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Effects of nutrient-rich small fish Mola and Darkina in carp polyculture concurrently with rice-fields connected ditches/ponds

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Abstract
An investigation was conducted for simultaneous production of rice and fish in framers' plot from July-December 2012 in North-west region of Bangladesh. It consisted of three treatments and each having five replicates. The experimental species were rui (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus cirrhosus*), silver carp (*Hypophthalmichthys molitrix*), silver barb (*Barbodes gonionotus*), bata (*Labeo bata*), mola (*Amblypharyngodon Mola*) and dark in a (*Esomus danricus*). In rice plot different carps and mola were stocked in T_1-Treatment (RC_M), carps and dark in a in T_2-Treatment (RC_D) and both mola and dark in a with carps in T_3-Treatment (RC_{MD}). The stocking rates of carps were same (20/dec.) in all treatments. Mola and dark in awere stocked only in a ditch area basis at a rate of 150g/dec. in treatments T_1 and T_2, respectively. Whereas, treatment T_3 was stocked with 75g mola and 75g dark in ape decimal. Some important water quality parameters *(i.e.* temperature, transparency, DO, pH and alkalinity) were recorded at monthly interval. Those parameters did not vary significantly except alkalinity among all treatments. Forty eight genera (48) of phytoplankton and fifteen genera (15) of zooplankton were identified during the experimental period under different treatments. The gross production of fishes was the highest (1, 023 kg ha^{-1}) in T_3 and the lowest (994 kg ha^{-1}) in T_2. Between the treatments (T_1 and T_2), dark in a production was 4% higher than mola. In cash earning, mola contributed just double of darkina between RC_M and RC_D treatments. Among the treatments carp production was more or less similar, but the production of rice and straw were higher in T_3. Both mola and dark in a reproduced two to three times during the experiment in different plots. So, the total fish production was enhanced for their self-recruit characteristics. Among all fishes, mola played a major part for increasing BCR because of their high market value. Among the three treatments, the highest BCR (2.70) was recorded in T_1, where 232.56 kg ha^{-1} mola was produced. Carp-SIS polyculture in rice-field provided the farmers with nutrient-rich mola and dark in a and also cash income with carps as well. From the concurrent culture, the fish excreta accumulated in the soil, which would increase rice production in the following year. In order to meet soaring demand of fish for food and nutrition for the people of Bangladesh, there is great potential for increased fish production in the rice fields.

Keywords: Small fish, Darkina, farmers, Bangladesh

Introduction
Rice culture has been practiced in Asia for 5000-6000 years, and the harvesting of wild fish from rice fields can be considered as a prelude to fish culture (Fernando 1993) [26]. The earliest records of fish culture in rice fields originate from China, circa 2000 years ago (Li 1988), followed by India, 1500 years ago (Tamura 1961) [64]. Other countries with a recorded history of rice-fish culture are Indonesia, Malaysia, Thailand, Japan, Madagascar, Italy and Russia (Halwart, 1994) [34]. Bangladesh is one of the most densely populated countries in the world, covering an area of 144,000 km^2 with a population of 164 million. The people of Bangladesh are commonly referred to as '*Macche- Bhate Bangali'* (*i.e.* the people made of fish and rice). Rice and fish have been an essential part of the life of Bangladeshi people from time immemorial. The staple foods of the people of Bangladesh are rice and fish. Rice is the foremost agricultural crop in Bangladesh with an annual production of over 29 million tons per annum (BRKB 2010) [9], while annual fish production is 3.68 million tons (DoF 2012). The demand for rice and fish is constantly increasing in Bangladesh with nearly three million

people being added each year to the population of the country (Chowdhury 2009). Nevertheless, integrated rice-fish farming offers a solution to this problem by contributing to food, income and nutrition. Not only the adequate supply of carbohydrate, but also the supply of animal protein is significant through rice-fish farming. Fish, particularly small fish, are rich in micronutrients and vitamins, and thus human nutrition can be greatly improved through fish consumption (Larsen *et al*. 2000, Roos *et al*. 2003) [43, 55]. Despite this potential, however, integrated rice-fish farming technology has not yet improved food security in Bangladesh because of the low-level of adoption. To be sustainable, food production in Bangladesh should integrate resource management (Shankar *et al*. 2004) [62]. As has happened elsewhere (Ahmed and Garnett 2010; Ahmed et al. 2010b) [1, 1, 3], integrated rice-fish farming warrants greater attention from development agencies and government organizations. According to Dey *et al*. (2005) [21], the level of success of rice-fish farming in Bangladesh will depend on the local agro-ecological situation and the prevailing socioeconomic conditions. The integration of rice and fish production is recognized as an efficient means for agricultural land use (Khoo & Tan 1980) [40], and offers great potential in terms of animal protein supply and income generation for small-scale rice farmers (Mukherjee, 1995) [50]. Despite these proclaimed benefits, rice-fish culture has not been widely adopted by Asian rice farmers. Fish is usually regarded as a secondary crop. Fish is the main source of animal protein, providing 17.23 kg $year^{-1}$ of the average per capita total intake of protein and 58% of the total animal protein intake in Bangladesh (DoF, 2010) [10]. Rice farming is the main occupation for the majority of rural households in most Asian countries including Bangladesh. In recent years, rice production has become less profitable for farmers due to stagnant yields and high input costs. Hence, there is a move towards diversification out of rice monoculture. One of these is the age-old practice of integrating fish culture with rice farming. In fact, biological control has been proven to be more profitable than prophylactic or threshold-based pesticide treatments (Rola and Pingali, 1993) [53]. Moreover, farmers have experienced that the concurrent culture of fish with rice often increases rice yields, particularly on poorer soils and in unfertilized crops, probably because under these conditions the fertilization effect of fish is greatest. With savings on pesticides and earnings from fish sales, increases in net income on rice-fish farms are reportedly 7–65% higher than on rice monoculture farms (Halwart, 1999, pp. 130–141). Fish culture in rice fields may be practiced at several management levels. In its most simple form, fish stocks are not managed. Wild fish enter the paddy during flooding and are captured at the end of the rice growing season. This method of raising fish together or concurrently with rice is as old as rice culture itself. Other techniques are based on either managed concurrent culture of fish with rice, or on rotational production of fish and rice crops. This experiment was concurrent system of rice-field.

Materials and methods

Experimental sites

The experiment was carried out in Dinajpur district of northern part of Bangladesh. These areas are in narrow floodplain ridges and linear depressions. River crossing the region are entrenched 5-6m below the level of the surrounding landscape. The geographical situation of the experimental site was under sub-tropical climate, characterized by three distinct seasons, the winter season from November to February and pre-monson period or hot season from March to April and monsoon period from May to October (Edris *et al.*, 1979) [25]. The rain start later and ends earlier in this region and kharif growing season is correspondingly shorter. The soils are deep, rapidly permeable, sandy loams and sandy clay loams predominate. Ample ground water is available at a shallow or moderate depth. Surface water supplies available for dry season irrigation are limited and could diminish with increased exploitation of ground water.

Design of the experiment

The experiment was conducted in 15 different size farmers' rice plots (avg. 37-64 dec.) in Chirrirbandar upazilla of Dinajpur district in Bangladesh. The experiment was consisted three treatments with five (5) replicates of each treatment among the rice-fields in combination with mola and darkina from July to December 2012. Carp fingerlings were stocked in all the treatments. Three treatments were consisted: *T_1- Rice-fields with carp & mola* (RC_M) - The stocking densities of Indian major and minor carps were considered for both surface of the rice-fields and the ditches, whereas mola was considered for only ditch area basis. *T_2- Rice-fields with carp & darkina* (RC_D) **-** The stocking densities of all carps were considered as **T_1**, whereas darkina was considered for only ditch area basis. *T_3- Rice-fields with carp, mola & darkina* (RC_{MD}) - The stocking densities of carps were considered as similar way whereas mola and darkina was considered for only ditch area basis.

Land, dyke and ditch preparation

Certain modification must be made to rice fields for raising fish (Khoo and Tan, 1980) [40]. The height of the embankment surrounding the field must be raised so as to maintain adequate water depth for fish in the field. Dykes separating the plots were raised about 50cm. Wet land preparation was followed in the present experiment, which was also practiced in most tropical countries (Singh *et al.*, 1980). The plots were ploughed in two occasions. First time, by using power tiller 10-12 days before rice transplantation and second time, by using country plough 2 days before transplantation. The land was then leveled properly by laddering and removed weeds before rice seedlings plantation.

Fertilization and rice plantation

According to BRRI (1999) [11], the fertilizers *i.e.* triple super phosphate (TSP) and murate of potash (MP) were applied in the rice plots at the rate of 150 kg ha^{-1} and 75 kg ha^{-1}, respectively. All fertilizers were applied evenly to the plots 2-3 days before transplantation the seedlings *i.e.* in the final ploughing and leveling. Urea was applied 15, 55 and 70 days of transplantation of rice seedlings with one-third of the total dose during each application. Some farmers were selected High yielding variety (HYV) rice '*BR-11*' and others were selected local variety '*Swarna*' and '*Pijam*' for this experiment. Another aspect of high seedling rates is the possible restriction of fish movement into the ricefield, thus restraining the access to food organisms. This phenomenon has been reported in transplanted ricefields by Halwart *et al*. (1996) [36]. Wider spacing or leaving rows unplanted, as a management strategy to enhance fish production in transplanted ricefields has been recommended by. Alternate row spacing of 35 cm and 15 cm was followed for transplanting rice seedling following Hossain *et al.* (1990) [38]. The plant to plant distance was 20 cm. The alternate row spacing would provide sufficient gap for easy movement of fish which agree to adequate sunlight for biological production.

Stocking & management

After 12 days of rice seedling plantation, fishes were stocked. The stocking density (20/dec.) of carps, rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus cirrhosus*), silver carp (*Hypophthalmichthys molitrix*), silver barb (*Barbodes gonionotus*), bata (*Labeo bata*) and mola/darkina (*Amblypharyngodon mola/Esomus danricus*) were 5, 3, 5, 3, 2, 2 in number and 150g per decimal, respectively in different plots to the experimental design (Table 1). General stocking density of carps in rice field was half (20/dec.) than the pond (40/dec.) followed by Dutta *et al.* (1979) [24]. Because of the water volume was low in rice-field than the pond. Farmers were bought carps fingerlings form local fingerlings traders who collected them from rural nurseries. Fingerlings of the small fishes (mola & darkina) where collected from perennial ponds & rice-field of the near-by farmers, where farmers keep them together with major carps and the small fishes naturally breed. Water level in the field was maintained at 25-40 cm during culture period whereas the depth of the ditch was maintained at least 1 meter. Rain was the main source of water but if any, deep tube-well was used for irrigation. It was continued from July to December 2012 for total harvest of fishes

	Treatments								
	T_1 - RC_M			**T_2 - RC_D**			**T_3 - RC_{MD}**		
Fish Species	**TAB (20/dec.)**	**DAB**	**Wt. (g)**	**TAB (20/dec.)**	**DAB**	**Wt. (g)**	**TAB 20/dec.)**	**DAB**	**Wt. (g)**
Carps									
Rui (25%)	186	-	14.20	242	-	12.60	320	-	16.00
Catla (15%)	112	-	14.60	145	-	17.80	192	-	11.80
Mrigal (25%)	186	-	14.60	242	-	14.00	320	-	15.40
S. carp (15%)	112	-	15.40	145	-	17.20	192	-	14.80
S. barb (10%)	74	-	17.20	97	-	19.20	128	-	16.40
Bata (10%)	74	-	11.80	97	-	14.60	128	-	9.80
Small Fishes									
Mola	-	DAB	150G, NC	-	-	-	-	DAB	75g, NC
Dark in a	-	-	-	-	DAB	150g, NC	-	DAB	75g, NC

RC_M – Rice-Field with Mola, **RC_D** – Rice-Field with Darkina, **RC_{MD}** – Rice-Field with Mola & Darkina
TAB- Total Area Basis = rice-field area + ditch area, DAB- Ditch Area Basis (only ditch area), NC-Not Counting

For proper management of rice, all activities were done according to the recommendation of Farming System and Environmental Studies (FSES, 1996) [29] of Bangladesh Agricultural University, Mymensingh. Water level in the rice fields was kept as low as 2-4 cm until 12 days after rice plantation to allow the rice seedlings well established and to initiate tillers growth. Then the water level was maintained 30-40 cm in rice fields. Fishes were fed irregularly with the farmers' economic ability of family maintenances.

Water quality monitoring

Five water quality parameters *(i.e.* temperature, transparency, DO, pH and alkalinity) were recorded every month between 9:00 and 11:00 AM. Water temperature was recorded with a Celsius thermometer. Transparency was measured from the ditches of rice field with a Secchi disc of 20 cm diameter. Alkalinity and DO of water samples were measured by Portable kit (HANNA). pH was also measured by portable pH meter (HANNA).

Plankton identification

Water samples were collected from five different places of pond by using plankton net. Samples were preserved in small plastic bottles with 10% buffered formalin. According to APHA (1992), identification of plankton to genus level was carried out using the keys from Prescott (1962) [62] and Bellinger (1992) [6, 19, 30, 46, 48].

Sampling of fishes

Fishes were sampled (10-20 individuals of each species) by seine net/cast net at monthly intervals to assess their growth (length and weight) by measuring scale and electronic balance (HC-K5KA), respectively.

Harvesting of rice and fishes

At the end of the experiment, rice was harvested plot-wise. To determine the yield of rice grain and straw, representative samples of rice were taken from each plot comprising an area of 10 m^2 randomly from 3-4 places. Rice plants were cut just from the surface level of the water. The grain and straw were cleaned and sun dried to 14% moisture content and weighed plot-wise. After three months from stocking, large carps were harvested small amount twice or thrice in a month for household consumption but farmers used to record properly. Partial harvesting of Mola started two months after stocking both for family consumption and sold as brood fish. After harvesting of rice, all experimental fishes were harvested by repeated netting and dewatering of the experimental plots. Only 10-20 individuals of carps from each species in each of the plots were measured for length and weight, and then species-wise bulk weight of the remaining fishes from each plot was taken. But mola was bulk weighed and add all the partial harvesting. The following parameters were used to evaluate the growth of fishes:

1. Weight gain (g) = Average final weight (g) - average initial weight (g)

2. $$\text{Survival rate (\%)} = \frac{\text{No. of fish harvested}}{\text{Initial no. of fishes}} \times 100$$

3. $$\text{Specific growth rate (\%)} = \frac{\log_e W2 - \log_e W1}{T2 - T1} X100 \text{ (Brown, 1957)}$$

Specific growth rate (%) = (Brown, 1957)
Here,
W_1= the initial live body weight (g) at time T_1 (day)

W_2= the final live body weight (g) at time T_2 (day)

4. Gross Yield = No of fish caught × Average final weight
5. Net Yield = No of fish caught × Average weight gained

Benefit-cost (BCR) analysis

An economical analysis of different treatments was performed on the basis of the expenditure incurred and the total estimated return from the selling price of rice, rice straw, carps and mola. All input costs were recorded. The net benefit was calculated using the following formula: Net benefit = total cost – total return/investment. Benefit-cost ratio (BCR) was calculated as:

$$BCR=\frac{Total\ revenue}{Total\ cost}$$

Statistical analysis

Water quality parameters fish yield parameters were compared using one-way ANOVA. Since the experimental plot sizes were different, plot size was used as covariate during the ANOVA (Gomez and Gomez, 1984) [32]. The percentage data were arc-sine transformed. If main effects were significantly different, differences among the treatments were tested with Tukey's multi-comparison test of means. The analyses were run at 5% significance level using statistical package (SPSS version 20.00).

Results

Water quality parameters

The overall mean values of each water quality parameters of all treatments for the entire experimental period are shown in Table 2. The monthly variation of temperature, transparency, dissolved oxygen, pH and alkalinity are graphically presented in Fig. 5-8.

Table 2 Mean values (±SE) and range of some water quality parameters in different treatments

Parameter	T_1	T_2	T_3	F-value	Level of Sign./ r^2
Temperature (^{0}C)	26.88 ^{a} ±0.64 (21.00-32.00)	26.28 ^{a} ±0.63 (21.00-31.00)	26.68 ^{a} ±0.86 (19.00-33.00)	0.181	NS 0.001
Transparency (cm)	29.64 ^{a} ±0.95 (22.00-39.00)	30.24 ^{a} ±1.03 (21.00-41.00)	30.08 ^{a} ±0.86 (22.00-41.00)	0.107	NS 0.001
pH	8.29^a (6.93-8.90)	8.15^a (7.56-8.98)	8.11^a (6.98-8.95)	1.013	NS 0.025
DO (mg L^{-1})	5.04 ^{a} ±0.18 (3.10-6.80)	5.08 ^{a} ±0.16 (3.3-6.80)	5.03 ^{a} ±0.15 (3.50-6.30)	0.022	NS 0.000
Alkalinity (mg L^{-1})	99.96 ^{b} ±2.03 (85.00-122.00)	105.20 ^{ab} ±2.44 (87.00-125.00)	108.27 ^{a} ±2.33 (89.00-127.00)	3.752	* 0.093

Significance level: (+) P≤0.1, * P≤0.05, ** P≤0.01, * P≤0.001, P>0.05=NS, not significantr^2= coefficient of determination

Water temperature

The values of water temperature in T_1, T_2 and T_3 ranged from 21-32, 21-31 and 19-33^{0}C, respectively. The value of maximum temperature was found in the month of August and that of minimum in the month of December (Fig. 5).

Dissolved oxygen

The mean values of DO were similar among the treatments. During the study period, the lowest DO recorded where carps and mola were present; the highest was observed both the two treatment where carps with darkina and carps with mola in September & October, respectively. The highest fluctuation of DO recorded in T_1 treatment (Fig. 8).

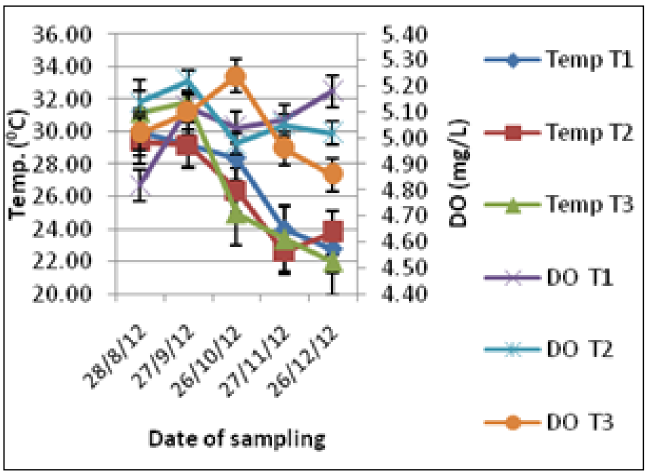

Fig 1: Relationship between DO and Temperature Water in different treatments

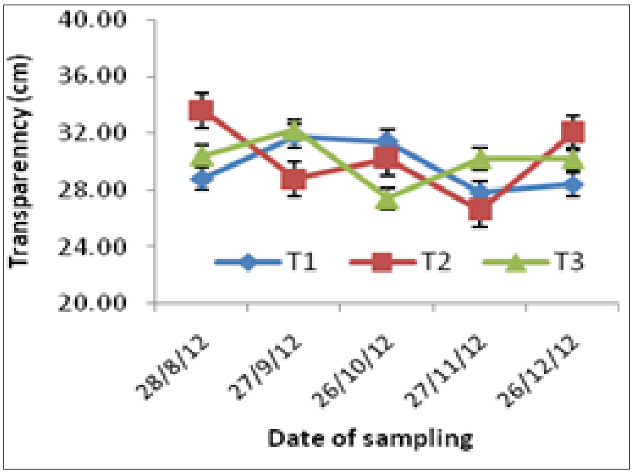

Fig 2: Mean (±SE) transparency of in different treatments

Transparency

The water transparency varied from 21-41 cm with the mean values of 29.64 ±0.95, 30.24 ±1.03 and 30.08 ±0.86 cm in treatment T_1, T_2 and T_3, respectively. The monthly variations of transparency were fluctuated throughout the experiment. The highest and lowest value was observed from T_2 in August and November, respectively (Fig. 6).

PH

The level of pH varied from 6.93-8.90, 7.56-8.98 and 6.98-8.95 in T_1, T_2 and T_3, respectively. The mean values of pH always recorded above the eight (8). The highest and lowest value was observed from T_2 in August and September, respectively (Fig. 7).

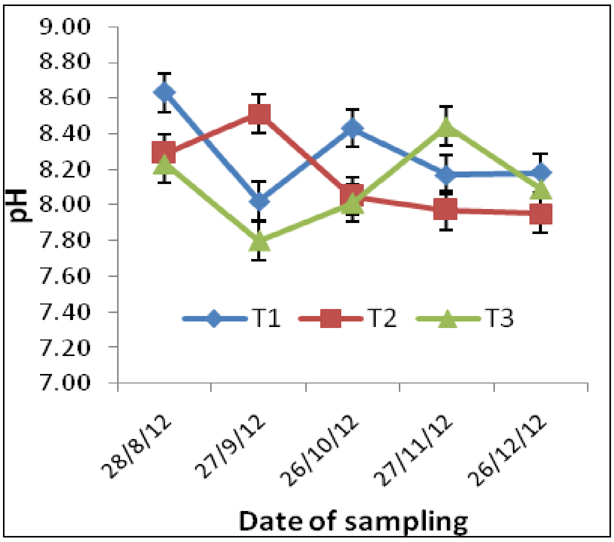

Fig 3: Mean (±SE) pH of water in different treatments

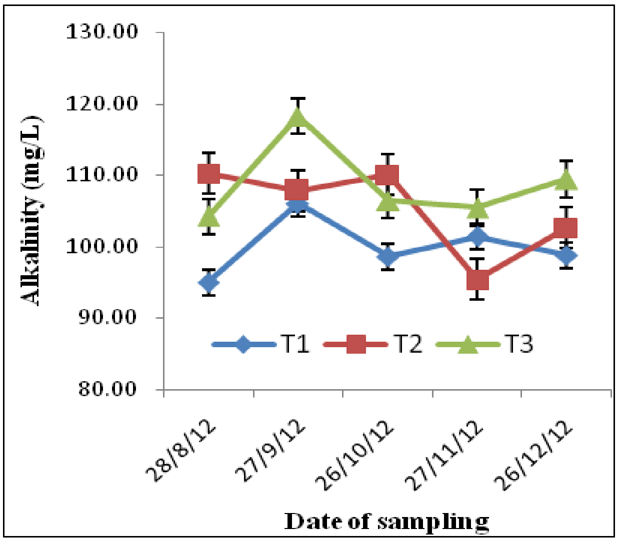

Fig 4: Mean (±SE) Alkalinity of water in different treatments

Total Alkalinity

The mean values total alkalinity were found 99.96 ±2.03 in T_1, 105.20 ±2.44 ion T_2 and 108.27 ±2.33 mg L^{-1} in T_3 (Fig. 9). Except November, the lowest alkalinity showed in T_1 treatment. The total alkalinity varied from 85 - 127 mg L^{-1} throughout the experiment.

Plankton

Only the plankton organisms were identified group-wise up to genus label among the all rice-fields throughout the experiment. The populations of plankton were categorized to be six planktonic groups consisting of 63 genera in rice-fields under different treatments (Table 3). The total planktonic organisms mainly composed of four groups of phytoplankton and two groups of zooplankton. Some 48 genera of phytoplankton belonging to Bacillariophyceae (11), Chlorophyceae (23), Cyanophyceae (10) and Euglenophyceae (3) were recorded. Fifteen genera (15) of zooplankton were also identified belobging to Rotifera (7) and Crustacea (8).

Table 3. Generic status of plankton with their different groups recorded from the rice-fields.

Phytoplankton	
Bacillariophyceae	*Actinella, Cyclotella, Diatoma, Fragillaria. Mellosira, Navicula, Nitzchia, Pinnularia, Urirella, Synedra, Tabellaria*
Chlorophyceae	*Actinastrum, Ankistrodesmus, Botryococcus, Ceratinum, Chlorella, Chlorogonium, Coelastrum, Coscinodiscus, Closterium, Cosmarium, Crucigenia, Gonatozygon, Oocystis, Pediastrum, Phytoconis, Scenedesmus, Selenastrum, Sphaerocystis, Spirogyra, Tetraedon, Treubaria, Ulothrix, Volvox*
Cyanophyceae	*Anabaena, Anacystis, Aphanizomenon, Aphanocapsa, Chroococcus, Gleocapsa, Gomphosphaeria, Merismopedia, Microcystis, Oscillatoria*
Euglenophyceae	*Euglena, Phacus, Trachelomonas*
Zooplankton	
Rotifera	*Asplanchna, Brachionus, Filinia, Keratella, Lecane, Polyarthra, Trichocera*
Crustacea	*Cyclops, Diaptomus, Leptodora, Daphnia, Diphanosoma, Ceriodaphnia, Moina,* Nauplius

Different growth parameters of fishes

The mean value of initial weight, final weight, weight gain, survival, specific growth rate, gross yield and net yield were estimated in different treatments in Table 5.

The average individual stocking weight (g) of carps were varied from 9-20 g and mola 1-4 g. The stocking weight of rui, catla and bata were significantly differ but the harvesting weight of silver carp, silver barb and bata were significantly differ among the treatments. Among the all species of carps, the highest weight (307.40±16.39 g) of silver carb was in T_1 and the lowest weight (100.80±3.89 g) of bata was in T_2 treatment. Usually the weight gain of all carp fingerlings follow by the harvesting weight, while the initial weight were near similar to each other. In silver carp and silver barb were significant different in case of the weight gain parameter among the treatments. The highest specific growth rates were recorded in T_1 treatment in favor of silver carp (1.92). That parameter was highly significant in catla, silver barb and bata among the treatment. In all carp fishes, minor carp bata comprises was the lowest SGR in T_2 (1.29). But the lowest survivality consisted of silver barb in T_1 treatment. In T_3 treatment silver carp and rui were the same survival rate (62%). The survival rate of catla and bata were significantly differences among the treatments. During the experiment, in all species, mrigal comprised of the highest gross yield (207.73 ±10.40 kg ha^{-1}) in T_3 treatment and followed in T_1 (178.63 ±15.38 kg ha^{-1}) and in T_2 (160.18 ±14.60 kg ha^{-1}), respectively. Furthermore, the all growth parameters of gross yield of bata was the lowest in T_3 (37.51 ±1.71 kg ha^{-1}) treatment. The gross yield only in silver carp was significantly differences among the all treatments. The self recruiting species, mola & darkina were started to breed from second month. Then started to partial harvest and finally has been added to the total harvest. The net yield of all fishes were recorded similar trend which followed by gross yield. The gross yield & net yield of mola & darkina were significantly differences between the two treatments. None of the growth parameters of mrigal was significantly differences among the treatments.

Table 2 Mean (±SE) multicomparison of yield parameters of rui, catla, mrigal, silver carp, silver barb, Bata, mola and darkina in different treatments

Species/Treatment	T_1	T_2	T_3	Level of Sign. / r^2
Rui				
Individual stocking wt. (g)	14.20 ^{ab} ±0.86	12.60 ^{b} ±0.67	16.00 ^{a} ±1.09	* / 0.105
Individual harvesting wt. (g)	160.00 ±3.53	165.40 ±9.46	182.00 ±5.18	NS / 0.311
Weight gain (g)	145.80 ±4.15	152.80 ±9.00	166.00 ±5.82	NS / 0.276
SGR (% bwd^{-1})	1.61 ±0.05	1.71 ±0.02	1.62 ±0.05	NS / 0.002
Survival (%)	63.20 ±1.93	62.40 ±3.41	62.00 ±3.96	NS / 0.006
Gross yield (kg ha^{-1})	124.73 ±3.61	126.47 ±6.64	138.87 ±7.96	NS / 0.166
Net Yield (kg ha^{-1})	107.19 ±4.45	110.91 ±6.44	119.11 ±8.33	NS / 0.119
Catla				
Individual stocking wt. (g)	14.60 ^{ab} ±1.40	17.80 ^{a} ±0.58	11.80 ^{b} ±0.58	** / 0.137
Individual harvesting wt. (g)	197.00 ±9.43	182.00 ±5.61	195.00 ±22.02	NS / 0.001
Weight gain (g)	182.40 ±10.34	164.20 ±5.66	183.20 ±21.64	NS/ 0.000
SGR (% bwd^{-1})	1.74 ^{ab} ±0.08	1.55^{a} ±0.02	1.86 ^{a} ±0.05	**/ 0.079
Survival (%)	60.90 ^{b} ±2.15	69.00 ^{a} ±1.87	66.40 ^{ab} ±2.42	* / 0.181
Gross yield (kg ha^{-1})	88.24 ±4.51	93.12 ±4.19	95.09 ±8.65	NS/ 0.049
Net Yield (kg ha^{-1})	77.42 ±5.14	79.93 ±4.08	86.35 ±8.29	NS/ 0.000
Mrigal				
Individual stocking wt. (g)	14.60 ^{a} ±1.50	14.00 ^{a} ±0.83	15.40 ^{a} ±0.81	NS / 0.021
Individual harvesting wt. (g)	228.00 ±22.67	217.00 ±15.93	152.80 ±12.48	NS / 0.070
Weight gain (g)	213.40 ±21.99	203.00 ±16.91	237.40 ^{a} ±12.93	NS / 0.068
SGR (% bwd^{-1})	1.83 ±0.07	1.82 ±0.06	1.86 ±0.05	NS / 0.010
Survival (%)	64.00 ±3.91	59.60 ^{a} ±2.69	66.60 ±1.50	NS / 0.027
Gross yield (kg ha^{-1})	178.63 ±15.38	160.18 ±14.60	207.73 ±10.40	NS / 0.125
Net Yield (kg ha^{-1})	160.60 ±15.37	142.89 ±14.70	188.72 ±10.83	NS / 0.118
Silver carp				
Individual stocking wt. (g)	15.40 ^{a} ±1.44	17.20 ^{a} ±1.24	14.80 ^{a} ±0.66	NS / 0.009
Individual harvesting wt. (g)	156.00 ^{b} ±2.44	165.00 ^{b} ±1.58	192.00 ^{a} ±9.69	*** / 0.583
Weight gain (g)	140.60 ^{a} ±3.20	147.80 ^{b} ±2.45	177.20 ^{a} ±10.01	** / 0.550
SGR (% bwd^{-1})	1.55 ±0.06	1.51 ±0.05	1.70 ±0.05	NS / 0.192
Survival (%)	56.80 ±2.10	66.00 ±3.78	62.00 ^{a} ±2.82	NS / 0.090
Gross yield (kg ha^{-1})	65.61 ^{b} ±2.25	80.83 ^{ab} ±5.21	88.72 ^{a} ±7.71	* / 0.415
Net Yield (kg ha^{-1})	54.19 ^{b} ±2.96	68.09 ^{ab} ±5.78	77.76 ^{a} ±7.86	* / 0.398
Silver barb				
Individual stocking wt. (g)	17.20 ^{a} ±1.16	19.20 ^{a} ±1.43	16.40 ^{a} ±0.81	NS / 0.016
Individual harvesting wt. (g)	307.40 ^{a} ±16.39	244.40 ^{b} ±8.99	161.60 ^{ab} ±19.58	* / 0.208
Weight gain (g)	290.20 ^{a} ±16.41	225.20 ^{b} ±8.61	245.20 ^{ab} ±19.36	* / 0.199
SGR (% bwd^{-1})	1.92 ^{a} ±0.05	1.77 ^{b} ±0.04	1.84 ^{ab} ±0.05	* / 0.058
Survival (%)	52.60 ±1.07	63.20 ^{a} ±4.95	55.00 ±3.34	NS / 0.014
Gross yield (kg ha^{-1})	79.89 ±4.68	76.37 ±6.99	71.69 ±8.37	NS / 0.046
Net Yield (kg ha^{-1})	71.40 ±4.64	66.89 ±7.43	63.59 ±8.29	NS / 0.000
Bata				
Individual stocking wt. (g)	11.80 ^{ab} ±0.80	14.60 ^{a} ±1.02	9.80 ^{b} ±0.49	** / 0.103
Individual harvesting wt. (g)	104.00 ^{ab} ±5.09	100.80 ^{b} ±3.89	116.10 ^{b} ±2.76	* / 0.227
Weight gain (g)	92.20 ±5.31	86.20 ±4.54	103.30 ±7.64	NS / 0.105
SGR (% bwd^{-1})	1.45 ^{ab} ±0.06	1.29 ^{b} ±0.06	1.65 ^{a} ±0.03	* / 0.189
Survival (%)	54.20 ^{b} ±5.24	75.20 ^{a} ±2.41	65.40 ^{ab} ±2.83	** / 0.163
Gross yield (kg ha^{-1})	57.45 ±9.44	57.07 ±7.71	37.51 ±1.71	NS / 0.229
Net Yield (kg ha^{-1})	51.62 ±9.25	49.86 ±7.49	32.67 ±1.81	NS / 0.225
Mola				
Gross yield (kg ha^{-1})	232.55±10.04	--	133.78±3.71	*** / --
Net Yield (kg ha^{-1})	221.14±8.98	--	129.13±3.38	*** / --
Darkina				
Gross yield (kg ha^{-1})	--	277.24±17.86	148.83±12.94	*** / 0.809
Net Yield (kg ha^{-1})	--	265.46±16.95	144.19±13.06	*** / 0.800

Mean values with different superscripts in each row indicate a significant difference (P<0.05) based on Tukey's test Significance level: * P≤0.05, ** P≤0.01, *** P≤0.001, P>0.05=NS, not significantr^2= coefficient of determination

The gross yield of all species among the different treatments have been presented in Fig. 5. The total gross production was the highest in T_3 (1022.77 kg ha^{-1}) and lowest in T_1 (961.33 kg ha^{-1}). The total gross yield was categorized the following groups: carps, mola, darkina and other SIS. Considering from that, the yield of all groups have been shown in Fig. 6. The highest yield of carps, mola, darkina and other SIS were recorded 643.80 kg ha^{-1}, 232.56 kg ha^{-1}, 277.24 kg ha^{-1} and 134.19 kg ha^{-1} in T_3, T_1, T_2, and T_1, respectively.

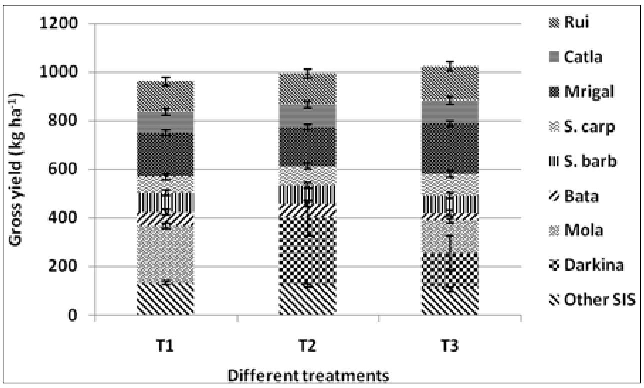

Fig 5: Total gross yield (±SE) with different species between the treatments

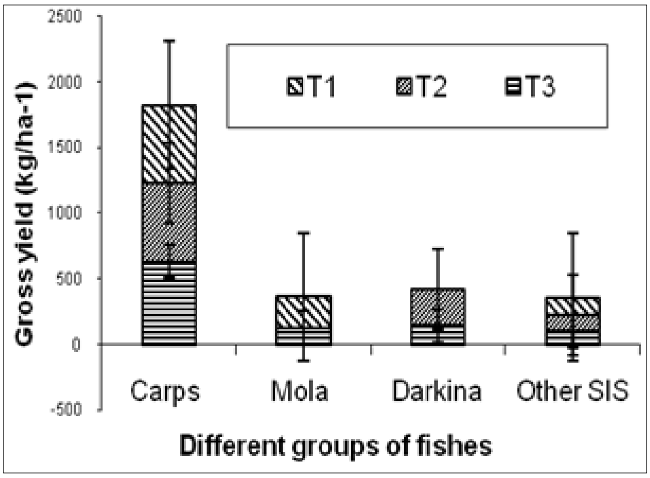

Fig 6: Mean fish yield (±SE) with different category among the treatments

Yield of rice grain and straw

The gross yield of rice gain and straw were presented treatment-wise during the experimental period (Fig. 7). The grain and straw yield ranged between 2262- 3658 and 3562-5050 kg ha^{-1}, respectively.

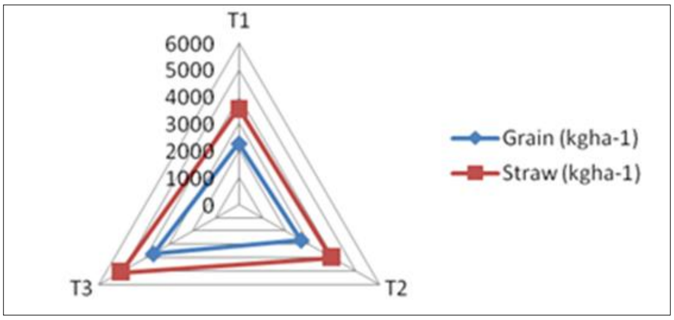

Fig 7: Mean rice grain and straw yield in different treatments

From the all component of income (%) were observed in Fig. 8. Between the two small fishes mola contributed 24% in T_1 and darkina 28% in T_2. And the combined treatment in T_3, mola donated 13% and darkina 15% as well.

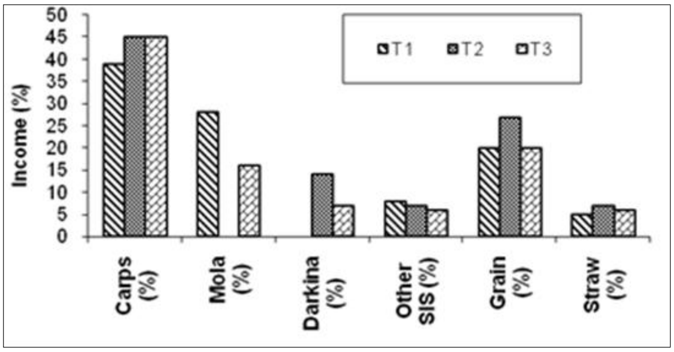

Fig 8: Income (%) of different category of fishes, grain and straw among three treatments

Economic analysis

The costs and benefits appraisal on a per hectare basis covering the 150 days culture period is shown in Table 5. Among the all fishes, the market price of mola was high. So, molas had more significance for the control of BCR. Among the treatments the highest BCR was 2.70 in T_1 treatment.

Table 4: Comparison of economics parameters among the different treatments based on 1 haditch connected rice-field area

Items	Treatments		
	T_1	T_2	T_3
Financial inputs			
Pond preparation cost			
Embankment repair	13279	12298	21226
Lime	876	652	528
Fertilizer (urea & TSP)	548	408	330
Stocking cost			
Carps	8508	8905	8193
Mola	3178	-	957
Darkina	-	2363	957
Pond management cost			
Rice bran	14475	20805	9045
Netting & others	8034	7686	3473
Rice plot management cost			
Ploughing & seedling	10438	11622	12180
Fertilizer (MP, urea & TSP)	5219	5811	6090
Irrigation	12177	10761	15746
Deweeding & harvesting	8631	9736	10420

Total cost	**85365**	**90860**	**88653**
Financial returns			
Carps	90105	90583	100035
Mola	65069	-	36741
Darkina	-	28184	16132
Other SIS	18591	13590	12542
Grain	44457	56646	43694
Straw	12177	13504	14210
Total returns	230401	202508	223356
Net benefits	145036	111657	134702
Benefit-cost ratio (BCR)	2.70 : 1	2.23 : 1	2.52 : 1

Currencies are given in Bangladesh Taka

Discussion

Water quality parameters

Temperature

Temperature of water is the most important factor which regulates growth, metabolism, reproduction and feeding activity as well. Water temperature in the rice fields oscillated between 24.93-34.33°C under different treatments of the present study. Nearly similar ranges of water temperature were reported by Kunda (2008) [66], Ghosh (1992) [30], Uddin (1998) [65], Chowdhury (1999) [17], Mondal (2001) [49]. and in their studies in rice fields and they obtained ranges as 27-40.10, 27-29, 21.9-33, 27-31.20, 26.90-29.60 and 25.32-32.04 ^{0}C, respectively. Recording to them the ranges of water temperature obtained in the present study are within the suitable range for fish culture. In the rice-field, rice-plants also carry on the water temperature optimum in hot days in summer. As a result, fish takes a comfortable environment in rice-field area. However, the water temperature of the experiment was influenced by the gradual decrease of temperature with the advent of winter season.

Transparency

In the fish culture, transparency is the indication of water productivity. Reid and Wood (1976) revealed that the transparency of water was influenced by silt, micro-organisms, organic matter, season, light intensity, fertilization, grazing pressure and rainfall. In the experiment, the value of transparency was observed (22-41 cm) the suitable range which followed by Amin & Salauddin (2008) in the rice field (20.33-37.67 cm).

PH

It is the key factor of water. The pH in the natural water has great importance as it regulates the productivity of water body. All the rice-fields were comprised of the mean value of pH above 7 which indicate the fertile environment. The findings of pH were support by the research of Mondal (2001) [49]. and Amin & Salauddin (2008) [4] in rice-fields.

DO

Dissolved oxygen is the prime issue for fish in the water body. The value of DO was found 3.10-6.80 mg L^{-1} in the rice-fields during the study. Kunda *et al*., (2009) [49], Saikia & Das and Amin & Salauddin (2008) [4]. Were found 5.29-9.62, 5.8-9.6 and 3.02-7.31 mgL^{-1} in their experiment in rice-field. The above findings were the agreement with the present research.

Alkalinity

Total alkalinity is the regulating factor for the productivity of water. High Alkalinity is good for fish production, because it can supply sufficient carbon (CO_2 & H_2CO_3) for phytoplankton. Boyd (1979) [8]. Reported that the total alkalinity levels for normal water may range from less than 500 mg L^{-1} to more than 5 mg L^{-1}. In the present study, the total alkalinity was found to range from 85-127 mg L^{-1}. The recorded alkalinity value of present study was more or less coincided by Kunda *et al*., 2009 [66]. (60 -160 mg L^{-1}) and Roy, 2004 [59] (60 -180 mg L^{-1}). Hence, the observed all water quality parameters over the entire period in all treatments showed favorable environment for fish culture.

Effect of species permutation

Rice fields, together with their contiguous aquatic habitats and dry land comprise a rich montage of rapidly changing ecotones, harboring a rich biological diversity, maintained by rapid colonization as well as by rapid reproduction and growth of organisms (Fernando, 1995, 1996) [27, 28]. In developing countries, many rural farmer and fisher families cannot obtain a ample variety of nutritious food in their local markets or are simply too poor to purchase it. Cultivated species may be complemented with particular significance for indigenous communities and for poor and vulnerable communities especially in times of shortage of main staples. Concerning nutrition and food security, wild and gathered foods, including from the aquatic habitat are provide important miscellany. Many reports suggest that integrated rice-fish farming is ecologically sound because fish improve soil fertility by increasing the availability of nitrogen and phosphorus (Giap *et al*. 2005, Dugan *et al*. 2006) [31, 23]. The feeding behavior of fish in rice fields causes aeration of the water. Integrated rice-fish farming is also being regarded as an important element of integrated pest management (IPM) in rice crops (Berg 2001, Halwart and Gupta 2004) [7, 34]. Fish plays a significant role in controlling aquatic weeds and algae that carry diseases, act as hosts for pests and compete with rice for nutrients. Fish have been reported to control weeds in ricefields, either through direct consumption of weeds (e.g. *P. gonionotus*), or through specific feeding behaviour (Piepho, 1987 cited in Cagauan, 1991; Moody, 1992; Cagauan, 1995). Aquatic production, in addition to the rice crop itself, is a vitally important resource for rural livelihoods in developing countries. Local consumption and marketing are particularly important for food security, as it is the most readily available, most reliable and cheapest source of animal protein and other nutrients for both farming households and the landless. In rice field culture, fishes should be tolerant environment characterized by: shallow water, high (up to 40°C) and variable temperatures (range of 10°C in one day), low oxygen levels and high turbidity (Hora and Pillay 1962; Khoo and Tan 1980) [37, 40]. Rothuis *et al.* (1998d) [57] recorded a daily maximum temperature and minimum oxygen concentration in ricefields of 41.7^{0}C and 0.40 ppm respectively, in a wet season rice-fish experiment at the same station. Fluctuations in the deeper peripheral trench were less extreme, and the authors concluded that the trench helped fish to endure times of unfavorable conditions in the field. In general, the necessity of a trench in rice-fish systems should be judged on absolute values rather than on the means of water parameters. Desirable characteristic of fish growth could attain marketable size when the rice is ready for harvest. The cyprinids, particularly the common carp and the Carassius have the longest documented history, having been described by early Chinese writers. The common carp has figured prominently since ancient times up to the present and is raised in rice fields in more countries than the other species. The grass carp and silver carp figure prominently, particularly in China, and the silver barb (*Barbodes gonionotus*) in Bangladesh, Indonesia, and Thailand, and the Indian major carps such as catla (*Catla catla*), mrigal (*Cirrhinus cirrosus*) and rohu (*Labeo rohita*) in Bangladesh and India (Halwart and Gupta, 2004) [34]. In the present study, some Indian major and minor carps were stocked with nutrient rice small fish, mola and darkina. Inauguration of the experiment, among the all carps mean initial weight were more or less similar. But the harvesting weight was occurred differently. Rice, carp & mola were grown in T_1 treatment. Here, Minor carp, silver barb was the highest growth among the three treatments. Major carps: rui and silver carp were lower harvesting growth in T_1 treatment than the other two. But in same treatment, mrigal is 5% higher in T_2 and 50% higher than T_3 treatment. In Indonesia, short growing period is possible since the local preference is for small fish averaging 125-200 g (Costa-Pierce, 1992) [30, 46]. The lowest survival rate (52%) of silver barb was recorded and also ranged from 52 to 64% of all carps in T_1 treatment. The gross yield in T_1 treatment was the highest of silver barb among the carps and mola. The growth of silver barb in rice-field was similarity with the findings of Rothuis A. J. (1994) [57]. The gross yield of that silver barb was higher 10% and mola was higher 73% in Treatment T_1. But the lowest gross yield (65.61 kg ha^{-1}) of silver carp was observed in T_1 and also recorded 18% and 26% lower in T_2 and T_3, respectively. Mola may competent with silver carp for their food in that treatment. Within the treatment T_1, only mola contribute 24% of the total fish production and also returns 16% from all items (*i.e* fish, grain & straw) collectively (Fig. 6 & 8). These findings are more or less similar by Alim *et al.* (2004) [3]. The production of rice grain and straw (T_1) were near about with Wahab *et al.* (2008) [42]. Another nutrient-rich fish, darkina was stocked with carps i n similar way concurrently with rice. The harvesting weight of rui and silver carp were similar in T_2 treatment and also both were lower than T_1 treatment. Hossain *et. al* (1988) [39] recorded the growth of different carp species of silver barb (13-92 g), rui (113-189 g), catla (62-69 g) and mrigal (90-115g). The final weights of different carps were shown similarity with the present study. The harvesting weight and gross yield parameters were counting 40-58% variability. But the SGR of rui was higher in T_2 than T_1 and the SGR of bata was lower in T_2 among the treatments. The survival rate of catla, silver carp and bata were the highest (66-75%) in T_2 among the treatments. These results were followed by Giap, Yi and Lin (2005) [31] in rice-fields. And also the survibility of catla & bata were varied significantly among the treatments. The lowest gross yield of mrigal and silver barb were performed in T_2. Whereas, the gross yield of bata was similar both in T_1 and T_2. The net production of darkina was much (265 kg ha^{-1}) within the treatments which contribute 28% of total production. Mondal (2001) [49] was found the similarity of dhela (*Rohtee cotio*) and carp culture in rice fields. Mola, darkina and different carps were stocked combined to evaluate the performance in rice fields. In present study, except silver barb of all the other carps were observed higher weight gain in T_3 treatment. But silver barb was the highest growth (245g) among the all species in T_3 treatment. MCC (1994) [47] reported silver barb growth rate was higher in rice field. In Vietnam silver barb is the common species in rice fish culture (Rothuis A.J, 1994) [57]. The mean survibility of catla and mrigal were same in T_3 treatment during the study. Middendorp (1992) [48] found the coexistence of introduce indigenous fish production in ricefields which also speculated the abundant small indigenous fish (*Rasbora* spp. & *Esomus* spp.) and shrimp (*Macrobrachium lanchesteri* De Man) served as primary feed for piscivorous predators whereas introduced fish escaped predation because of their size advantage. According to Rose *et al.* (2003, 2007), mola & darkina is the source of vitamin A, calcium and iron. The vitamin A content in SIS varies, from <100 μg of retinol equivalents (RE)/100 g raw edible parts, to >2,500 μg RE/100 g raw edible parts in mola *aman* rice yield positively. The integration of rice and fish has a beneficial effect on the rice yield. Ruddle (1982) reported a 15% increase in rice yield when fish are stocked. In the study, the production of rice grain (2262-3658 kg ha^{-1}) and straw (3562-5050 kg ha^{-1}) were followed by Kunda *et al.*, 2008 [66]. The farmers of rice-field owner utmost used their own resources (land, labor, rice bran) within households facilities which reduced the operational cost and finally increased benefit cost ratio (BCR). In an analysis of 18 rice-fish studies Lightfoot, van Dam & Costa-Pierce (1992) [30, 46]. found a similar trend, which could be explained in part by the specific rice-fish agronomy, and in part by direct positive effects of fish. According to Halwart (1994) [36], many of the aquatic organisms found in rice ecosystem play an important role as the biological control agents of vectors and pests. The comparatively lower fertilizer doses used in rice fish plots suggest that fish culture in rice fields reduces the need for fertilizer inputs. Earlier there was speculation that rice fish farming might use 50 to 100% more fertilizer than rice farming without fish (Chen, 1954) [15]. As with the finding an experimental study has shown that rice fish culture could reduce fertilizer use by 30% (Li *et al.* 1995). This is due to the increase in organic matter through fish excreta and the remains of supplementary feeds (rice bran) (Coche, 1967) [18]. In raining fish hatching could be accommodated in rice-fields. Immediately after the rain star, hatchlings move into the whole area of rice plots and use abundant natural food (Barman and Little, 2006) [5]. Rice field is a very suitable place for SIS production. Different types of small fishes such as mola, darkina, chanda, chapila, puti, dhela, taki so many are reproduces in the rice field. Rice–field generates natural breeding pool for self recruiting species (SRS). Hence, manifold interactions between fisheries and agriculture through the common use of land and water resources and concurrent production activities to support rural communities and supply urban areas with the needed quantity and variety of food. Improved integration between the two sectors is therefore an important means to enhance fish production and food security. So, the carp-SIS polyculture in rice-field supply nutrient-rich small fishes in their farmers' diet and also got cash income with carps as well. From the concurrent culture may accumulate the fishes excreta in the bottom which will be increased for next rice cultivation. As a result, this work will help to produce SIS in a large volume and came a plenty opportunity to make different combination of important SIS culture concurrently.

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