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Comparison between cage and pond production of Thai Climbing Perch (*Anabas testudineus*) and Tilapia (*Oreochromis niloticus*) under three management systems

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Abstract

An experiment was conducted to compare production and economic performance of Thai Climbing Perch (*Anabas testudineus*) and Tilapia (*Oreochromis niloticus*) under three management systems. The nursed juveniles of Thai Climbing Perch (6.22 ± 0.15g) and Tilapia (22.52 ± 0.73g) were stocked at 50 Thai Climbing Perch per 1m^3 cage and 50 Tilapia per 80m^2 open pond (Caged Perch); 50 Tilapia per 1m^3 cage and 50 Thai Climbing Perch per 80 m^2 open pond (Caged Tilapia); and both 50 Thai Climbing Perch and 50 Tilapia per 80m^2 pond (Mixed culture) as three treatments with three replicates for each. Pelleted feed (35% crude protein) was given twice daily (8.0 h and 16.0 h) at a rate of 10% body weight of Thai Climbing Perch for first month and 5% body weight of Thai Climbing Perch for rest of the culture period (90 days) to cages for the integrated cage-pond culture and to open ponds for the mixed culture. Among the measured water quality parameters transparency (cm), alkalinity (mg l^{-1}), nitrite-nitrogen (mg l^{-1}), and chlorophyll-*a* (µg l^{-1}) were significantly different among the treatments. A total of 43 genera of phytoplankton and 16 genera of zooplankton were identified from the pond water. The mean abundance of total macro-benthic organisms was not significantly different (P>0.05). The mean survival rate of Thai Climbing Perch was high, ranging from 86.67% to 98.67%. Gross yield of Thai Climbing Perch was the highest in the Caged Perch. Survival of Tilapia was also high, ranging from 94.00% to 96.67%. The combined FCRs were 0.75, 0.77 and 0.85 in the Caged Perch, Mixed culture and Caged Tilapia systems, respectively. Economic analysis revealed that a significantly higher (P<0.05) cost-benefit ratio was obtained in the Caged Perch treatment. Therefore, it is concluded that the integrated cage-pond culture system with the high-valued Thai Climbing Perch in cages and low-valued Tilapia in open ponds may be a better option for rural pond aquaculture considering the production and economic benefit.

Keyword: Cage culture, Integrated aquaculture, Climbing Perch, Tilapia

Introduction

Among the various culture systems, integrated aquaculture is considered as a sustainable small scale aquaculture system. The nature of integration may be of various types, the integrated cage-pond fish culture technique is a new and innovative one. Cage aquaculture has certain advantages over other aquaculture systems that are potentially important in terms of uptake by rural poor and landless people. Using cages to grow fish are use of existing ponds that are currently not utilize, ease of feeding, ease of stocking and harvesting, less expense associated with treating or preventing disease, easier stock management and monitoring compared with pond culture.

In cage aquaculture technical simplicity with which farms can be established or expanded, lower capital cost, feeding, growth and health of stocked fishes can be monitored on a daily basis without much disturbance, cultured species are well and harvesting of cultured species would be easier and cost-effective. 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 the receiving waters (Beveridge, 1984; Ackefors, 1986; Lin, 1990).

In polyculture, ponds are stocked together with several species of different feeding habits. It is impossible to target feeding to only high-valued species, because low-valued species would consume the feed resulting in economic inefficiency unless a suitable integrated system is adopted. Compared to the nutrient utilization efficiency of about 30% in most intensive culture systems (Beveridge and Phillips, 1993; Acosta-Nassar *et al*., 1994), the nutrient utilization efficiency could reach more than 50% in integrated cage-cum-pond culture systems, resulting in the release of much less nutrients to the surrounding environment (Yi, 1999). In case of poor farmers, they have limited financial resources so they can not turn their whole ponds to culture high-valued species using expensive commercial feed. 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. There are a very few literatures on the integrated cage and pond production of Climbing Perch and/or Tilapia. So, present work was undertaken to fill up the gap of the available information on the integrated cage and pond production system of Climbing Perch and Tilapia. The specific objectives of the research were- to identify the suitable culture system of Thai Climbing perch and Tilapia among integrated cage-ponds and mixed pond culture systems, to assess growth and production and the impact of these systems on pond ecology, identify the problems, needs and opportunities of cage-pond aquaculture for promoting Thai Climbing Perch and Tilapia culture technology and to compare the economic benefits of these systems.

Materials and Methods

Experimental design

An on-station trial was undertaken with 3 treatments and 3 replications for each. The treatments were Caged Perch, Caged Tilapia and Mixed culture. Thai Climbing Perch (*Anabas testudineus*) and Tilapia (*Oreochromis niloticus*) were stocked in cages and open water of ponds to give caged and open pond fish ratios 1:1 in Caged Perch and Caged Tilapia treatments, where as in Mixed culture treatment the fish ratios was also 1:1. In Caged Perch treatment, 50 Thai Climbing Perch fingerlings were stocked in cage and 50 Tilapia fingerlings were stocked in open pond. In Caged Tilapia treatment, 50 Thai Climbing Perch fingerlings were stocked in open pond and 50 Tilapia fingerlings were stocked in cage. In Mixed culture treatment, both species i.e. 50 Thai Climbing Perch and 50 Tilapia fingerlings were stocked in open water of the pond.

Experimental site and pond preparation

The experiment was conducted at the Fisheries Field Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh. The field trial was carried out for a period of 120 days from 16 October, 2006 to 12 February, 2007. Nine earthen ponds each having an area of 80m^2 and an average depth of 1.5m were used for this experiment. The ponds were rectangular in shape, equal in size, depth, basin configuration, bottom types and contour and fully exposed to prevailing sunlight and were previously used for research. The main sources of water of the ponds were rainfall and deep tube-well. Before starting the experiment, ponds were renovated and cleaned of aquatic vegetation. All unwanted fishes and other larger aquatic organisms were eradicated by application of rotenone at the rate of 2.5g m^{-3}. Open ponds stocked with Climbing Perch were fenced by 1m height nylon net and bamboo poles. Lime ($CaCO_3$) was applied to the pond water at the rate of 250kg ha^{-1}. One week after liming, the ponds were filled with water from adjacent deep tube-well. Then the ponds were fertilized with cattle manure, urea and TSP at the rate of 1000, 50 and 50kg ha^{-1}, respectively.

Cage construction and suspension

Six cages were constructed each with size of 1m^3 (1m×1m×1m). The cages were square shaped, made of iron frame and covered by black nylon net with tied nylon twine. The mesh size was small enough (8mm to15mm) not to allow the experimental fish fry escape and large amount of water can easily pass through the cages. One edge of upper side of each cage was kept open and tied with nylon threads for management practice. One cage was installed in each Caged Perch and Caged Tilapia pond with the help of one horizontal and two vertical bamboo poles before stocking. The cages were installed at 15cm above the pond bottom at the middle of each pond giving a water volume of 0.85m^3. The cages were tied fixed with bamboo frame by nylon ropes. Bamboo made platforms between pond banks and cages was used for easy feed supply and observation of the cages.

Stocking and management

Thai Climbing Perch fry were collected from a nearby commercial hatchery and Tilapia juveniles were collected from Bangladesh Fisheries Research Institute (BFRI), Mymensingh. Both Thai Climbing Perch and Tilapia were nursed for 25 days before stocking. The average mean initial weight of the fingerlings of Thai Climbing Perch and Tilapia were 6.22 ± 0.15g and 22.53 ± 0.73g respectively. Feed was formulated to contain 35% protein and prepared by local feed machine. A feeding plate (42cm×26cm×4cm) was hung from the upper corners of the cage with the help of nylon rope in each cage. Feeds were supplied at 10% body weight of Thai Climbing Perch for first month and 5% body weight for rest of the culture period. Formulated pelleted feed was given twice daily at 8:00 h and 16:00 h. Feeding rates were adjusted monthly after fish sampling and weighing. In Caged Perch and Caged Tilapia treatments the feeds were supplied in cages, whereas in Mixed culture treatment feeds were supplied in open pond. The cages were lifted from water at every 15 days interval to check the net and cleaning purpose. The proximate composition of the feed is given in Table 1.

Table 1. Proximate composition of the prepared feed

Component	Moisture (%)	Protein (%)	Lipid (%)	Fiber (%)	Ash (%)	NFE*(%)
Prepared feed	11.2	34.9	7.9	4.1	12.1	29.8

The percentages are given on a wet weight basis
* NFE = nitrogen free extracts

Harvesting of fish and estimation of yield parameters

At the end of the experiment, cage fishes were harvested by scoop net and open water fishes were harvested after draining the ponds. The individual length and body weight of fishes were recorded by a wooden measuring board (precision 0.1cm) and a balance (Denver-xp-3000; precision 0.1g) respectively. Specific growth rate (SGR), feed conversion ratio (FCR), and net yields were calculated as follows:
SGR = [ln (final weight) – ln (initial weight) ×100]/ No. of days of the experiment
FCR = Feed applied (dry weight)/ Live weight gain
Net yield = total biomass at harvest – total biomass at stocking

Determination of water quality parameters

The water quality measurements and sample collection were made between 8.00 h and 9.00 h on each sampling day. Water samples were collected by using a horizontal tube sampler from three locations of each pond and pooled before analysis. Water quality parameters like temperature (Celsius thermometer), dissolved oxygen (YSI digital DO, model 58), pH (CORNING 445 pH meter) and transparency (Secchi disc) were monitored on weekly basis. Before nutrient analysis, water samples were filtered through micro-fibre glass filter paper (Whatman GF/C), using a vacuum pressure air pump. Total alkalinity (Titrimetric method) and NH_3–N, NO_2–N, NO_3–N and PO_4–P concentrations (HACH kit model DR 2010) in the filtrate were measured on a monthly basis (APHA, 1992). The filter paper was kept in a test tube containing 10ml of 90% acetone, ground with a glass rod and preserved in a refrigerator for 24 h. Later, chlorophyll-*a* was determined using a spectrophotometer (Milton Roy Spectronic, model 1001 plus) at 750nm and 664nm wave length following Boyd, 1979.

Determination of plankton abundance

Qualitative and quantitative study of plankton was done on monthly basis. Ten liters of water samples were randomly collected from five different sites of each pond and passed through a plankton net (mesh size 45μm) and finally concentrated to 50ml with 5ml formalin (40% Formaldehyde) for preservation and subsequently study. A compound binocular microscope (Olympus BH-2 with phase contrast facilities) was used for the study of plankton and enumerated using a Sedgewick-Ruffer counting cell (S-R). One (1) ml sub-sample of each stored sample was transferred to the cell and left to settle for 10 minutes. Phytoplankton and zooplankton present on 10 squares of the cell chosen randomly and counted. Calculation of plankton was done by using the following formula:

N = (P×C×100)/L (Azim *et at*. 2001)

Where

N = the number of plankton cells or units per litter of original water
P = the number of plankton counted in ten fields.
C = the volume of final concentrate of the sample (ml)
L = the volume (liters) of pond water sample

Determination of benthic fauna

Samplings of macro-benthos were carried out using Ekman dredge (mouth area 225cm^2). Benthos samples were collected monthly from three locations, just beneath the cage, middle of the pond, and one side of the pond in all ponds. Each sample was washed through a series of standard brass sieves of mesh sizes 0.2mm for a preliminary separation of benthos and larger particles from mud and wager. The organisms and trash was poured into a white plate to pickup the live organisms by means of fine forceps. Collected organisms were preserved in 10% formalin for laboratory analysis. The organisms were classified into major taxonomic groups and were counted with the help of magnified glass whenever necessary. The abundance of macroscopic organism was expressed as density (individuals/m^2) by the following formula of Welch, 1948.

$$N= [O / (A \times S)] \times 10000$$

Where,

N = Number of macroscopic organisms in 1m^2 of pond
O = Number of organisms actually counted
A = Transverse area of Ekman dredge in cm^2
S = Number of samples taken at one sampling station

Economical analysis

Economic analysis was conducted to determined economic returns of different treatments based on market prices in Bangladesh for harvested fishes and all other items expressed in Taka. The wholesale price per kg of Thai Climbing Perch was 250 Taka and Tilapia was 80 Taka. The prices of inputs and fish correspond to the Mymensingh wholesale market prices in 2007 and are expressed in Bangladeshi Taka (1US$=68.5 BDT).

Statistical analysis

All the data collected during experiment were recorded and preserved on a computer spreadsheet. Growth and yield parameters and economic performance of the experiment were analyzed statistically by one-way ANOVA and DMRT (Duncan Multiple Range Test) using the SPSS (Statistical Package for Social Science) statistical software. If a main effect was significant, the ANOVA was followed by DMRT at *P<0.05*.

Results and Discussion

Water quality parameters

No significant difference (*P>0.05*) of temperature was found by ANOVA among the treatment (Table 2). The highest mean values of water transparency were recorded in Caged Perch and the lowest in Caged Tilapia treatment. Dissolved oxygen (DO), pH, NH_3-N, NO_2-N and PO_4-P, did not show that there were no significant difference (*P>0.05*) among the three treatments.

Table 2. Mean (± SE) values of water quality parameters from three different treatments

Variables	Mean (DMRT)			
	Caged Perch	Caged Tilapia	Mixed culture	Significance $^{\Psi}$
Water quality parameters				
Temperature (^{0}C)	21.29 ± 0.42	21.38 ± 0.42	21.06 ± 0.44	NS
Dissolved Oxygen (mg l^{-1})	6.56 ± 0.08	6.51 ± 0.07	6.65 ± 0.09	NS
pH	8.08	8.01	8.01	-
Transparency (cm)	30.94 ± 0.85^a	25.98 ± 0.82^b	29.65 ± 0.98^a	*
Alkalinity (mg l^{-1})	153.87 ± 7.28^a	142.27 ± 7.51^a	130.13 ± 7.55^b	*
Ammonia-nitrogen (mg l^{-1})	0.167 ± 0.023	0.142 ± 0.028	0.098 ± 0.026	NS
Nitrite-nitrogen (mg l^{-1})	0.008 ± 0.001^a	0.003 ± 0.001^b	0.004 ± 0.001^b	*
Nitrate-nitrogen (mg l^{-1})	0.049 ± 0.023	0.039 ± 0.009	0.023 ± 0.004	NS
Phosphate-phosphorus (mg l^{-1})	2.45 ± 0.45	2.57 ± 0.41	2.59 ± 0.46	NS
Chlorophyll-*a* (µg l^{-1})	97.11 ± 6.37^b	143.91 ± 9.46^a	99.82 ± 9.60^b	*

The mean (± SE) values with different superscripts in the same row were significantly different.
Ψ Result from repeated measures one-way ANOVA, NS = Not significant (*P>0.05*), * Significant (*P<0.05*)

The alkalinity of pond water of different treatments ranged from 78mg l^{-1} and 190mg l^{-1}. The mean value of alkalinity in mixed culture treatment was significantly lower than that of Caged Perch and Caged Tilapia treatments, when ANOVA was performed. Some variations of the overall values of nitrate-nitrogen were found in all treatments. The mean values of chlorophyll-*a* showed significant difference (*P<0.05*), when ANOVA was performed and the highest in Caged Tilapia and the lowest in Mixed culture treatment.

Plankton abundance

The mean abundance of phytoplankton under different treatments is presented in Table 3. In all treatments, Chlorophyceae was the most dominant group. The mean values of Chlorophyceae were significantly different (*P<0.05*) and the highest values were observed in Caged Tilapia treatment (78.13×10^3cells l^{-1}) and the lowest in Mixed culture (16.90×10^3cells l^{-1}) treatment. Bacillariophyceae ranked second in respect of abundance and, Euglenophyceae was the fourth. A total of 7 genera of Rotifera and among them *Brachionus* was the dominant genus. There was no significant difference of Crustacean abundance observed in Caged Perch and Mixed culture treatment, but significant difference was observed in Caged Tilapia with Caged Perch and Mixed culture treatments. Total plankton abundance was significantly different and the highest value (144.33×10^3cells l^{-1}) was observed in Caged Tilapia and the lowest value (44.90×10^3cells l^{-1}) was observed in Caged Perch treatment.

Table 3. Mean (± SE) values of different groups of plankton abundance recorded from three different treatments in over the experimental period

Variables	Mean (DMRT)			
	Caged Perch	Caged Tilapia	Mixed culture	Significance $^{\Psi}$
Plankton Groups				
Bacillariophyceae	13233.33 ± 2.96^b	43966.67 ± 7.02^a	15333.33 ± 2.51^b	*
Chlorophyceae	18100 ± 3.91^b	78133.33 ± 17.74^a	16900 ± 1.57^b	*
Cyanophyceae	4566.667 ± 0.37^b	7966.667 ± 0.52^a	6633.333 ± 0.95^a	*
Euglenophyceae	4066.667± 0.79	5333.333 ± 0.95	5300 ± 1.12	NS
Crustacea	3600 ± 1.12	5433.333 ± 0.62^a	3600 ± 0.64^b	*
Rotifera	1333.333 ± 0.19	3500 ± 0.63	8766.667 ± 4.68	NS
Total plankton	44900 ± 5.86^b	144333.3 ± 19.59^a	56533.33 ± 5.09^b	*

The mean (± SE) values with different superscripts in the same row were significantly different.
Ψ Result from repeated measures one-way ANOVA, NS = Not significant (*P>0.05*), * Significant (*P<0.05*)

Benthos production

The major groups of benthic fauna Chironomidae, Oligochaeta and Mollusca, and however there was a group as un-identified. The abundances of different groups of benthic organisms are presented in Table 4. The abundance of total benthic population was found as 1082.47 individuals m^{-2} in Caged Perch, 1286.91 individuals m^{-2} in Caged Tilapia and 1370.86 individuals m^{-2} in Mixed culture treatment. Chironomidae was found as the most dominant group of benthic fauna, Oligochaeta was the second dominant group, but there was significant difference (*P<0.05*) of Molluscs among the treatment. The rest of the benthic fauna was un-identified group and there was no significant difference of abundance of un-identified group among the treatments.

Table 4. Mean (± SE) values of different groups of benthic fauna recorded from three different treatments over the experimental period

Variables	Mean (DMRT)			
	Caged Perch	Caged Tilapia	Mixed culture	Significance $^{\Psi}$
Benthic fauna				
Chironomidae	663.70 ± 84.29	718.03 ± 174.29	722.96 ± 163.32	NS
Oligochaeta	228.15 ± 48.16	379.26 ± 60.31	385.19 ± 74.62	NS
Molluscs	26.67 ± 5.05^b	$24.69 \pm 6.25a^b$	152.09 ± 44.81^a	*
Un-identified (benthos)	163.95 ± 20.87	164.94 ± 32.09	110.62 ± 14.88	NS
Total benthos	1082.47 ± 99.7	1286.91 ± 208.1	1370.86 ± 202.5	NS

The mean (± SE) values with different superscripts in the same row were significantly different.
Ψ Result from repeated measures one-way ANOVA, NS = Not significant (*P>0.05*), * Significant (*P<0.05*)

Growth and yield parameters

The growth and production performance of Thai Climbing Perch and Tilapia in three treatments are presented in Table 5. The average initial weight of Thai Climbing Perch was 6.22g individual^{-1}. In case of Tilapia, the average mean initial weight of individual was 22.52g individual^{-1}. The average final weight of individual Thai Climbing Perch was 27.33g individual^{-1}. The mean final weight of individual Thai Climbing Perch varied significantly ($P<0.05$) among the treatments and the higher yield was observed in Caged Perch and lower in Caged Tilapia treatment. The final weight of individual Tilapia ranged from 78.42g to 106.81g individual^{-1}. The mean values of final weight of Tilapia showed that there was no significant difference among the treatments. The mean values of FCR were significantly different ($P<0.05$) among the treatments, and the highest value was observed in Caged Tilapia treatment and the lowest in Caged Perch treatment. The combined FCR in Caged Perch, Caged Tilapia and Mixed culture treatments were 0.72, 0.79 and 0.71, respectively**.** The gross production of Thai Climbing Perch ranged from 136.27 to 212.5kg ha^{-1} 120 d^{-1}. The highest production was observed in Caged Perch treatment and the lowest in Caged Tilapia treatment. ANOVA showed that there was no significant difference of gross production of Tilapia among the treatments. The highest survival rate was 98.67% in Caged Perch treatment and the lowest (86.67%) in Caged Tilapia treatment.

Table 5. Comparison of mean (±SE) values of growth and yield parameters of Climbing perch and Tilapia in three different treatments

Variables	Mean (DMRT)			
	Caged Perch	Caged Tilapia	Mixed culture	Significance $^{\Psi}$
Climbing perch				
Individual stocking weight (g)	6.77 ± 0.07	6.10 ± 0.12	6.30 ± 0.25	NS
Individual harvesting weight (g)	32.83 ± 0.61^{a}	22.18 ± 0.31^{c}	26.93 ± 0.33^{b}	*
Individual weight gain (g)	26.06 ± 0.63^{a}	16.08 ± 0.35^{c}	20.63 ± 0.09^{b}	*
Specific growth rate (% day^{-1})	1.29 ± 0.02^{a}	1.06 ± 0.02^{c}	1.19 ± 0.02^{b}	*
Gross yield (kg ha^{-1} 120 d^{-1})	205.00 ± 4.02^{a}	138.33 ± 2.08^{c}	168.33 ± 2.20^{b}	*
Net yield (kg ha^{-1} 120 d^{-1})	162.69^{a}	100.21^{c}	128.96^{b}	*
FCR	2.8 ± 0.03^{c}	3.98 ± 0.09^{a}	3.41 ± 0.04^{b}	*
Survival (%)	98.67^{a}	86.67^{b}	97.33^{a}	*
Tilapia				
Individual stocking weight (g)	22.27 ± 0.79	20.73 ± 0.68	17.57 ± 1.71	NS
Individual harvesting weight (g)	92.91± 1.89	84.75 ± 3.94	94.90 ± 6.53	NS
Individual weight gain (g)	70.64 ± 2.09	64.02 ± 3.80	77.33 ± 6.95	NS
Average daily gain (g/day)	0.579 ± 0.017	0.525 ± 0.031	0.634 ± 0.057	NS
Specific growth rate (% day^{-1})	1.172 ± 0.035	1.153 ± 0.041	1.386 ± 0.099	NS
Gross yield (kg ha^{-1} 120 d^{-1})	553.64 ± 19.86	511.91 ± 17.75	581.28 ± 40.02	NS
Net yield (kg ha^{-1} 120 d^{-1})	414.45	382.35	471.47	NS
Survival (%)	94.00	96.67	96.00	NS
Combined				
FCR	0.72^{b}	0.79^{a}	0.71^{b}	*
Gross yield (kg ha^{-1} 120 d^{-1})	758.64^{a}	650.24^{c}	749.61^{b}	*
Net yield (kg ha^{-1} 120 d^{-1})	577.14^{a}	482.6^{b}	600.43^{a}	*

The mean (±SE) values with different superscripts in the same row were significantly different.
Ψ Result from repeated measures one-way ANOVA
NS = Not significant ($P>0.05$)
* Significant ($P<0.05$)

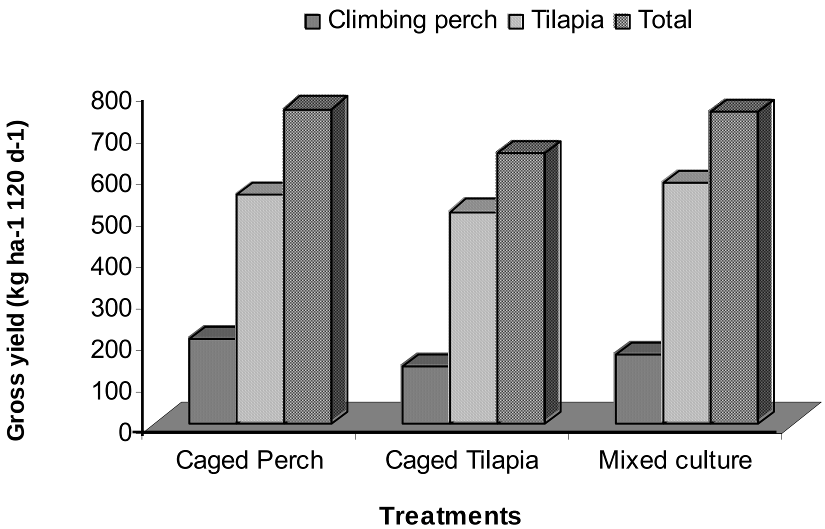

Fig. 1. Comparative production performance (kg ha^{-1} 120 d^{-1}) of Thai Climbing Perch and Tilapia in caged perch, caged tilapia and mixed culture treatments

Economic comparison

The economic analysis of fish production per pond ($80m^2$) of each treatment was given in Table 6. Thai Climbing Perch juveniles, feed, fencing and cage making materials were expensive inputs comparative to other inputs. There was no significant difference of total operational cost in Caged Perch and Mixed culture treatment, but significant difference was observed among Caged Tilapia, Caged Perch and Mixed culture treatments. A significantly higher net return was observed in Caged Perch treatment and lowest in Caged Tilapia treatment.

Table 6. Comparisons of gross and net income with cost-benefit analysis in each treatment (Tk./pond)

Variables	Mean (DMRT)			
	Caged Perch	Caged Tilapia	Mixed culture	Significance Ψ
GROSS REVENUE				
Climbing perch	410.4 ± 8.03[a]	276.7 ± 4.2[c]	335.0 ± 4.4[b]	*
Tilapia	353.6 ± 12.7	327.2 ± 11.4	372.4 ± 25	NS
Total	764.0 ± 14.4[a]	603.9 ± 17.2[c]	707.4 ± 18.4[b]	*
OPERATIONAL COST				
Climbing perch juveniles	100	100	100	NS
Tilapia juveniles	75	75	75	NS
Lime and fertilizers	35	35	35	NS
Net for fencing	-	100	100	-
Cage	100	100	-	-
Pelleted feed	114.8 ± 2.4	109.5 ± 3.2	114.2 ± 3.1	NS
Total	424.8 ± 2.4[b]	519.5 ± 3.2[a]	424.2 ± 3.1[b]	*
NET RETURN (Tk. $pond^{-1}$ 120 d^{-1})	339.2 ± 12.4[a]	84.4 ± 14.8[c]	283.2 ± 17.1[b]	*

The mean (±SE) values with different superscripts in the same row were significantly different.
Ψ Result from repeated measures one-way ANOVA, NS = Not significant (*P>0.05*), * Significant (*P<0.05*)

Water quality parameters

Production of sufficient fish food organisms depends on the water quality parameters. In this experiment, water temperature ranged from 15.3°C to 28.5°C. Boyd (1982a) reported that the range of water temperature from 26.06 to 31.97°C is suitable for fish culture. Taking the winter season into account, it may be considered that the range of water temperature was within the acceptable range of fish culture. The mean water transparency in Caged Tilapia ponds was lower (25.98cm) which indicated that open pond Thai Climbing Perch did not effectively consume the natural food organisms developed due to the nutrients derived from cage wastes. Suitable dissolved oxygen concentrations were found in the ponds, because of addition of freshly oxygenated water from the deep tube well. According to Swingle (1967) pH from 6.5 to 9.0 is suitable for pond fish culture and pH more than 9.5 is unsuitable. The measured pH in the present study in different treatments was slightly alkaline (7.0mg l^{-1} to 8.9mg l^{-1}) which indicated good productivity of the pond water.

Boyd (1982b) advocated that total alkalinity should be more than 20mg l^{-1} in fertilized ponds as fish production increases with increase in total alkalinity. In this study, the highest mean alkalinity of 153.87 ± 7.28mg l^{-1} was measured in Caged Perch treatment. Chen (1988) found that lower than 1mg l^{-1} of ammonia gas content in pond water was acceptable for pond fish culture. The concentration of ammonia-nitrogen was within acceptable limits, and there was no significant difference of mean ammonia-nitrogen among the treatments. The level of nitrite-nitrogen in caged tilapia treatment was lower, but the reason was unknown. ANOVA showed that there was no significant difference of mean nitrate-nitrogen among the treatments. Phosphate-phosphorus (PO_4-P) content in all experimental ponds ranged from 0.08mg l^{-1} to 5.32mg l^{-1}, which agreed with the findings of Wahab *et al*. (1995), Hossain (2004) and Afroz (2004), they found phosphate-phosphorus (PO_4-P) ranged from 0.09 mg l^{-1} to 5.2 mg l^{-1}, 0.04 mg l^{-1} to 2.41 mg l^{-1} and 0.01 mg l^{-1} to 2.14 mg l^{-1}, respectively. On the basis of phosphate-phosphorus (PO_4-P) content, it may be concluded that all experimental ponds indicated a favorable environment for biological production. Chlorophyll-*a* values ranged from 45.22µg l^{-1} to 205.87µg l^{-1}, which was similar to the findings of Hossain (2004) and Afroz (2004). They recorded chlorophyll-*a* content ranged from 31.00µg l^{-1} to 225.00µg l^{-1} and 97.98µg l^{-1} to 220.15µg l^{-1}, respectively. In case of chlorophyll-*a* the highest values of 143.91 ± 9.46µg l^{-1} was observed in Caged Tilapia treatment compared to Caged Perch and Mixed culture treatments.

Plankton abundance

The plankton community constitutes a major component of aquatic systems and indicates the productive status of a pond. In Caged Tilapia treatment, Tilapia was in cage and Thai Climbing Perch in open pond. In the open pond Thai Climbing Perch did not effectively consume the phytoplankton community; as a result, there was phytoplankton bloom in the pond. Although Thai Climbing Perch has been described as omnivorous, it has a tendency toward carnivorousness (Besra, 2000). Rabanal and Hosillos (1957) reported that Tilapia was primarily an herbivore, but under crowded conditions it would vigorously consume micro-fauna, crustaceans, worms and small fishes. In Caged Perch treatment, Tilapia in open pond effectively consumed phytoplankton, zooplankton and decaying suspended organic matter as a result the abundance of plankton community was lower. In mixed culture treatment, both Thai Climbing Perch and Tilapia were in open pond, where Tilapia freely consumed phytoplankton so algal bloom did not appear in these ponds.

Benthos production

In Caged Perch and Caged Tilapia treatment no feeds were added in open pond and neither fertilizer were added in any treatment. Beveridge (1984), Ackefor (1986) and Lin (1990) reported 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 that water, Cage culture thus may influence the aquatic environment. During the present study, the major groups of benthic fauna recorded from all treatments were Chironomidae, Oligochaeta, Mollusca and un-identified group. The dominance of these groups of macro-benthos has been reported by Das and Islam (1983), Habib *et al*. (1984) and Shamsi and Jafri (1994), from tropical fresh water pond, Kumar and Mitra (1986), from ox-bow Lake, respectively. Chironomidae was the most dominant group in these studies as well.

Growth and production performance

Survival of Thai Climbing Perch was higher where that might be due to good quality seed and stocking of comparatively larger juveniles. Growth of Thai Climbing Perch was slightly lower due to the experiment was conducted in winter season. In Caged Perch treatment the Thai Climbing Perch were in cage and feed was supplied in the cage, therefore, wastes derived from the feed discharged into the open pond increased the productivity of open pond (Lin and Diana, 1995; Yi *et al*., 1996; Yi and Lin, 2001). This influenced the vigorous growth of phytoplankton which was eaten by Tilapia as a result net production in Caged Perch treatment was higher followed by other treatments. Net production of Thai Climbing Perch was highest (0.16t ha^{-1} 120 d^{-1}) in Caged Perch treatment which was agreed with the findings of Asaduzzaman *et al*. (2006). They found the highest total net yield of 0.13t ha^{-1} over a period of 150days culture period. In Caged Tilapia treatment, Tilapia was in cages and feed was supplied in cages. Very low amount of wastes derived from feed was discharged into the open pond. At the same time, open pond Thai Climbing Perch did not effectively consumed the phytoplankton community as a result growth and production was lower in this treatment. Net production in Caged Tilapia treatment was lower (482.6kg ha^{-1} 120 d^{-1}) compared to Caged Perch (577.14kg ha^{-1} 120 d^{-1}) and Mixed culture (600.43kg ha^{-1} 120 d^{-1}) treatments. In mixed culture treatment, both species were in open pond and feed as supplied in open pond so interspecies and intra-specific competition occurred for food between Tilapia and Thai Climbing Perch, as a result growth of Thai Climbing Perch was lower in this treatment followed by caged perch treatment.

It may be concluded that integrated cage-cum-pond culture with high-valued Thai Climbing Perch in cages and Tilapia in open ponds might be a more suitable option than the conventional mixed culture system. This is due to higher yield, maximum feed efficiency and more economic return. Good quality, large size Thai Climbing Perch juveniles and moderate stocking densities are essential for successful cage culture. In future, more research and field trials will be needed to validate the findings of this research and showing the benefits of this new technology.

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