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## Research Article

# Shrimp polyculture: An economically viable and environmentally friendly farming system in low saline coastal region of Bangladesh

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**Abstract**

Shrimp polyculture with carp species has a great potential in economic development of Bangladesh. At present, shrimp polyculture technology is being most extensively used by shrimp farmers in the coastal regions of the country; however, the mechanism of scientific culture system is not well understood. Therefore, to evaluate the economic feasibility of shrimp (*Penaeus monodon*) polyculture with carp over mix culture of shrimp with prawn (*Macrobrachium rosenbergii*) and monoculture of shrimp, a study was conducted for a period of six months from July to December 2016 in selected ghers (modified low-lying rice fields with raised dykes, used for seasonal production of shrimp) at Kaliganj Upazila of Satkhira District, Bangladesh. Water quality was within the suitable range for shrimp culture. During the study period, environmental sustainability in terms of soil quality was achieved in polyculture of shrimp with carps and tilapia (*Oreochromis niloticus*). Growth performance and total yield of shrimp (2087.87±34.47 kg/ha) and prawn (1789.47±27.45 kg/ha) were also significantly (P<0.05) improved in polyculture of shrimp with carps and tilapia compared to shrimp monoculture and mix culture of prawn and shrimp, respectively. The economic sustainability was also found to achieve in polyculture of shrimp with carps and tilapia (*Oreochromis niloticus*) in terms of the Benefit-cost ratio (BCR), which was significantly (P<0.05) higher (2.49±0.03) compared to other culture systems (1.96±0.06 in shrimp monoculture and 1.26±0.03 in shrimp and prawn mix culture).

**Keywords:** Shrimp polyculture, Ggrowth performance, Economic analysis, Low saline area

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## Introduction

"Ghers"- are modified low-lying rice fields with raised dykes, used for seasonal production of shrimp, fish and other aquatic products (Kabir and Eva, 2014). Coastal aquaculture of Bangladesh is mainly composed of shrimp and prawn farming in ghers (Shamsuzzaman *et al*., 2017). In gher farming system, the water is inundated and logged for a long time and shrimp/prawn fries are put into it. It takes 3-6 months for the shrimp and prawns to be grown up and reach commercial size. At present the unit production of shrimp in gher is 0.71 MT/ha in Bangladesh and it produces 2.5% of the global production of shrimp (Shamsuzzaman *et al*., 2017). However, unplanned shrimp cultivation sometimes diversely affects the soil and agriculture yields, ecology, biodiversity and sustainability of agriculture in the coastal regions of Bangladesh. Generally shrimp requires saline water for its normal growth and therefore, when monsoon rainfall comes early and rains heavily, the shrimp producers keep on adding extra salt into the water to ensure better growth of shrimp. The extra salt that is added to the field increases the level of soil salinity. Therefore, this saline water degrades the soil quality of fresh lands that adversely affect the local vegetation, plants and trees, crops, fishes, livestock, environment, ecology, and population health and disease patterns (Rahman *et al*., 2013). More than 244,000 ha of land in southern Bangladesh are now reported by the Department of Fisheries as registered for shrimp or prawn culture (Belton *et al*., 2011) and an estimated 53% of this areas are known to be affected by salinity because of shrimp cultivation (Rahman *et al*., 2013). Shrimp polyculture with other species (Martinez-Cordova and Martinez-Porchas, 2006), can be used in low saline coastal areas to minimize the prevailing problems in shrimp farming in Bangladesh as because diversification of species can diminish the impact of discharged effluent and assimilate most of the wastes generated from monoculture of shrimp (Zhen-Xiong *et al*., 2001; Martínez-Porchas *et al*., 2010). Shrimp polyculture also can increase the productivity of aquaculture species without hampering the existing environmental condition. Low saline shrimp polyculture is beneficial for controlling diseases caused by Ich *(Cryptocaryon irritans)*, external trematodes, and most of ectoparasites and protozoa parasite that cannot live long in low salinity (Chakraborti and Bandyapadhyay, 2011), but can also increase many other diseases and parasites. The present study was designed to compare the growth and production performance of shrimp in monoculture, mix culture with prawn and in polyculture with carp fishes in low saline coastal area of Bangladesh.

## Materials and methods

The experiment was conducted for a period of six months from July to December, 2016 in nine experimental ghers under Kaliganj Upazila of Satkhira District (22º27´12.33´´N and 89º02´05.03´´E) (Fig. 1). The surface area of the studied ghers was ranged from 0.97 to 1.17 ha with an average depth of 1.5 m. All the ghers were irregular in shape, rain fed and well exposed to sunlight.

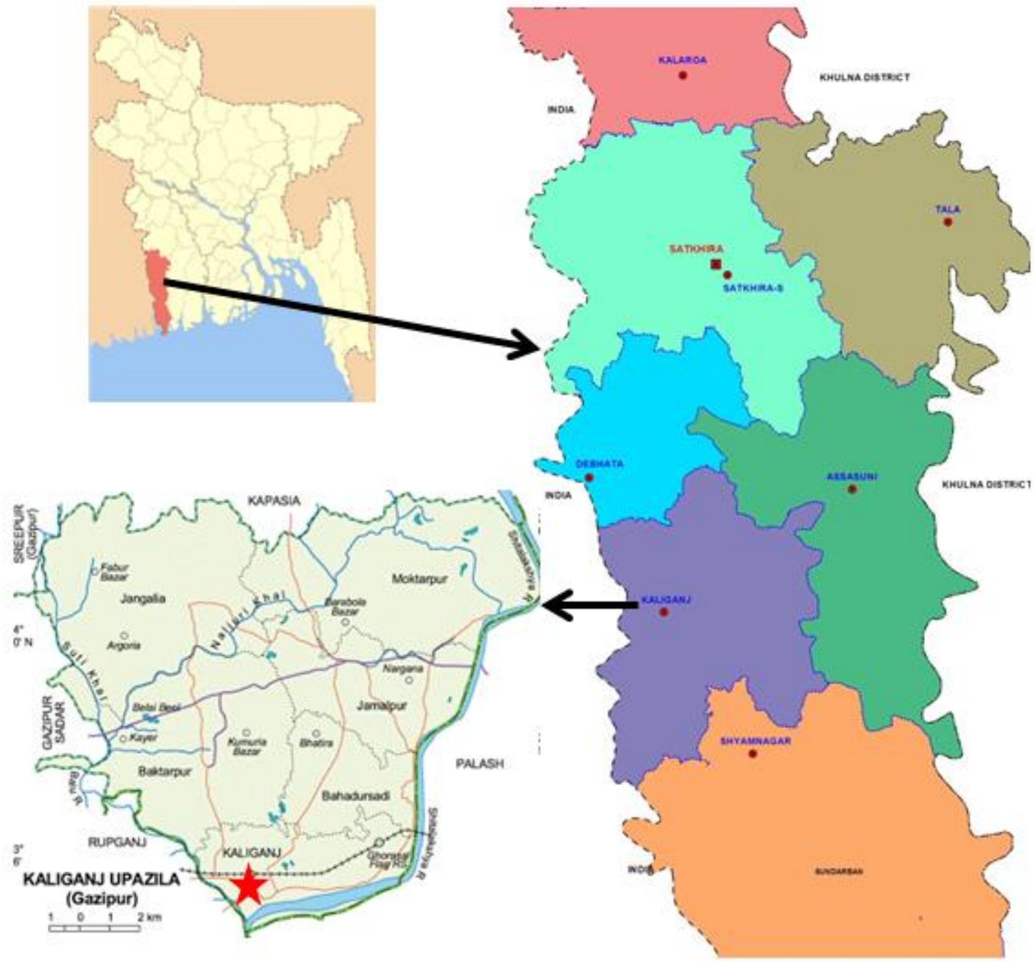


**Figure 1: Location of the study area (indicated with red star).**

Three different treatments ($T_1$, $T_2$, and $T_3$) were assigned each with three replications. The monoculture of shrimp (*Penaeus monodon*) with stocking density of 109915/ha ($T_1$), mix culture of shrimp and prawn (*Macrobrachium rosenbergii*) with stocking density of shrimp 74100/ha and prawn 28405/ha ($T_2$) and polyculture of shrimp, prawn and fish with stocking density of shrimp 61750/ha, prawn 24700/ha and fish 2470/ha were used. Average initial stocking weight of shrimp, prawn, silver carp (*Hypophthalmichthys molitrix*), catla (*Catla catla*), rohu (*Labeo rohita*) and tilapia (*Oreochromis niloticus*) 0.25±.0.06, 2.19±0.03, 104.33±2.08, 107.67±2.52, 106.00±2.00 and 4.50±0.25g, respectively. Stocking density and stocking size of shrimp, prawn and fishes were selected according to the information gained from local fish farmers. Semi-intensive culture (where shrimp obtain nutrients primarily from artificial feeds and are stocked at higher densities, necessitating management practices, such as pond drainage to maintain water quality) practice was followed in all the three treatments.

Aquatic weeds were removed from all the experimental ghers manually. Deep drains (about 2.5m) at the two border side of the ghers were made and soil was used to make the embankment. Embankments were made wider (1m) for preventing of escaping during the rainy season. Slope of embankment was 1:3 m. Inlet and outlet were placed to maintain the water level of the ghers. Unwanted fishes and other predatory species were removed through repeated netting from the ghers. After that, the ghers were ploughed and treated with lime (CaO, 240 kg/ha). Seven days after liming, all the ghers were fertilized with cow dung 1900 kg/ha, urea 24 kg/ha and Triple super phosphate (TSP) 18 kg/ha. One week after basal fertilization, all ghers were stocked with shrimp PL in treatment $T_1$, shrimp and Prawn PL in treatment $T_2$ and shrimp, prawn and fin fishes in treatment $T_3$. All the fishes were collected from hatchery and transported in oxygenated bags. Before stocking, PL was acclimatized to increase the survival rate. After stocking, weekly fertilization of urea 8 kg/ha and TSP 5 kg/ha was followed for all treatments. Dry cow dung, urea and TSP were applied fortnightly at the rate of 5 kg/decimal, 100 g/decimal and 50 g/decimal, respectively. Supplementary feeding was done twice daily at an average rate of 5% of biomass for the first 3 months and at 3% for the rest of rearing period.

Water samples were collected monthly between 10:00 and 11:00 am for analysis of various physico-chemical parameters using dark bottles. Water temperature and transparency were measured using a Celsius thermometer and a black and white standard colour coded Secchi disc of 30 cm diameter. Water pH was measured using an electronic pH meter (Jenwary 3020) and dissolved oxygen (DO) was measured directly with a DO meter (Lutron DO-5509). Nitrate-nitrogen and phosphate-phosphorus concentrations were measured using the Hach Kit (DR/2010, a direct-reading spectrophotometer) with high range chemicals (Nitra Ver. 5 Nitrate Reagent Powder Pillows for 25 mL sample for Nitrate-nitrogen and Phos Ver. 3 Phosphate Reagent Powder Pillows for 25 mL sample for phosphate-phosphorus analysis). Ammonia-nitrogen and total alkalinity were measured using HACH kit (model FF-2, No. 2430-01; Loveland, CO, USA). Salinity was measured by using a hand Refractometer. Samples of bottom sediment were collected randomly before and after culture period from each treatment following the procedures described by Bangladesh Soil Research Institute (BSRI). Soil quality in terms of soil salinity (ppt), soil pH, organic matter (Walkley and Black, 1934) and total nitrogen (Hesse, 1971) of the selected ghers were monitored. Soil samples were tested in the laboratory of Soil Resource Development Institute (SRDI), Shyampur, Rajshahi.

Shrimp, prawn and fishes were sampled every 30 days by cast net for monitoring weight gain, survival rate (%) and specific growth rate (SGR % / day), and total yield (kg/ha) that were calculated using the following equations:

Total yield (kg/ha) = Sum of individual weight of harvested fish
Weight gain (g) = Mean final weight (g) - Mean initial weight (g)
Survival rate (%) = (Fish harvested nos. / Fish stocked nos.) × 100
SGR (%/day) = $[(\text{Ln } W_2 - \text{Ln } W_1) \times 100] / (t_2 - t_1)$,

Where, $W_1$ and $W_2$ are mean initial and final weight (g/fish) and $t_1$ and $t_2$ (days) are time of start and end of the culture period.

Net profit and benefit-cost ratio (BCR) were determined by the following formula:

Net profit = total returns from harvest − total cost of production
Benefit-cost ratio (BCR) = Net profit / total cost of production

Water quality, sediment quality, growth and production parameters (weight gain, survival rate, and SGR) and economic parameters (total cost, total profit and BCR) were analyzed by one-way ANOVA (Analysis of Variance). Sediment quality parameters were compared between before and after culture by paired *t-test*. When a mean effect was significant, the ANOVA was followed by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984). The percentages and ratio data were analyzed using arcsine transformed data. All analysis was performed using SPSS (Statistical Package for Social Science) version 20.0 (IBM Corporation, Armonk, NY, USA).

## Results

Mean values of water quality parameters recorded during the study period are shown in Table 1. Water temperature ranged from 20.00 to 30.50ºC; water transparency varied from 23.50 to 35 cm; pH ranged between 7.00 to 8.00; dissolved oxygen varied between 4.60 to 6.15 $mgL^{-1}$, salinity ranged between 2.70 to 3.10 ppt; nitrate-nitrogen was 0.05 to 0.17 mg/L; phosphate-phosphorus was 0.10 to 0.46 mg/L; ammonia-nitrogen was 0.01 to 0.15 mg/L and total alkalinity fluctuated between 112.00 to 140.00 mg/L. No significant change in the mean values of water temperature, transparency, pH, dissolved oxygen, salinity, and total alkalinity was observed ($p<0.05$). But significant ($p<0.05$) differences were observed in the mean values of nitrate-nitrogen, phosphate-phosphorus and ammonia-nitrogen among the treatments during the study period.

Mean values of soil quality parameters before and after the culture period are shown in Table 2. There was no significant difference ($p>0.05$) in soil quality parameters among the treatments before fish culture. But after culture, significant differences ($p<0.05$) were found for organic matter and total nitrogen content among the treatments. The outcomes of paired *t-test* comparing before and after culture condition are presented in Table 3.

**Table 1: Mean (±SD) values of water quality parameters recorded from different treatments.**

| Parameters | Treatments | | | *p-value* |
|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | |
| Water temperature (ºC) | 26.96±0.19[a] (20.12-30.50) | 26.95±0.04[a] (20.15-30.50) | 26.89±0.22[a] (20.00-30.50) | 0.848 |
| Water transparency (cm) | 29.56±0.34[a] (24.00-35.00) | 29.53±0.27[a] (23.50-35.00) | 29.47±0.09[a] (24.21-35.00) | 0.922 |
| pH | 7.57±0.32[a] (7.00-8.00) | 7.58±0.23[a] (7.00-7.85) | 7.60±0.23[a] (7.15-7.90) | 0.748 |
| Dissolved oxygen (mg/L) | 5.27±0.06[a] (4.60-6.15) | 5.25±0.10[a] (4.60-5.90) | 5.28±0.37[a] (4.80-5.80) | 0.924 |
| Salinity (ppt) | 2.96±0.08[a] (2.80-3.10) | 2.93±0.05[a] (2.70-3.10) | 2.91±0.04[a] (2.80-3.00) | 0.721 |
| Nitrate-nitrogen (mg/L) | 0.10±0.01[b] (0.05-0.14) | 0.11±0.01[b] (0.06-0.16) | 0.13±0.01[a] (0.07-0.17) | 0.008 |
| Phosphate-phosphorus (mg/L) | 0.28±0.01[c] (0.10-0.37) | 0.31±0.01[b] (0.11-0.42) | 0.34±0.02[a] (0.11-0.46) | 0.004 |
| Ammonia-nitrogen (mg/L) | 26.96±0.19[a] (20.12-30.50) | 26.95±0.04[a] (20.15-30.50) | 26.89±0.22[a] (20.00-30.50) | 0.002 |
| Total alkalinity (mg/L) | 29.56±0.34[a] (24.00-35.00) | 29.53±0.27[a] (23.50-35.00) | 29.47±0.09[a] (24.21-35.00) | 0.416 |

$T_1$ = Monoculture of shrimp, $T_2$ = Mix culture of shrimp and prawn, and $T_3$ = Polyculture of shrimp with carps and tilapia. Mean values with different superscript letters in the same row indicate significant differences ($p$<0.05).

**Table 2: Mean (±SD) values of soil quality parameters recorded from different treatments before and after culture period.**

| Criteria | Parameters | Treatments | | | *p-value* |
|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | |
| **Before culture** | Soil salinity (ppm) | 2.97±0.05[a] | 2.87±0.06[a] | 2.90±0.10[a] | 0.317 |
| | pH | 7.53±0.06[a] | 7.60±0.10[a] | 7.57±0.11[a] | 0.702 |
| | Organic matter (%) | 1.22±0.03[a] | 1.21±0.02[a] | 1.23±0.01[a] | 0.553 |
| | Total nitrogen (%) | 0.27±0.01[a] | 0.27±0.01[a] | 0.26±0.01[a] | 0.296 |
| **After culture** | Soil salinity (ppm) | 2.93±0.06[a] | 2.81±0.06[a] | 2.82±0.06[a] | 0.105 |
| | pH | 7.49±0.02[a] | 7.55±0.10[a] | 7.48±0.18[a] | 0.703 |
| | Organic matter (%) | 2.60±0.01[a] | 2.54±0.02[b] | 2.39±0.06[c] | 0.002 |
| | Total nitrogen (%) | 0.53±0.02[a] | 0.48±0.02[b] | 0.45±0.01[b] | 0.001 |

$T_1$=Monoculture of shrimp, $T_2$=Mix culture of shrimp and prawn, and $T_3$=Polyculture of shrimp with carps and tilapia. Mean values with different superscript letters in the same row indicate significant differences ($p$<0.05).

**Table 3: Comparison of soil quality parameters before and after the culture period.**

| Parameters | Treatments | Before | After | *t-value* | *p-value** |
|---|---|---|---|---|---|
| Soil salinity (ppt) | $T_1$ | 2.97±0.05 | 2.93±0.06 | 0.634 | 0.591 |
| | $T_2$ | 2.87±0.06 | 2.81±0.06 | 2.429 | 0.136 |
| | $T_3$ | 2.90±0.10 | 2.82±0.06 | 1.979 | 0.186 |
| pH | $T_1$ | 7.53±0.06 | 7.49±0.02 | 1.710 | 0.229 |
| | $T_2$ | 7.60±0.10 | 7.55±0.10 | 3.500 | 0.073 |
| | $T_3$ | 7.57±0.11 | 7.48±0.18 | 2.563 | 0.124 |
| Organic matter (%) | $T_1$ | 1.22±0.03 | 2.60±0.01 | -74.177*** | 0.000 |
| | $T_2$ | 1.21±0.02 | 2.54±0.02 | -79.400*** | 0.000 |
| | $T_3$ | 1.23±0.01 | 2.39±0.06 | -35.436*** | 0.001 |
| Total nitrogen (%) | $T_1$ | 0.27±0.01 | 0.53±0.02 | -30.237*** | 0.001 |
| | $T_2$ | 0.27±0.01 | 0.48±0.02 | -32.500*** | 0.001 |
| | $T_3$ | 0.26±0.01 | 0.45±0.01 | -113.000*** | 0.000 |

$T_1$=Monoculture of shrimp, $T_2$=Mix culture of shrimp and prawn, and $T_3$=Polyculture of shrimp with carps and tilapia. *Result from paired t-test, ***$p \leq 0.001$, mean±SD.

Organic matter (%) and total nitrogen (%) were significantly ($p<0.05$) increased after culture period. The growth performance of shrimp, prawn and fish were analyzed in terms of final weight (Table 4), weight gain (Table 5), survival rate (Table 6) and specific growth rate (Table 7). Final weight of shrimp ranged between 31.48±0.91g in treatment $T_1$ to 39.50±0.66g in treatment $T_3$. Final weight of prawn was between 75.25±0.66g in $T_2$ and 83.92±1.13g in $T_3$. Final weight of *H. molitrix, C. catla, L. rohita* and *O. niloticus* were 1017.42±2.50, 1019.17±1.89, 817.75±7.51 and 294.70±5.90g, respectively. Highest weight gain (g) of shrimp was observed in treatment $T_3$ followed by $T_2$ and $T_1$ treatments, respectively. The weight gain of prawn was also highest in $T_3$ (81.71±1.07g) followed by $T_2$ (73.08±0.67g). The survival rate of shrimp ranged between 74.76±1.9 ($T_1$) to 85.60±0.40% ($T_3$). The survival rate of prawn was also highest in treatment $T_3$ (86.33±0.58 %). The survival rate of fin fishes ranged between 91.44±0.69 (*O. niloticus*) to 97.22±0.69% (*L. rohita*). Specific growth rate of shrimp was highest in treatment $T_3$ (1.21±0.05%/day) and lowest in $T_1$ and $T_2$ (1.18±0.06 and 1.19±0.02%/day), respectively. Prawn had specific growth rate of 0.86±0.01%/day in $T_2$ and 0.88±0.00%/day in $T_3$. Specific growth rate of *H. molitrix, C. catla*, *L. rohita* and *O. niloticus* were 0.55±0.00, 0.54±0.01, 0.50±0.01 and 1.01±0.02%/day, respectively.

Total yields (kg/ha) of shrimp, prawn and fishes are shown in Table 8. The highest total yield of shrimp was obtained in $T_3$ (2087.87±34.47 kg/ha). Total yield of prawn was also highest in $T_3$ (1789.47±27.45 kg/ha). Extra total yield of fin fishes (1748.76±166.50 kg/ha) was also obtained from $T_3$ together with shrimp and prawn production. There was significant difference ($p<0.05$) in total yield among three culture systems with highest total yield (5626.11±47.82 kg/ha) obtained from $T_3$ (polyculture system) followed by treatment $T_2$ (mix culture of shrimp and prawn) and $T_1$ (monoculture of shrimp).

**Table 4: Final weight (g) of shrimp, prawn, silver carp, catla, rohu and tilapia in T1, T2 and T3 treatments for 180 days of culture period.**

| Species | Treatments | | |
|---|---|---|---|
| | **$T_1$** | **$T_2$** | **$T_3$** |
| *P. monodon* | 31.48±0.91 | 34.83±1.38 | 39.50±0.66 |
| *M. rosenbergii* | | 75.25±0.66 | 83.92±1.13 |
| *H. molitrix* | | | 1017.42±2.50 |
| *C. catla* | | | 1019.17±1.89 |
| *L. rohita* | | | 817.75±7.51 |
| *O. niloticus* | | | 294.70±5.90 |

$T_1$=Monoculture of shrimp, $T_2$=Mix culture of shrimp and prawn, and $T_3$=Polyculture of shrimp with carps and tilapia.

**Table 5: Weight gain (g) of shrimp, prawn, silver carp, catla, rohu and tilapia in T1, T2 and T3 treatments for 180 days of culture period.**

| Species | Treatments | | |
|---|---|---|---|
| | **$T_1$** | **$T_2$** | **$T_3$** |
| *P. monodon* | 31.25±0.93 | 34.57±1.41 | 39.23±0.60 |
| *M. rosenbergii* | | 73.08±0.67 | 81.71±1.07 |
| *H. molitrix* | | | 913.08±2.40 |
| *C. catla* | | | 911.50±1.32 |
| *L. rohita* | | | 711.75±8.60 |
| *O. niloticus* | | | 290.20±6.14 |

$T_1$=Monoculture of shrimp, $T_2$=Mix culture of shrimp and prawn, and $T_3$=Polyculture of shrimp with carps and tilapia.

**Table 6: Survival rate (%) of shrimp, prawn, silver carp, catla, rohu and tilapia in T1, T2 and T3 teatments for 180 days of culture period.**

| Species | Treatments | | |
|---|---|---|---|
| | **$T_1$** | **$T_2$** | **$T_3$** |
| *P. monodon* | 74.76±1.91 | 77.22±1.07 | 85.60±0.40 |
| *M. rosenbergii* | | 77.97±1.33 | 86.33±0.58 |
| *H. molitrix* | | | 95.00±1.00 |
| *C. catla* | | | 95.83±0.76 |
| *L. rohita* | | | 97.22±0.69 |
| *O. niloticus* | | | 91.44±0.69 |

$T_1$=Monoculture of shrimp, $T_2$=Mix culture of shrimp and prawn, and $T_3$=Polyculture of shrimp with carps and tilapia.

**Table 7: Specific growth rate (% bwd-1) of shrimp, prawn, silver carp, catla, rohu and tilapia in T1, T2 and T3 treatments for 180 days of culture period.**

| Species | Treatments | | |
|---|---|---|---|
| | **$T_1$** | **$T_2$** | **$T_3$** |
| *P. monodon* | 1.18±0.06 | 1.19±0.02 | 1.21±0.05 |
| *M. rosenbergii* | | 0.86±0.01 | 0.88±0.00 |
| *H. molitrix* | | | 0.55±0.00 |
| *C. catla* | | | 0.54±0.01 |
| *L. rohita* | | | 0.50±0.01 |
| *O. niloticus* | | | 1.01±0.02 |

$T_1$=Monoculture of shrimp, $T_2$=Mix culture of shrimp and prawn, and $T_3$=Polyculture of shrimp with carps and tilapia.

**Table 8: Total yield (kg ha-1) of shrimp, prawn, silver carp, catla, rohu and tilapia in T1, T2 and T3 treatments for 180 days of culture period and 1 ha of gher.**

| Species | Treatments | | |
|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ |
| *P. monodon* | 2585.79±30.85 | 1992.90±71.35 | 2087.87±34.47 |
| *M. rosenbergii* | | 1666.71±39.27 | 1789.47±27.45 |
| **Sub total** | | 3659.61±75.68 | 3877.34±230.65 |
| *H. molitrix* | | | 477.48±6.15 |
| *C. catla* | | | 482.49±3.90 |
| *L. rohita* | | | 589.11±3.90 |
| *O. niloticus* | | | 199.68±3.30 |
| **Sub total** | | | 1748.76±166.50 |
| **Total** | 2585.79±30.85$^c$ | 3659.61±75.68$^b$ | 5626.11±47.82$^a$ |

$T_1$=Monoculture of shrimp, $T_2$=Mix culture of shrimp and prawn, and $T_3$=Polyculture of shrimp with carps and tilapia. Values are expressed as mean ±SD and values in the same row having different superscripts are significantly different ($p$<0.05).

Comparison of economic return among three treatments is shown in Table 9. The total input cost was significantly higher (607934.00±95.00 BDT/ha) in $T_3$ and lower (514656±1278.63 BDT/ha) in $T_1$. On the other hand, the total income was significantly higher (2123761.83±17920.71 BDT/ha) in $T_3$ and the lowest total income was obtained from $T_1$ (1163603.41±13883.05 BDT/ha). Similarly, highest net profit was obtained from $T_3$ (1515827.83±17920.72 BDT/ha) followed by $T_2$ (1145714.26±34761.97 BDT/ha) and $T_1$ (648315.75±13677.01 BDT/ha), respectively. However, the Benefit-cost ratio (BCR) was significantly ($p$<0.05) higher in $T_3$ with a value of 2.49±0.03 followed by 1.96±0.06 in $T_2$ and 1.26±0.03 in $T_1$ respectively.

**Table 9: Comparison of economic parameters among the treatments. Calculation was for 1 ha of ghers and 180 days of culture period.**

| Items | | Treatments (mean values in BDT*) | | |
|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ |
| Gher preparation | | 3600.00 | 3600.00 | 3600.00 |
| Inlet-outlet PVC pipe | | 7000.00 | 7000.00 | 7000.00 |
| Liming | | 3400.00 | 3400.00 | 3400.00 |
| Fertilizer | Urea | 4800.00 | 4800.00 | 4800.00 |
| | TSP | 2400.00 | 2400.00 | 2400.00 |
| | Cow dung | 1200.00 | 1200.00 | 1200.00 |
| Seed cost | | 109915.00 | 179075.00 | 203034.00 |
| Molasses + rice bran | | 3200.00 | 3200.00 | 3000.00 |
| Feed | | 265000.00 | 265000.00 | 265000.00 |
| Eggs | | 9114.00 | 9114.00 | 8500.00 |

**Table 9 (Continued):**

| Items | Treatments (mean values in BDT*) | | |
|---|---|---|---|
| | **$T_1$** | **$T_2$** | **$T_3$** |
| Chemicals | 9658.67 | 9658.67 | 5000 |
| Pump machine | 6500.00 | 6500.00 | 6500.00 |
| Labour | 36000.00 | 36000.00 | 36000.00 |
| Netting | 3500.00 | 3500.00 | 3500.00 |
| Transportation | 10000.00 | 10000.00 | 10000.00 |
| Land rent** | 30000.00 | 30000.00 | 30000.00 |
| Others | 10000.00 | 10000.00 | 10000.00 |
| Total cost (BDT/ha) | $514656^{c}$ | $584447.67^{b}$ | $607934.00^{a}$ |
| Total income (BDT/ha) | $1163603.41^{c}$ | $1730161.93^{b}$ | $2123761.83^{a}$ |
| Net profit (BDT/ha) | $648315.75^{c}$ | $1145714.26^{b}$ | $1515827.83^{a}$ |
| Benefit-cost ratio (BCR) | $1.26^{c}$ | $1.96^{b}$ | $2.49^{a}$ |

$T_1$=Monoculture of shrimp, $T_2$=Mix culture of shrimp and prawn, and $T_3$=Polyculture of shrimp with carps and tilapia. Values in the same row having different superscripts differ significantly ($p$<0.05). *Currencies are given in Bangladeshi Taka, BDT (1 US$ = 80 BDT). ** Valuation of land at its rental price.

## Discussion

During the culture period, there was no significant ($p$<0.05) change in the mean values of water temperature, transparency, pH, dissolved oxygen, salinity and total alkalinity. There were significant differences ($p$<0.05) in the mean values of nitrate-nitrogen among the treatments. The highest value of nitrate-nitrogen was found in $T_3$ (0.13±0.01 mg/L) and the lowest was found in $T_1$ (0.10±0.01 mg/L). The recommended level of nitrate for shrimp farming is 0.0 to 0.3 ppm and for prawn farming is <0.1ppm (McNevin, 2004; Mazid, 2009). Presence of higher value of nitrate-nitrogen in $T_3$ in the present study might be due to higher fecal output of fishes. There was also significant difference ($p$<0.05) in the mean values of phosphate-phosphorus among three treatments with the highest value recorded in $T_3$ (0.34±0.02 mg/L) and lowest value in $T_1$ (0.28±0.01 mg/L) while both were above the recommended limit for shrimp culture. According to Boyd (1998) the suitable range of phosphate-phosphorus in pond water is 0.005-0.2 mg/L. Presence of the highest value of phosphate-phosphorus in $T_3$ might be due to input of feeds and fertilization in the culture system, along with proper recycling of this waste into nutrients by fish activities in water. There was significant difference ($p$<0.05) in the mean values of ammonia-nitrogen among three treatments. Highest and lowest values were observed in $T_3$ (0.09±0.01 mg/L) and $T_1$ (0.06±0.00 mg/L), respectively, which was within the recorded ammonia-nitrogen range (0.07-0.28 ppm) found by Ahsan *et al*. (2014) in polyculture of prawn and carp. Presence of the highest value of ammonia-nitrogen in $T_3$ might be due to diversification of specimens, which increases fecal output in water column.

There was no significant difference ($p$<0.05) between the mean values of soil salinity and pH before and after culture period. That means these culture systems in low saline water had no impact on soil salinity and pH. There was a significant change ($p$<0.05) in the soil organic matter and total nitrogen content after culture period, with highest organic matter and total nitrogen were accumulated in $T_1$ (2.60±0.01 and 0.53±0.02%) and lowest were in $T_3$ (2.39±0.06 and 0.45±0.01%). As some subordinate species can feed on and assimilate most of the wastes generated from shrimp culture (dead plankton and the uneaten feeds), a higher efficiency of nitrogen utilization and diminishing of impact of effluent discharge was observed in polyculture system compared to monoculture system, which supports the findings of Zhen-Xiong *et al*. (2001) and Martínez -Porchas *et al*. (2010). There was also evidence that the diversification of species influenced the productivity status in polyculture system, which might be due to better decomposition and nutrient cycling through higher efficiency of nitrogen utilization. A similar observation was also made by Zhen-xiong *et al*. (2001); Hooper *et al*. (2005) and Balvanera *et al*. (2006).

There were significant differences ($p$<0.05) in the mean values of final weight and weight gain in shrimp among three treatments. This might be due to different stocking density of shrimp and species diversification. Although the stocking density between 10-20 PLs/$m^2$ is ideal for successful shrimp farms, recommended by Ramanathan *et al*. (2005), which was similar to $T_1$ (445 shrimp PL/deci), but lower stocking density in $T_2$ (300 shrimp PL and 115 prawn/deci) and $T_3$ (250 shrimp PL and 100 prawn/deci) gave more space and food for growth of shrimp and prawn. The increase in final weight and weight gain in the present study was attributed to be the lower stocking density, which was agreed with the findings of Chowdhury *et al*. (1991) and Ahsan *et al*. (2014). Less intra-species competition for food and space might also be responsible for higher growth in $T_3$. Similar findings also was reported by Wohlfarth *et al.* (1985), who stated that polyculture fits sustainable aquaculture as the polyculture species do not compete for the same feed resources. Another reason for better growth performance in $T_3$ might be improved water quality in polyculture of shrimp, which is in agreement with the findings of Midlen and Redding (1998) and Zhang *et al*. (1999). They stated that, polyculture can improve water quality, since in monoculture farming systems; the excess nutrients that result from uneaten feed increases the phytoplankton, which in turn, changes the dissolved oxygen dynamics and brings negative ecological impact to the aquaculture activity itself.

Survival rate (%) of shrimp and prawn was higher in polyculture system as compared to mono and mix culture in the present study. Specific growth rates of shrimp and prawn were also significantly ($p$<0.05) increased with decreasing stocking density and with differences of culture system, which indicate that the growth rate was higher in lower densities which is in agreement with findings of Das *et al*. (1992), who reported that the growth rate is inversely related to stocking density.

There was significant ($p$<0.05) difference in total yield among the three treatments. In $T_3$ total obtained yield was a 5626.11±47.82 kg/ha/180 day which was 34.95% higher than that of $T_2$ and 54.04% higher than that of treatment $T_1$, this can be because polyculture causes proper utilization of available resources in more efficient way. Similar observation was noted by Bolognesi Da Silva *et al.* (2006). Higher fish production in polyculture system is also reported by Hossain and Islam (2006); Alam *et al*. (2008) and Anil *et al*. (2010).

There was significant difference ($p$<0.05) in total cost, total income, net profit and benefit-cost ratio (BCR) among the three treatments. The economic analysis showed that, total cost in treatment $T_3$ was 3.86% and 15.34% higher than that in treatments $T_2$ and $T_1$, respectively. But the total income in treatment $T_3$ was 18.53% and 45.21% higher than that in treatments $T_2$ and $T_1$, respectively. Net profit was also found higher in treatment $T_3$ than that in treatments $T_2$ and $T_1$. This might be due to higher growth rate and survivability of shrimp and prawn in $T_3$ (polyculture system) with additional production of fishes in this treatment. Higher net profitability in shrimp polyculture system was also found by Ali *et al*. (2013). It was found that, BCR was highest in treatment $T_3$ (2.49±0.03) followed by $T_2$ (1.96±0.06) and $T_1$ (1.26±0. 03), respectively. Similarly higher BCR was reported when shrimp was cultured with tilapia in shrimp tilapia-polyculture system (Shofiquzzoha *et al*., 2009).

In the present study, it was observed that polyculture system of shrimp with prawn and fish was better in all aspect of growth performance and economic feasibility (weight gain, specific growth rate, survival rate, total yield, net profit and BCR). Although the production cost was higher in polyculture system, it was more than counterbalanced by high productivity of shrimp, prawn and additional production from fishes. Polyculture of shrimp was also beneficial in terms of environmental well-being of low saline coastal areas of Bangladesh. So, polyculture of shrimp with fishes would be more profitable to fish farmers than mix culture of shrimp with prawn and monoculture of shrimp, which will promote the national economy and reduce environmental impact caused by shrimp monoculture.

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## References

**Ahsan, M.N., Parvez, M.S., Rouf, M.A., Joarder, I. and Aktar, S., 2014.** Production performance of over-wintered freshwater giant prawn (*Macrobrachium rosenbergii*) in polyculture with common carp (*Cyprinus carpio*) for an early crop.

*Journal of Research in Agriculture and Animal Science*, 2(**11**), 7-13.

**Alam, M.J., Islam, M.L. and Tuong, T.P., 2008.** Introducing tilapia (GIFT) with shrimp *(Penaeus monodon)* in brackishwater rice-shrimp system: impact on water quality and production. *Bangladesh Journal of Fisheries Research*, 12(**2**), 187-195.

**Ali, H., Haque, M.M. and Belton, B., 2013.** Striped catfish (*Pangasianodon hypophthalmus*, Sauvage, 1878) aquaculture in Bangladesh: an overview. *Aquaculture Research*, 44, 950-965. DOI:10.1111/j.1365-2109.2012.03101.x.

**Anil, S.K., Gunalan, B., Jetani, K.L., Trivedi, K.G. and Soundarapandian, P., 2010.** Determine the economic feasibility of the polyculture system (giant tiger shrimp and mullet). *African Journal of Basic and Applied Sciences*, 2(**3-4**), 124-127.

**Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.S., Nakashizuka, T., Raffaelli, D. and Schmid, B., 2006.** Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology Letters*, 9(**10**), 1146-1156. DOI:10.1111/j.1461-0248.2006.00963.x.

**Belton, B., Karim, M., Thilsted, S., Murshed-E-Jahan, K., Collis, W. and Phillips, M., 2011.** *Review of aquaculture and fish consumption in Bangladesh.* Studies and Reviews 2011-53. The WorldFish Center, Penang, Malaysia. 71 P.

**Bolognesi Da Silva, L., Barcellos, L.J.G., Quevedo, R.M., de Souza, S.M.G., Kreutz, L.C., Ritter, F., Finco, J.A. and Bedin, A.C., 2006.** Alternative species for traditional carp polyculture in southern South America: initial growing period. *Aquaculture*, 255(**1-4**), 417-428. DOI:10.1016/j.aquaculture.2005.12.024.

**Boyd, C.E., 1998.** *Water quality for pond aquaculture.* Research and Development Series No. 43. International Centre for Aquaculture and Aquatic Environments, Alabama Agricultural Experiment Station, Auburn University, Alabama, USA: 37 P.

**Chakraborti, J. and Bandyapadhyay, P.K., 2011.** Seasonal incidence of protozoan parasites of the black tiger shrimp (*Penaeus monodon*) of Sundarbans, West Bengal, India. *Journal of Parasitic Diseases*, 35(**1**), 61-65. DOI:10.1007/s12639-011-0032-9.

**Chowdhury, R., Bhattacharjee, H. and Angell, C., 1991.** *A manual for operating freshwater prawn hatchery.* Bay of Bengal Programme, Manuals and guides, Madras, India. 1336 P.

**Das, M., Islam, M.A. and Mughal, G.U., 1992.** Induced breeding and fry rearing of *Clarias batrachus* (linn). *Bangladesh Journal of Zoology*, 20, 87-95.

**Gomez, K.A. and Gomez, A.A., 1984.** *Statistical procedures for agricultural research*, 2nd edition. John Wiley and Sons, Hoboken, New Jersey, USA. 704 P.

**Hesse, P.R., 1971.** *A textbook of soil chemical analysis*, first edition. John Murray Publishing House, London, UK: 520 P.

**Hooper, D.U., Chapin lll, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A.J., Vandermeer, J. and Wardle, D.A., 2005.** Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs*, 75(**1**), 3-35. DOI:10.1890/04-0922.

**Hossain, M.A. and Islam, M.S., 2006.** Optimization of stocking density of freshwater prawn *Macrobrachium rosenbergii* (de Man) in carp polyculture in Bangladesh. *Aquaculture Research*, 37, 994-1000. DOI:10.1111/j.1365-2109.2006.01518.x.

**Kabir, M.H. and Eva, I.J., 2014.** Environmental impacts of shrimp aquaculture: the case of Chandipur village at Debhata Upazila of Satkhira district, Bangladesh. *Journal of Asiatic Society of Bangladesh*, 40(**1**), 107-119.

**Martinez-Cordova, L.R., and Martinez-Porchas, M., 2006.** Polyculture of Pacific white shrimp, *Litopenaeus vannamei*, giant oyster, *Crassostrea gigas* and black clam, *Chione fluctifraga* in ponds in Sonora, Mexico. *Aquaculture*, 258, 321-326. DOI:10.1016/j.aquaculture.2006.03.026.

**Martínez-Porchas, M., Martínez-Córdova, L.R., Porchas-Cornejo, M.A., López-Elías, J.A., 2010.** Shrimp polyculture: A potentially profitable, sustainable, but uncommon aquacultural practice. *Reviews in Aquaculture*, 2(**2**), 73-85. DOI:10.1111/j.1753-5131.2010.01023.x.

**Mazid, M.A., 2009.** *Training manual on water quality management in shrimp farm.* Bangladesh Quality Support Programm- Fisheries, UNIDO, Dhaka, Bangladesh, 108 P.

**McNevin, A.A., 2004.** *Water quality monitoring of Mahajamba Bay, Madagascar*. PhD Dissertation, Auburn University, Auburn, Alabama, USA: 244 P.

**Midlen, A. and Redding, T.A., 1998.** *Environmental management for aquaculture.* Kluwer Academic Publishers, Dordrecht, Netherlands: 223 P.

**Rahman, M.C., Salam, M.A., Rahman, N.M.F., Rahman, M.M. and Hossain, M.M., 2013.** Present status and potentiality of shrimp in Bangladesh. *Australian Journal of Basic and Applied Sciences*, 7(**7**), 281-286.

**Ramanathan, N., Padmavathy, P., Francis, T., Athithian, S. and Selvaranjitham, N., 2005.** *Manual on polyculture of tiger shrimp and carps in freshwater*. Tamil Nadu Veterinary and Animal Sciences University, Fisheries College and Research Institute, Thothukudi. 161 P.

**Shamsuzzaman, M.M., Islam, M.M., Tania, N.J., Al-mamun, M.A., Barman, P.P. and Xu, X., 2017.** Fisheries resources of Bangladesh:

Present status and future direction. *Aquaculture and Fisheries*, 2(**4**), 145-156. DOI:10.1016/j.aaf.2017.03.006.

**Shofiquzzoha, A.F.M., Alam, M.J. and Moniruzzaman, M., 2009.** Species diversification in coastal aquaculture: Production potentials of shrimp *(Penaeus monodon)* with mono and mixed sex tilapia. *Bangladesh Journal of Fisheries Research*, 13(**2**), 179-184.

**Walkley, A. and Black, I.A., 1934.** An examination of the Degtjareff method for determination of soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(**1**), 29-38. DOI:10.1097/00010694-193401000-00003.

**Wohlfarth, G.W., Hulata, G., Karplus, I. and Halevy, A., 1985.** Polyculture of the freshwater prawn *Macrobrachium rosenbergii* in intensively manured ponds, and the effect of stocking rate of prawns and fish on their production characteristics. *Aquaculture*, 46(**2**), 143-156. DOI:10.1016/0044-8486(85)90198.x.

**Zhang, H., Li, D. and Wang, Y., 1999.** The impacts of tilapia polyculture in shrimp ponds on the structure of plankton communities. *Journal of Fisheries and Aquatic Science*, 6(**4**), 114-116.

**Zhen-xiong, Q., De-shang, L., Man-ping, Z. and Shuang-lin, D., 2001.** Comparative studies on nitrogen budgets of closed polyculture systems. *Chinese Journal of Oceanology and Limnology*, 19, 233-242. DOI:10.1007/bf02850660.