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Co-Culture of Lotus and Hybrid Catfish to Recycle Waste From Intensive Feeding

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Final Report

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Abstract

An experiment was conducted in nine 200-m^2 earthen ponds at the Asian Institute of Technology (AIT), Thailand from 17 July 2003 to 3 March 2004 (230 days). The objectives of the study were to assess the feasibility of co-culture of lotus and hybrid catfish in intensively fed ponds, to assess nutrient recovery from feed waste by lotus plants, to assess pond mud characteristics after lotus-fish co-culture, and to compare catfish growth with and without lotus integration. There were three treatments in triplicate: (1) catfish at 25 fish m^{-2}; (2) lotus at 50 seedlings $pond^{-1}$; and (3) lotus-catfish co-culture (lotus 50 seedlings $pond^{-1}$ and catfish at 25 fish m^{-2}). Lotus plants, root intact, were transplanted to ponds of treatments with lotus at a density 50 plants $pond^{-1}$. Hybrid catfish were stocked at a density 25 fish m^{-2} in treatments with catfish. Experimental catfish were fed with commercial floating pelleted feed. Feeding rate was adjusted for each pond separately based on the monthly fish growth measurement and estimated average catfish survival. There were no nutrient inputs in lotus ponds. Catfish growth performance was not significantly different ($P > 0.05$) between catfish and co-culture treatments. However, catfish survival was unpredictably low. There were no significant differences in lotus growth performance between lotus and co-culture treatments; however, total harvested lotus biomass was lower in comparison with previous production records in similar ponds. Lotus co-culture with catfish or lotus culture in ponds resulted in reduced pond mud nutrient concentrations. Nutrient loss from mud in a 1-ha pond was 0.32 tonnes N, and 0.44 tonnes P, out of which 44 kg N and 9.3 kg P were incorporated into the harvested lotus biomass. Most of the water quality parameters remained in the safe range for catfish growth and thus, integration of lotus and catfish could be a potential strategy to recover nutrient from intensive catfish feeding systems.

Introduction

Semi-intensive and intensive fish culture systems are characterized by applications of organic and inorganic fertilizers, supplemental feeds, and high protein diets to achieve high production. After continuous input of manures, inorganic fertilizers and fish feed, organic matter and nutrients accumulate at high concentrations in pond mud. Green and Boyd (1995) reported that the nutrients accumulated in pond mud accounted for about 70% of total nitrogen (TN) and 35-40% of total phosphorus (TP) in intensively manured tilapia ponds. One hectare of pond mud was reported to have the equivalent of 3.0 tonnes of triple super phosphate (TSP) and 2.8 tonnes of urea (Yang and Hu, 1989), 2.30 tonnes of TSP and 1.85 tonnes of urea (Shrestha and Lin 1997) or 4.11-4.81 tonnes of TSP and 3.44-3.92 tonnes of urea (Yi et al., 2002) in fertilized ponds, and 12.4-12.9 tonnes of urea and 7.7-9.2 tonnes of TSP in intensively fed ponds (Mon, 2000). Although the absorbed nutrients, especially phosphorus (P), may release back to the water column, the quantity released is limited and most nutrients remain in the pond mud (Shrestha and Lin, 1996). Thus, recovering nutrients from pond mud is a major concern on waste recycling in aquaculture.

Use of pond mud to fertilize land crops could be an efficient way to recover nutrients from aquaculture pond mud (Muller, 1978; Little and Muir, 1987; Christensen, 1989; Shrestha and Lin, 1997) because the crops can absorb nutrients directly from mud (Denny, 1972; Boyd, 1982; Smart and Barko, 1985). However, the high labor cost involved in removing pond mud poses serious question to its practicality (Edwards et al., 1986). Alternatively, rooted aquatic macrophytes may have a great potential to be used to recycle adsorbed nutrients in pond mud. Shrestha and Lin (1997) used a rooted semi-aquatic plant, taro (*Colocasia esculenta*), to recover P contained in pond mud and concluded that the P concentration was sufficient to support taro growth. Mon (2000) and Yi et al. (2002) also reported that nutrients contained in old pond mud were sufficient for the growth of lotus (*Nelumbo nucifera*).

Lotus is an emergent aquatic macrophyte that is commonly planted in nutrient-rich fields or ponds. Lotus is an important and popular cash crop in many Asian countries. Various parts of lotus plants can be used as foods, medicine, religious ornaments, fuel, and cosmetic ingredients. Lotus has been co-cultured or cultured rotationally with fish in China for many years (Hoffmann, 1934 cited by Edwards, 1987), and also rotated with tilapia seed production in some parts of the sewage-fed areas around Ho Chi Minh City, Vietnam (Little and Tuan, 1995). The rotation of fish and aquatic macrophytes may give farmers two crops to market rather than one (Edwards, 1987). However, little research has been done to determine the efficiency of nutrient removal from pond mud by lotus or its economic return. Recently, Yi et al. (2002) reported that the growth and survival of Nile tilapia (*Oreochromis niloticus*) was much lower in a lotus-tilapia co-culture system than that in tilapia monoculture due to lower phytoplankton biomass and poor water quality caused by shading effects of lotus leaves. They suggested that airbreathing species such as snake head (*Channa striata*) or catfish (*Clarias* sp.), which can tolerate very low DO concentrations and are commonly cultured in intensive systems, may be the better choice for co-culture of lotus and fish.

The purposes of this study were to assess the feasibility for co-culture of lotus and hybrid catfish in intensively fed ponds, to assess nutrient recovery from feed wastes by lotus plants, to assess pond mud characteristics after lotus-fish co-culture, and to compare fish growth in monoculture and in co-culture of lotus and fish.

METHODS AND MATERIALS

The experiment was conducted in nine 200-m^2 earthen ponds at the Asian Institute of Technology (AIT), Thailand from 17 July 2003 to 3 March 2004 (230 days). There were three treatments in triplicate: (1) catfish at 25 fish/m^2; (2) lotus at 50 seedlings/pond; and (3) co-culture (lotus 50 seedlings/pond and catfish at 25 fish/m^2).

Prior to the start of the experiment, all ponds were drained completely, dried for 2 weeks, then filled with freshwater from a nearby canal to a depth of 10 cm a day prior to lotus planting. Lotus plants, root intact, were collected from a nearby community pond and were transplanted on 17 July 2003 to ponds containing treatments with lotus at a density of 50 plants/pond. After lotus planting, water was added weekly to all ponds and water depth was increased up to 1 meter as the height of lotus increased. Water depth was maintained at 1 m, but there was no water exchange throughout the experimental period. Hybrid catfish (mean individual weight 6.2 g) were purchased from a local farm and stocked on 22 September 2003 at 25 fish m^{-2} in treatments with catfish. Experimental catfish were fed with commercial floating pelleted feed (32% crude protein, CP Catfish Feed). Daily feed ration was determined and adjusted monthly based on measurements of fish size and estimated catfish survival (Tonguthai et al., 1993). Feeding rate (% body weight per day) varied with fish size, and was 10% for fish smaller than 20 g, 8% for fish from 20-50 g, 5% for fish 50-100 g, and 3% for fish larger than 100 g. Daily ration was determined and readjusted for each pond separately; daily ration was divided in two parts and supplied in the morning (0900 h) and in the afternoon (1500 h).

During the experiment, matured lotus pods with seeds were harvested periodically, weighed and nutrient contents (TN and TP) determined. At harvest, all ponds were drained completely. Catfish were harvested after 162 days of culture, and different parts of lotus (flower, pod, lead, stem and root) were harvested separately after 230 days of culture.

Dissolved oxygen (DO), temperature, and pH measurements were made at 0900 h biweekly from water depths of 25 cm above the bottom, 25 cm below water surface, and the midpoint between these depths. Integrated water samples were taken biweekly at 0900–0930 h from the entire water column near the center of each pond for analyses of alkalinity, total ammonia nitrogen (TAN), nitrate nitrogen (nitrate-N), nitrite nitrogen (nitrite-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP), soluble reactive phosphate (SRP), chlorophyll *a*, total suspended solids and total volatile solids following standard methods (APHA et al., 1985). Secchi disk depth was measured in situ according to the same schedule.

Total nutrient budget (N and P) in the ponds was calculated from the above measures. The nutrient budget for N and P were calculated based on inputs from soil, water, stocked catfish, and feed; and outputs were calculated based on harvested catfish and lotus, drained water and nutrients accumulated in the mud.

Nutrient input and output in the water was calculated by multiplying the nutrient concentration by total water volume. Mud samples were collected by taking nine cores (with 5 cm plastic tubes from 10 cm of pond bottom) before filling the pond and after harvest, and mixed in a composite sample for initial and final nutrient levels of mud. Total nitrogen and phosphorus concentration in catfish feed, as well as components of lotus and catfish carcasses (at stocking and at harvest) were analyzed following the methods described by Yoshida et al. (1976).

Data were analyzed statistically by analysis of variance and *t*-test (Steel and Torrie, 1980) using SPSS (version 11.0) statistical software. Differences were considered significant at an alpha of 0.05. Means were given with ± standard error (S.E.).

Results

Growth performance parameters showed that catfish growth was not significantly different between treatments ($P > 0.05$; Table 1). Mean total and daily weight gain of catfish was slightly higher in the co-culture treatment than the catfish treatment, but was not significantly different between treatments. Catfish production was limited due to poor survival in both treatments. Mean survival was only 45% in the catfish treatment and 27% in the co-culture treatment, but catfish survival rate was not significantly different between treatments ($P > 0.05$; Table 1). Consequently, there was an exceptionally high FCR (> 4) in both treatments, due to our overestimate of the number of catfish surviving in each pond, which resulted in an overestimate of daily feed ration. Apparent FCR for catfish was not significantly different between treatments ($P < 0.05$; Table 1). The low catfish survival in this study could not be ascribed to the negative effect of lotus on catfish growth, as catfish treatment without lotus also had poor survival. Net catfish yield in catfish and co-culture treatments were 66.3 and 41.0 tonnes·ha^{-1}·year^{-1}, respectively and were not significantly different. Total lotus biomass harvested in lotus alone and co-culture treatments were 361.9 and 300.0 kg pond^{-1}, respectively and were not significantly different ($P > 0.05$, Table 2). Lotus production also varied largely within each treatment. In general, poor lotus growth was observed in both treatments.

Catfish feed accounted for the largest TN input in catfish (78.5%) and co-culture (64.2%) treatments, followed by mud, stocked catfish, and water (Table 3). In the lotus treatment, almost all nitrogen input was contained in the mud (99.9%). Major phosphorus input in all treatments was through bottom mud followed by feed, stocked catfish, and water. In catfish and co-culture treatments, mud accounted for 56% and 60% of TP inputs, respectively. In the lotus treatment, mud constituted 99.8% of TP inputs. Feed accounted for 44.6% and 39.0% of TP inputs in catfish and co-culture treatments, respectively. At harvest, mud constituted the largest output of TN and TP, followed by harvested catfish, drained water, and harvested lotus. TN and TP retained in lotus harvest were not significantly different between lotus and co-culture treatments. In lotus and co-culture treatments, TN and TP contained in mud declined over the experimental period. In contrast, TN content in mud from the catfish treatment increased 1.5 fold over the experimental period, while TP content in mud decreased slightly. During the experimental period, a large portion of TN and TP inputs were not accounted for; unaccounted nitrogen was ranged from 16.5 to 49.4% of the total inputs in different treatments and was significantly lower in the lotus treatment. Unaccounted phosphorous ranged from 33.5 to 43.6% of total inputs and was not significantly different among treatments.

Mean DO at dawn ranged from 0.8 to 2.5 mg l^{-1} and was significantly higher in the lotus treatment than catfish and co-culture treatments ($P < 0.005$; Table 4; Figure 1). DO concentration in the co-culture treatment remained constantly low throughout the experiment and exceeded 1 mg l^{-1} only at two sampling times. In contrast, DO values in the catfish treatment varied largely during the initial phase of the experiment and remained low during the latter half of the experiment.

Mean water temperature ranged from 22.2 to 29.6 °C, with no significant difference between treatments. pH ranged from 6.7 to 7.9 in different treatments over the experimental period and was not significantly different among treatments (Table 4). Total alkalinity increased over time in all treatments, but remained significantly lower in the lotus treatment than in the catfish and co-culture treatments ($P < 0.05$; Table 4; Figure 3).

TAN concentration was significantly lower in lotus treatment than catfish and co-culture treatments ($P < 0.05$; Table 4). TAN concentration fluctuated widely with occasional peaks during the experimental period in the treatments with catfish, however, TAN concentration in the lotus treatment remained stable and low (< 1 mg l^{-1}; Figure 4). Mean NO_2-N and NO_3-N concentrations were not significantly different among treatments and remained low during the study. Mean TKN and TP concentrations in water were significantly lower in the lotus treatment than catfish and co-culture treatments ($P < 0.05$; Table 4). TKN and TP concentrations increased over time in catfish and co-culture treatments (Figure 5 and Figure 6), whereas TKN and TP in the lotus treatment remained low and stable throughout the study.

Chlorophyll-a concentration, TSS and TVS, were significantly different among treatments, highest in the catfish treatment, intermediate in the co-culture treatment and lowest in the lotus treatment ($P < 0.05$; Table 4). Chlorophyll-a concentrations in catfish and co-culture treatments peaked in the midway of culture, and the highest concentration in the catfish treatment (331 μg l^{-1}) was more than double that observed in co-culture treatments (160 μg l^{-1}; Figure 7). Chlorophyll-a concentration in the lotus treatment remained low. Total suspended solids and total volatile solids fluctuated widely in the catfish treatment, while they remained stable and low in lotus and co-culture treatments (Figure 8 and Figure 9). Mean Secchi disk visibility was significantly different among treatments, and the highest value was observed in the lotus treatment followed by co-culture and catfish treatments ($P < 0.05$; Table 4).

DISCUSSION

Catfish growth performance was not adversely affected by lotus, suggesting that it may be feasible to culture catfish with lotus in an intensive feeding system. Catfish growth rate in the present study was not different between catfish and co-culture treatments, and was comparable to catfish growth rates reported previously by Lin and Diana (1995) in catfish and tilapia co-culture. Net catfish yield (41 and 66 tonnes ha^{-1} $year^{-1}$) observed in the present study was comparable to the production rage (40 to 80 tonnes ha^{-1} $year^{-1}$) reported for commercial catfish culture in Thailand (Panayotou et al., 1982; Tong-uthai et al., 1993). Areerat (1987) described a production range of 12.5 to 100 tonnes ha^{-1} $crop^{-1}$ (3–5 months) for hybrid catfish cultured at high density (30–60 fish m^{-2}). The yield in this present study was also much lower than the 220 tonnes ha^{-1} $year^{-1}$ achieved from the same site in a previous study (Yi et al. 2003), due mainly to survival less than 50% in this study compared to survival over 90% in the previous study. Tonguthai et al. (1993) reported that average survival in hybrid catfish ponds typically ranges from 40 to 70%, indicating that variable survival is common.

Total harvested lotus biomass was not significantly different between lotus and co-culture treatment despite the heavy nutrient input through feed in the co-culture ponds, while no nutrient was supplied to the lotus treatment during the experiment. Added nutrients during catfish rearing had no influence on lotus growth, so the nutrients contained in the pond mud appeared sufficient to support lotus growth. Yi et al. (2002) also observed that fertilizer input in lotus-tilapia pond had no effect on lotus growth performance. Previously, Shrestha and Lin (1997) found that, in pot experiments, pond mud diluted to 50% was sufficient to support the growth of cowpea (*Vigna unguiculata* L. Walp.), a terrestrial legume, and taro, a semi-aquatic crop. However, lotus yield observed in the present study was about half the yield reported by Yi et al. (2002) in lotus-tilapia and lotus culture systems. The nutrient content in pond soils may not have contributed to the poor lotus production, as lotus yield in co-culture was lower than that in the lotus treatment. In November and December, lotus plants started drying, which resulted in a drastic reduction of lotus standing crop. In one co-culture pond that had a good lotus crop during the initial stage of the experiment, lotus biomass at harvest was about 80% lower than in the other two replicates for the same treatment. The poorer lotus production may be the result of seasonal changes in lotus growth during winter.

Old pond mud in the present study contained nutrients equivalent to 2.80 to 3.84 tonnes of urea and 5.50 to 6.30 tonnes of TSP per hectare. This is similar to the nutrient range reported by Yi et al. (2002), but higher than reported by Shrestha and Lin (1997) and Yang and Hu (1989). Lotus cultivation contributed to the reduction of nutrients in pond mud, removing 0.70 tonnes of urea and 2.20 tons of TSP per hectare. This reduction was lower than that reported by Yi et al. (2002), which was likely caused by poor lotus growth in the present study. Lotus biomass incorporated only 1% of the TN and TP inputs to the pond in this experiment, whereas incorporation of 12.8% TN and 4.4% TP was reported by Yi et al. (2002). Nutrient budget analysis could not account for 16–49% of N and 33–44% of P in this study. The unaccounted nitrogen might have lost from the system by ammonia gas volatilization and/or denitrification in the sediment (Boyd, 1990). A lower proportion of nutrients remained in the mud in co-culture treatments compared to the catfish treatment, with the opposite pattern for unaccounted nutrients. This result supports the contention of Yi et al. (2002) that lotus can enhance denitrification and ammonia volatilization or transfer both nitrogen and phosphorus to deeper layer of soil with the extension of lotus roots. It is also likely that some nutrients contained in the upper layer of mud washed out of the pond with drained water during harvest, and thus were not accounted for by the nutrient budget. Tucker and Hargreaves (2003) indicated that elevated solid levels in discharge water at draining were due mainly to sediments scoured from the pond near the bottom.

ANTICIPATED BENEFITS

The study demonstrated that it is feasible to culture hybrid catfish with lotus under intensive feeding conditions and major pond water quality parameters in co-culture systems remained in the safe range for catfish growth. Co-culture has the potential to improve nutrient utilization efficiency of intensive catfish culture system as lotus uses nutrients from pond mud, and thus helps to condition pond water quality. However, utilization of nutrients was rather small, while volatization may have been more effective in reducing nutrients from lotus ponds. The study may provide catfish farmers an alternative culture technique to minimize the nutrient wastage from the system and improve the net profit by generating addition income from lotus production.

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Table 1. Growth performance of catfish in monoculture or co-culture with lotus.

Parameters	**Treatment 1** (monoculture)	**Treatment 3** (co-culture)
STOCKING		
Density (fish m^{-2})	2.5	2.5
Total no. of fish	5000	5000
Mean weight (g $fish^{-1}$)	6.3 ± 0.0	6.3 ± 0.0
Total weight (kg $pond^{-1}$)	31.2 ± 0.1	31.4 ± 0.2
HARVEST		
Mean weight (g $fish^{-1}$)	300.7 ± 38.6	321.0 ± 33.7
Total weight (kg $pond^{-1}$)	620.0 ± 178.9	395.5 ± 151.4
Survival rate (%)	45.1 ± 15.5	27.0 ± 12.8
Weight Gain		
Mean weight gain (g $fish^{-1}$)	294.4 ± 38.6	314.7 ± 33.7
Daily weight gain (g $fish^{-1}$ day^{-1})	1.8 ± 0.2	1.9 ± 0.2
Total weight gain (kg $pond^{-1}$)	588.7 ± 178.9	364.2 ± 151.5
FCR	4.1 ± 1.7	4.8 ± 1.6
Net Yield (t ha^{-1} $year^{-1}$)	66.3 ± 20.2	41.0 ± 17.1
Gross yield (t ha^{-1} $year^{-1}$)	69.8 ± 20.1	44.6 ± 17.1

Values are mean ± S.E. (n = 3), no values were significantly different between treatments.

Table 2. Growth performance of lotusin monoculture or co-culture with catfish.

Parameters	**Treatment 2** (monoculture)	**Treatment 3** (co-culture)
TRANSPLANTING		
Density (seedlings $pond^{-1}$)	50	50
HARVEST		
Leaf (kg $pond^{-1}$)	109.55 ± 9.42	58.57 ± 8.01
Pod (kg $pond^{-1}$)	13.84 ± 2.12	14.10 ± 6.72
Flower (kg $pond^{-1}$)	1.91 ± 0.46	0.18 ± 0.13
Root and stem (kg $pond^{-1}$)	236.57 ± 11.68	227.12 ± 9.42
Total biomass (kg $pond^{-1}$)	361.87 ± 299.96	299.96 ± 21.97
Gross Yield (t ha^{-1} $year^{-1}$)	28.71 ± 1.47	23.80 ± 1.74

Values are mean ± S.E. (n = 3), no values between treatments were significantly different.

Table 3. Nutrient budget (kg pond^{-1}) for different treatments.

Parameters	Total Nitrogen			Total Phosphorus		
	Treatment 1 (catfish)	*Treatment 2* (lotus)	*Treatment 3* (co-culture)	*Treatment 1* (catfish)	*Treatment 2* (lotus)	*Treatment 3* (co-culture)
Inputs						
Mud	25 ± 11.8 (19.6)	35 ± 8.9 (99.9)	35.7 ± 8.6 (33.5)	25.1 ± 2.8 (55.7)	25 ± 3.7 (99.8)	22 ± 2.8 (60.1)
Water	0.01 ± 0.0 (0.01)	0.01 ± 0 (0.05)	0.02 ± 0.0 (0.02)	0.04 ± 0.00(0.1)	0.04 ± 0 (0.2)	0.05 ± 0.00 (0.1)
Catfish	2.1 ± 0.01 (1.8)		2.17 ± 0.01 (2.4)	0.26 ± 0.0 (0.6)		0.26 ± 0.00 (0.7)
Feed	93.5 ± 1.2 (78.5)		67.9 ± 15 (64.2)	19 ± 0.25 (43.6)		14.3 ± 3.2 (39.0)
Total	121 ± 12.5 (100)	34.5 ± 8.9 (100)	106 ± 23.6 (100)	45.1 ± 2.5 (100)	25 ± 3.6 (100)	36.6 ± 3.7 (100)
Outputs						
Catfish	34.5 ± 9.9 (28.4)		22.0 ± 8.4 (20.8)	9.4 ± 2.7 (20.8)		5.9 ± 2.29 (16.3)
Lotus		0.7 ± 0.35 (2.2)	1.00 ± 0.07 (0.9)		.16 ± .07 (0.7)	0.21 ± 0.03 (0.6)
Water	1.87 ± 0.02 (1.5)	0.1 ± 0.08 (0.4)	1.80 ± 0.39 (1.7)	0.76 ± 0.13 (1.7)	0.2 ± .09 (0.9)	0.67 ± 0.18 (1.8)
Mud	37.1 ± 2.7 (30.6)	28 ± 1.2 (80.9)	29.9 ± 1.9 (28.3)	19.8 ± 1.6 (44.0)	14 ± 2.3 (54.8)	15.9 ± 0.9 (43.6)
Total	73.5 ± 12.6 (60.6)	29 ± 0.8 (83.5)	55 ± 10.5 (51.7)	29.9 ± 2.3 (66.5)	14 ± 2.2 (56.4)	22.8 ± 2.7 (62.4)
Gain						
Catfish	32.34 ± 9.96		19.84 ± 8.43	9.12 ± 2.71		5.72 ± 2.29
Lotus		0.76 ± 0.35	1.00 ± 0.07		0.16 ± 0.07	0.21 ± 0.03
Water	1.86 ± 0.02	0.12 ± 0.08	1.78 ± 0.39	0.72 ± 0.13	0.18 ± 0.09	0.62 ± 0.18
Mud	11.55 ± 10.20	6.58 ± 10.14	5.78 ± 6.71	5.27 ± 1.86	11.16 ± 2.37	6.05 ± 2.01
Unaccounted	47 ± 10.8 (39.4)	5.7 ± 9.7 (16.5)	51 ± 13.6 (49.4)	15.1 ± 4.2 (33.5)	11 ± 2.2 (43.6)	13.8 ± 1.5 (37.6)

Values are mean ± S.E. (n = 3), values in the parentheses show the percentage of total inputs.

Table 4. Mean values of water quality parameters in different treatments over the experimental period.

Parameters	**Treatment 1** Catfish	**Treatment 2** Lotus	**Treatment 3** Co-Culture
DO (mg l^{-1}) at dawn	1.7 ± 1.2^{ab}	2.5 ± 0.6^{b}	0.8 ± 0.3^{a}
Temperature (°C)	27.6 ± 1.3	26.1 ± 1.1	26.2 ± 1.1
pH (range)	6.7 - 7.3	7.0 - 7.7	6.7 - 7.9
Alkalinity (mg l^{-1})	177.9 ± 10.5^{a}	109.0 ± 1.5^{b}	181.3 ± 9.9^{a}
TAN (mg l^{-1})	1.7 ± 0.1^{a}	0.6 ± 0.2^{b}	1.7 ± 0.2^{a}
NO_2 - N (mg l^{-1})	0.03 ± 0.01	0.01 ± 0.00	0.01 ± 0.00
NO_3 - N (mg l^{-1})	0.20 ± 0.05	0.18 ± 0.01	0.16 ± 0.01
TKN (mg l^{-1})	7.2 ± 0.3^{a}	0.4 ± 0.1^{b}	6.07 ± 0.7^{a}
TP (mg l^{-1})	5.3 ± 0.2^{a}	2.0 ± 0.2^{b}	4.6 ± 0.2^{a}
SRP (mg l^{-1})	0.03 ± 0.00^{a}	0.07 ± 0.02^{ab}	0.15 ± 0.04^{c}
Chlorophyll-a (μg l^{-1})	154.7 ± 25.9^{a}	27.8 ± 12.9^{b}	88.5 ± 27.6^{c}
TSS (mg l^{-1})	595 ± 107.9^{a}	34.6 ± 4.7^{b}	128 ± 31.9^{bc}
TVS (mg l^{-1})	133.5 ± 13.5^{a}	18.4 ± 2.4^{b}	56.4 ± 5.2^{c}
Secchi disk visibility (cm)	7.8 ± 1.8^{a}	54.8 ± 7.6^{b}	14.4 ± 4.3^{c}

Values are mean ± S.E. (n = 3), mean values in the same row with different superscripts were significantly different.

Figure 1. Mean DO (0900 h) in each treatment over time.

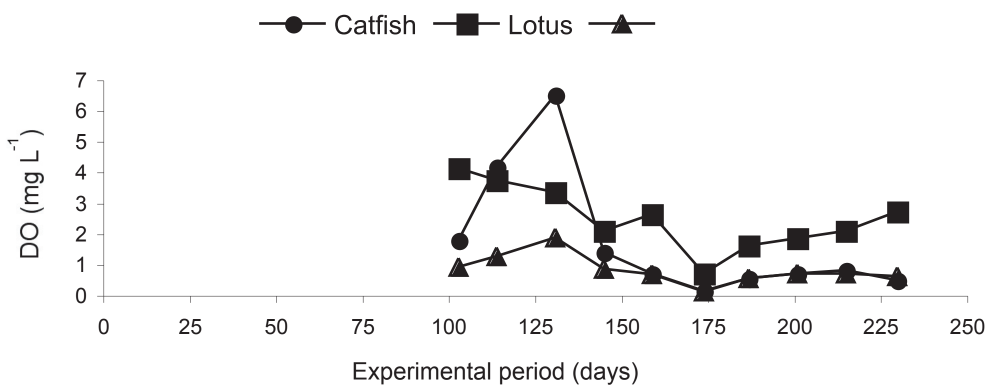


Figure 2. Mean temperature (0900 h) in each treatment over time.

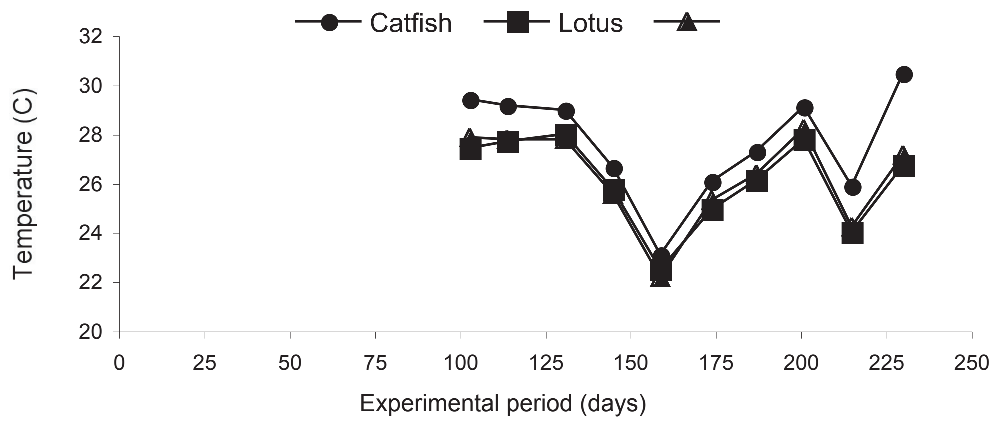


Figure 3. Mean total alkalinity (0900 h) in each treatment over time.

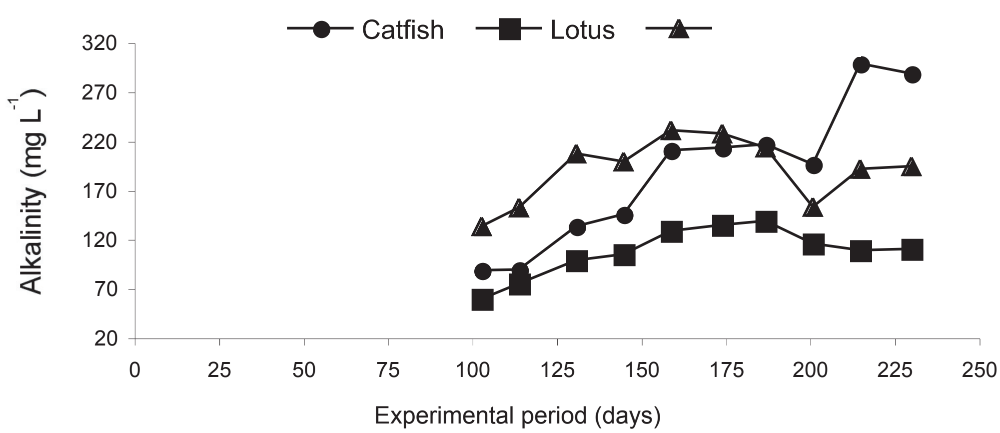


Figure 4. Mean TAN (0900 h) in each treatment over time.

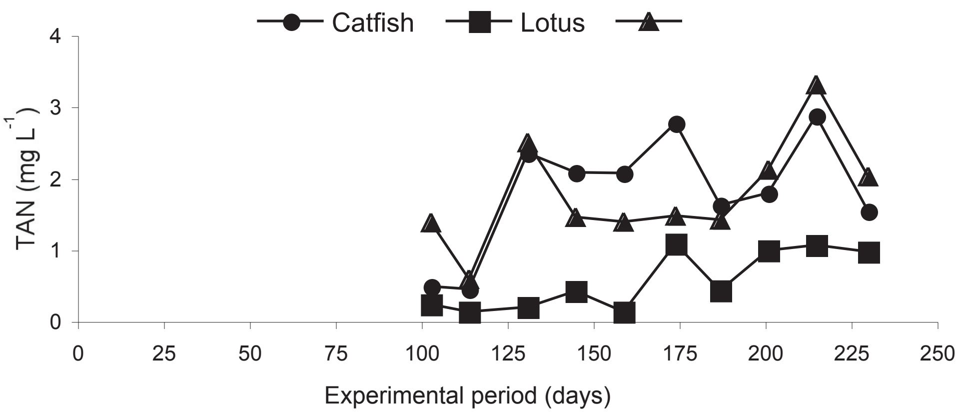


Figure 5. Mean TKN (0900 h) in each treatment over time.

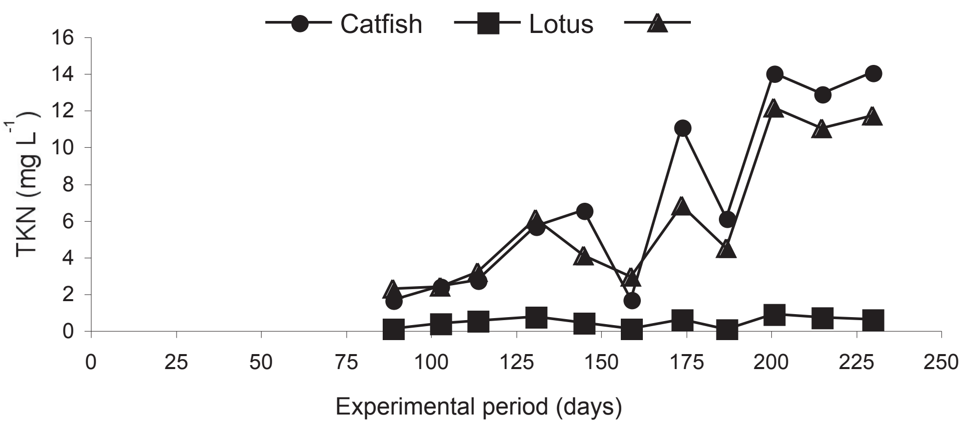


Figure 6. Mean TP (0900 h) in each treatment over time.

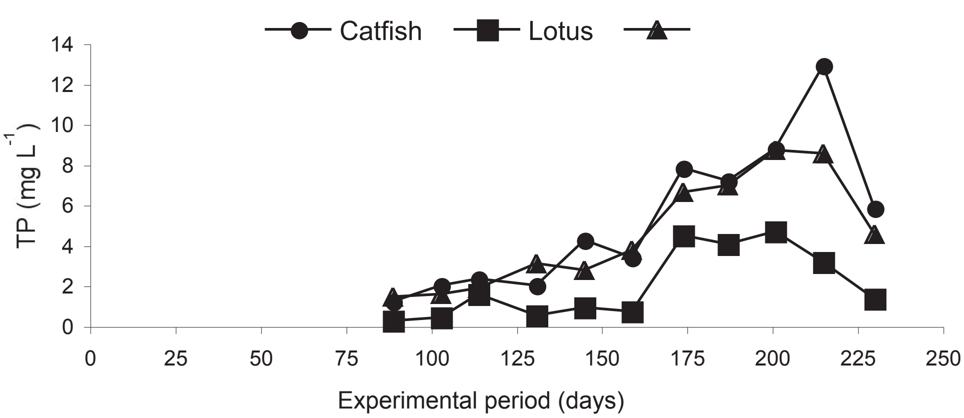


Figure 7. Mean chlorophyll a (0900 h) in each treatment over time.

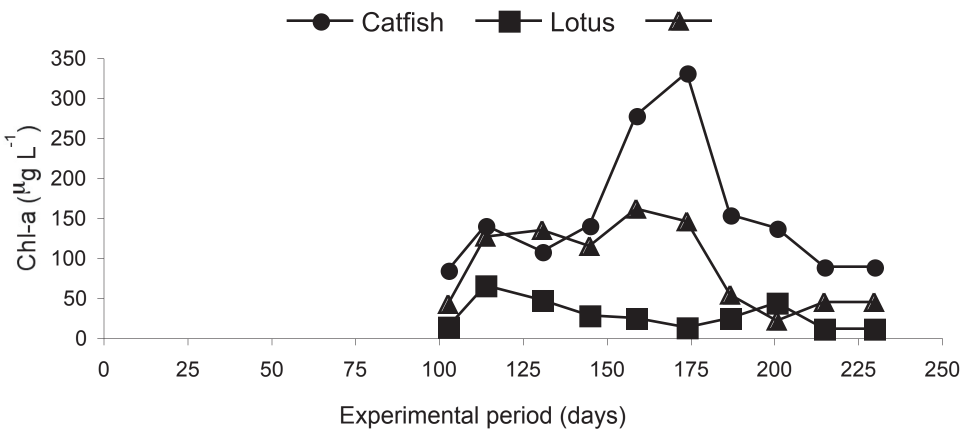


Figure 8. Mean TSS (0900 h) in each treatment over time.

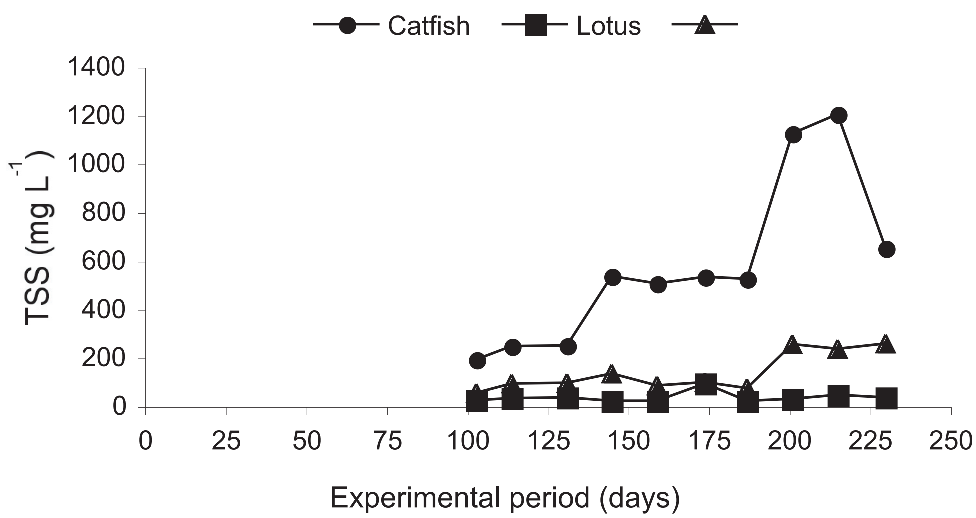
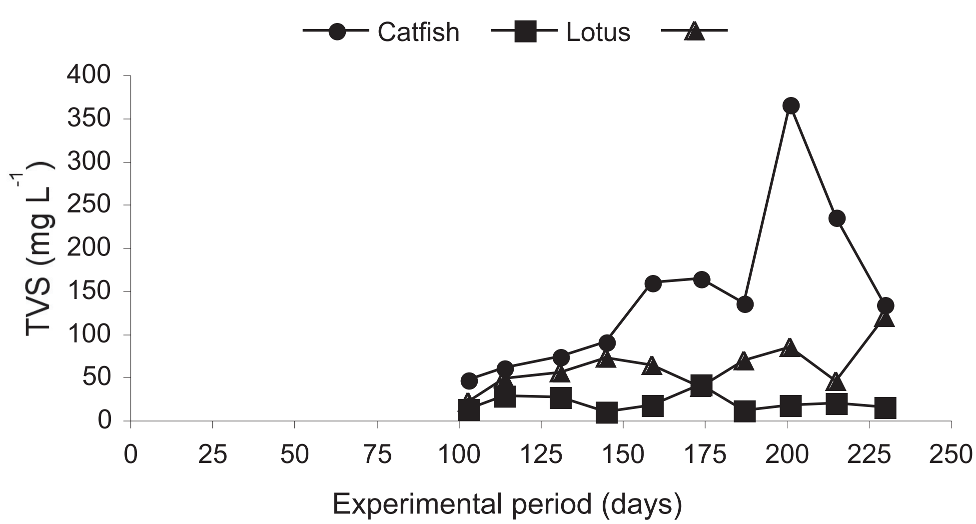


Figure 9. Mean TVS (0900 h) in each treatment over time.



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