CULTURE OF MIXED-SEX NILE TILAPIA WITH PREDATORY SNAKEHEAD

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Abstract

An experiment was conducted in eighteen 200-m^2 fertilized earthen ponds at the Asian Institute of Technology, Thailand, during March-October 2000. This experiment was designed to assess the efficiency of snakehead (*Channa striata)* in controlling recruitment of mixed-sex Nile tilapia (*Oreochromis niloticus*) in ponds and to assess growth and production characteristics of Nile tilapia in monoculture and polyculture with snakehead. There were six treatments: (A) monoculture of sex-reversed all-male tilapia; (B) monoculture of mixed-sex tilapia; (C) polyculture of snakehead and mixed-sex tilapia at 1:80 ratio; (D) polyculture of snakehead and mixed-sex tilapia at 1:40 ratio; (E) polyculture of snakehead and mixed-sex tilapia 1:20 ratio; (F) polyculture of snakehead and mixed-sex tilapia at 1:10 ratio. Both generic types of Nile tilapia were stocked at 2 fish m^{-2} at sizes of 10.5-11.6 g and 7.2-8.1 g, respectively.

Results show that snakehead were able to completely control Nile tilapia recruitment at all tested predator:stocked-prey ratios and the best predator:stocked-prey ratio was 1:80. The addition of snakehead into Nile tilapia ponds did not result in significantly greater tilapia growth, but significantly lowered total net and gross yields of adult plus recruited tilapia. Snakehead growth was density-dependent, decreasing significantly with increasing stocking densities. While snakehead biomass gain was not significantly different at stocking density from 0.025 to 0.1 fish m^{-2}, the gain was significantly lower at stocking density of 0.2 fish m^{-2}. The present experiment demonstrates that snakehead were able to control Nile tilapia recruitment completely and provide an alternative technique for Nile tilapia culture.

Introduction

The aquaculture of species at lower trophic levels, such as tilapia, presents the greatest potential for efficiency (Welcomme 1996). However, overpopulation of tilapia in confined ponds causes stunted growth due to shortage of natural food, particularly in semi-intensive culture. Various methods of population control have been applied (Mair and Little 1991), such as culture in cages, culture with predators, intermittent harvesting, hybridization, induction of sterility, and production of super-male fish (YY-male). However, population control of tilapias by culture with predators has been practiced worldwide but not well studied. Various predatory fish species have been used with varying success in combination with different tilapia species depending on their availability. These species include snakehead (*Channa striata* or *Ophiocephalus striatus*) (Pongsuwana 1956, Chimits 1957, Tongsanga 1962, Chen 1976, Cruz and Shehadeh 1980, Hopkins *et al*. 1982, Wee 1982, Balasuriya 1988); *Ophiocephalus obscuris* (de Graaf *et al*. 1996); *Micropterus salmoides* (Swingle 1960, Meschkat 1967, McGinty 1985); *Lates niloticus* (Meschkat 1967, Planquette 1974, Lazard 1980, Bedawi 1985, El Gamal 1992); *Hemichromis fasciatus* (Bardach *et al*. 1972, Lazard 1980); *Cichla ocellaris* (Lovshin 1977, McGinty 1983, Verani *et al*. 1983); *Clarias sp.* (Meecham 1975, Bard *et al*. 1976, Lazard 1980, Janssen 1985, de Graaf *et al*. 1996); *Cichlasoma managuense* (Dunseth and Bayne 1978); *Elops hawaiiensis* (Fortes 1980); and *Megalops cyprinoides* (Fortes 1980). However, the difficulty in breeding or obtaining predators of the correct size often resulted in limited application of this population control method (Balarin and Hatton 1979, Penman and McAndrew 2000).

Snakehead have long been regarded as valuable food fish and widely cultured in the Far East (Wee 1982). It was reported to be used in polyculture with tilapia to control tilapia population, or with carps to keep out other extraneous pest fish in the pond system (Wee 1982). Snakehead are highly predaceous as they swallow their prey whole (Diana *et al*. 1985), and have been shown to effectively prey on live tilapia fry (Kaewpaitoon 1992). A population including 5% (predator:stocked-prey ratio of 1:20) snakehead with tilapia has been demonstrated to control tilapia recruitment (Balasuriya 1988). Negligible tilapia recruitment was generally found during harvest where snakehead existed in tilapia ponds.

The purposes of the experiment were to assess the efficiency of snakehead in controlling overpopulation of mixed-sex Nile tilapia (*Oreochromis niloticus*) in ponds, and to assess the growth and production of Nile tilapia in monoculture and polyculture with snakehead.

Materials and methods

The experiment was conducted using a randomized complete block design in eighteen 200-m^2 earthen ponds at the Asian Institute of Technology (AIT), Thailand. There were six treatments with triplicates, one in each block: (A) monoculture of sex-reversed all-male tilapia; (B) monoculture of mixed-sex tilapia; (C) polyculture of snakehead and mixed-sex tilapia at 1:80 ratio; (D) polyculture of snakehead and mixed-sex tilapia at 1:40 ratio; (E) polyculture of snakehead and mixed-sex tilapia 1:20 ratio; (F) polyculture of snakehead and mixed-sex tilapia at 1:10 ratio.

The Chitralada strain (Thai strain) of Nile tilapia was used in the present experiment. Nile tilapia fry were obtained from AIT Hatchery, while snakehead fingerlings were purchased from a local market. Sex-reversed Nile tilapia (10.5-11.6 g) and mixed-sex Nile tilapia (7.2-8.1 g) were stocked at 2 fish m^{-2} in treatment A and treatments B through F, respectively, while snakehead (88.0-100.0 g) were stocked at 0.025, 0.05, 0.1 and 0.2 fish m^{-2} in treatments C, D, E, and F, respectively, on 30 March 2000. During the experiment, approximately 10% of the initial Nile tilapia stock was seined, counted and weighed en-masse biweekly for each pond. All fish were harvested on 10 October 2000 after 194 days of culture. Daily weight gain (g $fish^{-1}d^{-1}$), yield (kg $pond^{-1}$) and extrapolated yield (kg ha^{-1} $year^{-1}$) were calculated.

All ponds were dried for one month prior to the experiment to eliminate wild fish. Each pond dike was enclosed with a fine mesh net fence about 1 m tall, supported by bamboo sticks, with the lower end of the net buried in the dike soil to prevent entry of wild fish and movement of stocked snakehead from one pond to another. All ponds were fertilized with urea and triple super phosphate (TSP) at a rate of 28 kg nitrogen (N) and 7 kg phosphorus (P) ha^{-1} $week^{-1}$. Initial pond fertilization took place two weeks prior to fish stocking. Water depth in all ponds was maintained at 1 m throughout the experiment by adding water weekly to replace evaporation and seepage losses.

Integrated water samples were taken biweekly from the entire water column near the center of each pond at about 1000 h for analyses of pH, alkalinity, total ammonium nitrogen (TAN), nitrite nitrogen, nitrate nitrogen, total Kjeldahl nitrogen (TKN), soluble reactive phosphorus (SRP), total phosphorus (TP), chlorophyll *a*, total suspended solids (TSS) and total volatile solids (TVS) (APHA *et al.* 1985; Egna *et al.* 1987). Secchi disk visibility, temperature and dissolved oxygen (DO) were also measured at the time of collecting water samples with a Secchi disk and YSI model 54 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio, USA), respectively. Diel measurements for temperature, DO and pH were conducted monthly in each pond at 0600, 1000, 1400, 1600, 1800, and 0600 h.

Data were analyzed statistically by analysis of variance and linear regression (Steele and Torrie, 1980) using SPSS (version 7.0) statistical software package (SPSS Inc., Chicago, USA). Differences were considered significant at an alpha level of 0.05. Statistical analyses for survival rates (%) were performed on the transformed data by arcsine transformation. Mean values of survival rates were given in the back-transformed scale followed by their confidence limits. All other means were given with ±1 standard error (S.E.).

A partial budget analysis was conducted to determine economic returns of the different monoculture and polyculture systems tested (Shang 1990). The analysis was based on farm-gate prices in Thailand for harvested fish and current local market prices for all other items expressed in US dollar (US$1 = 40 baht). Farm-gate price of snakehead and Nile tilapia varied with size: snakehead at $0.25 kg^{-1} for size 100-200 g, $0.50 kg^{-1} for size 200-300 g, $0.75 kg^{-1} for size 300-400 g, and $1.00 kg^{-1} for size above 400 g, and Nile tilapia at

$0.125 kg^{-1} for size below 50 g, and $0.375 kg^{-1} for size 100-200 g. Market prices for fingerlings of snakehead ($0.15 kg^{-1}), sex-reversed Nile tilapia ($0.0125 piece^{-1}) and mixed-sex Nile tilapia ($0.0042 pieces^{-1}), urea ($0.1875 kg^{-1}) and TSP ($0.3125 kg^{-1}) were applied to the analysis. The calculation for cost of working capital was based on an annual interest rate of 8%.

Results

Growth performance parameters of adult Nile tilapia were not significantly different among all treatments ($P > 0.05$, Table 1). Tilapia offspring were only found in monoculture of mixed-sex tilapia. Both sex-reversal and predator techniques were able to control the recruitment of Nile tilapia completely. However, neither sex reversal nor polyculture resulted in significantly faster growth of adult tilapia compared with monoculture of mixed-sex tilapia ($P > 0.05$). Furthermore, both techniques resulted in significantly lower total net and gross yields of adult plus recruited tilapia ($P < 0.05$, Table 1).

Survival of snakehead was not significantly different among polyculture treatments ($P > 0.05$, Table 2). Snakehead growth (mean weight at harvest and daily weight gain) was density-dependent, decreasing significantly with increased stocking densities ($P < 0.05$, Table 2 and Fig.1). Mean weight at harvest and daily weight gain of snakehead were inversely related to stocking density of snakehead or predator:stocked-prey ratio ($r = -0.904$, $P < 0.05$ for mean weight, and $r = -0.985$, $P<0.05$ for daily weight gain). Snakehead biomass gain (total weight gain and net yield) was not significantly different ($P > 0.05$) within stocking densities of 0.025 to 0.1 fish m^{-2} (treatments C, D and E). At a stocking density of 0.2 fish m^{-2} (treatment F), snakehead biomass gain was significantly lower than in other densities ($P < 0.05$, Table 2 and Fig. 2). The significantly reduced individual growth and biomass gain at the stocking density of 0.2 fish m^{-2} indicated that carrying capacity of snakehead was exceeded.

The additional net yield from snakehead did not cause significantly higher combined net yield of adult tilapia and snakehead ($P > 0.05$), but resulted in significantly higher combined gross yield of adult tilapia and snakehead ($P < 0.05$, Table 3). When recruited tilapia were included, the combined net yield in the monoculture of mixed-sex tilapia (treatment B) was significantly higher than that in all other treatments ($P < 0.05$), while the combined gross yield in the monoculture of mixed-sex tilapia was similar to those in the polyculture with higher predator:stocked-prey ratios (treatments E and F, $P > 0.05$, Table 3). The results indicate that the predator:stocked-prey ratio of 1:80 (treatment C) is enough to completely control Nile tilapia recruitment.

Table 1. Growth performance (mean ± SE) of Nile tilapia in fertilized earthen ponds during 194-day culture. Rows of values with superscripts indicate variables with significant differences among treatments (ANOVA, p<0.05). Values with similar letter superscripts are not significantly different.

Parameters	Treatments					
	A (sex-reversed)	B (mixed-sex)	C (1:80)	D (1:40)	E (1:20)	F (1:10)
Stocking						
Density (fish m^{-2})	2	2	2	2	2	2
Total number (fish $pond^{-1}$)	400	400	400	400	400	400
Mean weight (g $fish^{-1}$)	9.0±0.4	7.4±0.1	7.7±0.1	7.5±0.3	7.6±0.0	7.7±0.3
Total weight (kg $pond^{-1}$)	3.62±0.17	2.96±0.05	3.08±0.04	3.01±0.12	3.02±0.01	3.07±0.13
Harvest						
Adult tilapia						
Total number (fish $pond^{-1}$)	331±10	330±12	322±4	312±8	323±9	327±10
Mean weight (g $fish^{-1}$)	157.7±17.5	149.8±16.3	158.0±10.0	152.9±13.5	158.2±15.3	155.3±13.9
Total weight (kg $pond^{-1}$)	51.90±4.60	49.03±3.89	50.88±3.17	47.64±4.18	50.94±4.05	50.60±3.92
Survival Rate (%) Range	82.90 (78.28-87.07)	82.61 (77.97-86.81)	80.52 (75.69-84.93)	77.99 (72.97-82.63)	80.93 (76.14-85.30)	81.88 (77.17-86.15)
Daily weight gain (g $fish^{-1}$ d^{-1})	0.77±0.09	0.73±0.08	0.77±0.05	0.75±0.07	0.78±0.08	0.76±0.07
Total weight gain (kg $pond^{-1}$)	48.28±4.43	46.07±3.93	47.80±3.21	44.63±4.12	47.92±4.06	47.53±3.87
Net yield (t ha^{-1} $year^{-1}$)	4.54±0.42	4.33±0.37	4.50±0.30	4.19±0.39	4.51±0.38	4.47±0.36
Gross yield (t ha^{-1} $year^{-1}$)	4.88±0.43	4.61±0.37	4.79±0.30	4.48±0.39	4.79±0.38	4.76±0.37
Recruited tilapia						
Total number (fish $pond^{-1}$)	----	951±191	----	----	----	----
Mean weight (g $fish^{-1}$)	----	9.9±0.5	----	----	----	----
Total weight (kg $pond^{-1}$)	----	9.32±1.65	----	----	----	----
Net and gross yield (t ha^{-1} $year^{-1}$)	----	0.88±0.15	----	----	----	----
Combined adult and recruited fish						
Total net yield (t ha^{-1} $year^{-1}$)	4.54±0.42 [a]	5.21±0.22 [b]	4.50±0.30 [a]	4.20±0.39 [a]	4.51±0.38 [a]	4.47±0.36 [a]
Total gross yield (t ha^{-1} $year^{-1}$)	4.88±0.43 [a]	5.49±0.22 [b]	4.79±0.30 [a]	4.48±0.39 [a]	4.79±0.38 [a]	4.76±0.37 [a]

Table 2. Growth performance (mean ± SE) of snakehead in fertilized earthen ponds during 194-day polyculture with Nile tilapia. Rows of values with superscripts indicate variables with significant differences among treatments (ANOVA, $p<0.05$). Values with similar letter superscripts are not significantly different.

Parameters	Treatments					
	A (sex-reversed)	B (mixed-sex)	C (1:80)	D (1:40)	E (1:20)	F (1:10)
Stocking						
Density (fish m^{-2})	----	----	0.025	0.05	0.1	0.2
Total number (fish $pond^{-1}$)	----	----	5	10	20	40
Mean weight (g $fish^{-1}$)	----	----	94.5±2.4	93.7±3.5	95.8±2.2	95.7±2.2
Total weight (kg $pond^{-1}$)	----	----	0.47±0.01	0.94±0.03	1.92±0.04	3.83±0.09
Harvest						
Total number (fish $pond^{-1}$)	----	----	4±0	8±0	19±1	35±2
Mean weight (g $fish^{-1}$)	----	----	441.3±18.1^{a}	292.0±11.6^{b}	179.3±12.0^{c}	123.3±4.2^{d}
Total weight (kg $pond^{-1}$)	----	----	1.91±0.12^{a}	2.43±0.04^{b}	3.33±0.13^{c}	4.30±0.08^{d}
Survival Rate (%)	----	----	90.75 (70.25-99.83)	83.64 (60.06-97.81)	95.47 (78.49-99.72)	88.23 (66.43-99.32)
Daily weight gain (g $fish^{-1}$ d^{-1})	----	----	1.79±0.08^{a}	1.02±0.04^{b}	0.43±0.07^{c}	0.14±0.02^{d}
Total weight gain (kg $pond^{-1}$)	----	----	1.43±0.13^{a}	1.49±0.04^{a}	1.42±0.17^{a}	0.47±0.15^{b}
Net yield (t ha^{-1} $year^{-1}$)	----	----	0.14±0.01^{a}	0.14±0.00^{a}	0.13±0.02^{a}	0.05±0.01^{b}
Gross yield (t ha^{-1} $year^{-1}$)	----	----	0.18±0.01^{a}	0.23±0.00^{b}	0.31±0.01^{c}	0.41±0.00^{d}

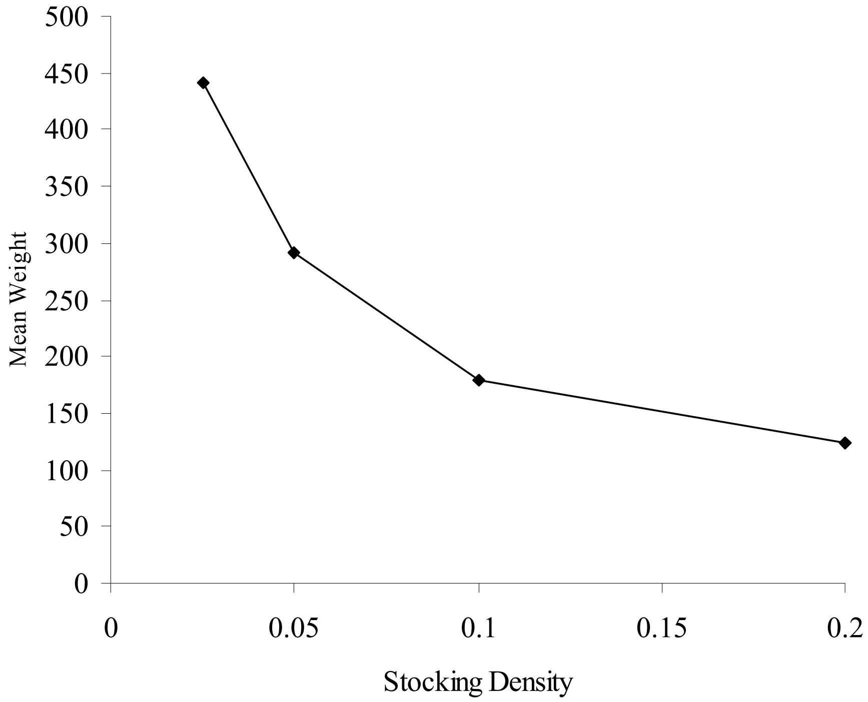

Figure1. Final mean weight of snakehead (g) at different stocking densities (fish m^{-2}) of snakehead in the snakehead and Nile tilapia polyculture after 194 days.

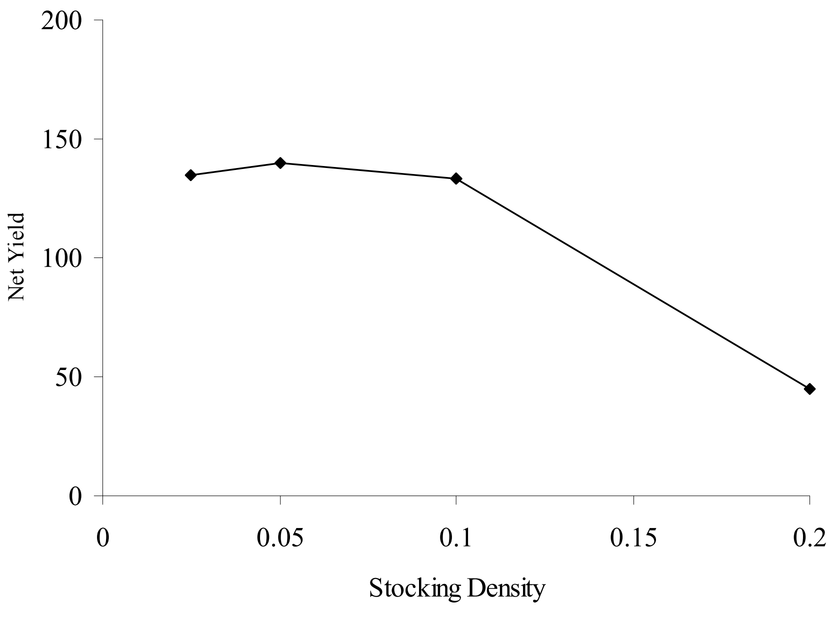

Figure 2. Net yield of snakehead ($kg{\cdot}ha^{-1}\ yr^{-1}$) at different stocking densities (fish m^{-2}) of snakehead in the snakehead and Nile tilapia polyculture after 194 days.

Table 3. Combined yields (mean ± SE) of Nile tilapia and snakehead in fertilized earthen ponds during 194-day culture. Rows of values with superscripts indicate variables with significant differences among treatments (ANOVA, p<0.05). Values with similar letter superscripts are not significantly different.

Parameters	Treatments					
	A (sex-reversed)	B (mixed-sex)	C (1:80)	D (1:40)	E (1:20)	F (1:10)
Adult tilapia + snakehead						
Net yield (t ha^{-1} $year^{-1}$)	4.54±0.42	4.33±0.37	4.63±0.30	4.39±0.39	4.64±0.39	4.52±0.35
Gross yield (t ha^{-1} $year^{-1}$)	$4.88±0.43^{abc}$	$4.61±0.37^{a}$	$4.97±0.29^{bc}$	$4.71±0.40^{ab}$	$5.11±0.38^{c}$	$5.16±0.36^{c}$
Adult and recruited tilapia + snakehead						
Net yield (t ha^{-1} $year^{-1}$)	$4.54±0.42^{a}$	$5.21±0.22^{b}$	$4.63±0.30^{a}$	$4.34±0.39^{a}$	$4.64±0.39^{a}$	$4.52±0.35^{a}$
Gross yield (t ha^{-1} $year^{-1}$)	$4.88±0.43^{ab}$	$5.49±0.22^{c}$	$4.97±0.29^{ab}$	$4.71±0.40^{a}$	$5.11±0.38^{bc}$	$5.16±0.36^{bc}$

Physical and chemical parameters of pond water were not significantly different among all treatments at all sampling times throughout the entire experimental period (P > 0.05). The mean values of water quality parameters were also not significantly different among all treatments (P > 0.05, Table 4).

The partial budget analysis (Table 5) indicated that all treatments in this experiment were profitable, and mixed-sex Nile tilapia culture (treatments B through F) produced significantly higher net return than sex-reversed Nile tilapia culture (treatment A). Snakehead and Nile tilapia polyculture at the lowest predator:stocked-prey ratio (1:80, treatment C) had the highest net return and ratio of added income to added cost, followed by the treatment at the ratio of 1:20 (treatment E).

Table 4. Average values of water quality parameters (mean ± SE) measured throughout the experiment.

Parameters	Treatments					
	A (sex-reversed)	B (mixed-sex)	C (1:80)	D (1:40)	E (1:20)	F (1:10)
DO at dawn (mg L^{-1})	2.43±0.39	2.25±0.23	2.38±0.19	2.05±0.27	2.36±0.17	2.03±0.17
Temperature (C)	27.9-37.4	27.4-36.7	27.8-37.3	27.8-36.9	27.8-36.6	27.8-35.9
pH	6.5-9.6	6.5-10.3	6.4-9.8	6.5-10.0	6.5-10.4	6.5-10.2
Alkalinity (mg L^{-1} as $CaCO_3$)	52±6	54±5	54±9	59±6	54±4	58±4
TKN (mg L^{-1})	6.62±0.88	6.24±0.73	6.48±0.41	5.76±0.26	6.42±0.49	6.46±0.34
TAN (mg L^{-1})	2.48±0.57	2.36±0.26	2.37±0.28	2.04±0.43	2.24±0.27	2.18±0.09
Nitrite-N (mg L^{-1})	0.19±0.04	0.22±0.01	0.20±0.01	0.14±0.02	0.21±0.04	0.21±0.02
Nitrate-N (mg L^{-1})	0.64±0.17	0.63±0.04	0.79±0.13	0.49±0.14	0.69±0.12	0.76±0.009
TP (mg L^{-1})	0.51±0.24	0.51±0.09	0.62±0.08	0.62±0.26	0.70±0.13	0.66±0.12
SRP (mg L^{-1})	0.29±0.22	0.18±0.08	0.35±0.06	0.35±0.24	0.38±0.10	0.33±0.10
Chlorophyll *a* (mg m^{-3})	35±11	46±8	31±8	42±13	44±10	41±12
Secchi disk visibility (cm)	24±2	24±3	25±0	22±1	24±2	23±3
TSS (mg L^{-1})	95±15	109±5	91±6	107±14	91±11	117±14
TVS (mg L^{-1})	20±3	26±2	20±1	25±4	22±4	26±4

Table 5. Partial budget analysis (US $) for sex-reversed and mixed-sex Nile tilapia monoculture (treatments A and B) and snakehead and mixed-sex Nile tilapia polyculture (treatments C through F) in the 194-day experiment (based on 200-m^2 ponds).

Parameters	Treatments					
	A (sex-reversed)	B (mixed-sex)	C (1:80)	D (1:40)	E (1:20)	F (1:10)
GROSS REVENUE						
Adult tilapia	19.46	18.39	19.08	17.87	19.10	18.98
Recruited tilapia	----	1.16	----	----	----	----
Snakehead	----	----	1.91	1.82	1.67	1.08
Total	19.46	19.55	20.99	19.69	20.77	20.05
VARIABLE COST						
Tilapia fingerlings	5.00	1.67	1.67	1.67	1.67	1.67
Snakehead fingerlings	----	----	0.07	0.14	0.29	0.58
Urea	6.75	6.75	6.75	6.75	6.75	6.75
TSP	6.56	6.56	6.56	6.56	6.56	6.56
Cost of working capital	0.78	0.64	0.64	0.64	0.65	0.66
Total cost	19.09	15.62	15.69	15.76	15.92	16.22
NET RETURN	0.37	3.93	5.30	3.92	4.85	3.83
ADDED COST	3.33	----	0.07	0.14	0.29	0.57
ADDED RETURN	-0.09	----	1.44	0.14	1.22	0.50
ADDED INCOME/ADDED COST	-0.03	----	20.41	0.97	4.22	0.87

Discussion

This experiment showed that snakehead were able to completely control recruitment of Nile tilapia at a very low predator:stocked-prey ratio of 1:80, indicating high efficiency in recruitment control. A similar ratio (1:85) was used by Cruz and Shehadeh (1980) to control the Nile tilapia recruitment successfully. *Lates niloticus* was reported to have a similar predation efficiency (1:84) (Planquette 1974), while other piscivorous species such as *Hemichromis fasciatus* (1:17-1:48, Bardach *et al*. 1972, Lazard 1980), *Cichla ocellaris* (1:15, Lovshin 1977), *Clarias lazera* (1:10, Bard *et al*. 1976), *Cichlasoma managuense* (1:4, Dunseth and Bayne 1978), *Elops hawaiiensis* (1:20, Fortes 1979), *Megalops cyprinoides* (1:10, Fortes 1980), *Clarias gariepinus* (1:2.7, de Graaf *et al.* 1996), and *Ophiocephalus obscuris* (1:30, de Graaf *et al*. 1996) were less effective.

The present experiment clearly showed that the carrying capacity of snakehead was exceeded at the predator:stocked-prey ratio of 1:10, and poor growth occurred due mainly to the limited food items available. Snakehead is carnivorous and highly predacious on aquatic organisms such as insects, fish including its own species, frogs, shrimps and even small aquatic snakes (Wee 1982). In another study, snakehead had better growth at the same predator:stocked-prey ratio with smaller stocking size (0.3 g) and harvest size (108.5 g; Balasuriya 1988). In comparison, stocking size was 95.7 g in the present experiment. The results of the present experiment suggests that the standing crop of snakehead at stocking density of 2 Nile tilapia m^{-2} should below 4.30 kg per 200 m^2 or 215 kg ha^{-1} to achieve good growth.

In other studies, high yields of harvestable-size tilapia were reported and final size of harvested tilapia increased with effective predators (Swingle 1960, Lovshin 1977, Dunseth and Bayne 1978, Edwards *et al*. 1994). However, there were no significant differences in final size and yield of harvested adult tilapia among treatments in this study, and total production combining adult and recruited tilapia was significantly reduced in all polyculture treatments as the recruits were eaten. This is consistent with the results using other piscivorous species reported by Mair and Little (1991), Lovshin (1977), Fortes (1980), McGinty (1983, 1985) and Edwards *et al*. (1994).

The growth of sex-reversed all-male Nile tilapia was only 5% faster than mixed-sex tilapia, and this difference was not statistically significant in the present experiment. In comparison, the sex-reversed all-male tilapia grew more than 10% faster than mixed-sex tilapia in other experiments (Pascual and Mair 1997). Stunting with mixed-sex tilapia culture, caused by competition for food between recruits and stocked tilapia, was not observed in the present experiment. Green and Teichert-Coddington (1994) also did not find significant differences between sex-reversed and mixed-sex Nile tilapia growth in ponds. Dan and Little (2000) reported that growth difference between sex-reversed and mixed-sex Thai strain of Nile tilapia (new-season seed) was significant when cultured in ponds but not significant when cultured in cages. Clearly, there are system-specific differences that may affect the growth, production, and stunting of mixed-sex tilapia.

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