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Effect of different stocking densities of *Amblypharyngodon mola* (Hamilton, 1822) on the growth of Indian major carps in polyculture system

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Abstract
An experiment on the effect of different stocking densities of mola (*Amblypharyngodon mola*) on the growth of Indian Major Carps (IMC) was conducted for 90 days. Four treatments (T_0, T_1, T_2 and T_3) in triplicates were tried. Catla, Rohu and Mrigal fingerlings were stocked at the rate of 8000 nos. ha^{-1} in 2:2:1 ratio respectively in each treatment. Mola were stocked at the rate of 15,000 nos. ha^{-1}, 25,000 nos. ha^{-1}, and 35,000 nos. ha^{-1} in treatment T_1, T_2 and T_3 respectively. T_0, with only IMCs, served as the control. Highest production was obtained in T_1, followed by T_0, T_2 and T_3 but not significantly (p>0.05) different. Water quality parameters were significantly (p<0.05) different between specific treatments. A total of 25 genera of plankton were recorded during the study period. The study indicated that the high density of mola exerts a negative impact on the production of rohu and mrigal. Based on the total production and profit, T_1 was found to be the best.

Keywords: *Amblypharyngodon mola*, IMC Indian major carps, polyculture

Introduction
Fisheries and aquaculture are one of the essential sources of food, nutrition and livelihoods for hundreds of millions of people across the world. World per capita fish supply was 20.1 kg in 2014 [1].

Pond-based aquaculture is generally the most widely practised and profitable way of growing aquatic animals. The main advantage of pond aquaculture is that, with the applicability of fertilizer/manure the natural food is made available in that pond effectively. The technique of obtaining the profit from aquaculture is utilizing all its resources which are available in the water body. In order to maximize the production per unit area, the polyculture of fishes is based on the concept of total utilization of different trophic levels of pond. Polyculture may produce an expected production of fish with different feeding habits if stocked in proper ratios, densities, and combinations [2].

Polyculture of Indian Major Carps (IMC) *Catla catla* (Catla), *Labeo rohita* (Rohu) and *Cirrhinus mrigala* (Mrigal) has been practised in the country for a good reason because the species occupy some of the major naturally occurring ecological niches of the water body. Instead of eliminating the native small indigenous fishes from the aquaculture ponds, measures should be taken to optimize their production since these small fishes make use of the unutilized food resources and niches in pond ecosystem [3, 4].

Amblypharyngodon mola (mola) is a small indigenous fish species (SIS) belonging to the family Cyprinidae and order Cypriniformes. SIS are considered as the fishes which attain maximum growth of approximately 25 cm at maturity [5]. *A. mola* is commonly known as Mola carplet, Pale carplet in English; Moah, Moa in Assam; Dhawai in Uttar Pradesh; Makhni in Punjab; Moraru in Odisha and Tallamaya in Andhra Pradesh [6]. Mola is a natural inhabitant of ponds, canals, *beels*, slow-moving streams, ditches, baors, reservoirs and inundated fields [6-9]. Mola is distributed in India, Bangladesh, Pakistan and Myanmar [6]; also, has been reported from Afghanistan [10]. Mola is a surface feeder and feeds on unicellular algae, protozoa, rotifer and crustaceans [11]. It breeds twice a year with one peak in May and another in September in both pond and *beel* [12].

Hence, mola is a self-recruiting species. Mola is particularly most demanded for its very high content of vitamin A than any other edible fish [13]. Mola per 100g raw contained 2680 RAE vitamin A, 0.9g Calcium, 5.7mg Iron and 3.2mg Zinc [14, 15]. Upon analysing different parts of mola, it showed that the eyes contain the highest proportion of the total vitamin A, followed by the viscera [5, 16, 17]. Mola is a good source of calcium because mostly it is eaten whole with bones. In recent times, it has also been promoted in ornamental fish trade and its moderate demand and availability has been reported in ornamental fish markets [18]. Mola is highly preferred by common people in its smoke and sundry form in North East India. Mola can prevent xeropthalmia of growing children[19]. The conservation status of mola is categorized as 'lower risk least concern' (LR Lc) by the Conservation Assessment and Management plan [20].

There are several reports of the culture of mola with Major carps polyculture system [21-24]. However, in any impounded water body stocking density is a major factor for better productivity. It affects the amount of natural food available per fish and the level of supplementary feeding required [25, 26]. Introduction of mola in carp polyculture system, therefore, will have some impacts on the growth of the carps [21, 27]. The reviewed literature suggests that the information of stocking density of mola, on the growth of carps in IMC polyculture system is scanty.

Thus, with the above-mentioned points in mind the present study was envisaged to study the effect of different stocking densities of mola on the growth of IMC. Physical, chemical and biological water quality parameters in relation to total stocking densities were also analyzed. The economic turnover for the whole polyculture system was studied for future perspectives.

Materials and Methods

Experimental Area

The experiment was conducted in the Fish farm of the College of Fisheries (26°13´N 92°30´S), Assam Agricultural University, Raha, in Nagaon district of Assam. The experiment was performed for 90 days from July to September 2017.

Tank preparation

The experiment was carried out in twelve numbers of outdoor rectangular cemented tanks. All the tanks had similar size (6m×4m×1m) with surface area 24m^2. Ten-centimeter soil bed was provided in each tank.

Fertilization of tanks

The dose of quick lime applied to each tank was 400 kg ha^{-1} yr^{-1}. Quick lime was applied in the split dose, 30% (120 kg ha^{-1} yr^{-1}) was applied during preparation and remaining quantity was applied in monthly instalments. After a week of liming the tanks were filled with water. The total raw cow dung was applied at the rate of 9000 kg ha^{-1} yr^{-1}. The initial dose of raw cow dung was applied @ 20% (1800 kg ha^{-1} yr^{-1}) of total required amount in each tank. Rest 80% was applied as split up equal dose in monthly intervals. For the initial dose, cow dung was mixed with water and distributed evenly over the water surface. Subsequent instalments were applied in heaps. Fifteen days after raw cow dung application, urea and single super phosphate were applied at the rate of 222 kg ha^{-1}yr^{-1} and 390 kg ha^{-1} yr^{-1} respectively. Urea and single super phosphate were split up into 12 equal instalments to apply at monthly intervals.

Stocking of fish

The experiment included four treatments (T_0, T_1, T_2 and T_3) in triplicates. Catla, rohu and mrigal fingerlings were stocked at the rate of 8, 8 and 4 numbers. (8000 numbers. ha^{-1}) in 2:2:1 ratio respectively in each treatment. Mola fry were stocked at the rate of 36, 60 and 84 numbers. (15,000, 25,000 and 35,000 numbers. ha^{-1}) in treatment T_1, T_2 and T_3 respectively. Before stocking fishes were measured for length and weight.

Post stocking management

Rice polish (50%) and mustard oil cake (50%) were fed at the rate of 3% body weight of IMC in each treatment. The amount of feed was adjusted fortnightly, based on the sampling weight of IMC. The requirement of supplementary feed was given in the feeding tray at the corner of tanks in daily morning (8.00am) and evening (4.00pm) throughout the experimental period.

Growth of fishes

Fishes were sampled fortnightly to estimate the growth in term of weight and length and also to check up their health condition. Groth parameter analysis was done with the help of following parameters:

Weight gain

Weight gain (g) = Weight gain (g) = Mean of final weight (g)– Mean of initial weight (g)

Survival rate (%)

$$\text{Survival rate (\%)} = \frac{\text{Number of fishes harvested}}{\text{Initial number of fishes}} \times 100$$

Specific growth rate (SGR)

$$\text{SGR (\% body weight day}^{-1}) = \frac{[\text{Ln (Final weight)} - \text{Ln (Initial weight)}}{\text{Culture period (Days)}} \times 100$$

Feed conversion ratio (FCR)

$$\text{FCR} = \frac{\text{Feed fed (dry)}}{\text{Weight gain of animal (g)}}$$

Fish yield (kg ha^{-1})

Total fish yield was calculated at the end of the experiment using the following formula:

Gross yield

Gross yield (kg ha-1) = Total fish harvested (g), converted to kg ha^{-1}

Net yield

Net yield (kg ha^{-1}) = Total fish weight harvested (g) - Total initial weight (g), converted to kg ha^{-1}

Water quality analysis

Water quality parameters were estimated fortnightly. Water samples were collected morning (5.00 am) and evening (5.00 pm). Temperature of water was measured by using a mercury thermometer with minimum scale 0.1 °C and accuracy ±0.1 ^{0}C. The transparency of experimental tanks was determined by using Secchi disc.

Dissolve oxygen (mgl^{-1}), Free carbon dioxide (mgl^{-1}), pH, Total alkalinity (mg $CaCO_3l^{-1}$), Total hardness (mg $CaCO_3l^{-1}$),

Ammonia - nitrogen (mgl^{-1}), Nitrate - nitrogen (mgl^{-1}), Phosphate - phosphorus (mgl^{-1}) and Chlorophyll - a (μgl^{-1}) were determined by followed standard method and procedure [28].

For plankton analysis plankton samples were collected fortnightly. A Sedgwick-Rafter cell was used for counting the plankton. Calculation of plankton number was done by using the formula of Stirling (1985) as [29]: N= (A×1000×C) / (V×F×L)

Where, N is the number of plankton cells or units per litre of original water, A is the total number of plankton counted, C is the volume of final concentrate of the samples in ml, V is the volume of field in cubic ml, F is the number of fields counted and L is the volume of original water in litre. Identification of plankton to genus level was performed using keys from Bellinger (1992) [30].

Estimation of proximate composition of supplementary feed

Proximate analysis of supplementary feed included estimation of moisture, ash content, crude fat and crude protein. These were determined using standard AOAC method [31].

Economic analysis

Economic analysis was done on the local market price in terms of the Indian rupee and following formulas were used

$$\text{Percent return to variable cost} = \frac{\text{Net profit}}{\text{Total variable cost}} \times 100$$

$$\text{Percent profit to turn over} = \frac{\text{Net profit}}{\text{Total return}} \times 100$$

$$\text{Benefit cost ratio} = \frac{\text{Total return}}{\text{Total cost}}$$

Statistical analysis

Descriptive statistics of the data were calculated by using computer software Statistical Package for Social Science (SPSS Version 16.0)[32]. One-way analysis of variance (ANOVA) and the Tukey - HSD at 5% level of significance was used to compare the difference between the treatment mean. Variations of treatment means are presented in mean ± standard error.

Results and Discussions

Proximate composition of supplementary feed

Proximate composition of the experimental diet along with the feed formulation are presented in Table-1. Proximate composition was found to be 8.83 ± 0.77% moisture, 23.73 ± 1.78% crude protein, 7.03 ± 0.54% ash and 9.53 ± 1.34% crude fat.

Table 1: Feed formulation and proximate composition of the experimental diet

Ingredients	Inclusion level (%)
Rice polish	50
Mustard oil cake	50
Component	**Composition (%)***
Moisture	8.83 ± 0.77
Crude protein	23.73 ± 1.78
Crude fat	9.53 ± 1.34
Total ash	7.03 ± 0.54

*Values are given in Mean ± SE (n=3)

Water quality parameters

Aquaculture completely depends on the suitable water quality parameters. Suitable water quality parameters are necessary for healthy aquatic environment and also to get desired production of fishes. All the water quality parameters of all treatments were within the acceptable ranges for culture of fishes. The results obtained for water quality parameters measured in different treatments of the present study are presented in Table-2. Significant difference (p<0.05) was observed in transparency, dissolve oxygen (evening), free carbon dioxide (morning) and pH (morning) between some of the treatments. In present study all treatments had similar shape, size and maintained equal depth throughout the study period. This may be the reason for same range of water quality parameters. Temperature (morning and evening), dissolve oxygen (morning), free carbon dioxide (evening), pH (evening), total alkalinity, total hardness, nitrate-nitrogen, ammonia - nitrogen, phosphate-phosphorus and chlorophyll-a were not observed to be significantly (p>0.05) different among all treatments.

Morning water temperature in all experimental tanks ranged from 27.1 to 31.46 °C. Average morning water temperatures were 28.74 °C, 28.87 °C, 28.88 °C and 28.98 °C in T0, T1, T2 and T3 respectively with no significant (p>0.05) difference among treatments. Evening water temperatures in experimental tanks varied between 28.3 to 35.53 °C. Average evening water temperatures were 30.9 °C, 31.43 °C, 31.28 °C and 31.28 °C in T0, T1, T2 and T3 respectively where no significant (p>0.05) difference among treatments was observed. Evening water temperature in the present study was higher than morning water temperature because of sunlight penetration in water for the whole day. Temperature is an essential environmental factor affecting various chemical reactions and biological processes in water [33]. IMC can tolerate temperature ranging from 10 to 37.8 °C [34]. The suitable range of water temperature for fish culture was 25 °C to 35 °C recommended by Aminul (1996) [35]. Rahman *et al.* (1989) found water temperature 26.06 °C to 31.97 °C which was within the suitable range for pond fish culture [7]. Mollah and Haque (1978) recorded temperature ranging from 26 °C to 32.4 °C in pond water [36]. Kohinoor *et al*. (2005) recorded 28.56 °C and 28.60 °C average temperature in IMC and IMC with mola culture pond respectively [22]. All these findings support the present study.

The average transparency values of T_0 (27.23 ± 1.21 cm), T_1 (27.45 ± 0.97 cm), T_2 (27.70 ± 0.60 cm) were found to be significantly (p<0.05) different from T_3 (31.6 ± 0.71 cm). Transparency in all experimental tanks varied from 22.83 to 35.33 cm. Average transparency values were 27.23 cm, 27.45 cm, 27.70 cm and 31.6 cm in T0, T1, T2 and T3 respectively. T0, T1, T2 were significantly (p<0.05) different from that of T3. Boyd (1982) recommended a transparency range as 15 to 40 cm, appropriate for fish culture [33]. In present study highest stocking density of mola affected transparency when compared to other treatments. The reason may be due to the high grazing of plankton in T3 than other treatments. The present results were like the earlier findings of Roy *et al.* (2002) who recorded 23.31cm and 25.43 cm transparency in without and with mola ponds, respectively [6]. Findings of Kohinoor *et al.* (2015) also matches with the present study where they found 27.55cm and 36.70cm transparency in IMC and IMC with mola ponds respectively [24]. In the present experiment, the transparency values of water of experimental tanks indicated its productive range.

The morning dissolve oxygen in all experimental tanks fluctuated from 2.80 to 3.6mgl^{-1}. The average morning dissolve oxygen values were 3.21 mgl^{-1}, 3.11 mgl^{-1}, 3.01 mgl^{-1} and 3.04 mgl^{-1} in T0, T1, T2 and T3 respectively where no significant (p>0.05) difference among treatments was observed. The average values of evening dissolve oxygen in T_0 (6.33 ± 0.15 mgl^{-1}) was significantly (p<0.05) different from T_3 (5.67 ± 0.13 mgl^{-1}). The evening dissolve oxygen of all experiment tanks varied between 5.3 to 6.83 mgl^{-1}. The average evening dissolve oxygen was 6.33 mgl^{-1}, 6.01 mgl^{-1}, 5.83 mgl^{-1} and 5.67 mgl^{-1} in T0, T1, T2 and T3 respectively. T0 was significantly (p<0.05) different than T3. Morning dissolve oxygen was less than evening due to the respiration of fishes as well as plankton in whole night and in daytime phytoplankton produces oxygen through photosynthesis. In T3, evening dissolve oxygen was significantly less than the control and it may be due to the less density of plankton and more consumption of oxygen through respiration by mola as well as IMC. Ideal considered desired DO level maintained in pond water for fishes is 6-9 mgl^{-1} [33]. According to Banerjee (1967), optimum oxygen for good growth of cyprinids is 6-7 ppm, but they can also tolerate levels as low as 3ppm for short periods [37]. According to Cole and Boyd (1986), low dissolved oxygen concentrations may affect growth, yield, food conversion ratio and survival of fish[38]. The present results agree with earlier findings of DO in control and mola cultured ponds by Kohinoor *et al*. (1998), Roy *et al*. (2002), Kohinoor *et al*. (2005) and Debnath *et al*. (2013) where they recorded DO levels in the water of experimental tanks ranges from 3.67 to 6.26 mgl^{-1} [6, 21, 22, 27].

The average value of free CO_2 in T_0 (9.33 ± 1.90 mgl^{-1}) was found to be significantly (p<0.05) different from T_2 (13.48 ± 0.46 mgl^{-1}). The morning CO_2 in all experimental tanks varied from 1.33 to 15.33 mgl^{-1}. Average morning CO_2 values recorded were 9.33 mgl^{-1}, 11.95 mgl^{-1}, 13.48 mgl^{-1} and 10.86 mgl^{-1} in T0, T1, T2 and T3 respectively. In T0, morning CO_2 was significantly (p<0.05) different from T2. It may be due to respiration by plankton and fishes. The evening free CO_2 values were nil in all experimental tanks throughout the study. High concentration of CO_2 in water is harmful to the aquatic animals. During the winter months CO_2 concentration is high, while in summer and rainy seasons its value is very low [39, 40]. Baumann *et al*. (2012) study indicated that early life growth and survival of the fish is negatively affected by the increase in the concentration of CO_2 [41]. In intensively managed aquacultural waters, free CO_2 concentration normally fluctuated between 0 to >20 ppm in a 24-hour cycle with the lowest concentration during the hours of photosynthesis [42]. In the present study same trend of fluctuation of free CO_2 in all experimental tanks was seen. Free Carbon dioxide provides the inorganic carbon; therefore, it is required in natural water bodies for photosynthesis and hence been reported as a critical chemical parameter [43].

The average morning pH values in T_0 (7.04 ± 0.06) was found to be significantly (p<0.05) different than T_2 (7.5 ± 0.15). The morning pH values in all experimental tanks varied between 6.8 to 8.03. Average morning water pH values were 7.04, 7.19, 7.5 and 7.22 in T0, T1, T2 and T3 respectively. In T0 morning pH was significantly (p<0.05) different from T2. At night respiration by fishes as well as by plankton may increase CO2 level which significantly affects pH in T0 and T2. The evening pH values in all experimental tanks varied between 8.23 to 9.33. Average evening water pH values were 8.87, 8.86, 8.98 and 8.73 in T0, T1, T2 and T3 respectively with no significant (p>0.05) difference among treatments. The optimum range of water pH for fish culture is 6.5-9.0 and values above 9.5 are unsuitable as carbon dioxide becomes unavailable at higher pH [44]. pH of above 11.0 is lethal to fish. Acidic water reduces the appetite and retards the growth of aquatic animals. Das *et al*. (1995) suggested that a pH range of 6.12-8.6 is most suitable for survival of the IMC fry [44]. pH variation affects metabolism and other physiological processes. Neutral to slightly alkaline pH has been found to be most favourable for fish ponds [37, 45]. pH observed in the present study agreed with the earlier findings of Kohinoor *et al*. (1998), Roy *et al*. (2002), Kohinoor *et al*. (2005) and Debnath *et al*. (2013) where they recorded pH values in control and mola stocked ponds ranges from 7.00 to 9.03 [6, 21, 22, 27].

The total alkalinity values in all experimental tanks ranged from 80.33 to 112.0 mgl^{-1}. Average total alkalinity values were 95.52 mgl^{-1}, 103 mgl^{-1}, 102 mgl^{-1} and 95.5 mgl^{-1} in T0, T1, T2 and T3 respectively with no significant (p>0.05) difference among treatments. Water with a low alkalinity i.e. total alkalinity less than 20 mgl^{-1} has a low buffering capacity and shows wide fluctuation of pH [33]. Ponds with alkalinity greater than 300 mgl^{-1} may be unproductive because of limitation to carbon dioxide availability at such high concentration [46]. According to Boyd (1982), total alkalinity value ranges from 20 to 300 mgl^{-1} and alkalinity less than 20 mgl^{-1} creates stress on fish [33]. The present study is in support of earlier findings of Roy *et al.* (2002) where they recorded 93.77 and 91.06 mgl^{-1} total alkalinity values in without and with mola ponds, respectively [6]. Therefore, it can be concluded that the range of total alkalinity in the present experiment is within the ideal range and was not affected by different stocking densities of mola.

The total hardness values in all the experimental tanks ranged from 72.33 to 92.0 mgl^{-1}. Average total hardness values were 77.33 mgl^{-1}, 79.67 mgl^{-1}, 82.81 mgl^{-1} and 84.1 mgl^{-1} in T0, T1, T2 and T3 respectively with no significant (p>0.05) difference among treatments was observed. Soft water refers to water with 0 to 75 ppm $CaCO_3$ and has the lowest buffering capacity. Moderate hard water has 75 to 150 ppm $CaCO_3$. Hard water has 150 to 300 ppm $CaCO_3$ and very hard water had a concentration of $CaCO_3$ greater than 300 ppm, which has the highest buffering capacity [33, 47]. Hujare (2008) reported higher total hardness during summer than rainy and winter season [48]. Hardness increases due to the decrease in water volume and increase in the rate of evaporation at high temperature [49]. The hardness value of more than 15mg l^{-1} is required for the optimum health of warm water fishes [50, 51]. From the above reviewed literature, it is clear that the total hardness values recorded in the present study were within the optimum range for the experimental fish.

Nitrate-nitrogen values in all experimental tanks fluctuated between 0.87 to 4.53 mgl^{-1}. Average nitrate-nitrogen values were 2.81 mgl^{-1}, 2.75 mgl^{-1}, 2.6 mgl^{-1} and 2.63 mgl^{-1} in T0, T1, T2 and T3 respectively where no significant (p>0.05) difference among treatments was observed. The amount of nitrate-nitrogen (0.87 to 4.53 mgl^{-1}) as recorded from all treatment was higher than that of Mollah and Haque (1978), who recorded 0.091 to 0.77 mgl^{-1} [36], and Haque *et al*. (1998) recorded 0.86 to 0.90 mgl^{-1} in ponds [52]. The possible reason for higher values of nitrate-nitrogen in the present study is fertilization, which was a routine practice in the experimental tanks.

Phosphate-phosphorus values in all experimental tanks varied between 0.04 to 1.2 mgl^{-1}. Average phosphate-phosphorus values were 0.62 mgl^{-1}, 0.49 mgl^{-1}, 0.43 mgl^{-1} and 0.52 mgl^{-1} in T0, T1, T2 and T3 respectively where no significant (p>0.05) difference among treatments was observed. Phosphorus is one of the most critical single element in the maintenance of aquatic productivity. Earlier findings of Mollah and Haque (1978), Azim *et al.* (1995) and Kohinoor *et al.* (2001) support the present study [36, 53, 54]. They found that phosphate-phosphorus ranges from 0.1 to 2.75 mgl^{-1}. Based on the findings of above authors Phosphate-phosphorus in the present study was found in the suitable range for fish culture and was not affected by stocking densities of fishes.

Ammonia-nitrogen fluctuated in all experimental tanks from 0.01 to 0.06 mgl-^{1}. Average ammonia-nitrogen values were 0.033 mgl^{-1}, 0.036 mgl^{-1}, 0.038 mgl^{-1} and 0.044 mgl^{-1} in T0, T1, T2 and T3 respectively where no significant (p>0.05) difference among treatments was observed. The source of ammonia-nitrogen in water is excreta of cultured animals and microbial decay of nitrogenous compounds. Ammonia occurs in both ionized (NH_4) and unionised (NH_3) forms. Tucker and Boyd (1982) opined that the amount of ammonia reaching pond water through fish metabolite is proportional to the feeding rate[55]. In the present study, the levels of ammonia-nitrogen were insignificant in all treatment and gradual build up was observed in subsequent samplings due to increase in feeding rate. The ammonia values recorded during the present investigation were ranged from 0.01 to 0.06 mg l^{-1} and it was below the tolerance limit of the carps [56]. The level of ammonia-nitrogen (0.01 to 0.06 mgl^{-1}) as recorded from all treatments in the present study was lesser than that was reported by Dewan *et al*. (1991), who recorded 0.05 to 6.20 mgl^{-1} [57], Kohinoor *et al*. (1998) who recorded 0.15 and 0.14 mgl^{-1} in without mola and with mola ponds respectively [21]. The lower ammonia values in the present study may be due to the lower stocking density of fishes and shorter experimental period.

Chlorophyll- a in all experimental tanks varied between 18.81 to 195.87 μgl^{-1}. Average chlorophyll- a values were 96.57 μgl^{-1}, 75.41 μgl^{-1}, 69.92 μgl^{-1} and 67.97 μgl^{-1} in T0, T1, T2 and T3 respectively with no significant (p>0.05) difference among treatments. The probable reason behind fluctuation in chlorophyll-a concentration (18.81 to 195.87 μgl^{-1}) in water of the all experimental ponds during the study period was the periodicity of phytoplankton, which was enhanced by manuring. Khatri (1984) reported that phytoplankton and chlorophyll-a had a positive relationship with primary production [58]. The present study presents similar results as the findings of Haque *et al.* (1998) and Kohinoor *et al.* (1998) [21, 52]. Where Haque *et al.* (1998) found 59-159 μgl^{-1} chlorophyll-a in their experiment and Kohinoor *et al*. (1998) recorded 69.75 and 44.57 μgl^{-1} chlorophyll-a without and with mola tanks respectively [21, 52]. Chlorophyll-a was decreased with increasing density of mola and this may be due to feeding habits of mola who were fed on phytoplankton but there was no significant difference among all treatments due to routine fertilization.

Plankton

Total plankton number $litre^{-1}$ (mean ± SE) in different treatments recorded during the three months of the study period (July-September 2017) are presented in Table-3. A total of 25 genera of plankton were recorded in the entire experiment. Out of 25 genera of plankton 18 belonged to phytoplankton and 7 to zooplankton. The phytoplankton population recorded were found to be in 4 broad groups, viz. Bacillariophyceae, Chlorophyceae, Euglenophyceae and Cyanophyceae. Out of 18 genera of phytoplankton recorded, 7 belonged to Bacillariophyceae, 8 to Chlorophyceae, 1 to Euglenophyceae and 2 to Cyanophyceae. The zooplankton population recorded were observed to be of 3 broad groups viz. Cladocera, Copepoda and Rotifera. Out of 7 genera of zooplankton 2 belonged to Cladocera, 2 to Copepoda and 3 to Rotifera. In the present study, plankton appeared higher in treatment T_0 but no significant (p>0.05) difference was noticed among all treatments. Euglenophyceae and Cyanophyceae in T_0 were significantly (p<0.05) different than T_3. Chlorophyceae was the most dominant group and Cyanophyceae was the least dominant group among the phytoplankton population in all treatments. Among zooplankton, Cladocera was the most dominant group in T_0, T_1 and T_2 and Copepoda in T_3. Rotifera was the least dominant group in all treatments.

The planktons are both direct and indirect source of food for fish. They indicate the productive status of a pond. The abundant planktonic population in the experimental tanks throughout the study period may be due to regular fertilization into the ponds. A total of 25 genera of plankton were recorded during the study period. Phytoplankton composed of 18 genera belonged to Bacillariophyceae (7), Chlorophyceae (8), Cyanophyceae (2) and Euglenophyceae (1). Chlorophyceae showed both qualitative and quantitative dominance over other plankton groups in all treatments. Chlorophyceae was present in higher numbers indicating a positive bearing on the survival of fish [59]. Zooplankton composed of 7 genera belonged to Cladocera (2), Copepoda (2) and Rotifera (3). The present reported number of genera matches earlier findings of Wahab *et al.* (1994) and Roy *et al.* (2002)[6,60]. Wahab *et al.* (1994) who reported 25 genera of phytoplankton belonged to Chlorophyceae, Bacillariophyceae, Euglenophyceae and Cyanophyceae and 5 genera of zooplankton belonging to Crustacea and Rotifera [60]. Roy *et al.* (2002) were found 23 genera of phytoplankton belonged to Chlorophyceae, Bacillariophyceae, Euglenophyceae and Cyanophyceae and 8 genera of zooplankton belonging to Crustacea and Rotifera [6].

In present study average total number of different group of plankton per liter of water were Bacillariophyceae (11868, 13455, 12798 and 11877), Chlorophyceae (35237, 25700, 23604 and 20568), Cyanophyceae (1891, 582, 1188 and 762), Euglenophyceae (5288, 3922, 3231 and 2477), Cladocera (3565, 3034, 3068 and 2100), Copepoda (2248, 2231, 1628 and 2131) and Rotifera (934, 974, 803 and 758) in treatment T0, T1, T2 and T3 respectively. An average number of phytoplankton per litre of water was 54285, 44661, 40822 and 35685 in treatment T0, T1, T2 and T3 respectively. Again, average number of zooplankton per litre of water was 6748, 6240, 5500 and 4989 in treatment T0, T1, T2 and T3 respectively. The present findings of phytoplankton are more agreed with the findings of Kohinoor *et al.* (2001) and Shahin *et al.* (2011) [23, 54]. Kohinoor *et al*. (2001) recorded phytoplankton density at 30.02-40.79 x 10^3 l^{-1} and zooplankton density at 6.08-6.76 x 10^3 l^{-1} in monoculture ponds [54]. Shahin *et al.* (2011) found 45400-87100 plankton cells l^{-1} in polyculture pond[23]. Present results are dissimilar to the earlier findings of Kohinoor *et al.* (1998) and Debnath *et al*. (2013) [21, 27]. Kohinoor *et al*. (1998) recorded more density of phytoplankton and zooplankton compared to the present

study in polyculture ponds [21]. However, Debnath *et al.* (2013) recorded less density of phytoplankton and zooplankton compared to the present study in polyculture ponds [27]. It may be due to their longer experimental period and routine fertilization doses. Under the present study in all treatments total plankton population were insignificantly (p>0.05) different with highest plankton abundance in T0 where mola was not added and the lowest plankton was observed in T3 where the highest number of mola was stocked. This abundance of plankton may be due to the feeding habits of mola whose main food consists of blue-green algae, crustacean, and rotifera and this is supported by the findings of Mustafa (1991) [61]. In the treatments where phytoplankton abundance was high, zooplankton abundance was also high because abundance of zooplankton totally depends on phytoplankton production. Regular dominancy of phytoplankton over zooplankton was due to regular fertilization.

Table 2: Water quality parameters mean ±SE and range (in parenthesis) in different treatments recorded during the culture period

Parameters	Treatments			
	T_0	T_1	T_2	T_3
Temperature morning (°C)	28.74 ± 0.64 (27.13-31.23)	28.87 ± 0.65 (27.2-31.46)	28.88 ± 0.6 (27.16-31.26)	28.98 ± 0.66 (27.1-31.46)
Temperature evening (°C)	30.9 ± 0.97 (28.3-35.37)	31.43 ± 0.97 (28.63-35.53)	31.28 ± 0.96 (28.73-35.27)	31.28 ± 0.95 (28.53-35.1)
Transparency (cm)	27.23 ± 1.21^{a} (23.67-29.67)	27.45 ± 0.97^{a} (22.83-30)	27.70 ± 0.60^{a} (25.33-29)	31.6 ± 0.71^{b} (29.67-35.33)
pH morning	7.5 ± 0.15^{b} (7.1-8.03)	7.19 ± 0.04^{ab} (7.07-7.37)	7.04 ± 0.06^{a} (6.8-7.3)	7.22 ± 0.05^{ab} (7.07-7.3)
pH evening	8.87 ± 0.14 (8.4-9.3)	8.86 ± 0.12 (8.4-9.33)	8.98 ± 0.10 (8.63-9.07)	8.73 ± 0.11 (8.23-9.07)
DO morning (mg l^{-1})	3.21 ± 0.09 (2.9-3.6)	3.11 ± 0.05 (2.9-3.33)	3.01 ± 0.04 (2.80-3.13)	3.04 ± 0.06 (2.83-3.4)
DO evening (mgl^{-1})	6.33 ± 0.15^{b} (5.73-6.83)	6.01 ± 0.15^{ab} (5.33-6.47)	5.83 ± 0.15^{ab} (5.33-6.27)	5.67 ± 0.13^{a} (5.3-6.17)
Free CO_2 morning (mgl^{-1})	9.33 ± 1.90^{a} (1.33-13.33)	11.95 ± 0.62^{ab} (10-15.33)	13.48 ± 0.46^{b} (11.67-14.67)	10.86 ± 0.33^{ab} (9.67-12)
Free CO_2 evening (mgl^{-1})	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Total alkalinity (mgl^{-1})	95.52 ± 3.87 (81.67-109)	103 ± 3.96 (80.33-110.33)	102.05 ± 3.47 (88-112)	95.57 ± 2.89 (85.33-103.67)
Total hardness (mgl^{-1})	77.33 ± 1.32 (72.33-82.67)	79.67 ± 2.71 (72.33-92)	82.81 ± 1.84 (78.33-90.33)	84.1 ± 2.00 (76.67-91.67)
Nitrate- nitrogen (mgl^{-1})	2.81 ± 0.43 (1.17-4.53)	2.75 ± 0.40 (1.07-4.07)	2.6 ± 0.35 (1.37-3.97)	2.63 ± 0.39 (0.87-3.9)
Phosphorus-phosphate (mgl^{-1})	0.62 ± 0.14 (0.04-1.15)	0.49 ± 0.14 (0.09-1.2)	0.43 ± 0.12 (0.05-1.03)	0.52 ± 0.11 (0.06-0.97)
Ammonia – nitrogen (mgl^{-1})	0.033 ± 0.01 (0.02-0.04)	0.036 ± 0.01 (0.01-0.04)	0.038 ± 0.01 (0.01-0.05)	0.044 ± 0.01 (0.01-0.06)
Chlorophyll – a (µgl^{-1})	96.57 ± 18.57 (59.99-195.87)	75.41 ± 19.10 (40.27-180.67)	69.92 ± 16.87 (34.03-149.83)	67.97 ± 21.95 (18.81-173.31)

Values are given as mean ± SE (n= 21), the mean in a row with different superscripts are significantly (p<0.05) different.

Table 3: Total plankton abundance per litre in different treatments during the culture period

Group	T_0	T_1	T_2	T_3
Bacillariophyceae	11868 ± 1726	13455 ± 2613	12798 ± 2752	11877 ± 2655
Chlorophyceae	35237 ± 5811	25700 ± 4103	23604 ± 3728	20568 ± 4533
Euglenophyceae	5288 ± 629^{b}	3922 ± 696^{ab}	3231 ± 567^{ab}	2477 ± 347^{a}
Cyanophyceae	1891 ± 256^{b}	1582 ± 245^{ab}	1188 ± 194^{ab}	762 ± 264^{a}
Total Phytoplankton	54285 ± 7512	44661 ± 5483	40822 ± 5133	35685 ± 4586
Cladocera	3565 ±575	3034 ± 839	3068 ± 1067	2100 ± 951
Copepoda	2248 ± 346	2231 ± 797	1628 ± 556	2131 ± 415
Rotifera	934 ± 234	974 ± 280	803 ± 2293	758 ± 304
Total Zooplankton	6748 ± 759	6240 ± 599	5500 ± 661	4989 ± 452
Total Plankton	61034 ± 20921	50901 ± 17101	46323 ± 15664	40675 ± 13664

Values are given as mean ± SE (n= 7) the means in a row with different superscripts are significantly (p<0.05) different.

Growth and production of fishes

The growth and production details of catla, rohu, mrigal and mola in different treatments are presented in Table-4. Average net weight gain of catla was 161.44 ± 2.60g, 157.53 ± 6.36g, 156.90 ± 2.01g and 152.67 ± 3.07g in T_0, T_1, T_2 and T_3 respectively. Net weight gain of catla was highest in T_0 (161.44 g) followed by T_1 (157.53 g), T_2 (156.90 g) and T_3 (152.67 g) where no significant difference was observed (p>0.05) among the treatments. The present result is similar to the findings of Wahab *et al.* (2003) where catla was not affected by mola stocking at the rate of 25,000 nos. ha^{-1} [62]. This may be due to feeding habit of catla which is a zooplankton feeder and zooplankton in the experimental tanks were uniformly available throughout the study. However, these results of the present study are not collaborated with the findings of Kohinoor *et al.* (1998), Kohinoor *et al.* (2005) and Debnath *et al.* (2013) where the growth of catla was found to be affected by mola [21, 22, 27]. This may be because in their

study the density of mola was increased due to auto stocking. But in the present study, the auto stocking of mola in the experimental tanks was not seen due to shorter culture period and stocking of fry of mola in the experimental tanks.

Rohu highest average net weight gain was recorded in T_0 (163.43 ± 3.26g) followed by T_1 (162.58 ± 2.99g), T_2 (157.71 ± 1.28g) and T_3 (147.89± 1.08g). The T_0 and T_1 showed significantly (p<0.05) higher net weight gain of rohu compared to T_3. The highest net weight gain of rohu was observed in T_0 (163.43 g) followed by T_1 (162.58 g), T_2 (157.71 g) and T_3 (147.89 g). The T_0 and T_1 showed significantly (p<0.05) higher net weight gain of rohu compared to T_3. The present result is similar to the findings of Kohinoor *et al.* (1998), Kohinoor *et al.* (2005) and Debnath *et al.* (2013) where growth of rohu was found to be affected by mola [21, 22, 27]. Chandra and Haq (1986) mentioned that rohu and catla are plankton feeder and mrigal is an omnivore and bottom feeder, it prefers also aquatic vegetation, as well as submerged grass and debris[63]. Rohu and mola feed on same niches and therefore, there was overlapping in feeding habit in T_3 where mola stocking density was the highest. This might the reason of poor net weight gain of rohu in T_3 [34, 27, 64].

The highest average net weight gain of mrigal was observed in T_0 (150.36 ± 1.17g) followed by T_1 (149.89 ± 1.35g), T_2 (145.77 ± 0.40g) and T_3 (144.55 ± 0.99g). The T_0 showed significantly (p<0.05) higher net weight of mrigal compared to T_3. The highest net weight gain of mrigal was seen in T_0 (150.36 g) followed by T_1 (149.89 g), T_2 (145.77 g) and T_3 (144.5 g). The T_0 showed significantly (p<0.05) higher net weight of mrigal compared to T_3. The present result does not match with the earlier findings of Kohinoor *et al.* (2005) and Debnath *et al.* (2013) where mrigal was not affected by mola at the stocking rate of 50000 and 25000 nos. ha^{-1} [22, 27]. This may be attributed to bottom feeding habits of mrigal and also due to the reason that the fish feeds on decayed plant and animal matter, algae, detritus, mud etc. [65]. Mola diet consist mainly phytoplankton (75%), with the smaller amount of plants materials, detritus, and from the zooplankton mainly protozoa and rotifers [61, 66-69]. Under the present study mrigal growth was affected by mola may be due to the following reasons: vigorous feeding of supplementary feed by mola; competition of mrigal with mola for supplementary feed and due to insufficient detritus in the new tank, upon which mrigal feeds on. Average net weight gain of mola was 0.15 ± 0.00g, 0.14 ± 0.00g and 0.13 ± 0.01g in T_1, T_2 and T_3 respectively where no significant (p>0.05) difference was seen among treatments.

Catla SGR was highest in T_0 (2.84) followed by T_1 (2.81), T_2 (2.80) and T_3 (2.79). Rohu SGR% was highest in T_1 (2.85) followed by T_0 (2.84), T_2 (2.83) and T_3 (2.74). The SGR of rohu in T_1 was found significantly (p<0.05) higher than T_3. Mrigal SGR was highest in T_1 (2.77) followed by T_0 (2.73), T_2 (2.72) and T_3 (2.71). Among catla, rohu and mrigal in all treatments rohu showed the highest SGR 2.85 in T_1 and the lowest 2.71 was shown by mrigal in T_3. SGR of mola was highest in T_1 (1.92) followed by T_3 (1.92) and T_2 (1.86). In the present study SGR found for catla, rohu and mrigal in all the treatment does not follow the earlier findings of Debnath *et al.* (2013) [27]. Debnath *et al.* (2013) found less SGR than the present study [27]. This is because only counted number of mola were stocked in the treatments those was not enhance their number by auto stocking. Kohinoor *et al.* (2005) found more SGR in case the above-mentioned species in control but their findings in mola stocked tanks were similar to the present study [22]. The reasons behind the more SGR in control found by Kohinoor *et al.* (2005) may be due to fortnightly fertilization with cow dung that resulted excessive growth of plankton population which was 2 to 3 times more than the present study. Another reason may be due to the experimental period which was six months in their study period.

The FCR values recorded for IMC was not significantly (p<0.05) difference among the treatments. In the experiment supplementary feeding was adopted. However, IMC and mola also fed on plankton in all experimental ponds, hence the values of FCR did not fluctuate significantly.

The survival rate of fish species in all treatments was high. The factor behind that may be healthy seed stocked, favourable water quality, appropriate feeding etc. There was no significant (p>0.05) difference among the survival rates of catla, rohu, mrigal and mola in all treatments. Survival rates for catla were 87.5% in all treatments. The survival rate of rohu varied between 75 (T_3) to 87.5% (T_1). Mrigal survival rates ranged between 83.33 (T_3) to 91.67% (T_0, T_1, and T_2). Mola survival rates varied between 67.2 (T_2) to 73.1% (T_1). The present result is similar to the earlier findings of Kohinoor *et al.* (1998), Roy *et al.* (2002), Kohinoor *et al.* (2005) and Debnath *et al.* (2013) where they got survival rates average values ranging from 81.57 to 86.22 with or without mola [6, 21, 22, 27]. Mola survival rates were 73.1, 67.2 and 67.43 in T_1, T_2 and T_3 respectively where no significant (p>0.05) difference was seen among treatments. No earlier workers recorded survival rates of mola in their studies. Hence the results of present work could not be collaborated with earlier findings [6, 21, 22, 27].

Net yield of IMC recorded were 1107.1 ± 49.30, 1117.5 ± 69.42, 1053.0 ± 74.43 and 975.61 ± 74.96 kg ha^{-1} in T_0, T_1, T_2 and T_3 respectively where no significant (p>0.05) difference among all treatments were seen. Gross yield of IMC measured were 1202.3 ± 53.54, 1212.8 ± 71.42, 1145.3 ± 81.64 and 1064.5 ± 82.08 kg ha^{-1} in T_0, T_1, T_2 and T_3 respectively where no significant (p>0.05) difference among all treatments were observed. Net yield of mola recorded were 1.63 ± 0.08, 2.33 ± 0.07 and 3.13 ± 0.1 kg ha^{-1} in T_1, T_2 and T_3 respectively. Gross yield of mola were observed 2.00 ± 0.10, 2.83 ± 0.07 and 3.83 ± 0.19 kg ha^{-1} in T_1, T_2 and T_3 respectively. In the case of mola, significant (p<0.05) difference was observed in T_1, T_2 and T_3 for net yield and gross yields. Total gross yield of fishes after 3 months of culture period was 1202.3, 1214.8, 1148.13, and 1068.33 kg ha^{-1} in T_0, T_1, T_2 and T_3 respectively. Highest production was obtained in T_1 where mola was stocked at lowest density and this was followed by T_0, T_2, and T_3 but did not differ significantly (p>0.05). Kohinoor *et al.* (1998) got similar results where they found a production of 1126 kg ha^{-1} in 4 months polyculture of carps with encouraging contribution of mola (58.67 kg). But in the present study highest production of mola was found in T_3 (3.83 kg ha^{-1} in 3 months) which is not a significant one. The less production of mola in the present study may be attributed to a shorter experimental period and stocking of mola at its fry stage. Total fish production found in the present study is different from the earlier findings of Akhteruzzaman *et al.* (1998), Roy *et al.* (2002), Kohinoor *et al.* (2005) and Debnath *et al.* (2013) [6, 22, 27, 70]. Akhteruzzaman *et al.* (1998) obtained a production of 3728.40 kg ha^{-1} in 8 months from the polyculture of mola (*A. mola*), bata (*Labeo bata*) and bhangna (*Cirrhinus reba*) [70]. Roy *et al.* (2002) got production of 2412 kg ha^{-1} in 7 months from polyculture with grass carp, rohu, catla, mrigal and mola [6]. Kohinoor *et al.* (2005) achieved

production 1901 kg ha^{-1} in 6 months from IMC and mola culture pond [22]. Debnath *et al.* (2013) obtained 2034 kg ha^{-1} in 7 months from IMC and mola culture [27]. All these earlier findings are not conformity with the findings of present study. This may be due to difference of duration of experimental period, other fish species used for stocking and stocking of brood mola in the experiment unit where it reproduced during the study period.

The economic analyses of the fish production of each treatment are presented in Table-5. The analysis was based on the local market price for IMC and mola in terms of Indian rupee (₹). The Benefit -Cost ratio obtained were 2.04, 2.07, 1.96 and 1.85 in T_0, T_1, T_2 and T_3 respectively. The analysis revealed that net profit, percent return to variable cost, percent profit to turn over and BCR were higher in T_1 than all treatment. It implied that mola stocked with 15000 number ha^{-1} provides highest benefit.

Conclusion

The present investigation provides a basis for a better understanding of the relationship between stocking density, growth rate, survival, production, water quality variables and plankton availability in polyculture system of IMC with mola. Only the highest density treatment with mola was significantly different to control in terms of net weight gain of IMC. Culture of mola with IMC at stocking density 15000 and 25000 nos. ha^{-1} did not affect the growth of IMC. However, the stocking density of mola at 15000 ha^{-1} with IMC gave the highest production in 90 days. Therefore, it can be considered as the appropriate stocking density for culture of mola with IMC. The present study revealed that with the increasing stocking density of mola net weight gain of rohu and mrigal was affected severely. Therefore, it is not advisable to culture mola at high stocking density with carps without providing extra supplementary feed to them. The lesser density of mola at 15000 nos. ha^{-1} was found optimum for better production. Recently mola also enters in ornamental market which could provide more benefit to the farmers. Introduction of mola in carp polyculture system enhances the fish production and will also help in nutrition and food security of rural people. In the present study brood mola was not stocked with IMC to maintain the stocking density at desired level as findings of earlier studies reveals that due to auto stocking of mola during the experimental period growth of IMC was affected. However, partial harvesting of mola might be the option for maintaining the stocking density of mola. Most of the water quality parameters were not affected due to addition of mola. It is a positive sign for culturing mola with IMC. Use of manure and fertilizers helps to maintain plankton production. So, routine manuring and fertilization is necessary to reduce the impact of mola on the growth of IMC.

Table 4: Growth, survival and production of fishes in different treatments

Treatment No.	Fish species	Initial average weight (g)	No. of fish stocked	Final average weight (g)	Average Net weight gain (g)	SGR (%)	FCR	Average survival (%)	Net yield kg/ha /90days	Gross yield kg/ha /90days	IMC Total Net yield kg/ha /90days	IMC Total Gross yield kg/ha /90days
T_0	Catla	13.56±0.41	8	175±9.46	161.44±2.60	2.84±0.03	1.43±0.01	87.5±7.20	451.23±32.00	489.03±35.06	1107.1±49.30	1202.3±53.54
	Rohu	13.7±0.32	8	177.22±10.04	163.22±3.26	2.84±0.06^{ab}	1.41±0.02	83.33±4.17	434.95±13.54	471.72±15.95		
	Mrigal	14.09±0.20	4	164.44±2.37	149.33± 1.17	2.73±0.02	1.54±0.02	91.67±8.33	220.97±22.29	241.56±23.78		
T_1	Catla	13.53±0.34	8	171.11±6.66	156.33± 6.36	2.81±0.08	1.43±0.03	87.5±0.00	441.09±18.27	478.99±17.47	1117.5±69.42	1212.8±71.42
	Rohu	13.56±0.24	8	176.11±3.20	162.55±2.99	2.85±0.03^{b}	1.37±0.01	87.5±7.22	456.21±44.45	494.01±47.05		
	Mrigal	13.44±0.34	4	163.33±2.20	149.89±1.35	2.77±0.04	1.49±0.01	91.67±8.33	220.13±21.49	239.78±22.89		
	Mola	0.03±0.001	36	0.18±0.002	0.15±0.00	1.92±0.02	-	73.1±3.34	1.63±0.08^{a}	2.00±0.10^{a}		
T_2	Catla	13.63±0.47	8	170.56±1.55	157±2.01	2.80±0.03	1.41±0.01	87.5±7.20	439.28±35.98	477.49±39.36	1053.0±74.43	1145.3±81.64
	Rohu	13.44±0.34	8	171.11±1.62	157.67±1.28	2.83±0.01^{ab}	1.40±0.00	79.17±4.17	399.80±23.79	433.77±25.87		
	Mrigal	13.67±0.37	4	159.44±1.94	145.77±0.40	2.72±0.01	1.52±0.01	91.67±8.33	213.91±19.86	234.00±22.01		
	Mola	0.03±0.001	60	0.17±0.002	0.14±0.00	1.86±0.02	-	67.2±1.47	2.33±0.07^{b}	2.83±0.07^{b}		
T_3	Catla	13.40±0.29	8	166.11±2.17	153.22±3.07	2.79±0.01	1.37±0.03	87.5±7.20	428.27±40.11	465.87±43.66	975.61±74.96	1064.5±82.08
	Rohu	13.73±0.15	8	161.67±2.76	147.89±1.08	2.74±0.02^{a}	1.42±0.01	75±7.22	354.54±31.06	387.56±35.02		
	Mrigal	13.78±0.36	4	158.33±1.67	144.55± 0.99	2.71±0.02	1.45±0.01	83.33±8.33	192.80±19.63	211.11±21.14		
	Mola	0.03±0.001	84	0.16±0.002	0.13±0.01	1.92±0.14	-	67.43±3.09	3.13±0.19^{c}	3.83±0.19^{c}		

Values are given as mean ± SE the means in a column with different superscripts are significantly (p<0.05) different.

Table 5: Economic comparisons of different treatments based on a hectare culture over the area for 90 days culture period

Variable Cost									
Expenditure	Rate (₹)	Quantity kg/ha				Cost Indian rupee (₹)			
		T_0	T_1	T_2	T_3	T_0	T_1	T_2	T_3
Fertilizer									
Cow dung	0.6 /Kg	3109.08	3109.08	3109.08	3109.08	1865.448	1865.448	1865.448	1865.448
Urea	09 /Kg	55.5	55.5	55.5	55.5	499.5	499.5	499.5	499.5
SSP	09 /Kg	97.5	97.5	97.5	97.5	877.5	877.5	877.5	877.5
Lime	08 /Kg	170.9	170.9	170.9	170.9	1367.2	1367.2	1367.2	1367.2
Fish seeds									
Carps seeds (no.)	5 each	8000	8000	8000	8000	40000	40000	40000	40000
Mola seed (no.)	0.02 each		15000	25000	35000		300	500	700
Feed									
Mustard oil cake	18 /Kg	920.93	897.64	884.41	838.60	16576.74	16156.8	15919.2	15094.8
Rice polish	10 /Kg	920.93	897.64	884.41	838.60	9209.3	8976.4	8844.1	8386

Dewatering and desilting	5000					5000	5000	5000	5000
Labour wage	200 /day	90-man days	90-man days	90-man days	90-man days	18000	18000	18000	18000
Misc. Expenditure						1000	1000	1000	1000
Total Variable cost						94395.69	94042.82	93872.95	92790.45

Return									
Product	**Rate (₹)**	**Quantity kg/ha**				**Cost Indian rupee (₹)**			
		T_0	**T_1**	**T_2**	**T_3**	**T_0**	**T_1**	**T_2**	**T_3**
Total IMC sale	160/Kg	1202.3	1212.8	1145.3	1064.5	192368	194048	183248	170320
Mola sale	310/Kg	0	2	2.83	3.83	0	620	877	1187
Total return						192368	194668	184125	171507
Net Profit						97972.31	100625.18	90252.05	78716.55
Percent return to variable cost						103.79	107.00	96.14	84.83
Percent profit to turn over						50.93	51.69	49.02	45.90
BCR						2.04	2.07	1.96	1.85

References

1. FAO. The state of world fisheries and aquaculture. Food and Agriculture Organization of the United Nations, Rome, 2016
2. Halver JE. Special methods in pen fish husbandry. Akademiai Nyomda, Budapest, 1984, 146.
3. Roos N. Fish consumption and aquaculture in rural Bangladesh nutritional contribution and production potential of small indigenous fish species (SIS) in pond polyculture with commonly cultured carps. Ph.D. thesis, Research Department of Human Nutrition. The Royal Veterinary and Agricultural University, Frederiksberg, Denmark, 2001
4. Roos N, Islam MM, Thilsted SH. Small indigenous fish species in Bangladesh: contribution to vitamin A, calcium and iron intakes. The Journal of Nutrition. 2003a; 133(11):4021S-4026S.
5. Roy NC, Kohinoor AHM, Wahab MA, Thilsted SH. Evaluation of Performance of Carp-SIS Polyculture Technology in the Rural Farmers' Pond. Asian Fisheries Science. 2002; 15(1):41-50.
6. Rahman AKA. Freshwater Fishes of Bangladesh. The Zoological Society of Bangladesh, Department of Zoology, University of Dhaka, Dhaka, Bangladesh, 1989, 364.
7. Menon AGK. Checklist - Freshwater fishes of India. Records of Zoological Survey of India, Occasional. 1999; 175:1-366.
8. Saha BK, Islam MR, Saha A, Hossain MA. Reproductive biology of the Mola Carplet *Amblypharyngodon mola* (Hamilton) (Cypriniformes: Cyprinidae) from Netrakona Water. Bangladesh journal of scientific and industrial research. 2009; 44(3):377-379.
9. Coad BW. Fishes of Afghanistan, an annotated check-list (No. 14). National Museums of Canada, National Museum of Natural Sciences, 1981
10. Bhuiyan AL. Fishes of Dacca Asiatic Society of Pakistan. 1964, 13.
11. Haque ASMM, Rahman MR. Reproductive ecology of Mola (*Amblypharyngodon mola*). Journal of agriculture and rural development. 2008; 6(1):165-174.
12. Alam MJ, Dewan S, Rahman MR, Kunda M, Khaleque MA, Kader MA. Study on the Cultural Suitability of *Amblypharyngodon mola* with *Barbodes gonionotus* and *Cyprinus carpio* in a Farmers Rice Fields. Pakistan Journal of Biological Science. 2004; 7:1242-1248.
13. Thilsted SH, Roos N, Hassan N. The role of small indigenous fish species in food and nutrition security in Bangladesh. Naga, The ICLARM Quarterly, 1997; 20(3-4):82-84.
14. Roos N, Wahab MA, Chamnan C, Thilsted SH. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. The Journal of Nutrition. 2007; 137(4):1106-1109.
15. Roos N, Leth T, Jakobsen J, Thilsted SH. High vitamin A content in some small indigenous fish species in Bangladesh: perspectives for food-based strategies to reduce vitamin A deficiency. International Journal of Food Sciences and Nutrition. 2002. 53(5):425-437.
16. Roos N, Mazharul Islam M, Thilsted SH. Small fish is an important dietary source of vitamin A and calcium in rural Bangladesh. International Journal of Food Sciences and Nutrition. 2003b; 54(5):329-339.
17. Gupta S, Banerjee S. Indigenous ornamental fish: a new boon in ornamental fish trade of West Bengal. Fishing Chimes. 2012, 32(1):130-134.
18. Alam AKMA. Mini pond. CARITAS Bangladesh, Dhaka, 1985
19. CAMP. Report of the workshop on Conservation Assessment and Management plan (CAMP) for Fresh water Fishes of India. Zoo outreach organization and NBFGR, Lucknow 22-26 September 1997, 156.
20. Kohinoor AHM, Islam ML, Wahab MA, Thilsted SH. Effect of mola (*Amblypharyngodon mola* Ham.) on the growth and production of carps in polyculture. Bangladesh Journal of Fisheries Research. 1998; 2(2):119-126.
21. Kohinoor AHM, Hasan MA, Thilsted SH, Wahab MA. Culture of small indigenous fish species (SIS) with Indian major carps under semi-intensive culture system. Indian journal of fisheries. 2005; 52(1):23-31.
22. Shahin J, Mondal MN, Wahab MA, Kunda M. Effects of addition of tilapia in carp-prawn-mola polyculture system. Journal of Bangladesh Agriculture University, 2011; 9(1):147-158.
23. Roy NC, Wahab MA, Ray PC, Thilsted SH. Optimization of Stocking Density of Mola (*Amblypharyngodon mola*) in Carp Polyculture under Low Cost Management for Rural Bangladesh. World. 2015; 7(4):221-227.
24. Moore LB. Input of organic materials into aquaculture systems: Emphasis on feeding semi-intensive systems. Aquaculture Engineering. 1986; 5(2-4):123-134.
25. Hepher B. Principles of fish nutrition. In: Gerking. S. D. (Ed.) Ecology of Freshwater Fish production, Blackwell scientific publisher, Oxford, 1988, 447-465.
26. Debnath C, Sahoo L, Datta M, Dube K. Culture of *Amblypharyngodon mola* (Hamilton) in polyculture with carps-a field trial in Tripura. Indian Fisheries Association,

2013; 40:47-52.
27. APHA. Standard methods for the examination of water and waste water. American Public Health Association, Washinington DC, 2005
28. Stirling HP. Chemical and biological methods of water analysis for aquaculturalists. Institute of Aquaculture, University of Stirling, 1985.
29. Bellinger EG. A key to common algae: estuarine and some coastal species. The Institute of Water and Environment Management, London, UK, 1992
30. AOAC. Official Methods for Analysis of the Association of Official Analytical Chemistry. 16th edn., AOAC International Wasshington, USA, 1995.
31. SPSS Inc. Released SPSS for Windows, Version 16.0. Chicago, SPSS Inc, 2007.
32. Boyd CE. Water quality management for pond fish culture. Elsevier Scientific Publishing Co. Amsterdam-Oxford- New York, 1982, 318.
33. Jhingran VG, Pullin RS. A hatchery manual for the common, Chinese, and Indian major carps World Fish. 1985, 252.
34. Aminul IM. Qualities of water and soil in Aquaculture. Fish Week Compilation, DoF Publication, Ramna, Dhaka. 1996, 1000.
35. Mollah MFA, Haque AKMA. Studies on monthly variations of plankton in relation to the physicochemical conditions of water and bottom soil of two ponds. H. zooplankton. Bangladesh Journal of Fisheries. 1978; 1(2):99-103.
36. Banerjee SM. Water quality and soil condition of fish ponds in some states of India in relation to fish production. Indian journal of fisheries. 1967; 14(1, 2):115-144.
37. Cole BA, Boyd CE. Feeding rate, water quality, and channel catfish production in ponds. The Progressive Fish-Culturist. 1986; 48(1):25-29.
38. Desai PV. The impact of mining on the Mayemlake of bicholim, Goa. Current trends in Limnology. 1991; 1(1):279-288.
39. Misra SR, Saxena DN. Pollutional ecology with reference to physicochemical characteristics of Morar (Kalpi) river, Gwalior (M.). Current trends of immunology. 1991; 1(1):159-184.
40. Baumann H, Talmage SC, Gobler CJ. Reduced early life growth and survival in a fish in direct response to increased carbon dioxide. Nature Climate Change, 2012; 2(1):38.
41. Schmittou HR. High density fish culture in low volume cages. American Soyabean Association, New Delhi, India, 1998, 22-32.
42. Swingle HS. Experiment on pond fertilization. Bull. Alabama Agricultural Experiment Station. 1947; 34:264.
43. Das S, Bhattacharya BK, Goswamy UC. Effect on extreme pH on survivability of Indian major carps. The Journal of Inland Fisheries Society of India. 1995; 27(2):105-109.
44. Swingle HS. Relationships of pH of pond waters to their suitability for fish culture. Pacific Science Congress Proceedings 9 (1957), Fisheries. 1961; 10:72-75.
45. Adhikari S. Water and soil quality management in freshwater prawn farming. Fishing Chimes. 2000; 20(4):22-24.
46. Boyd CE. Water quality in ponds for aquaculture. Alabama Agricultural Experiment Station, Auburn University, Alabama USA, 1990, 482.
47. Hujare MS. Seasonal variation of physico-chemical parameters in the perennial tank of Talsande, Maharashtra. Ecotoxicology and Environmental Safety, 2008; 18(3):233-242.
48. Thirupathaiah M, Samatha CH, Sammaiah C. Analysis of water quality using physico-chemical parameters in lower manair reservoir of Karimnagar district, Andhra Pradesh. International Journal of Environmental Science and Technology. 2012; 3(1):172-180.
49. EPA (Environmental Protection Agency) Criteria for water quality, USEPA, Washington, DC, 1973.
50. Jhingran VG, Pullin RSV. A Hatchery Manual for Common Chinese and Indian Major Carp under Field Condition. ICLARM Studies and Reviews II, Manila, Philippines, 1988.
51. Haque SM, Wahab MA, Wahid MI, Haq MS. Impacts of Thai silver barb (*Puntius gonionotus*, Bleeker) inclusion in the polyculture of carps. Bangladesh. Fisheries Research. 1998; 2(1):15-22
52. Azim ME, Talukder GS, Wahab MA, Haque MM, Haq MS. Effect of liming and maintenance of total hardness levels on fish production in fertilized ponds. Progress in Agriculture. 1995; 6(2):7-14.
53. Kohinoor AHM, Wahab MA, Islam ML, Thilsted SH. Culture potentials of mola (*Amblypharyngodon mola*), chela (*Chela cachius*) and punti (*Puntius sophore*) under monoculture system. The Bangladesh Journal of Fisheries Research. 2001; 5(2):123-134.
54. Tucker CS, Boyd CE. Water quality in channel catfish culture. Tucker, C.S. (Ed.), Elsevier, Amesterdam. 1982, 134-174.
55. Jena J, Chandra Das P, Mondal S, Das R. Compatibility of silver barb *Puntius gonionotus* (Bleeker) with Indian major carps in a grow-out polyculture. Aquaculture Research. 2007; 38(10):1061-1065.
56. Dewan D, Wahab MA, Beveridge MCM, Rahman MH, Sarkar BK. Food selection, electivity and dietary overlap among planktivorous Chinese and Indian major carp fry and fingerlings grown in extensively managed, rain-fed ponds in Bangladesh. Aquaculture Research. 1991; 22(3):277-294.
57. Khatri TC. Seasonal variation in the ecosystem of the Lakhotia lake in Rajasthan. Indian Journal of Fisheries. 1984, 31(1):122-129.
58. Wahab MA, Ahmed ZF, Islam MA, Rahmatullah SM. Effect of introduction of common carp, *Cyprinus carpio* (L), on the pond ecology and growth of fish in polyculture. Aquaculture Research. 1995. 26:619-628.
59. Wahab MA, Ahmed ZF, Haq MS, Begum M. Compatibility of silver carp in the poly culture of cyprinid fishes. Progress in Agriculture. 1994; 5(2):221-227.
60. Mustafa G. Composite culture and biology of some indigenous fishes of Bangladesh. Ph D. Thesis. Faculty of Biological Science, Dhaka University, 1991, 299.
61. Wahab MA, Alim MA, Milstein A. Effects of adding the small fish punti (*Puntius sophore* Hamilton) and/or mola (*Amblypharyngodon mola* Hamilton) to a polyculture of large carp. Aquaculture Research. A, 2003; 34(2):149-163
62. Chandra KJ, Haq MS. Food and feeding habits of freshwater fish of Bangladesh a review. Journal of the Bangladesh Agricultural Research. 1986; 13(2):63-78.

63. Das SM, Moitra SK. Studies on the food of some common fishes of Uttar Pradesh, India. 1. Surface-feeders, mid-feeders and bottom feeders. Proceedings of National Academy of Science, India (B. Biological Science) 1956; 25(1-2):1-6.
64. Jhingran VG. Fish and fisheries of India, Hundustan Publishing Corporation, New Delhi, India, 1988
65. Dewan S. Investigations into the ecology of fishes of Mymensingh Lake. A PhD thesis submitted to the Department of Aquaculture and Management, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, 1973, 191-202
66. Miah MJU, Siddique WH. Studies on the food and feeding habits of mola, *Amblypharyngodon mola*, The Bangladesh Journal of Fisheries Research. 1992; 19(2):165-170.
67. Rahmatullah SM, Nurrunnabi SM, Salam MA. Studies on the food and feeding habits and electivity indices of young freshwater *Cyprinid mola*. Journal of the Bangladesh Agricultural Research. 1997; 24:81-86.
68. Kohinoor AHM. Development of culture technology of three small indigenous fish mola (*Amblypharyngodon mola*), punti (*Puntius sophore*) and chela (*Chela cachius*) with notes on some aspects of their biology. A PhD dissertation, Department of Fisheries Management, Bangladesh Agricultural University, Mynensingh, 2000
69. Kohinoor M, Rajts AHM, Khan FAM, Arief KH. Studies on the production performances of small indigenous fish species in Bangladesh. In Proceedings of National Workshop on Food-Based Strategies for Improving Nutrition in Bangladesh, 1998, 17-28.