EFFECTS OF ADDING SHRIMP (*Penaeus monodon*) INTO INTENSIVE CULTURE PONDS OF NILE TILAPIA (*Oreochromis niloticus*) AT DIFFERENT DENSITIES

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Abstract

This experiment was conducted in nine 200m^2 earthen ponds at the Asian Institute of Technology, Thailand for 133 days from 21 May to 2 October 2003, to investigate effects of adding shrimp (*Penaeus monodon*) into intensive Nile tilapia (*Oreochromis niloticus*) ponds on the growth performance, water quality and nutrient utilization efficiency in different stocking combinations of tilapia-shrimp polyculture. There were three treatments in triplicate each: tilapia at 1/m^2 and shrimp at 15/m^2 (low tilapia density), tilapia at 2/m^2 and shrimp at 15/m^2 (medium tilapia density), tilapia at 4/m^2 and shrimp at 15/m^2 (high tilapia density).

Mean daily weight gains and final mean weight of tilapia in the low tilapia density treatment was significantly greater than those in the medium and high tilapia density treatments, between which there was no significant difference. However, total weight gain, and net and gross yields of tilapia were highest in the high tilapia density treatment, intermediate in the medium tilapia density treatment, and lowest in the low tilapia density treatment. Final mean weight of shrimp was not significantly different among all treatments, however, survival and net and gross yields in the high tilapia density treatment were significantly poorer than those in the medium and low tilapia density treatments, between which there were no significant differences.

Nutrients incorporated by Nile tilapia biomass accounted for 48.01%, 52.89%, and 48.99% of TN, and 60.55%, 68.47% and 62.25% of TP inputted from fertilizer and pelleted feeds in the low, medium and high tilapia density treatments, respectively, while shrimp recovered only 1.10% and 0.33% of TN, and 0.55% and 0.27% of TP in the low and medium

tilapia density treatments. However, nutrients were lost through dead shrimps in the high tilapia density treatment. Overall mean DO concentrations at both surface and bottom were highest in the low tilapia density treatment, intermediate in the medium and lowest in the high tilapia density treatment. Overall mean concentrations of TAN tended to be higher at higher tilapia density.

The present experiment indicated that adding shrimp into Nile tilapia ponds is technically feasible, however, more research is needed to optimize the tilapia-shrimp polyculture system.

Introduction

Nile tilapia is commonly cultured in extensive, semi-intensive and intensive systems in tropical countries. Shrimp farming has now developed into an important export-oriented food industry especially in South Asian countries (Chakraborty and Sadhu, 2001). In recent years, many shrimp ponds have been abandoned in many parts of the world due to diseases, poor management and environmental degradation. Polyculture can increase economic return by maximizing use of the ecological conditions in shrimp ponds (Wang *et al.,* 1995). Polyculture of shrimp with filter-feeding fishes and molluscs increased the species diversity of the ecosystem in the ponds and maximize use of the space, and can improve the utilization of the organic materials. Tilapia culture, supplemented with low densities of shrimp, in abandoned shrimp ponds may provide an opportunity to develop a sustainable aquaculture system that will support local inhabitants who have not benefited from the shrimp bloom in many parts of the world (Yi and Fitszimmon, in press).

In a polyculture setting, tilapia and shrimp can utilize different niches in the culture setting (Yi *et al*., in press). The polyculture of shrimp and tilapia had increased the production of shrimp, with tilapia production as a secondary benefit (Akiyama and Anggawati, 1998). Saelee (2002) reported that the greater feed input in the polyculture than in shrimp monoculture did not worsen water quality, indicating Nile tilapia helps stabilize water quality through grazing natural foods. Yi *et al.* (in press) also found that the addition of Nile tilapia into shrimp ponds with shrimp as the main species can improve feed utilization efficiency, better economic returns and less environmental pollution.

The shrimp-tilapia polyculture, with the shrimp as the main species, was better than shrimp monoculture in terms of water quality, yield and profitability. However, the appropriate combination in tilapia-shrimp polyculture, with the main species as tilapia fed with high protein feed, has not been studied. Therefore, this experiment was conducted to determine the feasibility of adding shrimp into intensive tilapia culture ponds.

Materials and methods

This experiment was conducted at the Asian Institute of Technology (AIT), Thailand for 133 days from 21 May to 2 October 2003, to investigate effects of adding shrimp into intensive Nile tilapia ponds on the growth performance, water quality and nutrient utilization efficiency in different stocking combinations of tilapia-shrimp polyculture. Nine 200-m^2 earthen ponds (20 m x 10 m x 1 m) were used. There were three treatments in triplicate each: tilapia at 1/m^2 and shrimp at 15/m^2 (low tilapia density), tilapia at 2/m^2 and shrimp at 15/m^2 (medium tilapia density), tilapia at 4/m^2 and shrimp at 15/m^2 (high tilapia density). The treatments were allocated randomly to the experimental ponds.

Juvenile shrimps (PL_{15}) were nursed in a 200-m^2 pond at AIT for 45 days prior to the experiment. The nursed shrimps of an average size of 0.77 g were stocked in all ponds on 21 May 2003, while sex-reversed all-male Nile tilapia fingerings of 10 – 25 g in size were stocked 28 days after stocking shrimp. Prior to stocking tilapia, shrimps were fed with commercial pelleted feed (40% crude protein, Charoen Pokaphand Feed Mill Company, Thailand) specially formulated for *P. monodon* at 10% body weight per day for four times daily (0600, 1200, 1800 and 2200 h). Floating pelleted feed (30% crude protein, Charoen Pokaphand Feed Mill Company, Thailand) for tilapia was given twice daily (0830 and 1630 h) at 3% and 2.5% body weight per day for tilapia smaller and larger than 100 g, respectively.

The ponds were drained completely, dried, limed and filled with freshwater to a depth of 60 cm prior to the experiment. Hypersaline water (140 ppt) was added to the ponds to adjust the salinity level to 4 ppt. Water level in all ponds was maintained at 1.0 m by adding freshwater biweekly. The ponds were fertilized weekly for two times prior to stocking shrimps with urea at a rate of 28 kg N/ha/week and triple superphosphate (TSP) at a rate of 7 kg P/ha/week. No any chemicals were used in the experiment.

One air blower (5 Hp) was used to supply air for all ponds. PVC pipes of 2.54 cm in diameter were connected to the outlet of the air blower and extended to the pond dike of each pond. A polyethylene (PE) pipe of 18 m long and 1.6 cm in diameter was connected to the PVC pipe and extended to the bottom of each pond. On the PE pipe, there were 10 holes of 1.5 mm in diameter, and the distance between two adjacent holes was 2 m. Nine 3m long PE pipes were fixed alternatively on the main PE pipe at the middle of two holes with four on one side and five on the other side. On each 3-m long PE pipe, there were two holes of the same size as those on the main PE pipe. The PE pipes were sustained at 10 cm off the bottom using bamboo sticks. Aerators were operating daily for 24 hours except during feeding.

Dissolved oxygen (DO) and water temperature were measured daily at 0600 h at 25 cm below water surface and 25 cm above pond bottom, while salinity and pH were monitored weekly at 25 cm below surface at 0600 and 1400 h. Secchi disk visibility was measured weekly at 0900 h. Water samples were taken at 0900 h biweekly for analyses of total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), soluble reactive phosphorus (SRP), total phosphorus (TP), total suspended solids (TSS) and chlorophyll *a* (Parsons *et al*., 1984; APHA *et al*., 1985).

Nutrient budget was calculated based on the input and output of total nitrogen (TN) and total phosphorus (TP). TN and TP contents were analyzed in feeds sampled during the experiment, carcass of 20 shrimps and 3 Nile tilapia sampled from each pond at both stocking and harvest, and sediment sampled at the beginning and end of the experiment, using the methods described by Yoshida *et al*. (1976). Canal water (source water) was sampled during water filling, then analyzed for TKN, nitrate-N, nitrite-N and TP (APHA *et al*., 1985).

Results

Growth performance of tilapia and shrimp

Nile tilapia grew steadily in all treatments throughout the experimental period (Fig. 1). Mean daily weight gains ranged from 2.96 to 3.94 g/fish/day. Final mean weight and mean daily weight gains in the low tilapia density treatment was significantly greater than those in the medium and high tilapia density treatments ($P < 0.05$), between which there was no significant difference ($P > 0.05$). All other growth parameters at harvest including total weight, total weight gain, net yield and gross yield were largest in the high tilapia density treatment, intermediate in the medium tilapia density treatment, and smallest in the low tilapia density treatment ($P < 0.05$). Survival rate was highest in the medium tilapia density, intermediate in the low tilapia density, and lowest in the high tilapia density treatment ($P < 0.05$). Feed conversion ratio (FCR), ranging from 1.00 to 1.16, was significantly higher in the high tilapia density than that in the low and medium tilapia density ($P < 0.05$), between which there was no significant difference ($P > 0.05$, Table 1).

Recruited tilapias were harvested in all treatments. The mean weight of the recruited tilapia in the low tilapia density treatment was larger than that in the medium and high tilapia density treatments ($P < 0.05$), between which there was no significant difference ($P > 0.05$). However, the total weight and total number of recruited tilapia was highest in the high tilapia density treatment, intermediate in the medium tilapia density treatment and smallest in the low tilapia density treatment ($P < 0.05$, Table 1).

Growth of shrimps was fast in the first 28 days when they were fed with pelleted shrimp feed, however, it slowed down in the remaining culture period after feeding was stopped (Fig. 2). Final mean weight of shrimp was not significantly different among all treatments ($P > 0.05$). However, other growth parameters of shrimp including survival, total weight, gross and net yields in the high tilapia density treatment were significantly poorer than those in the medium and low tilapia density treatments ($P < 0.05$), among which there were no significant differences ($P > 0.05$, Table 2).

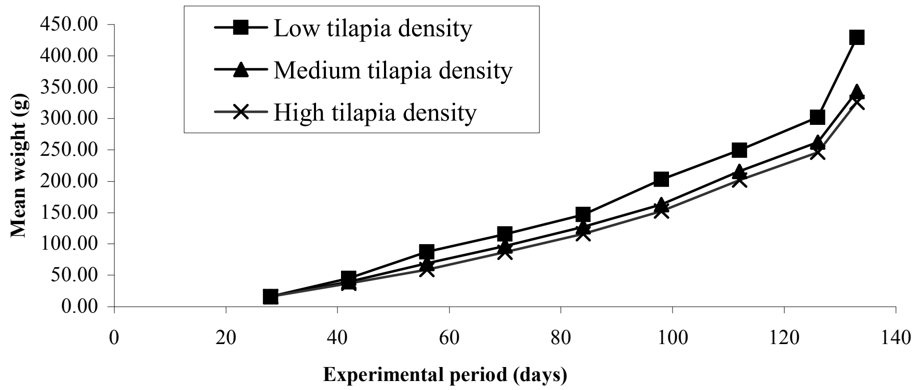

Fig. 1. Growth of Nile tilapia during the experimental period.

Table 1. Summary of growth performance of Nile tilapia cultured for 105 days in the tilapia-shrimp polyculture at low salinity.

Parameters	Unit	Treatments		
		Low tilapia density	Medium tilapia density	High tilapia density
Initial stocking				
Density	fish/m^2	1	2	4
Mean weight	g/fish	15.7 ± 0.1	15.7 ± 0.1	15.7± 0.1
Total weight	kg/pond	3.1 ± 0.0^a	6.3 ± 0.1^b	12.6 ± 0.1^c
Final Harvest				
Large Tilapia				
Mean weight	g/fish	429.5 ± 7.3^a	343.2 ± 1.2^b	326.0 ± 6.9^b
Total weight	kg/pond	66.9 ± 1.3^a	114.1 ± 3.2^b	184.2 ± 5.0^c
Survival	%	77.8 ± 1.3^b	83.1 ± 2.1^a	70.6 ± 0.6^c
FCR		1.00 ± 0.02^a	1.02 ± 0.03^a	1.16 ± 0.04^b
Total weight gain	kg/pond	63.8 ± 1.3^a	107.8 ± 3.2^b	171.6 ± 5.1^c
Mean daily weight gain	g/fish/day	3.94 ± 0.07^a	3.12 ± 0.01^b	2.96 ± 0.07^b
Net yield	t/ha/year	11.1 ± 0.2^a	18.7 ± 0.6^b	29.8 ± 0.9^c
Gross yield	t/ha/year	11.6 ± 0.2^a	19.8 ± 0.6^b	32.0 ± 0.9^c
Recruited tilapia				
Mean weight	g/fish	20.4 ± 1.8^a	13.8 ± 0.8^b	10.9 ± 1.1^b
Total weight	kg/pond	19.1 ± 1.3^a	31.4 ± 1.1^b	49.1 ± 2.7^c
Total number	fish/pond	855 ± 76^a	1410 ± 51^b	2209 ± 119^c
Net yield including recruitment	t/ha/year	14.4 ± 0.2^a	24.2 ± 0.7^b	38.4 ± 1.2^c
Gross yield including recruitment	t/ha/year	14.9 ± 0.2^a	25.3 ± 0.7^b	40.6 ± 1.2^c

Values with different superscripts in the same row are significantly different ($P < 0.05$).

Table 2. Summary of growth performance of shrimp cultured for 133 days in the tilapia-shrimp polyculture at low salinity.

Parameter	Unit	Treatment		
		Low tilapia density	Medium tilapia density	High tilapia density
Initial stocking				
Density	pieces/m^2	15	15	15
Mean weight	g/piece	0.77 ± 0.00	0.77 ± 0.00	0.77 ± 0.00
Final Harvest				
Mean weight	g/piece	5.04 ± 0.07	4.75 ± 0.10	3.94 ± 0.45
Total weight	kg/pond	4.40 ± 0.64[a]	3.56 ± 0.23[a]	1.07 ± 0.89[b]
Survival	%	29.0 ± 3.8[a]	25.0 ± 1.4[a]	8.4 ± 6.7[b]
Total weight gain	kg/pond	2.09 ± 0.64[a]	1.25 ± 0.23[a]	-1.24 ± 0.89[b]
Mean daily weight gain	g/ shrimp/day	0.032 ± 0.001[a]	0.030 ± 0.001[a]	0.016 ± 0.003[b]
Net yield	t/ha/year	0.29 ± 0.09[a]	0.17 ± 0.03[a]	-0.17 ± 0.12[b]
Gross yield	t/ha/year	0.60 ± 0.09[a]	0.49 ± 0.03[a]	0.15 ± 0.12[b]

Values with different superscripts in the same row are significantly different ($P < 0.05$).

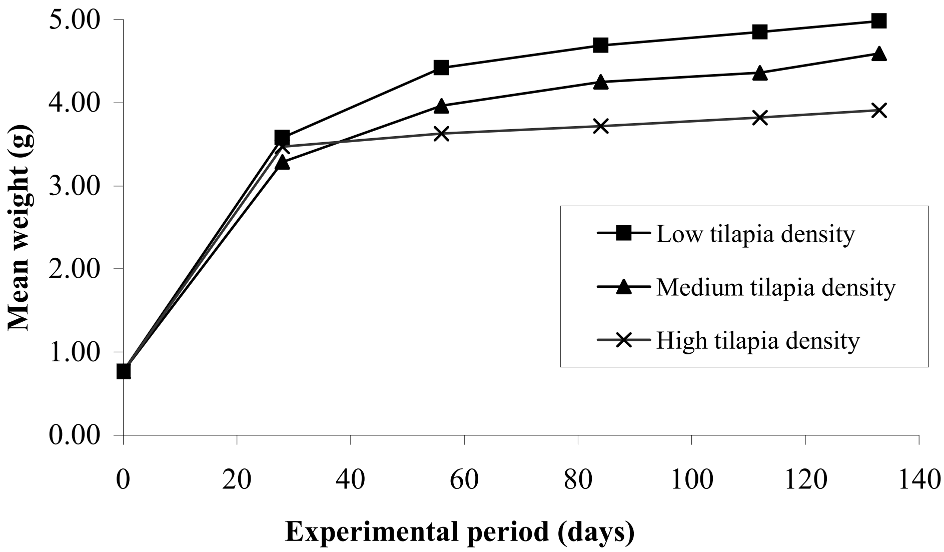

Fig. 2. Growth of shrimp during the experimental period.

Nutrient budget

The main nutrient input was the floating pellet feed for tilapia in all treatments during the 133-day experimental period. Nutrients recovered by tilapia were 2,246, 3,836 and 6,143 g N and 634, 1,107 and 1,728 g P in the low, medium and high tilapia density treatments, respectively. Nutrients recovered by shrimp were 52 and 24 g N, and 6 and 4 g P in the low and medium tilapia density treatment, respectively, however, 31 g N and 1 g P were lost through dead shrimp in the high tilapia density treatment. Nitrogen accumulated in the pond bottom was higher in the higher tilapia density treatments, while phosphorous was lower in the higher density tilapia treatments (Table 3).

The nutrients harvested by tilapia biomass accounted for about 48.01%, 52.89%, and 48.99% of TN, and 60.55%, 68.47% and 62.25% of TP inputted from fertilizer and pelleted feeds in the low, medium and high tilapia density treatments, respectively, while shrimp recovered only 1.10% and 0.33% of TN, and 0.55% and 0.27% of TP in the low and medium tilapia density treatments, respectively. However, nutrients were lost through dead shrimp in the high tilapia density treatment. Nutrients lost in sediment accounted for 15.65%, 19.28%, and 14.06% of TN and 33.54%, 18.90% and 10.70% of TP in the low, medium and high tilapia density treatments, respectively. The nutrients lost to the water column were 3.99%, 3.70% and 2.22% of TN, and 0.08%, 0.17% and 0.04% of TP in the low, medium and high tilapia density, respectively (Table 4).

Water quality

Water temperature and pH ranged from 28.0 to 35.7°C and from 7.0 to 9.7 throughout the experimental period, respectively. DO concentrations at dawn tended to be lower toward the end of the experimental period. Overall mean DO concentrations at both surface and bottom were highest in the low tilapia density treatment, intermediate in the medium tilapia density treatment, and lowest in the high tilapia density treatment ($P < 0.05$). At the end of the experiment, DO concentration at both surface and bottom in the high tilapia density treatment was significantly lower than those in the medium and low tilapia density treatments ($P < 0.05$), between which there was no significant difference ($P > 0.05$). There was no significant difference in total alkalinity concentrations among all treatments ($P > 0.05$). Overall mean concentration of TP was lowest in the medium tilapia density treatment, intermediate in the low tilapia density treatment, and highest in the high tilapia density treatment ($P < 0.05$). Overall mean concentration of SRP in the high tilapia density treatment was significantly lower than that in the medium and low tilapia density treatments ($P < 0.05$), between which there was no significant difference ($P > 0.05$). However, there were no significant differences in final concentrations of both TP and SRP among all treatments ($P > 0.05$). Overall mean concentrations of TAN tended to be higher in the higher tilapia density treatments ($P < 0.05$), while there were no significant differences in TAN concentrations at the end of the experiment among all treatments. Both overall mean and final concentration of TKN, nitrite-N and nitrate-N, chlorophyll *a* and TSS were not significantly different among all treatments ($P > 0.05$). Overall means of Secchi disk depths were significantly different with each other among all treatments ($P < 0.05$) however, the final values of Secchi disk depths were not significantly different among all treatments ($P > 0.05$, Table 5). Salinity level was 4 ppt in all ponds at the beginning of the experiment and decreased to zero ppt after seven weeks of culture, which remained zero during the rest of the culture period

Table 3. Input, output and balance of total nitrogen and total phosphorus in the tilapia-shrimp polyculture at low salinity during the entire experimental period.

Parameters	Total nitrogen (g)			Total phosphorus (g)		
	Low tilapia density	Medium tilapia density	High tilapia density	Low tilapia density	Medium tilapia density	High tilapia density
Input						
Fertilizer	560	560	560	140	140	140
Tilapia feed	3,578	6,187	11,400	792	1,370	2,524
Shrimp feed	540	505	516	115	108	110
Shrimp	59	59	59	3	3	3
Tilapia	88	176	353	22	43	86
Water	378	378	378	12	12	12
Total	5,203	7,866	13,267	1,084	1,675	2,875
Output						
Shrimp	111	83	28	9	7	2
Large tilapia	1,828	3,126	5,071	517	948	1,451
Small tilapia	506	886	1,425	139	203	363
Sediment	732	1398	1,763	351	306	297
Water	565	646	657	13	15	13
Total	3,742	6,139	8,943	1,028	1,478	2,126
Nutrient gain						
Shrimp	52	24	-	6	4	-
Tilapia	2,246	3,836	6,143	634	1,107	1,728
Nutrient loss						
Shrimp	-	-	31	-	-	1
Water	186	268	279	1	3	1
Sediment	732	1,398	1,763	351	306	297
Unaccounted	1,462	1,727	4,324	55	197	749
Nutrients recovered						
By shrimp	52	24	-	6	4	-
By Tilapia	2246	3836	6143	634	1107	1728

Table 4. Total nitrogen and total phosphorus distribution (%) in different components of the tilapia-shrimp polyculture system at low salinity.

Parameters	Total nitrogen (%)			Total phosphorus (%)		
	Low tilapia density	Medium tilapia density	High tilapia density	Low tilapia density	Medium tilapia density	High tilapia density
Feed and	100.00	100.00	100.00	100.00	100.00	100.00
Nutrient gain						
Shrimp	1.10	0.33	-	0.55	0.27	-
Tilapia	48.01	52.89	48.99	60.55	68.47	62.25
Sub total	49.11	53.22	48.99	61.10	68.73	62.25
Nutrient lost						
Shrimp	-	-	0.25	-	-	0.02
Water	1.49	2.16	1.33	0.08	0.17	0.04
Sediment	15.65	19.28	14.06	33.54	18.90	10.70
Unaccounted	33.75	25.35	35.38	5.28	12.20	26.99
Sub total	50.89	46.78	51.01	38.90	31.27	37.75
Total	100.00	100.00	100.00	100.00	100.00	100.00

Discussion

Nile tilapia grew very well at all three densities, giving mean daily weight gains of 2.96–3.94 g/fish/day in the present experiment. Growth and production of Nile tilapia were lower at higher density, showing that tilapia is density-dependent in terms of growth and production and that carrying capacity was not reached. Growth of Nile tilapia in the present experiment was similar to that in Nile tilapia ponds fed with pelleted feed (Diana *et al*., 1994; Diana *et al*., 1996; Diana *et al*., 1997). Daily weigh gain of Nile tilapia in all treatments was much higher than that (2.2 g/fish/day) achieved in the polyculture of prawn (*Macrobrachium rosenbergii*) and Nile tilapia (1 tilapia and 7 prawns/m^2) by García-Pérez *et al.* (2000). The present experiment indicates that the appearance of shrimps in Nile tilapia ponds did not affect the growth of Nile tilapia.

Growth of shrimp was good when they were fed with shrimp pelleted feed. After stocking Nile tilapia, only floating tilapia feed was given to the polyculture ponds, and consequently shrimp growth almost ceased. Results of the present experiment showed that the growth performance of shrimp was similar at the densities of 1 and 2 tilapias/m^2, beyond which the growth performance of shrimp was significantly poorer. In the intensive culture ponds receiving floating pelleted feed, tilapias monopolize the feed, however, some feed particles always get to the bottom where the shrimp, the bottom feeder, can get it (Midlen and Redding, 1998; Yi and Fitszimmons, in press). Shrimp can also feed on natural foods such as benthic blue-green algae, diatoms, bacteria and detritus (Lim, 1998; Chakraborty and Sadhu, 2001). The feed input was higher in the high density tilapia treatment than in the medium density tilapia treatment, thus, wastes from tilapia feeding was more in higher tilapia density treatment. However, the growth performance of shrimp was not significantly different between the low and medium tilapia density treatment, indicating that the quantity of waste feed particles and natural foods at the pond bottom might not be the limiting factor but the quality of feed items might be more important. When the stocking density of Nile tilapia was raised to more than 2 tilapias/m^2, water quality may have affected the growth of shrimps, having significantly poorer growth and low survival of shrimp in the high tilapia density treatment than that in the low and medium tilapia density treatments.

Table 5. Summary of overall mean and final values of water quality parameters measured at 0900 h in different treatments of the tilapia-shrimp polyculture at low salinity.

Parameters	Treatments		
	Low tilapia density	Medium tilapia density	High tilapia density
Overall mean values			
Alkalinity (mg/L as $CaCO_3$)	82 ± 4	78 ± 4	83 ± 2
TAN (mg/L)	0.15 ± 0.03[a]	0.17 ± 0.06[b]	0.18 ± 0.06[b]
Nitrite-N (mg/L)	0.03 ± 0.03	0.02 ± 0.01	0.02 ± 0.02
Nitrate-N (mg/L)	0.09 ± 0.00	0.09 ± 0.01	0.10 ± 0.00
TKN (mg/L)	2.69 ± 0.07	2.99 ± 0.05	3.18 ± 0.19
TP (mg/L)	0.08 ± 0.00[ab]	0.07 ± 0.00[a]	0.09 ± 0.00[b]
SRP (mg/L)	0.02 ± 0.00[a]	0.02 ± 0.00[a]	0.01 ± 0.00[b]
TSS (mg/L)	110 ± 4	113 ± 1	111 ± 4
Chlorophyll *a* (g/m^3)	61 ± 12	71 ± 16	73 ± 11
Secchi disk depth (cm)	34 ± 0.7[a]	29 ± 0.3[c]	32 ± 0.5[b]
Final values			
Alkalinity (mg/L as $CaCO_3$)	100 ± 10	76 ± 6	82 ± 2
TAN (mg/L)	0.10 ± 0.01	0.08 ± 0.01	0.10 ± 0.01
Nitrite-N (mg/L)	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Nitrate-N (mg/L)	0.10 ± 0.00	0.08 ± 0.00	0.09 ± 0.01
TKN (mg/L)	3.20 ± 0.07	3.69 ± 0.06	3.76 ± 0.29
TP (mg/L)	0.07 ± 0.01	0.09 ± 0.00	0.08 ± 0.01
SRP (mg/L)	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
TSS (mg/L)	69 ± 5	72 ± 1	66 ± 3
Chlorophyll *a* (g/m^3)	26 ± 2	64 ± 19	73 ± 67
Secchi disk (cm)	30 ± 2.9	24 ± 3.1	20 ± 2.9

Values with different superscripts in the same row are significantly different ($P < 0.05$).

Shrimp-tilapia polyculture has been practiced in extensive, semi-intensive and intensive culture systems. In most shrimp-tilapia polyculture systems, shrimp was cultured as major species, while tilapias were cultured as secondary species to reuse shrimp feed wastes and improve water quality (Gonzales-Corre, 1988; Akiyama and Anggawati, 1999; Saelee, 2002). However, shrimps can be added in Nile tilapia ponds as the secondary species to utilize tilapia feeding waste and natural foods and to achieve extra economic returns. The present experiment indicated that adding shrimp into Nile tilapia ponds is technically feasible, however, more research is needed to optimize the tilapia-shrimp polyculture system. Reducing shrimp density or feeding both floating and sinking feeds may be the alternative ways.

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