence their growth and survival (Diana *et al.* 1988). pH values were almost neutral (6.3-8.3) which indicates good productivity of the pond water. For pond fish culture the suitable range of pH is 6.5 to8.5 (Boyd 1990). Alkalinity of water was found to be in the range of 59 to 220 mg/l. The highest mean total alkalinity was measured in $T_{2:1}$, where the highest amount of pelleted feed was used as there was the highest stocking density of climbing perch in cages. The use of organic inputs may keep alkalinity at higher level (Knud-Hansen *et al.* 1992, Diana *et al.* 1994). Significantly higher concentration of NH_3-N was measured in $T_{2:1}$ might be due to the higher stocking density of climbing perch and application of higher amount of feed.

Survival of climbing perch was quite lower than other air breathing fishes. Survival of the caged hybrid catfish ranged from 54% to 92% (Lin et al. 1989, Lin 1990), which was higher than the present experiment (30 to 61.67%). Mass mortality of caged fish occurred during the first three weeks of stocking of the climbing perch in this experiment. The low survival might have been caused by poor quality of small size seed and high stocking density.

Climbing perch (Thai koi) is an exotic, newly introduced and high-valued fish species in Bangladesh. Therefore, little research and less breeding programs have been undertaken to improve growth and production performance of this species. This is a common problem for exotic fish species in many countries. Growth of climbing perch was very poor in the present experiment. Density might not be the main reason, evidenced by the non-significant growth differences across stocking densities. Small size, poor quality fry and low temperature may be the main reasons for poor growth. This experiment was conducted during September –January, most of which (November-January) was winter season. Low temperature may cause low feed intake with resultant poor growth.

Mean net yield of climbing perch was higher (0.13±0.01) in $T_{1:1}$ with lower stocking density. The lower net yield was found in $T_{2:1}$, with higher stocking density due to mainly huge mortality and affected by EUS (Epizootic Ulcerative Syndrome) diseases. The feed was given to the fish at the rate of 10% body weight per day in the first month and reduced up to 5% body weight in the rest of the culture period, which was not utilized properly might be due to comparatively lower feed intake during winter. FCRs were better in $T_{1:1}$ (11.31) compared to $T_{2:1}$ (25.13). FCR was very high mainly due to high mortality of cage climbing perch.

Survival of all carps was high in this experiment. Survival in control ponds ($T_{0:1}$) was significantly ($p<0.05$) lower than others treatments, might be due to absence of climbing perch and feed inputs. Net and gross yields of all carps were significantly lower ($p<0.05$) in $T_{0:1}$ than other treatments, due mainly to application of appropriate feeding ratio and resultant optimum loading of waste nutrients from cages to open ponds. In integrated cage-pond aquaculture systems, waste derived from cages can effectively support growth of filter feeding species such as Nile tilapia in open pond, and the growth of open-pond fish increases with increasing nutrient loading from cages (Lin 1990, Lin and Diana 1995, Yi, *et al.* 1996, Yi 1997, Yi and Lin 2000, 2001). However, waste released from cages to ponds in the present experiment was mainly in the form of feed materials instead of metabolic wastes of climbing perch, which may explain the good growth of common carp and mrigal.

Although low yields of climbing perch were recorded in this experiment, net revenues were positive but low in all treatments. This was mainly due to the premium price of climbing perch even at small size. The climbing perch has potential to be cultured in a cage-pond aquaculture system, but further improvements are needed.

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