EFFECTS OF STOCKING DENSITY ON TWO TILAPIA SPECIES RAISED IN AN INTENSIVE CULTURE SYSTEM

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Abstract: Tilapia aurea and *T. mossambica* fry were stocked in a flowing system at varying stocking densities (5, 10, 20, 30, 40, 50 and 60 fish/tank in 60 liters of water) in an intensive tank culture system. The fish were maintained for 115 days on commercial pelleted feed. In terms of length increase, weight gain, condition, total yield, and food conversion rates, *T. aurea* performed significantly better than *T. mossambica* at all stocking densities. The *T. mossambica* experienced much higher mortality and reduced growth due to an auto-immune reaction related to stocking density, which effectively limits the density at which this species can be stocked. Hypersensitivity reactions began when the biomass reached about 20g/liter with a turnover time of one-half hour, although further research is needed to completely quantify their crowding tolerance limits. *T. aurea* were still growing and feeding vigorously at termination of the experiment (with a maximum biomass of 66.2g/liter) and probably could have continued to grow to even greater biomass. *T. aurea* is preferable to *T. mossambica* in intensive fish culture or in tilapia polyculture due to the former's higher yields and greater resistance to crowding.

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Tilapia spp. (family Cichlidae) are widely cultured in tropical and sub-tropical areas. Endemic to the Middle East and North Africa, they were distributed throughout many underdeveloped areas to provide an inexpensive, easily raised protein source in subsistence-level pond culture (Chimits 1955, 1957). *Tilapia* spp. have several qualities which make them ideal culture species. They tolerate low dissolved oxygen and high ammonia concentrations and possess rapid growth capabilities while maturing early (Miranova 1970, Redner and Stickney 1979, Qeil 1966). This genus feeds on wide variety of plant matter and detrius, and several planktivorous species can be raised with little input of labor and resources, although commercial rations are readily accepted (Kelly 1956, Swingle 1960). These attributes allow the use of tilapia for plant removal in conjunction with sewage treatment and aquatic weed control situations; however, recent marketing studies demonstrate a demand for tilapia in the United States for human consumption (Bardach et al. 1972, Crawford et al. 1978).

Two species of tilapia were utilized in this study, *Tilapia aurea* and *T. mossambica*. Both species are planktivorous, with similar environmental requirements and reproductive behavior (Kelly 1956, Swingle 1960). *T. mossambica* have almost world-wide distribution where climate permits: most tilapia die when the temperature falls below 12°C for even a few hours (Chimits 1955, 1957, Allanson et al. 1971). In many situations, *T. mossambica* matures rapidly and at a small size, breeding continuously at temperatures above 18°C (Qeil 1966), resulting in stunting (Iles 1973). This problem can be circumvented by using monosex culture, which can be achieved by hand sorting, stocking all-male hybrids, or hormone treatments (Fram and Pagan-Font 1978, Guerrero 1975). *T. aurea* have recently been utilized in various culture and waste disposal systems in the United States with encouraging results (Stickney and Hesby 1978, McGeachin et al. 1980, Rakocy and Allison 1980).

The ability of tilapia to withstand poor water quality makes them useful not only in sewage lagoons but also for high density fish culture in tank systems. Increasing stocking density may cause deteriorating water quality, smaller average fish size, and lower feed conversion efficiency. A balance between the number of fish needed to produce maximum yield and minimum degradation of water quality must be found. This study examined the effects of stocking density on both *T. aurea* and *T. mossambica* in terms of average fish length, weight, condition, feed conversion, and total biomass.

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METHODS

The research was conducted at the Aquaculture Research Center wet lab of Texas A&M University, utilizing 42, 60-liter circular black polyethelene flow-through tanks. Water was pumped from the nearby Brazos River, stored in a 4 ha reservoir, and then secondarily pumped through 2 sand filters and into the tanks. The flow rate of 1.9 liters/minute provided a turnover time of 1/2 hour, with supplemental aeration by airstones. Drainage was provided by central Venturi drains, and hardware cloth screens kept the fish from jumping out of the tanks.

Water quality was monitored 3 times weekly; representative tanks of each treatment were checked for dissolved oxygen, temperature, and ammonia. Weekly pH measurements were also obtained. Oxygen and temperature were obtained with a dissolved oxygen meter, ammonia with an ammonia specific ion electrode in conjunction with a digital pH meter and pH with the digital pH meter.

Fry of both species (approximately 0.015 g each) were obtained by seining 0.05 ha ponds in which adult broodstock were maintained. Fry were held in 300-liter metal troughs for three weeks while being fed *ad libitum* on androgen-treated fish starter feed to sex-reverse the females (Guerrero 1975). This treatment effectively eliminates reproduction and also prevents growth differences due to sex.

Fry of each species were stocked into 60 liter tanks at densities of 5, 10, 20, 30, 40, 50, and 60 fish/tank, with 3 replicates of each stocking level and species. Commercial pelleted fish feed was used throughout the study, initially offered at 20 percent body weight daily, decreasing feeding rates to 10 percent on day 29 and finally 5 percent on day 56 as the fish grew. Tanks were drained and cleaned every two weeks, at which time the fish were removed, counted and weighed as a group (feeding rates were subsequently adjusted). Additional cleaning was provided by siphoning twice weekly. Fish were maintained in this manner for 115 days, from June 6 to September 29, 1978. At harvest, each fish was measured to the nearest 1.0 mm standard length and weighed to the nearest 0.1 g. A condition factor was calculated for each fish; $K = W \times 1000/L^3$, where W is weight to the nearest 0.1 g and L is standard length (Everhart et al. 1975). Overall increase in biomass and total quantity of feed offered were used to compute feed conversion ratios for each tank (FCR = weight of feed offered/weight gain).

Multiple regression analysis was done examining average fish length, weight, and condition as a function of species, stocking density, and replicate. Significant differences among various stocking densities within each species were resolved using Duncan's *multiple* comparison procedure (Ott 1977). Comparisons between the species at each density were done by t-tests; all statistical analysis were performed at L = 0.05 level of significance.

RESULTS AND DISCUSSION

Mortality

Mortalities were difficult to detect while the fish were young since carcasses were partially or entirely consumed by other fish. Biweekly counting provided a periodic measure of mortality. Sporadic deaths occurred during the first few weeks, but these ceased with the fish reached an average weight of 15 g. Both species demonstrated low mortality rates (below 5%) until the 81-day of the study, with the exception of the total loss of 2 tanks due to water system failure (Table 1). One replicate of the 60 fish/tank stocking density was lost for each species. These were eliminated from the analysis. *T. aurea* survival was 98 percent even at the highest stocking densities (Table 1), while *T. mossambica* suffered much reduced survival due to an auto-immune reaction (Henderson-Arzapalo et al. 1980). This reaction caused higher mortality rates with increasing stocking densities and almost half the population stocked at the highest original densities died. *T. aurea* are obviously more tolerant of crowded conditions as their overall survival was 98 percent or better at all stocking densities.

Table 1. Mortalities of *Tilapia aurea* and *T. mossambica* at each stocking density prior to the occurrence of the auto-immune reaction and upon termination of the experiment.

Stocking Density (fish/tank)[1]	Mortality before auto-immune reaction (percent) (81 days)		Mortality at termination (percent) (115 days)	
	T. aurea	*T. mossambica*	*T. aurea*	*T. mossambica*
5	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
20	0.0	1.7	0.0	15.0
30	1.1	4.4	1.1	34.4
40	1.7	1.7	1.7	34.2
50	1.3	3.3	1.3	25.3
60	1.7[2]	2.5[2]	1.7	47.4

[1] 60 liters/tank

[2] 100% mortality experienced in 1 of 3 replicate tanks due to water system failure; all calculations reflect in only tanks.

Water Quality

Stocking density caused the expected deterioration of water quality. Dissolved oxygen dropped and ammonia levels increased as stocking density increased. As expected, a similar trend occurred over time as the fish increased in size. Temperature varied between 25-29°C, alkalinity between 110-120 mg/liter, and pH between 7.2 to 8.3. Dissolved oxygen ranged between 5-7.8 mg/liter, and ammonia levels between 0.12 and 1.3 mg/liter total ammonia nitrogen. These values are well within the tolerance range of tilapia.

Final Fish Length

No overall significant difference in final body length was found between *T. aurea* and *T. mossambica*, however, different stocking densities within each species varied significantly. Mean standard length for *T. aurea* was 116.4 ± 8.9 mm, while for *T. mossambica* it was 117.6 ± 8.3 mm. No significant differences in length were detectable at densities of 5, 10, 50, and 60 fish/tank, while at 20 and 30 fish/tank *T. mossambica* were significantly longer, and at 40 fish/tank, *T. aurea* were greater in length. No pattern was recognizable within the stocking densities.

Final Fish Weight

Both species and stocking density caused significant differences in final average fish weight. *T. aurea* were heavier than *T. mossambica* overall, 69.05 ± 16.9 g as compared to 53.17 ± 11.1 g, respectively. A decrease in average fish weight occurred with increasing stocking density, although *T. aurea* appeared to be less affected than *T. mossambica*. *T. aurea* were significantly larger than *T. mossambica* at all stocking densities.

The growth rate for *T. mossambica* (Fig. 1) begins to level off much sooner than does the growth rate for *T. aurea* (Fig. 2). This decrease in growth rate of *T. mossambica* coincided with initiation of the auto-immune reaction.

Condition

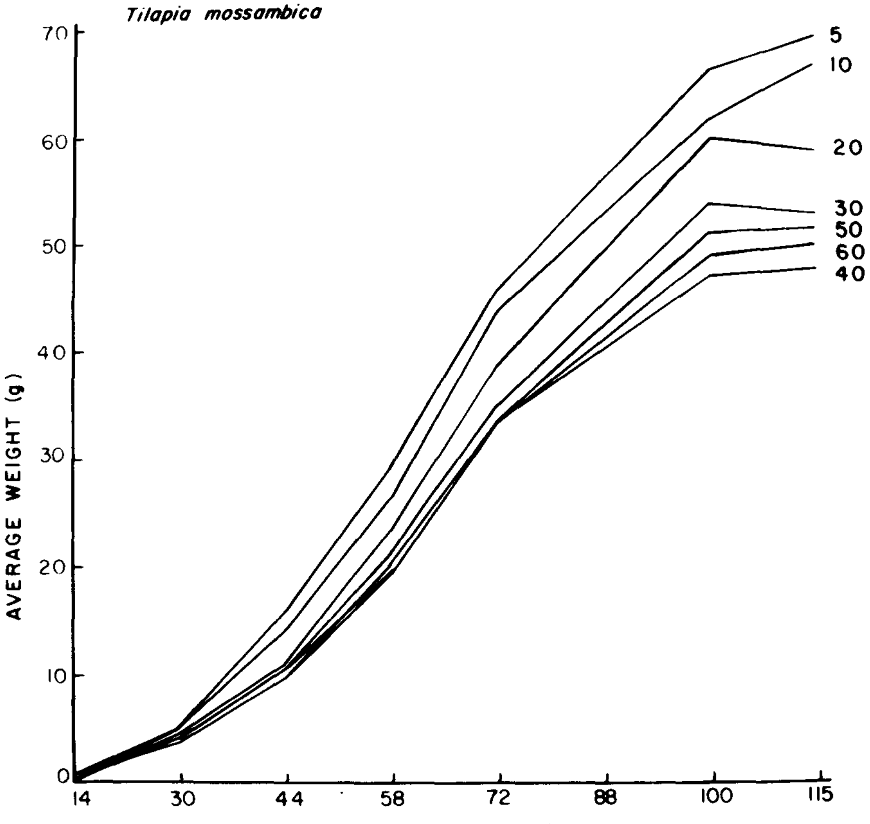

Fig. 1. Growth rate curves for *T. mossambica* over the experimental period (June 6 to September 29, 1978). Numbers at the end of each line represents the stocking density. (60 liters/tank water volume).

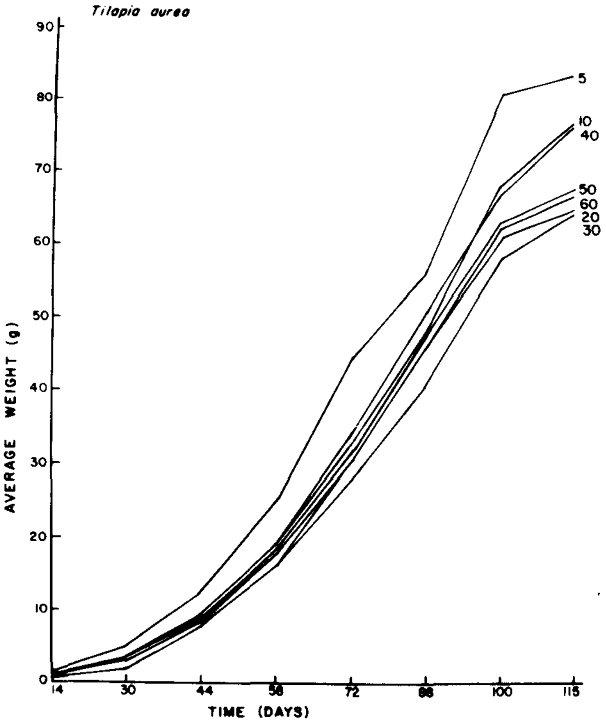

Fig. 2. Growth rate curves for *T. aurea* over the experimental period (June 6 to September 29, 1978). Numbers at the end of each line represents the stocking density. (60 liters/tanks water volume).

T. aurea tended to be slightly shorter and stockier overall than *T. mossambica*. A large number of *T. aurea* had shortened, fused, or missing vertebrae causing body shape to be more variable in that species; *T. mossambica* were generally fusiform in body shape. Both stocking density and species affected condition; average condition factor was 4.32 ± 0.60 for *T. aurea* and 3.24 ± 0.30 for *T. mossambica* (Table 2). Both species generally had higher condition factors as stocking density increased.

Feed Conversion Ratios

Average feed conversion ratio was lower for *T. aurea* than *T. mossambica* (1.5 ± 0.02 and 2.9 ± 0.65, respectively). *T. aurea* had better conversion rates at each stocking density as well (Table 3). Intermediate weight data were used mainly to adjust feeding rates, but these values also indicated decreasing *T. mossambica* feed conversion several weeks before actual mortalities began occurring. After the onset of the anaphylactic reaction, *T. mossambica* feed consumption decreased dramatically. Stocking density had no significant effect on *T. aurea* feed conversion.

Total Biomass

Statistical comparison of total yield per tank between the 2 species was not justified; at harvest, *T. aurea* tank biomass was far greater than *T. mossambica* at any stocking density (Table 4). This difference was caused primarily by the higher mortality rate experienced by *T. mossambica* due to anaphylaxis. A comparison of total biomass at earlier weighing intervals (Fig. 3 and 4) indicates both species were actually increasing at

Table 2. Final mean condition factors for *T. aurea* and *T. mossambica* at various stocking densities.

Species	Density (number/tank)[1]	Condition Factor[2]
T. aurea	5	3.96 c
	10	3.93 c
	20	3.94 c
	30	4.32 b
	40	4.68 a
	50	4.30 b
	60	4.34 b
T. mossambica	5	3.07 b
	10	3.19 b
	20	3.19 b
	30	3.17 b
	40	3.25 ab
	50	3.33 a
	60	3.24 ab

[1] 60 liters/tank water volume

[2] Condition factor = $W \times 1000/L^3$

a,b,c Means within each species followed by the same letter are not significantly different at the 0.05 level using Duncan's multiple comparison procedure.

about the same rate until the initiation of the hypersensitivity reaction in *T. mossambica* at about 20 g/liter. Since *T. aurea* were not affected in a similar manner under these intensely crowded conditions, they far surpassed *T. mossambica* in this intensive culture system.

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Table 3. Mean feed conversion ratios (FCR) for *T. aurea* and *T. mossambica* at various stocking densities from June 6 to September 29, 1979. (FCR = weight of feed offered/total weight gain).

Species	Density (number/tank)[1]	FCR[2]
T. aurea	5	1.72 a
	10	1.40 a
	20	1.50 a
	30	1.39 a
	40	1.43 a
	50	1.56 a
	60	1.62 a
T. mossambica	5	2.27 a
	10	2.21 a
	20	2.57 a
	30	3.19 b
	40	3.34 b
	50	2.79 ab
	60	4.13 c

[1] 60 liters/tank water volume

[2] FCR = weight of feed offered/total weight gain.

a,b,c, Means within each species followed by the same letter are not significantly different at the 0.05 level using Duncan's multiple comparison procedure.

Table 4. Total mean tank biomass for *T. aurea* and *T. mossambica* at termination.

Species	Density (number/tank)[1]	Tank Biomass (g)	Grams/Liter
T. aurea	5	419.7	6.99
	10	764.8	12.75
	20	1290.9	21.52
	30	1914.3	31.91
	40	3006.8	50.11
	50	3300.7	55.01
	60	3973.2	66.22
T. mossambica	5	345.1	5.75
	10	662.0	11.03
	20	991.1	16.52
	30	1037.0	17.28
	40	1230.4	20.51
	50	1908.8	31.81
	60	1424.9	23.75

[1] 60 liters/tank water volume

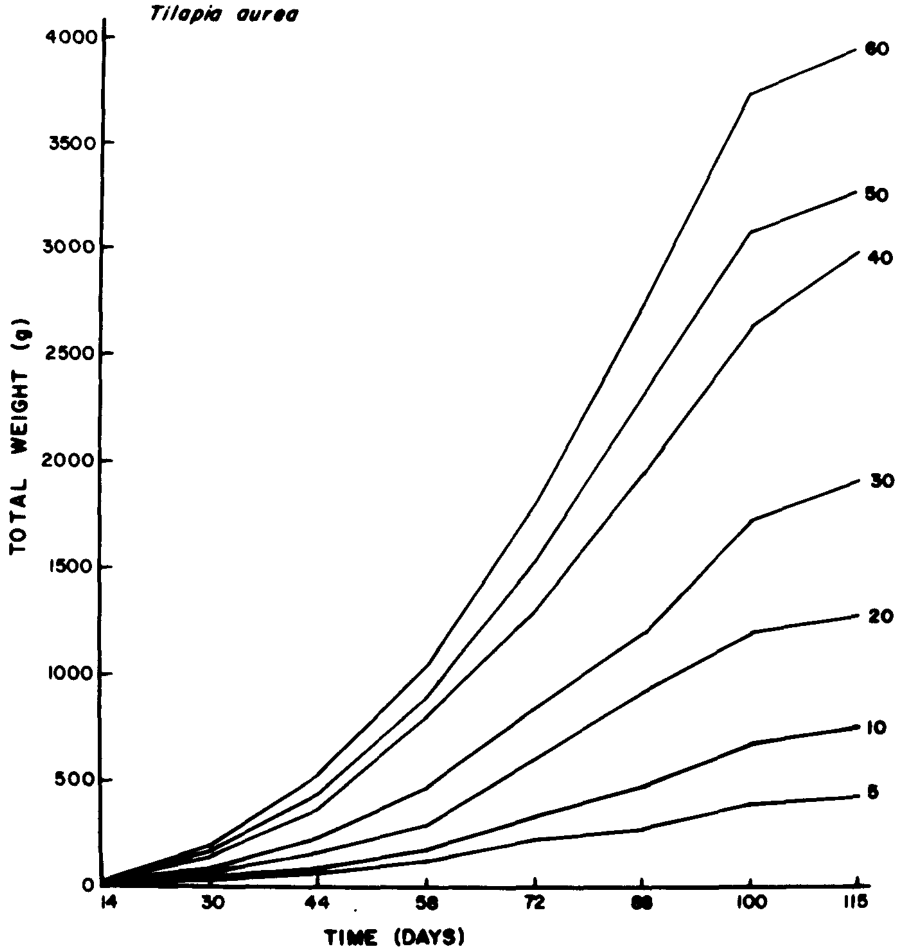

Fig. 3. Mean biomass of *T. aurea* (g/tank) at each stocking density over the experimental period (June 6 to September 29, 1978). Numbers at the end of each line denote initial stocking density in fish/tank. (60 liters/tank water volume).

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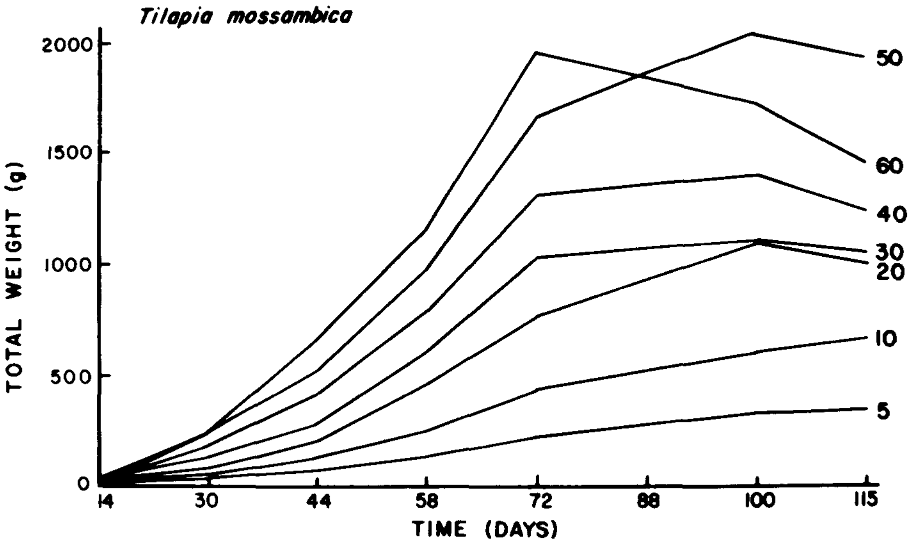

Fig. 4. Mean biomass of *T. mossambica* (g/tank) at each stocking density over the experimental period (June 6 to September 29, 1978). Numbers at the end of each line denote initial stocking density in fish/tank. (60 liters/tank water volume).

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