Finishing System for Large Tilapia

Interim Work Plan, Thailand Study 4

Yang Yi and C. Kwei Lin
Agricultural and Aquatic Systems
Asian Institute of Technology
Bangkok, Thailand

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Introduction

Nile tilapia (*Oreochromis niloticus*) is cultured primarily in the semi-intensive ponds based on fertilizers or on integrated systems with livestock (Edwards, 1986; 1991). The fish-livestock integrated systems for fish production has been practiced widely for centuries (Pillay, 1992). Nile tilapia cage culture has a relatively short history (Coche, 1982), beginning in the 1970s in the Ivory Coast (Coche, 1974). Since then, the technique has spread progressively to several other regions of the world (Coche, 1982). Caged fish are usually fed with high protein diets; wastes as dissolved nutrients, uneaten feed, and metabolic products from cages are either directly or indirectly released to the surrounding environment, causing accelerated eutrophication in those waters (Beveridge, 1984; Ackefors, 1986; Lin et al., 1989). Those wastes can be reused in fish-livestock integrated systems as a valuable resource in an integrated aquaculture system to generate natural foods for culture of filter feeding species such as Nile tilapia (Lin et al., 1989; Lin, 1990). Such an integrated aquaculture system has been practiced in catfish-tilapia (Lin et al., 1989; Lin, 1990; Lin and Diana, 1995) and in tilapia-tilapia (McGinty, 1991; Yi et al., 1996; Yi and Lin, 1996) cage-cum-pond integrated culture systems.

A series of experiments were designed to develop an integrated rotation culture system in which large Nile tilapia were stocked in cages suspended in earthen ponds while small Nile tilapia were stocked outside the cages in the open pond to utilize the cage wastes and could be harvested from the open pond to restock the cages. Large Nile tilapia (> 500 g) can fetch a much higher price in some countries than smaller Nile tilapia (250-300 g) commonly produced in fertilized pond systems. Caged Nile tilapia can reach 500 g within 90 days when stocked at 50 fish/m^3 in an integrated culture system with one cage in each 330-m^3 pond with 1.0 m or 1.2 m water depth. However, the derived wastes from a single cage were insufficient to generate abundant natural foods for the growth of open-pond tilapia (Yi et al., 1996). A greater biomass of large tilapia could be accomplished by adding more cages, not stocking at high densities in cages to maximize production of both caged and open-pond tilapia, and maintaining acceptable water quality (Yi et al., 1996). Growth performance of caged and open-pond tilapia significantly decreased and increased, respectively, with the increased number of cages from 1 to 4 per pond. However, the net yield of caged tilapia in each pond leveled off with the increased biomass of caged tilapia in a pond, indicating that the carrying capacity of caged tilapia might be exceeded in the earthen ponds stocked with small tilapia at 2 fish/m^3. The highest net yield of caged tilapia and total net yield of both caged and open-pond tilapia were achieved in the ponds with two cages, but the final size did not reach the desirable market size (> 500 g) (Yi and Lin, 1996). High numbers of open-pond tilapia decreased the growth of caged tilapia (McGinty, 1991), and lowering the stocking density of open-pond tilapia may be the best way to increase the harvested size of both caged and open-pond tilapia for optimizing the tilapia-tilapia cage-cum-pond integrated culture system.

The purposes of this study were to determine effects of stocking densities of open-pond small tilapia on the growth performance of both caged and open-pond tilapia and to compare the growth performance of both large and small tilapia in the integrated culture system and mixed pond culture system.

Table 1. Experimental design.

Small Nile Tilapia in Open Ponds	Large Nile Tilapia	
	Two Cages per Pond (2 x 200 Tilapia per Pond)	*No Cage in Pond (2 x 200 Tilapia per Pond)*
Low Stocking Density (1.4 fish/m^3)	Low-Integrated	Low-Mixed
High Stocking Density (2 fish/m^3)	High-Integrated	High-Mixed

Materials and Methods

The data were collected from an experiment conducted for 84 days during July-September 1995 at the Asian Institute of Technology (AIT) in Thailand. Four hundred large tilapia (122-125 g) were stocked in 4-m^3 net cages in each of six ponds with two cages, and at large in open water in each of six ponds without cages. Small tilapia (15-16 g) were stocked at two densities, 1.4 and 2 fish/m^3, in open water of all ponds four days after the large tilapia were stocked (Table 1). The stocking density of 1.4 fish/m^3 was chosen was that the main purpose of the study was to develop a rotation system and at such a stocking density the total number of harvested open-pond tilapia in a pond was just enough to be stocked in two cages in the pond for a next culture cycle. Both large and small Nile tilapia were sex-reversed males by methyl-testosterone treatment in fry stage.

The experiment was conducted in a 2 x 2 factorial design in twelve ponds, of which eight ponds were 335 m^2 in surface area with 1.2-m water depth (Table 1). Four of those eight ponds were designated as block I and the remaining four block II. To make up a triplicate experimental design, four ponds of 394 m^2 in surface area with 1.0-m water depth were designated as block III. The water volume of each pond was approximately 330 m^3. One replication from each treatment was assigned randomly to one pond in each block. Two metal frame cages (2 x 2 x 1.2 m) covered with 2-cm mesh nylon net were suspended to a depth of 1 m in each of the six ponds with cages. The 9-m^2 bottom of shallower ponds was deepened by 20 cm below each cage to keep cage floors 20 cm off pond bottoms. Two cages were arranged at the two ends of each pond and 2 m apart from bottom lines along the pond central line. To confine floating pellets within the cages, a fine mesh polyethylene net was fixed 5 cm above to 15 cm below the water surface on the outside of each cage. A wooden or bamboo walkway connected each cage to the pond bank. The cages were covered with nylon nets to prevent fish losses from jumping or bird predation.

Water was refilled weekly to replace water loss due to seepage and evaporation. No fertilizer was added to any experimental pond. Commercial floating pellets (crude protein 30%, Charoen Pokphand Co., Ltd.) were given to cages in the integrated culture system and open water in the mixed pond culture system at 0900 and 1600 hour six days per week. Feeding rates were 3%, 2.5% and 2% body weight of large tilapia per day during the first, second, and third months, respectively. The feed ration was adjusted daily based on the mortality and biweekly sample weight of large tilapia. Small tilapia stocked in open water in the ponds without cages were not given artificial feed.

Average weights of tilapia were determined biweekly by bulk weighing 40 large and small tilapia each per pond. Large tilapia in cages were sampled by dip net and tilapia at large by seine. Tilapia were harvested, counted, and bulk weighed at the end of the experiment.

The loadings of total nitrogen and total phosphorus by tilapia waste products from cages to pond water were estimated by deducting nitrogen (N) and phosphorous (P) contents in carcasses of harvested and dead caged tilapia from those in feed input.

Water samples integrated from the entire water column were taken biweekly from a platform at the center part of each pond at about 0900 hours for the analysis of pH, total ammonia-nitrogen and chlorophyll-*a* (APHA, 1985). Un-ionized ammonia-nitrogen was calculated by a conversion table for pH and temperature (Boyd, 1990). Water temperature and DO concentrations were measured

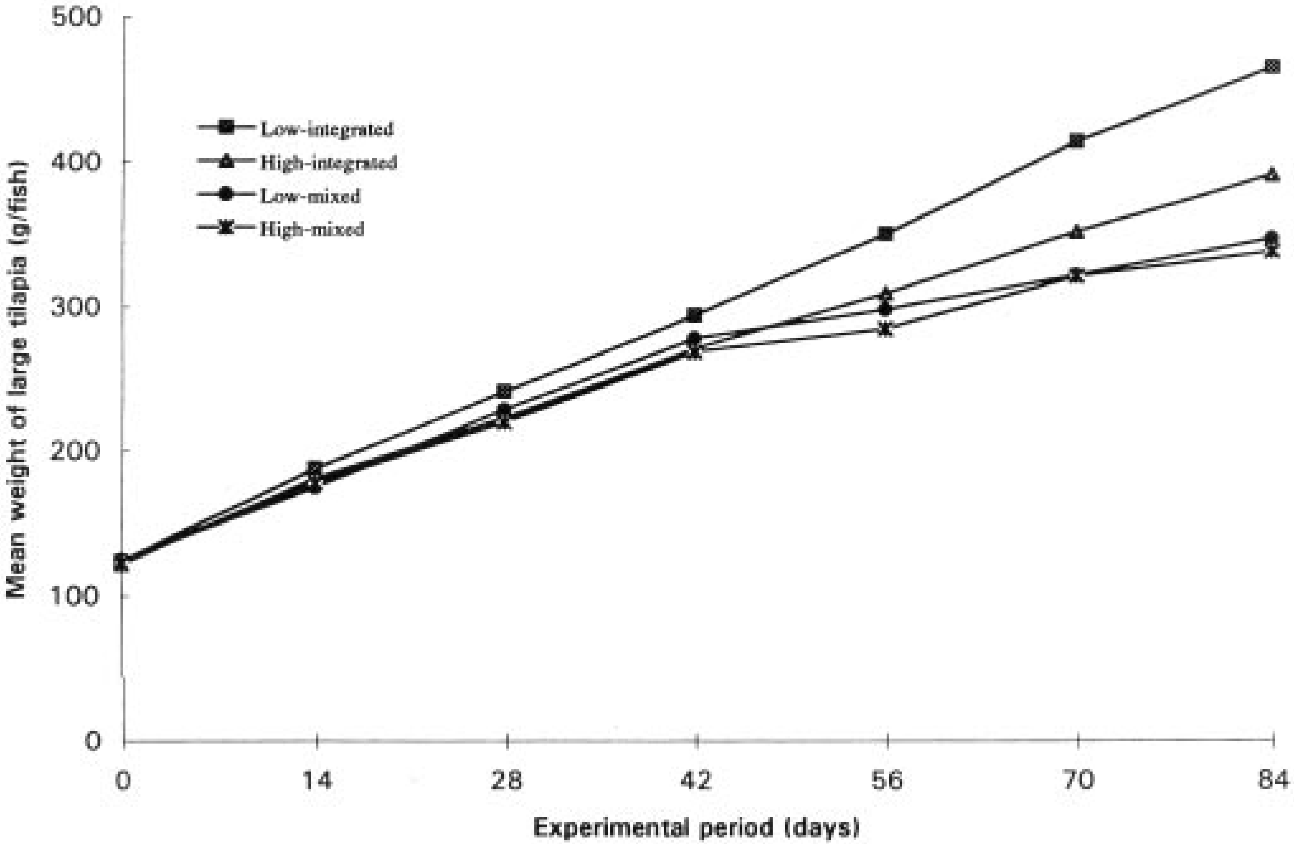

Figure 1. Growth of large Nile tilapia in the integrated and mixed pond culture systems over the experimental period.

in situ biweekly at 0600-0700 and 1500-1600 hours with an oxygen meter (YSI model 54).

Data were analyzed statistically by analysis of variance and regression (Steele and Torrie, 1980) using the Statgraphics 7 statistical software package. Differences were considered significant at an alpha of 0.05. All means were given with ± 1 standard error (S.E.).

Results

Effects of Stocking Densities of Open-pond Tilapia

Stocking densities of open-pond tilapia had significant effects on the growth of both caged and open-pond tilapia, and also on the feed conversion ratio in the integrated culture system (Tables 2, 3, and 4). Caged tilapia had higher survival in the low density treatment (98.8%) than in the high density treatment (97.5%), but there were no significant differences. The growth of caged tilapia began to differ at the time of the first sampling during the growout period (Figure 1). Mean individual weight and daily weight gain were significantly greater in the low density treatment (465 g and 4.06 g/fish) than in the high density treatment (391 g and 3.20 g/fish), giving significantly higher net yield in the low density treatment (4.3 t/ha/crop) than in the high density treatment (3.3 t/ha/crop). Feed conversion ratio was significantly lower in the low density treatment (1.22) than in the high density treatment (1.49).

Survival of open-pond tilapia was higher in the low density treatment (92.0%) than in the high density treatment (86.2%) but without significant differences. The growth of open-pond tilapia in the low density treatment with a daily weight gain of 1.35 g/fish and mean individual weight of 124 g was significantly faster than in the high density treatment with a daily weight gain of 1.02 g/fish and mean individual weight of 97 g (Figure 2). However, the extrapolated net yield of open-pond tilapia was similar in both treatments, that is, 1.6 and 1.5 t/ha/crop in the low and high density treatments, respectively.

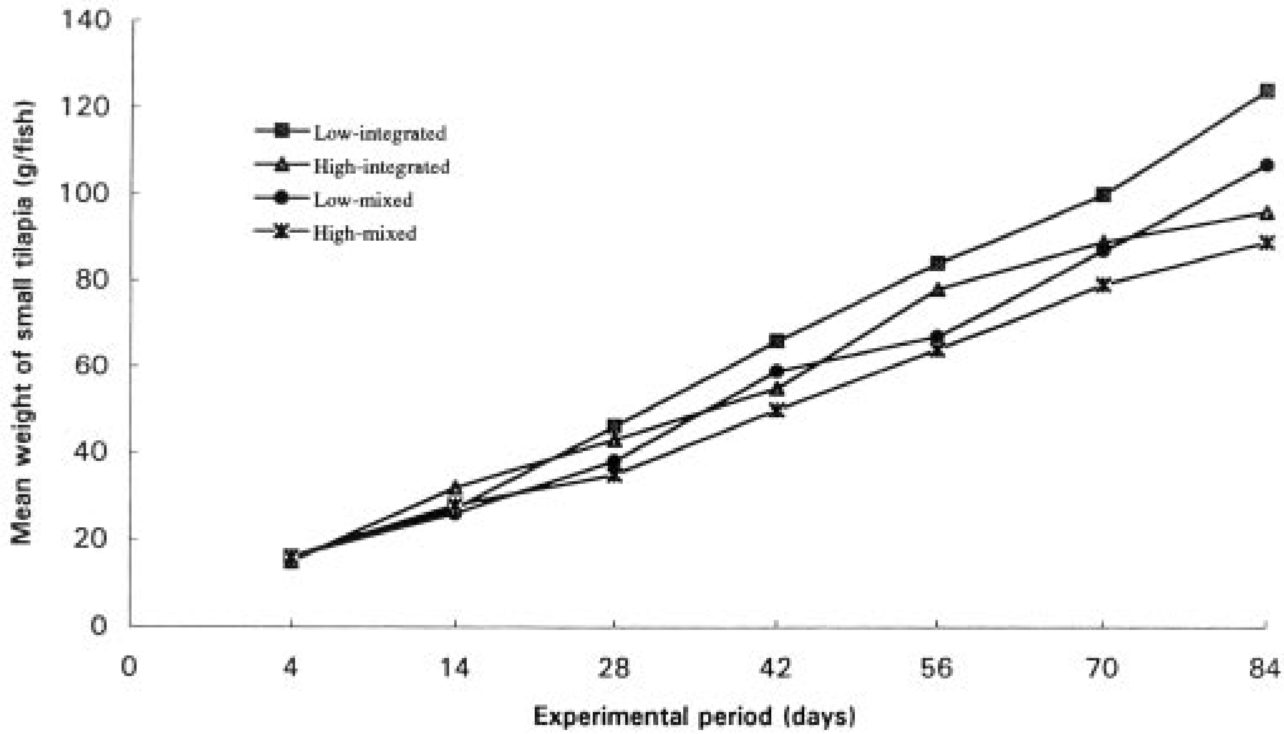

Figure 2. Growth of small Nile tilapia in the integrated and mixed pond culture systems over the experimental period.

Table 2. Growth performance of large Nile tilapia stocked in cages in the integrated culture system and in open water in the mixed culture system.

Performance Measures	Treatments			
	Low-Integrated	*High-Integrated*	*Low-Mixed*	*High-Mixed*
STOCKING				
Total No. (fish/pond)	400	400	400	400
Total Biomass (kg/pond)	49.5 ± 1.6	48.9 ± 2.3	50.0 ± 1.3	49.4 ± 0.3
Mean Wt. (g/fish)	124 ± 4.8	125 ± 3.2	122 ± 5.2	124 ± 0.7
HARVEST				
Total Biomass (kg/pond)	183.8 ± 4.0[a]	137.7 ± 4.0[c]	152.4 ± 4.8[b]	134.6 ± 1.8[c]
Mean Wt. (g/fish)	465 ± 11.5[a]	347 ± 10.5[c]	391 ± 19.4[b]	338 ± 4.3[c]
WEIGHT GAIN				
Total Biomass Gain (kg/pond)	134.4 ± 2.4[a]	87.6 ± 3.5[c]	103.5 ± 2.6[b]	85.3 ± 1.7[c]
Mean Wt. Gain (g/fish)	341 ± 7.6[a]	221 ± 9.2[c]	269 ± 13.9[b]	215 ± 4.2[c]
Daily Wt. Gain (g/fish/day)	4.06 ± 0.09[a]	2.64 ± 0.11[c]	3.20 ± 0.1[b]	2.56 ± 0.05[c]
Net Yield (t/ha/crop)	4.3 ± 0.1[a]	2.8 ± 0.1[c]	3.3 ± 0.1[b]	2.7 ± 0.1[c]
Survival (%)	98.8 ± 0.5	99.3 ± 0.1	97.5 ± 1.7	99.5 ± 0.5
Feed Conversion Ratio (kg feed/kg fish)	1.22 ± 0.02[a]	1.70 ± 0.03[c]	1.49 ± 0.01[b]	1.71 ± 0.07[c]
Gross Yield (t/ha/crop)	5.9 ± 0.1[a]	4.4 ± 0.1[c]	4.9 ± 0.2[b]	4.3 ± 0.1[c]

* Mean values with different superscript letters in the same row were significantly different ($P < 0.05$).

Table 3. Growth performance of small Nile tilapia stocked in open water in the integrated culture system and the mixed culture system.

Performance Measures	Treatments			
	Low-Integrated	*Low-Mixed*	*High-Integrated*	*High-Mixed*
STOCKING				
Density (fish/m^3)	1.4	1.4	2	2
Total No. (fish/pond)	462	462	660	660
Total Biomass (kg/pond)	7.2 ± 0.6	7.3 ± 0.3	10.0 ± 0.5	10.6 ± 0.9
Mean Wt. (g/fish)	16 ± 1.3	16 ± 0.6	15 ± 0.8	16 ± 1.4
HARVEST				
Total Biomass (kg/pond)	52.6 ± 0.7^{ab}	41.8 ± 2.4^{c}	54.7 ± 2.4^{a}	50.9 ± 1.7^{b}
Mean Wt. (g/fish)	124 ± 1.8^{a}	107 ± 8.3^{b}	97 ± 8.3^{bc}	89 ± 7.5^{c}
WEIGHT GAIN				
Total Biomass Gain (kg/pond)	45.4 ± 0.4^{a}	34.5 ± 2.3^{c}	44.7 ± 1.9^{a}	40.3 ± 1.7^{b}
Mean Wt. Gain (g/fish)	108 ± 3.1^{a}	92 ± 8.0^{b}	81 ± 7.7^{bc}	73 ± 6.1^{c}
Daily Wt. Gain (g/fish/day)	1.35 ± 0.04^{a}	1.14 ± 0.10^{b}	1.02 ± 0.10^{bc}	0.92 ± 0.08^{c}
Net Yield (t/ha/crop)	1.6 ± 0.0^{a}	1.2 ± 0.1^{c}	1.5 ± 0.1^{a}	1.4 ± 0.0^{b}
SURVIVAL (%)	92.0 ± 2.6	84.8 ± 10.1	86.2 ± 4.5	86.8 ± 7.4
GROSS YIELD (t/ha/crop)	1.8 ± 0.0^{a}	1.4 ± 0.1^{c}	1.8 ± 0.1^{a}	1.7 ± 0.1^{b}

* Mean values with different superscript letters in the same row were significantly different ($P < 0.05$).

The extrapolated total net yield including both caged and open-pond tilapia in the integrated culture system were significantly higher in the low density treatment (5.5 t/ha/crop) than in the high density treatment (4.5 t/ha/crop). The overall feed conversion ratio in the low density treatment was 0.92, which was significantly better than that in the high density treatment (1.04).

The total nitrogen and phosphorous contained in waste products from caged tilapia during the 84-day culture period were 4.86 and 5.00 kg N and 1.03 and 1.09 kg P in the low and high density treatments, respectively. Accordingly, those nutrient outputs fertilized the ponds at rates of 1.75 and 1.80 kg N/ha/day, and 0.37 and 0.39 kg P/ha/day, giving N:P ratios of 4.73 and 4.58 in the low and high density treatments, respectively.

Water temperature and pH in all ponds with cages ranged from 28.4 to 31.5°C, and from 7.0 to 7.8°C, respectively, throughout the experiment. The measured DO concentrations at dawn were apparently higher in the low density treatment than in the high density treatment throughout the experiment (Figure 3). Un-ionized NH_3-N concentration increased gradually from the initial level of 0 mg/l to the final levels of 0.07 and 0.05 mg/l in the low and high density treatments, respectively, throughout the experiment (Figure 4). The phytoplankton standing crops as expressed in chlorophyll-*a* concentrations were generally low but higher in the low density treatment than in the high density treatment (Figure 5).

Comparisons Between the Integrated and Mixed Pond Culture Systems

Large tilapia grew significantly better in cages in the integrated culture system than in open water in the mixed pond culture system at the same level of stocking densities of small tilapia (Table 2 and Figure 1). However, there were no significant differences in survival for all treatments, which

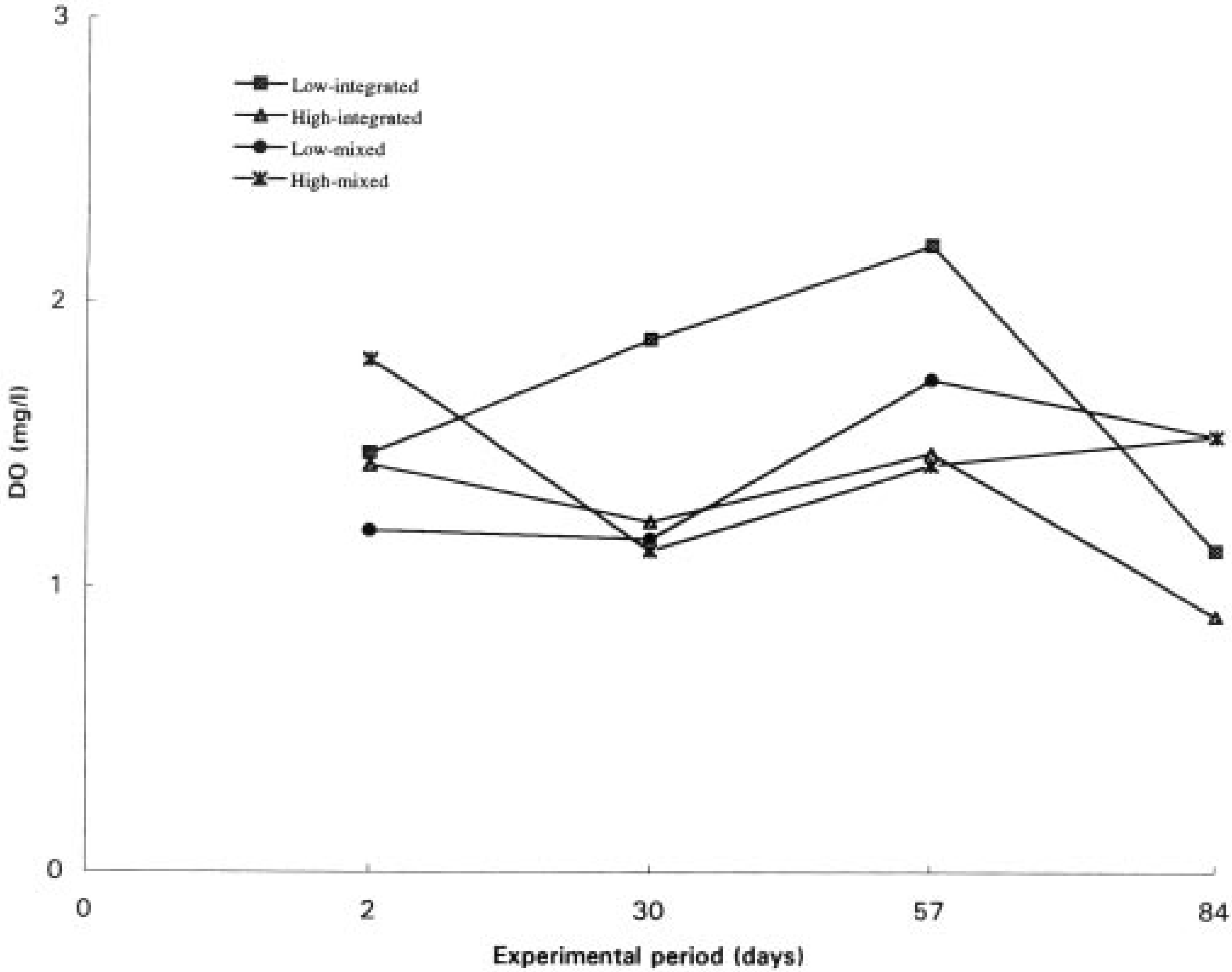

Figure 3. Fluctuations in DO at dawn in all treatments throughout the experimental period.

ranged from 97.5% to 99.5%. The extrapolated net yields of large tilapia in the integrated culture system were 4.3 in the low density treatment and 3.3 t/ha/crop in the high density treatment; these were significantly higher than those in the low (2.8 t/ha/crop) and high (2.7 t/ha/crop) density treatments in the mixed pond culture system. Feed conversion ratios were significantly lower in the integrated culture system than those in the mixed pond culture system. In the integrated culture system, the growth performance of large tilapia in the low density treatment was significantly better than in the high density treatment; however, it was similar between the low and high density treatments in the mixed pond culture system.

Survival of small tilapia, ranging from 84.8% to 92.0%, was not significantly different among all treatments (Table 3). At the same stocking density, the growth of small tilapia was significantly faster in the integrated culture system with daily weight gains of 1.35 and 1.02 g/fish and mean individual weights of 124 and 97 g than in the mixed pond culture system with daily weight gains of 1.14 and 0.92 g/fish and mean individual weights of 107 and 89 g in the low and high density treatments, respectively (Figure 2). In spite of the significantly better growth of small tilapia in the low density treatment (1.35 g/fish/day) than in the high density treatment (1.02 g/fish/day) in the integrated culture system, there were no significant differences in net yields between them (1.6 and 1.5 t/ha/crop, respectively). In the mixed pond culture system, however, the net yield of small tilapia in the high density treatment (1.4 t/ha/crop) was significantly higher than in the low density treatment (1.2 t/ha/crop), even though the growth of small tilapia was significantly faster in the low density treatment (1.14 g/fish/day) than in the high density treatment (0.92 g/fish/day).

Table 4. Combined growth performance of both large and small Nile tilapia cultured in the integrated culture system and the mixed pond culture system.

Performance Measures	Treatments			
	Low-Integrated	*Low-Mixed*	*High-Integrated*	*High-Mixed*
Initial Fish Biomass (kg/pond)	56.7 ± 2.1	57.4 ± 1.2	59.0 ± 2.2	60.0 ± 0.7
Final Fish Biomass (kg/pond)	236.4 ± 4.3[a]	179.5 ± 4.3[c]	207.1 ± 5.1[b]	185.3 ± 0.6[c]
Fish Biomass Gain (kg/pond)	179.7 ± 2.2[a]	122.1 ± 3.4[c]	148.1 ± 2.9[b]	125.5 ± 1.3[c]
Net Fish Yield (t/ha/crop)	5.8 ± 0.1[a]	4.0 ± 0.1[c]	4.8 ± 0.1[b]	4.1 ± 0.1[c]
Gross Yield (t/ha/crop)	7.8 ± 0.1[a]	5.9 ± 0.1[c]	6.8 ± 0.2[b]	6.1 ± 0.1[c]
Overall FCR	0.92 ± 0.01[a]	1.22 ± 0.01[d]	1.04 ± 0.01[b]	1.16 ± 0.03[c]

* Mean values with different superscript letters in the same row were significantly different ($P < 0.05$).

The combined extrapolated net yields of both large and small tilapia in the integrated culture system (5.8 and 4.8 t/ha/crop in the low and high density treatments, respectively) were significantly higher than in the mixed pond culture system (4.0 and 4.1 t/ha/crop in the low and high density treatments, respectively) at the same level of stocking density. A significantly better overall feed conversion ratio was achieved in the integrated culture system (0.92 and 1.04) than in the mixed pond culture system (1.22 and 1.16) in the low and high density treatments, respectively. There were no significant differences for all combined growth performance measures except overall feed conversion ratio between the low and high density treatments in the mixed pond culture system; however, all combined growth performance measures in the integrated culture system were significantly better in the low density treatment than in the high density treatment (Table 4).

Water temperature and pH in all treatments ranged from 28.0 to 31.5°C and 7.0 to 7.8°C, respectively, throughout the experimental period. The measured DO concentrations at dawn were apparently higher in the low density treatment in the integrated culture system than other treatments in most of the experimental period; however, DO concentrations in both low and high density treatments in the mixed pond culture system were higher than those in the integrated culture system at the end of the present experiment (Figure 3). Un-ionized NH_3-N concentrations increased gradually from the initial level of 0.00 mg/l to the final level of 0.03-0.07 mg/l for all treatments, which was higher in the integrated culture system than in the mixed pond culture system (Figure 4).

The phytoplankton standing crops as expressed in chlorophyll-*a* concentrations were lower in the integrated culture system than in the mixed pond culture system at the same level of stocking densities (Figure 5).

Discussion

The growth performance (excepting the survival rate) of caged tilapia in the low density treatment was significantly better than in the high density treatment. This confirmed that high numbers of open-pond tilapia decreased growth of caged tilapia (McGinty, 1991). The final mean individual weight of caged tilapia in the low density treatment (465 g) in this experiment was slightly smaller than the desirable market size (> 500 g). This was due to the smaller stocking size (124 g) and shorter growout period (84 days) compared with those (141-152 g and 90 days) in an earlier experiment (Yi et al., 1996). The present experiment was terminated 6 days earlier than the planned 90 days because AIT was facing the threat of a flood. The daily weight gain of caged tilapia in the low density treatment was slightly lower than in ponds with one cage in earlier experiments (Yi et al., 1996; Yi and Lin, 1996); however, it was still much higher than the values reported previously for intensive cage culture of Nile tilapia in ponds (Guerrero, 1979; Guerrero, 1980; McGinty, 1991), in lakes (Coche, 1977, and Campbell, 1978, cited by Coche, 1982) or in thermal effluent (Philippart et al., 1979, cited by Coche, 1982). Feed conversion ratio in the low density treatment was similar to that in ponds with one cage in an earlier experiment (Yi et al., 1996), and both were the lowest values among all the

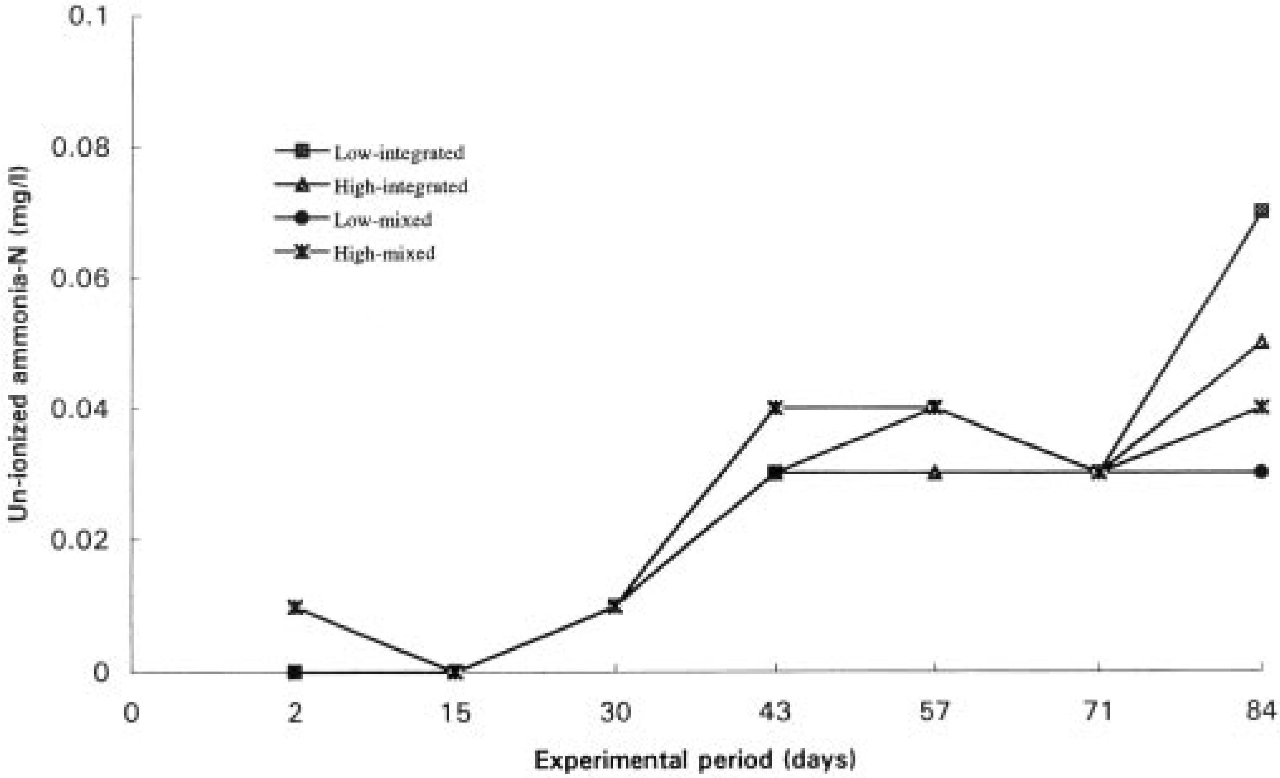

Figure 4. Fluctuations in un-ionized ammonia nitrogen at 0900 hr in all treatments throughout the experimental period.

series of experiments in this study (Yi et al., 1996; Yi and Lin, 1996), and also lower than that reported by Carro-Anzalotta and McGinty (1986), Guerrero (1979, 1980) and McGinty (1991) in ponds, and by Coche (1977, cited by Coche, 1982) and Campbell (1978, cited by Coche, 1982) in lakes. The better growth performance of caged tilapia in the low density treatment was due probably to the higher DO concentrations at dawn in the low density treatment than in the high density treatment.

Even though daily weight gain of open-pond tilapia was significantly higher in the low density treatment than in the high density treatment, there were no significant differences in net yields between these two treatments, due to the higher fish number and lower daily weight gain in the high density treatment. The daily weight gain of open-pond tilapia in the low density treatment was similar to that in ponds with three cages, and much higher than that in ponds with the lower and even same biomass of caged tilapia (one and two cages per pond) in earlier experiments (Yi et al., 1996; Yi and Lin, 1996). However, this value was still lower than the 2.4-2.7 g/fish in a catfish-tilapia cage-cum-pond integrated system (Lin, 1990) and also lower than 2.3 g/fish in a tilapia-tilapia cage-cum-pond integrated system (McGinty, 1991) due mainly to higher stocking density of open-pond tilapia in this experiment.

The extrapolated net yield for both caged and open-pond tilapia in the low density treatment was significantly higher than in the high density treatment and in earlier experiments (Yi et al., 1996; Yi and Lin, 1996) due to better growth performance of both open-pond and caged tilapia in this experiment; it was also higher than in a tilapia-tilapia cage-cum-pond integrated system McGinty (1991).

Further, lowering the stocking density of open-pond tilapia may increase harvested size of open-pond tilapia themselves, but may not achieve the higher total yield, which can be seen in the results reported by McGinty (1991). Also the main purpose of this study was to fatten large tilapia in cages to 500 g size and develop an integrated rotation system for utilizing cage wastes by small tilapia.

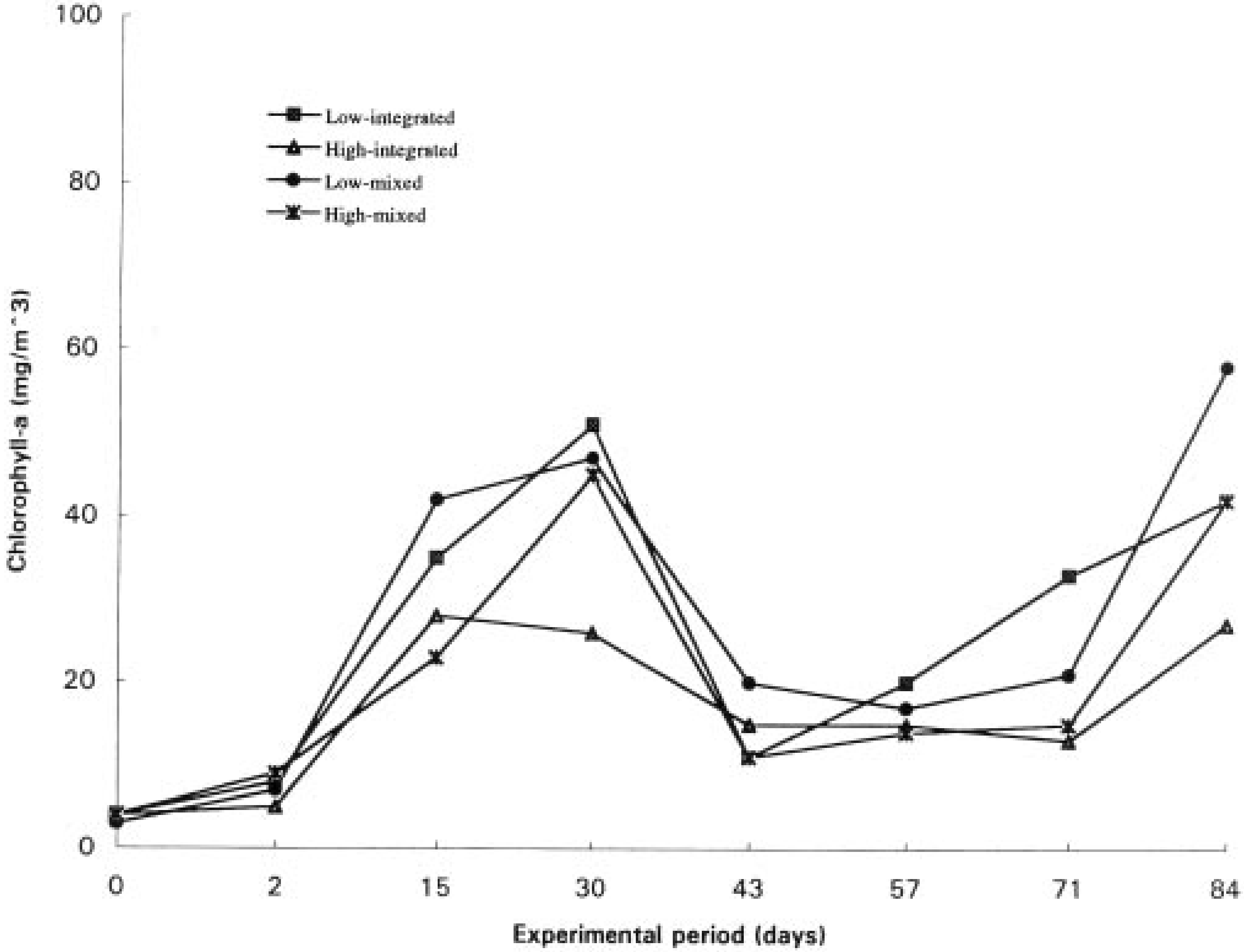

Figure 5. Fluctuations in chlorophyll-*a* at 0900 hr in all treatments throughout the experimental period.

At the 1.4 fish/m^3 stocking density of open-pond tilapia, the total number of harvested open-pond tilapia in a pond is just enough to be stocked in two cages in the pond and the size at harvest of open-pond tilapia is also just large enough to restock the cages for a next culture cycle, thus making the integrated culture system rotate. Therefore, the low density treatment was the optimal tilapia-tilapia cage-cum-pond integrated rotation culture system.

There were no significant differences in the survival of large tilapia between the integrated culture system and mixed pond culture system although the survival was slightly lower in the former two levels of stocking densities of small tilapia. However, the growth of large tilapia was significantly faster in the integrated culture system than in the mixed pond culture system at two levels of stocking densities of small tilapia in terms of daily weight gain, mean individual weight, and net and gross yields. This proved the statement that cage culture accelerates fish growth compared to the traditional open-water aquaculture (Schmittou, 1993). Furthermore, this rapid growth rate did not sacrifice the feed conversion ratio. In fact, feed conversion ratio in the integrated culture system was significantly better than that in the mixed pond culture system. The growth performance of small tilapia was also significantly better in the integrated culture system than in the mixed pond culture system at the same stocking density of small tilapia. Compared with the common pond culture system for tilapia, one major advantage is the possibility of controlling unwanted recruitment in the integrated culture system. In most cage culture, the initial stocking size of tilapia is quite small (Coche, 1982), and the fish consume costly feed before reaching sizes 100-150 g. However, Diana et al. (1996) indicated that supplemental feeding of Nile tilapia starting at 100-150 g size is probably the most effective to produce large-sized tilapia. In addition, feed costs usually account for the largest portion of total costs in the intensive fish culture. It is apparent that less working capital is needed in the integrated culture system than in other intensive culture systems due to harvesting and marketing tilapia every three months in the integrated culture system, and more frequent marketing also can make products get better prices. Therefore, this tilapia-tilapia cage-cum-pond integrated rotation system is particularly appropriate for small-scale farmers in countries such as Thailand, where large tilapia (> 500 g) fetch much higher market price than 250-300 g tilapia commonly harvested in fertilized ponds.

In the integrated culture system, the growth performance of large tilapia was significantly better in the low density treatment than in the high density treatment, which confirmed the statement that high numbers of open-pond tilapia decreased the growth of caged tilapia (McGinty, 1991). However, lowering stocking densities of small tilapia did not increase the growth of large tilapia in the mixed pond culture system, and small tilapia showed slower growth in the mixed pond culture system than in the integrated culture system. These are similar to the results reported by Knud-Hansen and Lin (in press) that the growth of adult Nile tilapia would not be affected by the co-existing fingerlings, but not the reverse. Their experiment was conducted in highly fertilized ponds, and it is difficult to imagine that adult tilapia limited fingerling growth by out-competing fingerlings for phytoplankton. They stated that it is more probable that territorial aggressive behavior noted among male tilapia (Balarin and Haller, 1982; Owusu-Frimpong, 1987) occurred only between fish of similar size or greater. Fishelson (1983) observed a strong correlation between social rank and aggressive activity among male tilapia. Fish high up on the hierarchy needed only to swim by lesser fish to maintain dominance. In the mixed pond culture system of the present experiment, supplemental feeds were given by pouring into the center of ponds. Large tilapia apparently dominated in getting feed, and small tilapia seemed to have little chance to getting feed. Thus, adults would not be affected by fingerlings. On the other hand, small tilapia in the mixed pond culture system showed a density-dependent growth pattern and a similar positive relationship between initial stocking density and net yield to those reported by Knud-Hansen (in press) and Milstein et al. (1988), indicating food limitation did not occur. Furthermore, small tilapia grew better when large tilapia were confined in cages than when they were mixed together with small tilapia. This may indicate that the co-existing large tilapia would affect the growth of small tilapia by territorial aggressive behavior. The results of this experiment may suggest that the competition for space is probably the main reason why small tilapia would be affected by large tilapia, but not the reverse at least in the ponds receiving supplemental feeds.

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