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ARTICLE

The Potential for Homestead Pond Polyculture of Tilapia and Carps in Coastal Bangladesh

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ABSTRACT

A fishers' women-led Participatory Action Research (PAR) was conducted in 30 homestead ponds to assess the potential for polyculture of Tilapia (Oreochromis niloticus) and major carps Rohu (Labeo rohita) and Catla (Catla catla) in two coastal fishing villages of Bangladesh. Three treatments, namely T1 (Tilapia 200 fish per decimal; 1 decimal=40 m2), T2 (Tilapia 200+ Rohu 32+ Catla 8 fish per decimal) and T3 (Tilapia 200+ Rohu 8+ Catla 32 fish per decimal), each with 5 replicates, were tried in Hossainpur and Anipara villages. Formulated commercial Mega-feed was applied to the ponds twice daily at an initial rate of 10% body weight (bw)/day of Tilapia down to 4% bw/day throughout the culture period. The water quality parameters of ponds including transparency, salinity and dissolved oxygen significantly varied among treatments except temperature and pH and remained within optimum range for carp polyculture except salinity. The survival rate, harvesting weight and yield of Tilapia were significantly highest in T1 (85.63±05%, 258.59±18.76 g & 11073±805 kg/ha, respectively) in Anipara and lowest in T3 (75.63±0.37%, 136.97±10.63 g & 5180±406 kg/ha, respectively) in Hossainpur. The gross fish production was the significantly highest in T1 (11354±806 kg/ha) of Anipara and lowest in T1 (6325±227 kg/ha) of Hossainpur. Statistically, the highest net return (866,627±84874 BDT/ha) was found in T1 of Anipara and lowest in T3 (279,389±46104 BDT/ha) of Hossainpur with a significantly higher benefit-cost ratio (BCR) obtained in T1 (3.26±0.20) for Tilapia and lower in T3 (1.58±0.10) for polyculture Tilapia and carp of Hossainpur. Therefore, it may be concluded that Tilapia production in small homestead coastal ponds has a higher potential than its mix with carps in polyculture for generating food and supplemental income opportunity for coastal fishers' women in Bangladesh.

1. Introduction

Aquaculture is the fastest growing food producer in the world over the last century[1] and Bangladesh ranked 5th position as per aquaculture production[2]. Inland capture and culture systems have contributed 83.72% to the total fish production (3.68 million metric tons) in 2014-2015[3]. The aquaculture sector plays an important role in the socio-economic

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development[4,5], nutrition supply[6], employment generation, poverty alleviation[7] and foreign exchange earnings[8] of the country. There are 4 million small homestead ponds[9] used for multiple purposes, such as bathing, washing and watering livestock; that are located close to their homestead[10]. The majority of homestead ponds are used for semi-intensive polyculture of fast growing fish species, particularly of major Indian and Asian carps, Rohu (Labeo rohita), Catla (Catla catla), Mrigal (Cirrhinus cirrhosus), Silver (Hypophthalmichthys molitrix), Grass carp (Ctenopharyngodon idella) and Common carp (Cyprinus carpio)[11]. It is widely believed that polyculture increases the productivity of the aquaculture system by efficient utilization of ecological resources within the environment[12,13]. Stocking of two or more complimentary fish species can increase the maximum standing crop of a pond by utilizing a wide range of available food items and the pond volume[12,14,15,16].

Tilapia (Oreochromis niloticus), one of the fast growing cultivable food fish species[17], in recent years, has become one of the most popular commercial aquaculture species[18] due to its fast growth, tasty flavour, good resistance to poor water quality and disease[19], and tolerance of a wide range of environmental conditions[20]. It offers a unique opportunity to poor people in developing countries, both as cultured species in household-pond systems in subsistence, and in commercial fisheries. It is also an important source of food[21], nutrition to subsistence farming households[22], and the sale of surplus production can provide additional income[23,24].

In the homestead pond aquaculture of Bangladesh, culture of tilapia has been promoted in small, seasonal roadside ditches and multiple ownership ponds for poor marginal farmers. The appropriate combination of culture species, densities and feeding strategies are the key to success in homestead pond aquaculture[15,25]. Though polyculture technologies of carps with many non-carp species are evolving in Bangladesh, the literature available on tilapia polyculture with carps in homestead ponds is scanty. However, most observations suggest that the farmers stock tilapia in their homestead ponds as an additional species to carps[26].

Although about 4.27 million households in rural Bangladesh own at least one homestead pond[8,9], fish culture in these ponds is still a new concept for the coastal fishers' households, who rely on Hilsa shad capture fisheries in the Southern coastal districts. The research presented here is aimed at exploring the fact if aquaculture might be a suitable option for alternative income generation activity for the fishers' households during Hilsa fishing ban periods, imposed from November to January, in a 40 km Andharmanik River Sanctuary, Kalapara, Patuakhali. If yes, what proposition of species combination will be appropriate for the coastal hypo-saline ponds? The target beneficiaries for this intervention were selected amongst the resource poor homestead pond owners in two fishing communities of Anipara and Hossainpur villages, located in the Kalapara Upazila, Patuakhali.

ECOFISH-Bangladesh project has been working in all coastal districts focusing on improvement of the livelihoods of the fishing households through helping women's access to finance and technologies. The fishers' women have been motivated on Hilsa fish conservation, compliance of different fishing rules and regulations, impacts of illegal fishing and using illegal gears, and potential for improvement of socio-economic condition by alternate income generation activities (AIGAs). They have been also trained in different AIGAs such as homestead pond aquaculture, vegetables cultivation, livestock rearing, pebbles making, etc. and received relevant livelihood supports from the project. In a Participatory Action Research (PAR) approach, the fishers' women involved in the Hilsa Shad Conservation Group (HCG) were provided with basic pond aquaculture training and empowered in managing their own ponds to relieve their male counterparts get involved in net repairing and other on-farm agricultural activities. Two hypotheses were tested to explore i) if there is any difference in fish production between only Tilapia monoculture and Tilapia and carp polyculture; and ii) if there is any difference in fish production between two neighbouring villages under the same management regime, where pond size, depth and environmental parameters are different.

2. Materials and Methods

2.1 Location and Duration of Experiment

The experiment was carried out from September 20, 2015 to March 18, 2016 (180 days) in 30 homestead ponds located in two fishing villages (Anipara and Hossainpur) in the Kalapara Upazila (an administrative unit equivalent to sub-district), Patuakhali district (Figure 1). Ponds were selected randomly from a list of 150 ponds in the study sites. Pond size, water area, water depth and key environmental parameters of all selected ponds were estimated before setting up the experiment. Ponds, in two villages, have slight variation in salinity regimes, but all are hypo-saline.

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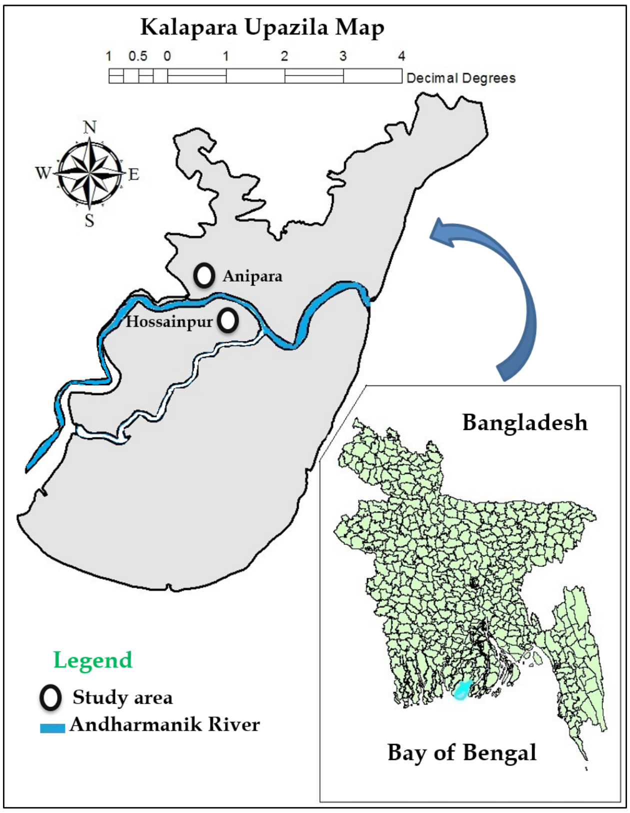

Figure 1. Location of the experimental sites

Anipara and Hossainpur are the two villages along the northern and southern side of the Andharmanik River sanctuary, respectively; the pond size, depth and environmental parameters are different. Pond areas in the studied villages varied from 10 to 14 decimal and mean depth of the ponds varied from 1.96 to 2.70 m (Table 1). In all ponds of the two villages, the depth of water column varied during culture period due to evaporation and rain, being at their maximum depth by the end of monsoon rain period.

2.2 Design of the Experiment

The research design consisted of three treatments, namely T_1 (Tilapia 200 fish per decimal; 1 decimal=40 m^2), T_2 (Tilapia 200+ Rohu 32+ Catla 8 fish per decimal) & T_3 (Tilapia 200+ Rohu 8+ Catla 32 fish per decimal) in Hossainpur and Anipara, each with five replicates. Before starting the experiment, all ponds were drained, dried and limed with powdered $CaCO_3$ at 1 kg/decimal. The ponds were filled up with rain. After 7 days of liming, the ponds were fertilized with 240 g/decimal urea and 116g/decimal triple super phosphate (TSP). The stocking was done on September 20, 2015.

2.3 Sources of Fingerlings

Fingerlings of GIFT (Genetically Improved Farmed Tilapia) and carps (Rohu and Catla) were collected from Sikder Nursery, Kalapara Upazila under Patuakhali district. Both the Tilapia fry and carp fingerlings were carried out from nursery to the experimental ponds in oxygenated polyethylene bags. The fingerlings of Tilapia, Rohu and Catla were on average 6.8 cm, 22.1 cm and 7.6 cm in length and 6.6 g, 22.1 g and 6.3 g in weight, respectively.

2.4 Selection of Feed

Mega floating feed (commercially produced in Bangladesh) was selected for the present experiment. This pellet feed was examined and found to have appreciable water stability and high nutritive value. The different types of "Mega Feed"[27] with proximate composition are nursery feed (crude protein-36.15%, lipid-12.24% & carbohydrate-23.48%), starter feed (crude protein-33.41%, lipid-12.10% & carbohydrate-28.48%), and grower feed (crude protein-30.11%, lipid-11.26% & carbohydrate-31.43%).

Table 1. Pond characteristics (mean±SE) in two villages

Characteristics	Anipara			Hossainpur		
	T_1	T_2	T_3	T_1	T_2	T_3
Pond area with dike (dec)	12.20±2.17	14.00±2.00	14.20±1.64	10.70±2.41	10.00±1.87	11.00±2.55
Water surface area (dec)	9.40±2.19	11.00±1.41	11.20±1.10	8.20±1.64	10.00±7.40	8.40±1.82
Pond depth (m)	2.13±0.28	1.96±0.06	2.03±0.10	2.60±0.27	2.19±0.17	2.70±0.61
Maximum water depth in monsoon (m)	1.60±0.11	1.55±0.07	1.58±0.08	1.74±0.08	1.59±0.13	1.62±0.13
Minimum water depth in winter (m)	1.30±0.00	1.10±0.00	1.20±0.00	1.08±0.11	0.98±0.04	1.04±0.09
Pond area receiving direct sunlight (dec)	8.00±1.22	9.00±1.41	8.40±0.89	5.80±1.48	5.00±1.00	5.40±0.89

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2.5 Feeding Strategy

Fingerlings were fed at the rate of 10% of body weight at the beginning of the experiment. The feeding rate was gradually reduced to 6% and 4% of the body weight in 2nd and 3rd month, respectively. The feeds were provided two times per day, in the morning (at 9.00 AM) and in the afternoon (at 4.00 PM). The feeds were dispersed by hand or pot broadcasted over the pond water.

2.6 Water Quality Parameters

Water quality parameters like temperature, water transparency, dissolved oxygen, pH and salinity were measured at fortnightly intervals, always at around the same hour (9.00 AM). Temperature, dissolved oxygen, pH and salinity were analyzed on the spot using a Multi Parameter detection device (Model No. HACH 40d, HACH Instruments Ltd, USA) and transparency was measured using a Secchi disc.

2.7 Sampling of Fish

Growth of fish under different stocking combinations was assessed by recording the rate of growth in terms of gain in length (cm) and in weight (g) of fish at fortnightly intervals. The fishes were sampled using a seine net and weighed with a portable digital balance to adjust feeding amounts. The length and weight were recorded by random sampling of 40 Tilapia, 20 Rohu and 20 Catla fish. Weight was taken with a digital top loading balance (TANITA-5 kg x 1 g) and length with a measuring scale. All data were recorded in a note book and spread sheet and finally the average length and weight of fish by treatment were calculated for every sampling day.

2.8 Study of Growth and Yield of Fish

Experimental data of different treatments were collected during growth trials and evaluated by using the following parameters:

2.8.1 Weight and Length Gain

Weight and length gain of experimental fish were calculated from the following formula:

Weight gain (g) = mean final fish weight (g) – mean initial fish weight (g)

Length gain (cm) = mean final fish length (cm) – mean initial fish length (cm)

2.8.2 Specific Growth Rate (SGR% per Day)

The specific growth rate was calculated from the following formula.

$$\text{Specific growth rate}\ (\%/\text{day}) = \frac{(\text{Log}_e W_2 - \text{Log}_e W_1)}{T_2 - T_1} \times 100$$

2.9 Economic Analysis

A simple economic analysis was performed to estimate the net profit from different treatments. The net return (profit) was measured by deducting the gross cost from the gross income incurred per pond. The benefit cost ratio was also measured as a ratio of gross income to gross cost. The cost of inputs was calculated on the basis of whole sale market prices of 2016. The cost of Mega floating feed was BDT 38.80/ kg and 46/kg for starter and grower feeds, respectively. The selling price for Tilapia, Rohu and Catla was estimated as BDT 110/kg. Since the production period was short so Rohu and Catla did not reach marketable size and thus fetch lower price and equal to that of Tilapia.

2.10 Statistical Analysis

Experimental data were analyzed with statistical software SPSS (Statistical Package for Social Sciences) version 16. Fish data were analyzed through one-way ANOVA to test the effect of different treatments on the performance of each fish species. The survival and specific growth rate (SGR) data were normalized using the arcsine of the square root transformation. Water quality data were also analyzed through One-way ANOVA using average value of the parameter in different treatments. When a main effect was significant, the ANOVA was followed by Duncan Multiple Range Test (DMRT) at 5% level of significance.

3. Results

3.1 Water Quality Parameters

The water quality parameters of ponds including temperature, transparency, pH, salinity and dissolved oxygen significantly varied among treatments except temperature and pH (Table 2). The mean water temperature (28.44±0.23 °C) and pH (7.22±0.13) were similar among all treatments (Table 2) in both villages. The transparency was found higher in T_1 (27.11 ± 0.94 cm) of Hossainpur and lower in T_2 (19.73±0.67 cm) of Anipara. The average value of dissolved oxygen was found significantly higher in T_1 (5.43±0.15 mgl^{-1}) of Anipara and lower in T_3 (4.23±0.11 mgl^{-1}) of Hossainpur village. The mean value of salinity was found significantly higher in all the ponds of Hossainpur than the ponds of Anipara (Table 2).

3.2 Growth and Production Performance

During stocking, the average individual weights of Ti-

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Table 2. Results of ANOVA and Duncan mean multi-comparisons of water quality parameters (mean value ± SE)

Variable	Treatment						Level of Significance	p-value
	Anipara			Hossainpur				
	T_1	T_2	T_3	T_1	T_2	T_3		
Temperature (^oC)	28.35 ± 0.23	28.35 ± 0.23	28.34 ± 0.23	28.44 ± 0.23	28.44 ± 0.23	28.44 ± 0.24	NS	0.998
Transparency (cm)	22.49 ± 0.80^b	19.73 ± 0.67^C	22.80 ± 0.70^b	27.11 ± 0.94^a	22.93 ± 0.73^b	22.11 ± 0.64^b	*	0.000
pH	7.22 ± 0.77	6.90 ± 0.12	7.12 ± 0.06	7.25 ± 0.12	7.17 ± 0.13	7.24 ± 0.13	NS	0.233
Dissolved Oxygen (mgl^{-1})	5.43 ± 0.15^a	4.64 ± 0.23^b	4.72 ± 0.17^b	4.69 ± 0.15^b	4.35 ± 0.12^b	4.23 ± 0.11^b	*	0.000
Salinity (ppt)	0.61 ± 0.02^b	0.61 ± 0.02^b	0.64 ± 0.02^b	0.78 ± 0.03^a	0.83 ± 0.03^a	0.81 ± 0.03^a	*	0.000

lapia, Rohu and Catla were 6.58, 22.09 and 6.31g. The initial individual weights of each fish species were not significantly different among treatments of two villages.

Tilapia showed significantly highest survival rate in T_1 (85.63±0.05 %) of Anipara. Tilapia also presented the significantly highest mean harvesting weight in T_1 (258.59±18.76 g) of Anipara and lowest in T_3 (136.97± 10.63 g) of Hossainpur (Figure 2; Table 3). Similarly, the mean value of growth rate for tilapia was significantly highest in T_1 (1.44± 0.10 g/day) of Anipara and lowest in T_3 (0.76±0.06 g/day) of Hossainpur. The SGR of tilapia was also found similar. The mean value of harvesting biomass and yield for tilapia was higher in T_1 of Anipara (11,354±806 kg/ha & 11,073±805 kg/ha) and lowest in T_3 of Hossainpur (5,429±406 kg/ha & 5,180±406 kg/ha). Finally, the production of tilapia was obtained comparatively higher from monoculture than polyculture with carps in both the villages.

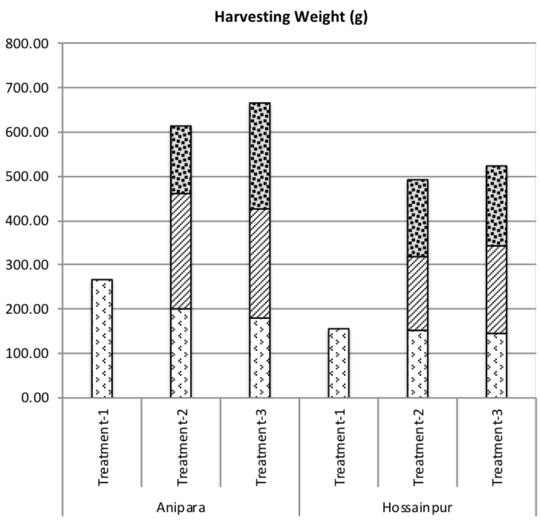

Figure 2. Harvesting weight (g) in different treatments of two villages

Rohu was presented significantly higher survival rate, harvesting weight and growth rate in T_2 (83.35±0.45 %), (263.02±49.97 g) and (1.34±0.28 g/day) of Anipara, respectively. Similarly, the SGR, harvesting biomass and the yield of rohu was significantly higher in T_2 (1.33±0.11 %/day), (1749±327 kg/ha) and (1602±327 kg/ha) of Anipara village, respectively in the polyculture composition.

Catla was affected by the polyculture composition and salinity both among the treatments in each village and between the villages. Catla presented significantly highest survival rate in T_2 (83.97±0.88 %), the highest harvesting weight in T_3 (242.34±66.46 g) from Anipara, where the ponds have comparatively lower salinity. Catla also showed significantly highest growth rate and SGR in T_3 (1.31±0.37 g/day) and (1.94±0.17 %/day) of Anipara, respectively. It was also found that the harvesting biomass (1,514±406 kg/ha) and net yield of catla (1,474.24±406.18 kg/ha) was higher in T_3 in the ponds of Anipara.

The gross production and mean yield of all fishes were significantly highest in T_1 (11,354±806 kg/ha) and (11,073±805 kg/ha) of Anipara and lowest in T_1 (6,325±227 kg/ha) and (6,058±228 kg/ha) of Hossainpur, respectively (Table 3; Figure 3). Finally, the mean value of FCR was observed higher in T_1 (0.89±0.04) of Hossainpur and lower in T_1 (0.44±0.03) of Anipara.

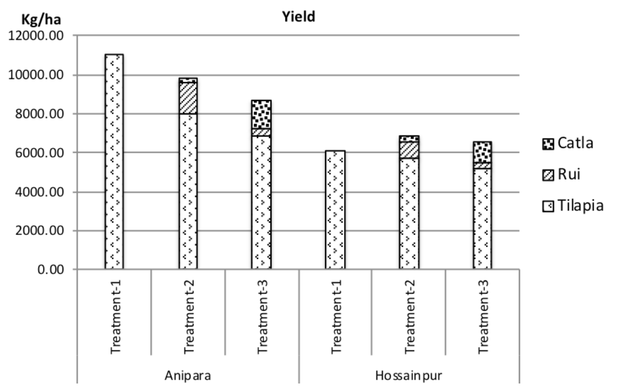

Figure 3. Average yield (kg/ha) in different treatments of two villages

3.3 Economic Analysis

Table 4 presented the ANOVA results of the income obtained by selling fish of the treatment at the prices of rural markets in Bangladesh in March, 2016. The average gross income was found significantly higher in T_1 (BDT 1,248,946±88,604/ha) of Anipara and lower in T_1 (BDT 695,725 ± 25,017 /ha) of Hossainpur (Table 4, Figure 4). Net return was found significantly higher in T_1 (BDT 866,627±84,874/ha) of Anipara and lower in T_3 (BDT

Table 3. Results of ANOVA and Duncan mean multi-comparisons for stocking weight and harvesting parameters of Tilapia, Rui and Catla (mean value ± SE)

Variable	Treatment						Level of Significance	p-value
	Anipara			Hossainpur				
	T_1	T_2	T_3	T_1	T_2	T_3		
Tilapia								
Stocking weight (g)	6.58 ± 0.0	6.58 ± 0.0	6.58 ± 0.0	6.58 ± 0.0	6.58 ± 0.0	6.58 ± 0.0	NS	1.000
Harvesting weight (g)	258.59 ± 18.76^{a}	192.97 ± 26.31^{b}	172.96 ± 23.27^{bc}	149.58 ± 6.03^{bc}	147.14 ± 7.15^{bc}	136.97 ± 10.63^{c}	*	0.000
Harvesting Biomass (kg/ha)	11354 ± 806^{a}	8261 ± 1089^{b}	7133 ± 934^{bc}	6325 ± 227^{bc}	5928 ± 288^{c}	5429 ± 406^{c}	*	0.000
Survival rate (%)	85.63 ± 0.05^{a}	82.80 ± 0.12^{b}	79.42 ± 0.15^{d}	81.04 ± 0.50^{c}	77.11 ± 0.36^{e}	75.63 ± 0.37^{f}	*	0.000
Growth rate (g/day)	1.44 ± 0.10^{a}	1.07 ± 0.15^{b}	0.96 ± 0.13^{bc}	0.83 ± 0.03^{bc}	0.82 ± 0.04^{bc}	0.76 ± 0.06^{c}	*	0.000
SGR (%/day)	2.05 ± 0.04^{a}	1.88 ± 0.08^{b}	1.83 ± 0.03^{bc}	1.76 ± 0.02^{bc}	1.75 ± 0.03^{bc}	1.71 ± 0.04^{c}	*	0.001
Yield (kg/ha)	11073 ± 805^{a}	7988 ± 1089^{b}	6872 ± 934b^{c}	6058 ± 228^{bc}	5675 ± 287^{c}	5180 ± 406^{c}	*	0.000
Rohu								
Stocking weight (g)		22.09 ± 00	22.09 ± 00		22.09 ± 00	22.09 ± 00	NS	1.000
Harvesting weight (g)		263.02 ± 49.97^{a}	245.63 ± 24.38^{ab}		164.98 ± 14.24^{b}	198.01 ± 7.65^{ab}	*	0.017
Harvesting Biomass (kg/ha)		1749 ± 327^{a}	389 ± 38^{c}		1035 ± 91^{b}	316 ± 12^{c}	*	0.000
Survival rate (%)		83.35 ± 0.45^{a}	79.29 ± 1.48^{b}		78.40 ± 0.49^{b}	79.76 ± 1.61^{b}	*	0.036
Growth rate (g/day)		1.34 ± 0.28^{a}	1.24 ± 0.14^{ab}		0.79 ± 0.08^{b}	0.98 ± 0.04^{ab}	*	0.017
SGR (%/day)		1.33 ± 0.11^{a}	1.33 ± 0.06^{a}		1.11 ± 0.05^{b}	1.22 ± 0.02^{ab}	*	0.038
Yield (kg/ha)		1602 ± 327^{a}	354 ± 38^{c}		896 ± 90^{b}	280 ± 12^{c}	*	0.000
Catla								
Stocking weight (g)		6.31 ± 00	6.31 ± 00		6.31 ± 00	6.31 ± 00	NS	1.000
Harvesting weight (g)		151.61 ± 36.96	242.34 ± 66.46		174.78 ± 16.05	183.54 ± 11.69	NS	0.445
Harvesting Biomass (kg/ha)		252 ± 60^{b}	1514 ± 406^{a}		262 ± 27^{b}	1142 ± 117^{a}	*	0.001
Survival rate (%)		83.97 ± 0.88^{a}	78.31 ± 0.66^{b}		74.87 ± 2.19^{b}	77.61 ± 1.47^{b}	*	0.003
Growth rate (g/day)		0.81 ± 0.21	1.31 ± 0.37		0.94 ± 0.09	0.99 ± 0.10	NS	0.445
SGR (%/day)		1.70 ± 0.14	1.94 ± 0.17		1.83 ± 0.05	1.86 ± 0.05	NS	0.521
Yield (kg/ha)		242 ± 60^{b}	1474 ± 406^{a}		253 ± 26^{b}	1103 ± 117^{a}	*	0.001
Total Fish Production (kg/ha)	11354 ± 806^{a}	10262 ± 1247^{a}	9035 ± 1075^{ab}	6325 ± 227^{c}	7226 ± 247^{bc}	6886 ± 435^{bc}	*	0.000
Yield (kg/ha)	11073 ± 805^{a}	9832 ± 1248^{a}	8700 ± 1074^{ab}	6058 ± 228^{c}	6824 ± 247^{bc}	6563 ± 434^{bc}	*	0.001
FCR	0.44 ± 0.03^{c}	0.56 ± 0.09^{bc}	0.63 ± 0.07^{b}	0.89 ± 0.04^{a}	0.83 ± 0.03^{a}	0.85 ± 0.06^{a}	*	0.000

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279,389±46,104/ha) of Hossainpur (Table 4). Similarly, the mean value of BCR was observed highest in T_1 (3.26±0.20) of Anipara and lowest in T_3 (1.58±0.10) of Hossainpur. Finally, the highest production and economic benefit were obtained from the monoculture of tilapia in comparatively lower saline ponds.

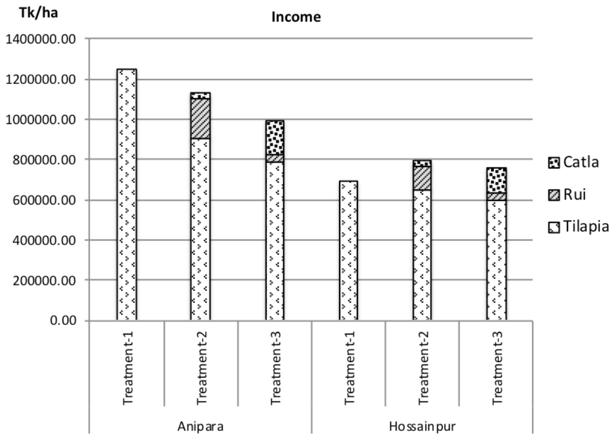

Figure 4. Average gross return (BDT/ha) in different treatments of two villages

4. Discussion

4.1 Water Quality Parameters

The growth of aquatic organisms depends on the water quality parameters of a water body[28]. Maintenance of all the factors becomes necessary for getting maximum yield from a fish pond. Good water quality is characterized by adequate oxygen, proper temperature, transparency and other environmental factors that affect fish culture[29,30].

Temperature changes affect fish metabolism, physiology and ultimately affect the production. Suitable water temperature for carp culture is between 24 and 30 ^{0}C[29]. The surface water temperature in this experiment of the ponds ranged from 26.16 to 30.35 ^{0}C which was suitable for tilapia and carps[19,30].

Transparency depends on several factors such as suspended clay particles, dispersion of plankton organisms, particulate organic matters and also the pigments caused by the decomposition of organic matters. The secchi disk transparency between 30 and 40 cm indicates optimum productivity of a pond for good fish culture[29]. The present experiment achieved much lower transparency than the optimum level in all the ponds except ponds under T_1 of Hossainpur. Since the ponds were not turbid or muddy rather greenish, this indicated the ponds were productive[29].

Water pH between 7 to 8.5 is suitable for biological productivity[29]. The pH values recorded from the ponds of two villages varied from 6.90 to 7.25, which was more or less similar to the findings of[30-32] and suitable for fish culture[29].

Dissolved oxygen of water of any culture system affects the growth, survival and physiology of fishes[33,34]. Oxygen depletion in water leads to poor feeding of fish, starvation and reduced growth either directly or indirectly[29]. The mean DO level in all the treatments of tilapia monoculture was found slightly higher compared to tilapia polyculture with carps but all observed values of DO were suitable for fish culture.

Fishes are very much sensitive to the salt concentration. Freshwater fish species generally show poor tolerance to large changes in salinity of water. Often salinity levels vary from species to species[18], the mean salinity level in this experiment ranged from 0.61 to 0.83 ppt. Tilapia can tolerate a wide range of salinity compared to Rohu and Catla that may affect the production of Rohu and Catla[20]. The overall better performance in the ponds in Anipara may have been attributed to the lower salinity even though the difference is quite low.

4.2 Growth and Production Performance

In the present research, polyculture of Tilapia and carps, Rohu and Catla was compared and contrasted against Tilapia monoculture. Each fish species stocked in the ponds has individual feeding niches and thus exerts influence on the environment in a somewhat different way, largely depending on their size and feeding regime. Tilapia utilizes natural foods organisms and detritus throughout ponds, whereas Rohu feeds in the middle column and Catla in the surface but their niches often overlaps in small homestead ponds. The productions of fishes in different treatments were found to vary among treatments due to difference in survival, growth rate and production. A variation in water quality parameters and depths of ponds between two villages were also apparent in this experiment.

Tilapia showed the highest survival rate (83.33%) due to its higher tolerance level of the variable environmental conditions[5,21] which is more or less similar with the findings of[28]. The highest weight gains of Tilapia (204.09 g) obtained in the present study was higher than[28,30,32,35]. In this study, a significant difference was observed among combined gross and net yields in different treatments. Calculated on per hectare basis over a 180- day culture period, treatment-wise highest mean gross and net production of tilapia was found in T_1 of Anipara and contributed to highest gross production among the treatments. These high gross and net were found in T_1 of Anipara might be due to proper food utilization capacity of tilapia and high survival rate of tilapia in shallow ponds[21]. Tilapia produc-

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tion in the present study was lower in comparison to[21] because the experiment was done during the winter season. However, this production was higher than those reported by[20,28,32] and in T_1, the higher production of Anipara, observed in comparison to other treatments might be due to better management practice as well as increased survival of tilapia in the low saline but deeper ponds[21].

Rohu showed the higher survival rate in different treatments. This high survival rates obtained for Rohu fish might have been due to the relatively large size of fingerlings stocked. The highest weight gains of Rohu (263 g) obtained in the present study was much higher than that of[28,30]. Calculated on per hectare basis over a 180 days' culture period, T_2 of Anipara yielded the highest total production of Rohu (1,749 kg/ha); the high gross and net yields found in Anipara may be due to proper food utilization capacity of Rohu and higher number of Rohu than Catla and also having lower salinity of ponds. Lower yield of Catla fish in the present study was found due to food competition with Tilapia in the shallow pond. The relatively similar findings on Rohu productivity were found in[36] and[37], whereas individual growth performance of Rohu was better than the Catla, as mentioned earlier the causes of higher stocking density of the species achieved higher growth in the experiment. Additionally, Rohu is an omnivore fish with preference for debris and decaying vegetation[38].

Catla showed the relatively lower survival rate in different treatments with Rohu. This lower survival rates obtained for Catla fish might have been due to the relatively lower size of fingerlings stocked in the shallow ponds and salinity of pond water. The lower production of Catla was found in almost all ponds between two treatments. Similar lower production of Catla was found in[36] and[28]. Thus, relatively lower growth of Catla in the experiment may be due to the lower production of natural food, especially zooplankton. There was a lacking of regular supply of inorganic fertilizers in the fish ponds[37]. In addition, it may be explained that the bottom feeders of benthic niches might have eaten away excess detritus from the pond as food which ultimately improved the environment for herbivorous fishes like Rohu[38]. Due to the absence of bottom feeder fish in the ponds, optimum utilization of the pond productivity may have not taken place, and there is room for inclusion of bottom feeding mrigal (Cirrhinus mrigala) /common carp (Cyprinus carpio) or freshwater prawn (Macrobrachium rosenbergii).

4.3 Economic Analysis

The statistical analysis showed that the net return and BCR values among the treatment were found significantly different (P>0.05). The highest net return and BCR obtained in T1 of Anipara (866,627 BDT/ha and 3.26, respectively) might be due to lower amount of feed used i.e. low cost feed used and relatively higher production of fishes obtained.

The present research findings revealed that the monoculture of tilapia is better than tilapia-carp polyculture in the household ponds of coastal region of Bangladesh for getting higher production and net return.

4.4 Effectiveness of Participatory Action Research Approach

Participatory action research was initiated through the training of the fishers' women. The impact of the preparatory and on-going trial monitoring training on the community level was very much effective. The design of the trial encouraged fisher's women to participate in the pond aquaculture activity with great enthusiasm. Community members eagerly waited to see the results from the research pond compared to the general pond in the two villages. Through the proper monitoring of the project personnel, it was ensured that the fishers' women were actively participated for feeding and health checking till the final harvesting. However, the overall outcomes of the on-farm research were felt positive. Since ECOFISH-Bangladesh project is a mostly development project, research in development approach would be suitable for carrying out demand-led research that would both produce science outputs and develop technologies for scaling up.

4.5 The Impacts

This experiment has exposed some insights into the promotion of aquaculture in the coastal areas of Bangladesh. Generally, many ponds of this area are very shallow with a maximum depth of approximately 1m. When a pond is shallow, the stocking capacity is very limited, water retention capacity is low and the pond is prone to drying out, this limits the period of production. This is particularly a problematic in this area where a substantial proportion of the ponds are rain-fed[39]. Many of the cultured species in Bangladesh are phytophagus[8], which means they are reliant on photosynthetic production, which, in the turbid waters of many Bangladeshi ponds, cannot take place at greater depths[40].

It is clear that now households with a pond are financially better off than those without. It will be interesting to investigate exact impact of the pond ownership on household nutrition by comparing the nutritional status of pond owning households against those without having a pond. Now, they are able to take the challenges to culture the

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fishes as an alternative livelihood options for their family consumption and households' nutrition.

5. Conclusion

In this participatory action research fishers' women have been empowered and their capacity in pond aquaculture has been tremendously developed. Between two sets of culture systems in two villages, the growth and production of fish was higher in Ainipara village ponds than those of Hossainpur. Exact reason for this difference is difficult to reveal from a single piece of research, however water salinity and pond depth may cause this difference. Pond water salinity was lower and pond depth was higher in Anipara. Tilapia monoculture was found the best performed technology among all ponds that was also shadowed by a relatively lower production in Hossainpur ponds. Polyculture of Tilapia-carp with higher number of Rohu showed better performance in the ponds of Hossainpur. Since Catla is zooplankton feeder and feeds on surface it may have competed with tilapia to some extent and may reduce the growth of tilapia. Rohu, in other side, is more robust in its dietary diversity and feeds on phytoplankton at the pond column and thus may not have directly affected the niche of tilapia neither its growth. Overall, tilapia monoculture is the suitable technology for coastal ponds, however tilapia-carp polyculture with rohu may be considered suitable considering the desire of the fishing households for polyculture instead of only tilapia monoculture.

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