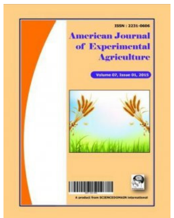

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Inclusion of Monosex Tilapia (*Oreochromis niloticus*) with Freshwater Prawn (*Macrobrachium rosenbergii*) in Polyculture Systems in the Ponds of Coastal Region: Impact of Stocking Density of Tilapia on Production and Profitability

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MSI and YM designed the study and wrote the protocol. Author MSI wrote the first draft of the manuscript. Author YM reviewed the experimental design and all drafts of the manuscript. Authors MSI, YM and NB managed the analyses of the study. Author MSI identified the planktons. Authors MSI, YM and NB performed the statistical analyses. All authors read and approved the final manuscript.

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ABSTRACT

Experiment was carried out to ascertain the impact of stocking density of monosex tilapia (*Oreochromis niloticus*) on production and profitability in freshwater prawn (*Macrobrachium rosenbergii*) farming system over a period of 150 days at farmers' shrimp ponds, Madrasha village, Bamorta union, Bagerhat district. There were three treatments *viz.* T_1, T_2 and T_3 with tilapia of 10,000, 15,000 and 20,000/ha, respectively and each having three replicates. Density of prawn at

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20,000/ha was maintained in all the treatments. Ponds were stocked with monosex tilapia and all male prawn juvenile. On average, 25 genera of phytoplankton and 6 genera of zooplankton were identified from pond water. Water quality parameters were within suitable ranges for tilapia and prawn in all the treatments. Mean weight of tilapia decreased significantly ($p<0.05$) with increasing stocking density but survival rate did not differ significantly. Higher production of prawn was obtained in T_1 (950.4 kg/ha) followed by T_2 (923.0 kg/ha) and T_3 (805.2 kg/ha). On the contrary, production of tilapia was significantly higher in T_3 (1,686.60 kg/ha) and T_2 (1,587.60 kg/ha) than in T_1 (1,310.0 kg/ha). However, the overall total production of tilapia and prawn was significantly ($p<0.05$) higher in T_2 (2,510.60 kg/ha) and T_3 (2,491.80 kg/ha) compared to T_1 (2,260.40 kg/ha). Higher profit was also found in T_2 (BDT 238,923.00/ha) followed by T_1 (BDT 222,557.00/ha) and T_3 (147,819.00/ha). Therefore, the results of the study implied that inclusion of tilapia at a density at 15,000/ha enhanced the total production and contributed greatly to earn higher profit.

Keywords: Freshwater prawn; monosex tilapia; stocking density; production; profit.

1. INTRODUCTION

Freshwater prawn, *Macrobrachium rosenbergii* is indigenous to South and Southeast Asia, parts of Oceania and Pacific islands. *M. rosenbergii* has been imported into many other tropical and subtropical areas of the world and the species is most favoured for farming [1]. Inland waters of Bangladesh are suitable for growth of many species of freshwater prawns. There are about 23 species of freshwater prawns including 10 species of *Macrobrachium*. Of them, *M. rosenbergii* is the most popular cultured species in Bangladesh due to its higher growth, size, disease resistance, salinity tolerance and high price in international and domestic market. It has much aquaculture potential and is commercially cultured in Bagerhat, Khulna, Pirojpur and other districts. Freshwater prawn is contributing around 30% of total shrimp export, which is about BDT 1,092.06 crore share out of the total export BDT 3,640.2 crore [2].

Polyculture of commercially important fish species is most popular all over the world especially in Asian countries (China and India). The first and most important issue in polyculture system is the possibility of increasing production in per unit area by better utilization of natural food of water bodies. Species selection also plays a vital role in this system that all the species should be benefited by the available food such as plankton, detritus and others, without competing with each other. Of all the species of fish, tilapia is the most acceptable food fish in many countries of the world including Bangladesh. Polyculture of prawn with a noncompeting of fish species may effectively boost up the pond production [3]. Ling [4] recommended polyculture of *Macrobrachium* together with non-carnivorous freshwater fish such as carps and tilapia. Polyculture of prawn/shrimp and tilapia may be the modern equivalent of the Chinese polyculture of carps [5]. Of late, there has been an enormous interest in the polyculture of freshwater prawn with finfish, especially with tilapia [6]. Prawn may culture with a suitable finfish which directly helps to enhance the production as a whole with an environment friendly situation [7]. Tilapia (*Oreochromis niloticus*) is a quick growing species and has ability to adapt in almost all aquatic systems all over Bangladesh. It is exotic species of Bangladesh. Firstly in 1970 the species was imported from Thailand by UNISEF. Secondly Bangladesh Fisheries Research Institute imported the species at 1987 from Thailand. It has high resistance to poor water quality, disease and tolerance to a wide range of environmental conditions. Tilapia has tremendous prospects as a superior food item both national and international market. Production and profitability of polyculture of tilapia and prawn depend on several factors. Stocking density of fish is one of the most imperative factors of them. Some sporadic works have been done in Bangladesh. Keeping the above facts in mind, the present study was undertaken to assess the impacts of stocking density of tilapia on production and profitability in polyculture system.

2. MATERIALS AND METHODS

2.1 Study Area and Design

The study was performed in 9 rectangular earthen shrimp pond of farmers at Madrasha village, Bamorta union of Bagerhat district from April to August, 2012. Ponds were with an area of 400 m^2 and average depth of water was 0.8—1.5 m each. The trial was conducted in a completely randomized design into three different treatments with three replications each. Stocking density of prawn (*Macrobrachium rosenbergii*) was same in all treatments. The differences of different treatments were stocking density of tilapia (*Oreochromis niloticus*). The stocking densities of tilapia were 10,000; 15,000 and 20,000/ha in T_1, T_2, T_3, respectively.

2.2 Pond Preparation and Management

All the experimental ponds were drained out and were fully exposed to sunlight. Ponds prepared by repairing the embankments and by removing all types of weeds. Before the trial, ponds were treated with lime ($CaCO_3$) at a rate of 250 kg/ha based on soil pH. The ponds were then filled with tidal water gradually up to a depth of 0.75 m from the nearby tidal canal through screen net. All unwanted organisms were eliminated using rotenone at the rate of 3 ppm and then lime ($CaCO_3$) was applied at the rate of 125 kg/ha for neutralizing its action. Fine mesh sized nylon net was used to fence on the dikes around the ponds to prohibit the potential disease carriers fauna such as snail, snake and others from outside. Water of the ponds was treated with extract of fermented molasses at the rate of 50 kg/ha daily for three consecutive days. The molasses was fermented for 24 hours with 25 kg rice bran and 250 tea spoonfuls yeast/ha. After 4~5 days, the colour of water turned into green. Ponds were then stocked with juvenile of freshwater prawn and mono-sex tilapia with a mean weight of 3.0 and 1.0 g, respectively. Juveniles of prawn and tilapia were collected from a local traders and care was taken to minimize the mortality during stocking. Sometimes, urea and triple super phosphate (TSP) was added at the rate of 39.0 kg/ha (1:2) at 1 month intervals to improve the primary production. Urea and TSP were used in five times. Fertilization enhanced the plankton production in the ponds. During the culture period, lime (@ 25.0—50 kg/ha, CaO) was used at 7~15 days intervals to maintain the pH and to destroy the pathogen of waterbodies.

2.3 Stocking and Feed Management

Male prawn juveniles were stocked at a density of 2 indv./m^2 and monosex tilapia were stocked in all the ponds at a density of 1.0, 1.5 and 2.0 indv./m^2, respectively. After 20—25 days of prawn stocking, tilapia stocked in all the ponds. Commercial pelleted shrimp/prawn feed (32.0% protein, 11.0% Moisture, 4.0% Crude lipid and 8.0% Crude fiber) procured from local market was applied 6 days in a week to the ponds at the rate of 10% of prawn biomass for first month and assuming 80—85% survival feed application was gradually reduced (3% of body weight for 2nd month and 2% of body weight for the rest of the months) to 2% body weight at the end of the culture period. Tilapia were fed with farm made feed (40% rice bran, 20% wheat flour, 15% corn flour, 20% fish meal and 5% mustard oil cake) twice per day at the rate of 10% of the total biomass for first two months and 5~3% body weight at the end of the culture period. Tilapia feed was used before 30—45 minutes of prawn feed applying owing to proper utilization of feed and to minimize the feed competition among the cultured species. Weights of minimum 5—10% of initially stocked prawn and tilapia in numbers were recorded fortnightly to estimate the biomass and adjust the feeding rate and also to observe the physical conditions of the species. Prawn and tilapia were sampled using cast net. Lime was applied to all the ponds at monthly intervals at the rate of 50.0—75.0 kg/ha based on water depth for keeping the good water quality of the ponds.

2.4 Water Quality and Plankton Estimation

Water quality parameters of the ponds like as temperature, dissolved oxygen (DO), pH, transparency, salinity, total alkalinity, nitrate nitrogen (NO_3–N) and ammonia (NH_3–N) were recorded twice a month. Temperature and DO were measured using digital DO meter (YSI model 58). Salinity was estimated using a portable refractometer (ATAGO, Hand-Held Refractometer). Transparency was measured using a Secchi disc and pH was determined using a pH meter (HACH). Total alkalinity was measured by titration method and inorganic nutrients (NH_3–N and NO_3–N) were determined using HACH kit (HACH Model FF–1A). DO, pH, temperature and transparency were measured directly from the ponds between 08:00 and 10:00 hours and the other parameters were measured at Water and Soil Quality Laboratory of Shrimp Research Station, Bangladesh Fisheries Research Institute, Bagerhat, Bangladesh.

For plankton determination, 10 litres water samples were collected monthly from different locations and depths of each pond and filtered through plankton net (mesh size-25 µm). Filtered samples were transferred to a measuring cylinder and made up to 50 ml with distilled water. Samples were preserved in small plastic bottles with 10% buffered formalin until examination. Plankton was counted using a Sedgewick–Rafter counting cell (S–R cell) under a binocular microscope (Olympus, M-4000D) following Stirling [8]. Plankton were identified up to genus level and enumerated. The plankton per litre of original water was estimated applying the following formula [9].

$$N = \frac{\mathrm{A \times 1000 \times C}}{\mathrm{V \times F \times L}}$$

Where,

N= Number of plankton cells or units per litre of original water.
A= Total number of plankton counted.
C= Volume of final concentration of the sample in ml.
V= Volume of a field =1 cu mm.
F= Number of the field counted.
L= Volume of original water in litre.

2.5 Harvesting and Production Parameters

At the end of the study, all prawn and tilapia were harvested by repeated netting (cast net and surrounding net) and completely drained out. All tilapia and prawn harvested from each pond were counted, measured and weighted individually. Weight gain per tilapia and prawn was calculated by deducting the average initial weight from the average final weight. Specific growth rate (SGR; % body weight gain per day) was estimated as follows:

SGR= [Ln (final weight) – Ln (initial weight) x 100]/ cultured period (day)

FCR= Feed consumed (g dry weight)/Live weight gain (g wet weight) of fish/prawn

2.6 Economical Analyses

Growth, production, net returns and cost–benefit ratio were analyzed using one way ANOVA to compare the treatments means. Plankton data and water quality parameters were compared in a repeated measure ANOVA. If the main effect was found significant, the ANOVA was followed by DMRT (Duncan's Multiple Range Test). All ANOVA were tested at 5% level of significance using SPSS (Statistical Package for Social Science) version 14.

A simple algebraic economic analysis was carried out to determine the net return and benefit–cost ratio of prawn and fish culture in different treatments. The following equation was used to quantify the profitability of prawn–tilapia culture in pond systems: *NR = TR – (FC + VC + Ii).*

Where NR = net return, TR = total revenue from prawn and tilapia sales, FC = fixed/common costs, VC = variable costs and Ii = interest on inputs. The cost-benefit ratio was determined as: Cost–benefit ratio (BCR): Total net return/Total input cost.

The prices of different kinds of inputs, prawn and tilapia correspond to the Bagerhat wholesale market prices in 2012. Prawn and tilapia were sold at the rate of Tk. 540.00 and Tk. 100.00–120.00, respectively.

3. RESULTS AND DISCUSSION

3.1 Growth and Production Performance of Freshwater Prawn and Tilapia

The results of growth and production performance of prawn and monosex tilapia are displayed in Table 1. Although similar sizes of prawn juveniles were stocked in all the treatments ponds, the individual final weight of prawn was higher in T_1 (66.0 g) and T_2 (65.0 g) than T_3 (61.0 g). The highest specific growth rate (SGR) of prawn was found in T_1 (1.65%) and T_2 (1.61%), which was significantly ($p<0.05$) different from that in T_3 (1.52%). Asaduzzaman et al. [10] observed that the SGR of prawn in a periphyton-based tilapia and prawn polyculture system was 1.63%, which was coincided to the present findings. Survival rate of prawn was also significantly higher in T_1 (72.0%) and T_2 (71.0%) than that of T_3 (66.0%). Uddin et al. [11] and Islam and Mahmud [12] reported that the survival of prawn ranged between 57–66% and 58–65%, respectively in polyculture system of prawn-tilapia, which were slightly lower than the present findings. MacRae et al. [13] and Kunda et al. [14] observed that the average survival rate of prawn was 38% and 49–57%, respectively recorded in prawn pond/*ghers*, which was lower than that of present findings. It was observed that growth rate and survival of prawn decreases with the increases of stocking density of tilapia. These were also associated with water depth and space of pond. SGR and survival of prawn in T_3 was significantly lower probably due to intra-specific competition between two species and within the species. Garcia-Perez et al. [15] stated that there are many factors that affect the survival of prawn like as environmental stress, water level, cannibalism, bird predation, predator fish, etc. Cannibalism during moulting period is a common phenomena and may be responsible for a monthly mortality of 4% [16]. Survival rate of monosex tilapia was ranged between 56.2 to 65.5%. Higher survival of tilapia was found inT_1 and T_2, and lower in T_3 (56.2%). The overall survival of tilapia was within the range of reported values in earthen ponds: 66–73% [12], 78.43% [7] and 57–66% [8], depending on the pond size, stocking size, stocking density, combination with other species and management practices. SGR of tilapia (3.98–4.13%) was not significantly different among the treatments. The SGR of tilapia ranged between 2.87 to 3.09 and 3.07 to 3.34%, respectively reported by Uddin et al. [17] and [12], which was almost similar with the present findings.

Food conversion ratio (FCR) of prawn was significantly lower in T_1 (2.7) than that of T_3 (3.6) and T_2 (3.2) but T_2 and T_3 were not significantly different. FCR of tilapia in three treatments ranged between 2.30–2.71. Higher FCR of tilapia was found in T_3 and lower in T_1. Highest production of prawn (950.4 kg/ha/150 days) was recorded in T_1, which was significantly different ($p<0.05$) from T_3 (805.2 kg/ha/150 days) but not significantly different from T_2 (923.0 kg/ha/150 days). Significantly higher production of tilapia was found in T_3 (1,686.6 kg/ha/150 days) than that of T_1 (1,310.0 kg/ha/150 days) and T_2 (1,587.6 kg/ha/150 days). Production of tilapia increased with increasing density but individual weight gradually decreased. Islam and Mahmud [12] found the net yield of prawn of 1,045.8 and 1,105 kg/ha/180 days, respectively in polyculture system with tilapia and in monoculture system in brackishwater ponds, which was higher than the results of present work. Whereas the production of prawn recorded by Asaduzzaman et al. [10], Kunda et al. [14], Asaduzzaman et al. [18], Raizada et al. [19] and Nair et al. [20] were 609.0–810.0 kg/ha, 294–596 kg/ha, 390.0 kg/ha, 600.0–1,000.0 kg/ha and 603.0 kg/ha, respectively which were lower than the production obtained in the present study. Significantly higher ($p<0.05$) combined production (2,510.60 kg/ha) of prawn and tilapia was achieved from T_2 than that of T_3 (2,491.80 kg/ha) and T_1 (2,260.40 kg/ha). The combined yield of prawn and tilapia reported by Asaduzzaman et al. [10] was 1,763.0 kg/ha/120 days which was lower than the present findings. The highest combined production obtained by Uddin et al. [11] in ponds stocked with 75% tilapia and 25% prawn was 1,691 kg/ha which was also much less than the present study.

3.2 Cost-benefit Analysis

The cost and profit of the study was presented in Table 2. The total cost was higher in T_3 (BDT 455,649.00/ha) and T_2 (BDT 450,009.00/ha) than in T_1 (BDT 447,859.00/ha). The total net profit was significantly higher in T_2 (BDT 238,923.00/ha) and T_1 (BDT 222,557.00/ha) than in T_3 (BDT 147,819.00/ha). The net profit recorded by Uddin et al. [21], Uddin et al. [22] and Uddin et al. [11] was Tk. 40,708.00–55,718.00/ha, Tk. 46,671.0–78,302.0/ha and Tk. 30,426.00–53,546.00/ha, respectively in polyculture system of prawn and tilapia which were much lower than the profit of the present study. The net profit reported by Islam and Mahmud [12]) was Tk. 236,797.0/ha/150–180 days in farming of prawn and tilapia which was similar with the findings of T_2 but higher than T_3 and T_1. Cost–benefit ratio (BCR) was significantly higher ($p<0.05$) in T_2 (1.53) than T_3 (1.32) and T_1 (1.49). The results of the study indicated that stocking density of tilapia affected the economic return positively. There was no adverse change on the water quality due to different density of tilapia. Inclusion of tilapia did not hamper the growth and production of prawn.

Of the phytoplankton *Skeletonema*, *Coscinodiscus*, *Rhizosolenia*, *Chaetoceros*, *Triceratium* and *Bacillaria* (Bacillariophyceae), *Spirogyra*, *Spirulina*, *Tetraspora* and *Selanestrum* (Chlorophyceae), *Anabaena*, *Nostoc* and *Microcystis* (Cyanophyceae), *Dinophysis*, *Ceratium* and *Pyrocystis* (Dinophyceae) and *Euglena* (Euglenophyceae). *Cyclops*, *Diaptomus* and *Nauplius* (Copepoda), *Brachionus* and *Trichocerca* (Rotifera) and *Diaphanosoma* (Cladocera) were the dominating genera of the zooplankton. Concentration of plankton population and their variation are shown in Fig. 1a and 1b, respectively. The abundance of phytoplankton was found to range from 9,000 to 19,000 cell/L (Fig. 1a) while zooplankton varied from 1,400 to 8,500 cell/L (Fig. 1b).

The phytoplankton and zooplankton recorded by Shofiquzzoha and Alam [7] at brackish water culture ponds was 8,000–16,000 and 1,000–9,000 cell/L, respectively which was more or less similar to present findings. The abundance of zooplankton of the present study was higher than the findings of Hossain [22] who recorded the zooplankton abundance of 225–2,190 cells/L in the Maheskhali channal, Cox's Bazar.

3.3 Water Quality Parameters

Water quality parameters of pond water such as temperature, transparency, pH, ammonia, salinity and alkalinity were measured and are presented in Table 3.

Water temperature varied from 27.0 to 32.3ºC in all the treatments and found to be more or less similar with recorded temperature (22–34°C) by Kunda et al. [14]. Salinity fluctuated from 6.5 ppt to 1.5 ppt and it was within the tolerable range to prawn [12]. Dissolved oxygen (DO) recorded to range between 4.0–5.1 mg/L. DO level of the present observation remained above (>3.5 mg/L) the suggested minimum level according to Boyd and Fast [23]. pH values varied from 7.1 to 7.7 was within the suitable range for fish and prawn. Other parameters such as transparency, total alkalinity, nitrate nitrogen (NO_3–N) and ammonia (NH_4–N) as recorded to range between 28.0–44.0 cm, 90.0–106.5 mg/L, 0.005–0.023 mg/L and 0.002–0.092 mg/L, respectively were within suitable range for prawn and fish. Significant difference (p>0.05) of water quality values was not found among the treatments.

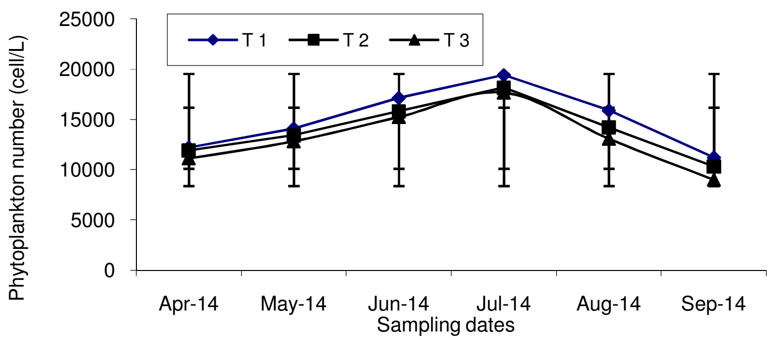

Fig. 1a. Variation in phytoplankton abundance (cell/L) at monthly intervals in three treatments

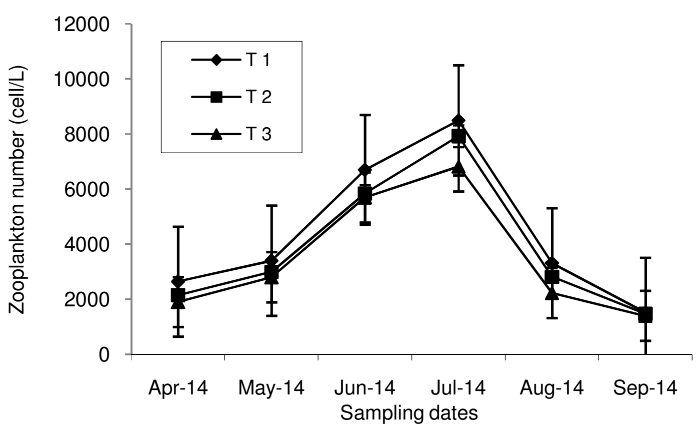

Fig. 1b. Variation in zooplankton abundance (cell/L) at monthly intervals in three treatments

Table 1. Growth and production performance (mean±S.E.) of *Macrobrachium rosenbergii* and *Oreochromis niloticus* in different treatments during the culture period

Species and production parameters	T_1 (30,000/ha)	T_2 (35,000/ha)	T_3 (40,000/ha)
Macrobrachium rosenbergii			
Stocking density (individual/m^2)	2.0	2.0	2.0
Average initial weight (g)	3.0±0.10	3.0±0.15	3.0±0.09
Average final weight (g)	66.0±3.46	65.0±3.85	61.0±4.46
Survival (%)	72.0±1.35	71.0±1.46	66.0±2.89
Specific growth rate (% day^{-1})	1.65 ± 0.12^{a}	1.61 ± 0.11^{b}	1.52 ± 0.11^{c}
FCR	2.7±0.21	3.2±0.20	3.6±0.15
Production (kg/ha/150 day)	950.4 ± 45.20^{a}	923.0 ± 40.31^{a}	805.2 ± 35.44^{b}
Oreochromis niloticus			
Stocking density (indv./m^2)	1.0	1.5	2.0
Average initial weight (g)	1.0±0.12	1.0±0.08	1.0±0.14
Average final weight (g)	200.0 ± 6.35^{a}	168.0 ± 7.25^{b}	150.0 ± 6.82^{c}
Survival (%)	65.5±3.2	63.0±2.5	56.2±2.7
Specific growth rate (% day^{-1})	4.13±0.30	4.02±0.19	3.98±0.26
FCR	2.30±0.34	2.50±0.20	2.71±0.19
Production (kg/ha/150 day)	$1,310.00\pm49.2^{c}$	$1,587.60\pm64.5^{b}$	$1,686.60\pm50.5^{a}$
Combined production (kg/ha/150 days)	$2,260.40\pm88.54^{c}$	$2,510.60\pm75.64^{a}$	$2,491.80\pm72.59^{b}$

Figures with different superscript in the same row differ significantly (p<0.05)

Table 2. Economical analysis of *Macrobrachium rosenbergii* and *Oreochromis niloticus* production in different treatments at the end of the study

Items	T_1 (30,000/ha)	T_2 (35,000/ha)	T_3 (40,000/ha)
Total gross return (Tk./ha)	670,416.00	688,932.00	603,468.00
Total cost (Tk./ha)	447,859.00	450,009.00	455,649.00
Net profit (Tk./ha)	222,557.00	238,923.00	147,819.00
Net profit margin (%)	49.69	53.09	32.44
Cost-benefit ratio (BCR)	1.49	1.53	1.32

Table 3. Mean (± SD with range) values of recorded water quality parameters in different treatments during the study period

Parameters	Treatments		
	T_1	T_2	T_3
Temperature (°C)	30.5±1.8 (27.0~32.1)	30.5±1.6 (27.0~32.3)	30.6±1.6 (27.0~32.2)
Salinity (ppt)	5.11±0.5 (1.5~6.5)	5.12±0.6 (1.7~6.4)	5.13±0.4 (1.5~6.4)
Dissolved oxygen (mg/L)	4.55±0.25 (4.0~5.1)	4.50±0.18 (4.1~5.0)	4.45±0.16 (4.0~4.8)
pH	7.4 (7.1~7.7)	7.5 (7.2~7.6)	7.3 (7.0~7.4)
Transparency (cm)	39.34±4.32 (29.0~40.0)	41.62±5.24 (28.0~42.0)	43.56±6.41 (28.0~44.0)
Total alkalinity (mg/L)	95.8±4.25 (90.0~100.5)	96.5±4.86 (91.0~105.1)	97.0±5.37 (91.0~106.5)
NO_3-N (mg/L)	0.010±0.003 (0.006~0.023)	0.011±0.002 (0.005~0.020)	0.012±0.003 (0.006~0.022)
NH_4-N (mg/L)	0.042±0.015 (0.002~0.089)	0.046±0.019 (0.002~0.090)	0.048±0.021 (0.002~0.092)

4. CONCLUSION

The results revealed that an addition of tilapia at a density at 15,000/ha increased the total production and contributed to earn higher profit. Therefore, from the results of this study, it may be concluded that for higher profit and production, a stocking density of 15,000 tilapia and 20,000 prawn/ha, respectively may be recommended for a tilapia and prawn polyculture system in coastal environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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