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Effects of Stocking Density on Patterns of Reproduction and Growth of Hybrid Tilapia in Concrete Tanks in Saudi Arabia

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Abstract

Effects of four stocking densities (50, 100, 150 and 200 fish m^{-2}) were investigated on some reproductive traits of hybrid tilapia (*Oreochromis niloticus* x *O. aureus*) in outdoor concrete tanks. For both sexes the gonadosomatic index was not significantly influenced by stocking density. Fast-growing fish mature early in the season (March), but spawning started late in May. Mean percentages of mature fish were significantly higher at stocking densities of 50-100 fish m^{-2} than at higher densities (150-200 fish m^{-2}). No effect of stocking density on size of fish at first maturity was found. Fecundity per female decreased with increasing stocking density, though significant difference was found only between the lowest density (50 fish m^{-2}) and other densities (100-200 fish m^{-2}). The fecundity per gram female did not show any definite pattern, but it was highest for fish stocked at the lowest density. Final mean weight and feed conversion ratios were significantly influenced by stocking densities.

Introduction

The crowding of fish adversely affects their reproduction. A depressed spawning in tilapia was reported at a stocking density of 100,000 fish ha^{-1} in ponds (Tal and Ziv 1978). Allison et al. (1979) reported an inverse relationship between stocking density and the number of young produced by *Tilapia aurea*. Tilapia did not spawn at a biomass greater than 16 kg m^{-3} in tanks and produced prolifically at a biomass of 4 kg m^{-3} in ponds (Lauenstein 1978). Balarin and Haller (1982) did not report successful spawning of tilapia in tanks stocked at above 10 kg m^{-3}. Similarly, the fecundity of carp (*Cyprinus carpio*) was found to decrease at high population densities (Yoshihara 1952), and the fecundity and fertility of the guppy (*Poecilia reticulata*) was found to be higher among females for the lowest than the highest density (Rose 1959; Warren 1973; Dahlgren 1979).

The present study was undertaken to determine the effects of four stocking densities on gonad maturation, spawning and fecundity of hybrid tilapia receiving food in proportion to their biomass. The study is based on the rearing of 3.77 g fingerlings in 10-m^2 outdoor concrete tanks, and the study was continued until 25-40% of fish in each tank were mature and continued spawning during the two subsequent months. Growth, survival and feed conversion ratio (FCR) of hybrid tilapia under these culture conditions are also reported here.

Materials and Methods

Two hundred (50 males, 150 females) 2-year-old hybrid tilapia (*Oreochromis niloticus* x *O. aureus*) with average weight of 450 g (females) and 600 g (males) were used for spawning in a 50-m^2 concrete indoor tank with 50-cm water level over a period of 21 d, 30 September to 20 October 1993. The broodfish were fed a 34% protein tilapia feed at the rate of 1% total biomass once daily. Harvested fry were reared in 900-l aerated fiberglass tanks having a flow-through system for 4 weeks on a PROVIMI Tilapia Starter Feed (crude protein 52%, crude fat 13%, crude fiber 0.8%, ash 7.5%, moisture 9%). After 4-weeks rearing, about 15,000 fingerlings with an average weight of about 1 g were transferred to three 10-m^2 (water level 50 cm) outdoor aerated concrete tanks and over-wintered until 28 February 1994. During this period the fish were maintained at a daily ration of 1% body weight. Water in each tank was completely changed daily with fresh ground water with a temperature of about 27 °C. Excreta and leftover feed were removed by sweeping while draining the water.

On 28 February 1994, uniform-size fish (average weight 3.77 g) were stocked in 8 10-m^2 (3.8 x 2.64 x 1.2 m) uniformly aerated outdoor concrete tanks at the rate of 50, 100, 150 and 200 fish m^{-2} in duplicate tanks. Fifty fish were individually weighed, dissected and sexed. The tanks had an 8-m high asbestos roof. In each tank the water level was 50 cm, and almost all the water was completely drained in the morning and replaced with fresh water. Fish were fed a 34% protein tilapia diet at the rate of 3% body weight daily. Feeding rate was adjusted after every 14 d based on the average weight of a random sample of 100-150 fish from each tank. The fish were returned to the same tank after group weighing. Daily ration was divided in two equal halves and offered at 0830 and 1530 h, 6 d a week.

For the determination of maturation size, cycle of gonad maturation and spawning, gonadosomatic index and fecundity, a random sample of 20 fish from each tank was obtained every two weeks after stocking, and the fish were sacrificed. Each fish was measured (TL), weighed, dissected and sexed. Gonads were extracted, weighed, and their maturation stage was assessed. Fecundity of ripe females was determined by gravimetric method. The methodology used for these determinations was the same as reported earlier (Siddiqui 1977).

Egg size and weight were determined for each mature female. Eggs were removed from the ovarian tissue and three random samples of 10-15 eggs were weighed in groups nearest to 0.001 g; and for length and width, 20 randomly sampled eggs were used.

The experiment was terminated on 4 July 1994. All tanks were drained, and fish from each tank were counted and weighed in groups. From the data obtained, final mean weight, survival and FCR (g feed consumed/g wet weight gained) were calculated. Growth patterns of males and females are based on bi-weekly samples.

Daily maximum-minimum water temperatures were recorded in one tank by a mercury thermometer suspended at 30-cm depth. Dissolved oxygen (DO), pH and NH_3-N levels were measured at weekly intervals, and alkalinity, salinity and water hardness every four weeks, in one tank of each treatment. All determinations were made between 0700 and 0800 h, before any exchange of water.

Analysis of variance was used to compare fecundity, mean percentages of mature fish, final mean body weight, % increase in weight, survival and FCR of hybrid tilapia in different treatments. Sheffe's range test was used to compare treatment means. Observed sex ratio within each treatment and among the treatments were compared by chi-square test. Percentages data were transformed to arc sin values prior to analysis (Zar 1974). All data were analyzed using a statgraphic software package. Level of significance was 0.05.

Results

Water Quality

The means of water temperature and other water quality parameters recorded from March to July 1994 are given in Table 1.

Table 1. Temperature and other water quality parameters recorded in tanks with different fish stocking densities.

Parameters	Mean±SD
Maximum temperature (°C)	27 ± 3
Minimum temperature (°C)	19 ± 4
Dissolved oxygen (mg l^{-1})	5.1 ± 1.2
pH	8.0 ± 0.3
Alkalinity as $CaCO_3$ (mg l^{-1})	201 ± 12
NH_3-N (mg l^{-1})	0.52 ± 0.21
Total hardness as $CaCO_3$ (mg l^{-1})	994 ± 105
Salinity (ppt)	1.6

Growth, Survival and FCR

The effects of stocking rate on final mean weight and FCR were significant (Table 2). Final mean weight decreased with increasing density. The rate of increase in weight (W) with total length (L) of fish decreased with increasing density of fish as demonstrated by the following equation:

$$50\ m^{-2}: \log W = 3.1743 \log L - 4.5601,\ r=0.9799,\ N=200$$
$$100\ m^{-2}: \log W = 2.9450 \log L - 3.9807,\ r=0.9836,\ N=200$$
$$150\ m^{-2}: \log W = 2.8699 \log L - 3.7450,\ r=0.9667,\ N=200$$
$$200\ m^{-2}: \log W = 2.6909 \log L - 3.2870,\ r=0.9904,\ N=200$$

Highest FCR was found for fish stocked at 200 fish m^{-2}. Survival of fish was not significantly affected by stocking density during this study. Divergence in growth of males and females was noted at the time of stocking, males being heavier than females, and the same trend continued throughout the study (Fig. 1).

Table 2. Growth, survival and feed conversion ratio of hybrid tilapia stocked at four different densities. Means in a column with different letters are significantly different (P<0.05).

Stocking rate (per m^2)	Weight (g) Initial	Final	% increase	Survival (%)	Sex ratio (% M:F)	FCR
50	3.77	57.83^a	1434^a	91^a	$35:65^a$	1.5^c
100	3.77	51.51^{ab}	1266^{ab}	93^a	$35:65^a$	1.5^c
150	3.77	44.78^b	1088^b	86^a	$39:61^a$	1.9^b
200	3.77	30.52^c	709^c	85^a	$36:64^a$	2.5^a

Sex Ratio, Gonad Maturation and Spawning

Overall ratio of females to males was 1.6:1.0, significantly deviating from 1:1 ratio. However, the sex ratio among different treatments remained almost the same (Table 3).

No apparent differences in the total length of smallest mature male (8.9 cm) and female (8.6 cm) and median size at maturity (50% maturation size) were found at different densities. Fish stocked at different densities were all mature at 13 cm TL (Figs. 2a and b).

The cycle of maturation of gonads and spawning was followed by defining four stages of maturation - 1) immature, 2) maturing, 3) mature, and 4) spent (Siddiqui 1977). Fish after spawning do not become completely spent as females with eggs/larvae in their mouth were in maturation stage 2, and males after spawning had flaccid testis but still full of sperm. Females with residual eggs in the ovary, and males with shrunken testis were considered as spent.

At the time of stocking (28 February 1994), the fish were in maturation stages 1 and 2. Males matured earlier than females, and in March a small percentage of fish (10% male, 1% female) had mature gonads. The percentage of mature fish gradually increased and in May, 44-58% of fish in different treatments were mature. Spawning started in late May and continued in the following months.

For both sexes, the mean gonadosomatic index was not significantly different among fish stocked at four different densities. Increase in ovary weight (Ow) with total body weight (Wt) of fish stocked at different densities is described by the following equation:

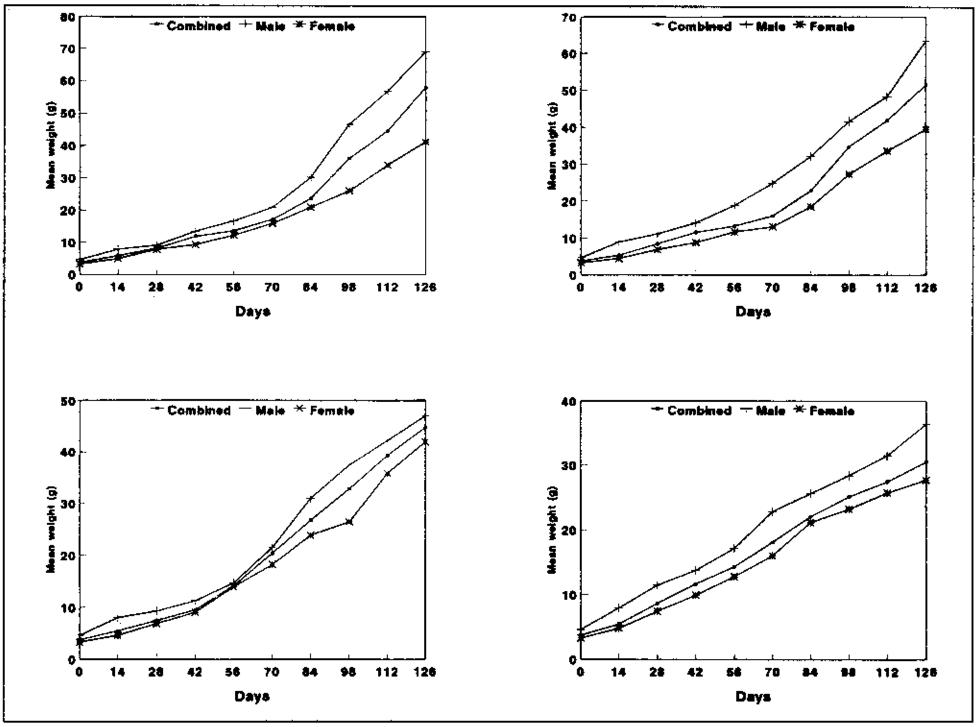

Fig. 1. Growth curves of hybrid tilapia stocked at 50 (a), 100 (b), 150 (c) and 200 (d) fish m^{-2}.

$$50\ m^{-2}: \log Ow = 2.0120 \log Wt - 7.9006,\ r=0.8177,\ N=112$$
$$100\ m^{-2}: \log Ow = 1.6432 \log Wt - 8.0248,\ r=0.7168,\ N=102$$
$$150\ m^{-2}: \log Ow = 1.4588 \log Wt - 7.2162,\ r=0.6656,\ N=107$$
$$200\ m^{-2}: \log Ow = 1.3008 \log Wt - 6.8634,\ r=0.6841,\ N=111$$

The mean percentage of mature fish was significantly higher at stocking densities of 50-100 fish m^{-2} than at densities of 150-200 fish m^{-2} (Table 4).

Table 3. Mean percentage of hybrid tilapia in different stages of maturity stocked at different densities. Means in a row with different letters are significantly different($P<0.05$).

Maturity stage	Stocking density·m^{-2}							
	50		100		150		200	
	M	F	M	F	M	F	M	F
1 Immature	21.7	24.3	16.9	24.1	21.8	21.9	25.9	27.4
2 Maturing	31.4	39.8	32.0	43.8	40.8	49.4	36.9	45.4
3 Mature	31.2	24.1	32.1	21.2	27.1	18.8	27.3	19.3
4 Spent	15.7	11.8	19.0	10.9	10.3	9.9	9.9	7.9
Mean % of 3 & 4	20.7^{a}		20.8^{a}		16.5^{b}		16.1^{b}	

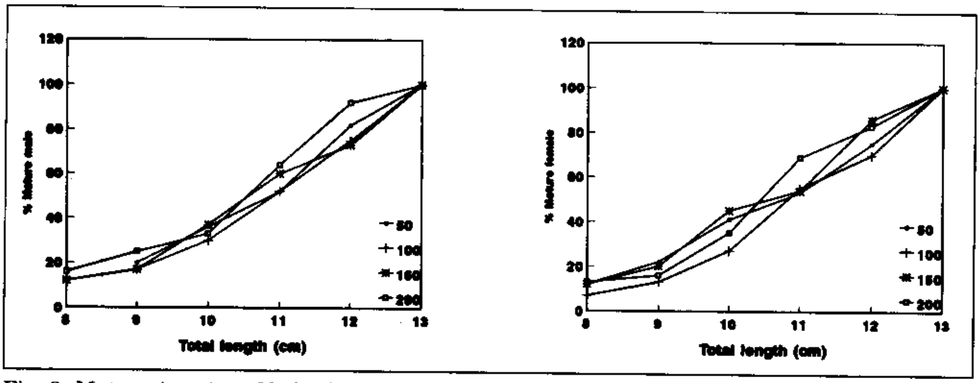

Fig. 2. Maturation size of hybrid tilapia stocked at four different (50, 100, 150 and 200 fish m^{-2}) densities.

Fecundity

Fecundity is defined here as the number of eggs present in a pair of mature ovaries. Fecundity was highest in fishes stocked at 50 fish m^{-2} and lowest at 200 fish m^{-2}, though there was no significant difference in fecundity of fishes stocked at 50, 100 and 150 fish m^{-2} (Table 4). The relationship of fecundity (F) to body weight (Wt) and length (L) for the different treatments was as follows:

50 m^{-2}: $\log F = 2.7231 \log L - 0.8446$, r=0.9176, N=40
$\log F = 0.8481 \log Wt + 3.0696$, r=0.9254, N=40
100 m^{-2}: $\log F = 2.5572 \log L - 0.6864$, r=0.8034, N=28
$\log F = 0.7941 \log Wt + 2.9865$, r=0.7525, N=28
150 m^{-2}: $\log F = 3.9437 \log L - 4.0885$, r=0.9646, N=28
$\log F = 1.2735 \log Wt + 1.3961$, r=0.9236, N=28
200 m^{-2}: $\log F = 3.0687 \log L - 1.8331$, r=0.9142, N=24
$\log F = 1.1179 \log Wt + 1.9894$, r=0.9035, N=24

No significant effect of stocking density was found on egg size and egg weight (Table 4).

Table 4. Fecundity (±SD) of hybrid tilapia stocked at four different densities. Means in a row with different letters are significantly different (P<0.05).

	Stocking density · m^{-2}			
	50	100	150	200
Number of females	40	28	28	24
Length (cm)	12.0±1.8	12.6±1.6	12.0±1.5	11.7±1.4
Weight (g)	30.8±15.1	35.7±12.8	31.3±11.7	29.4±10.0
Total fecundity	15,670	9,716	9,442	7,818
Eggs $female^{-1}$	392±166^{a}	347±134^{a}	337±162^{ab}	326±125^{a}
Eggs g^{-1} female	12.7^{a}	9.7^{b}	10.7^{b}	11.1^{ab}
Eggs cm^{-1} female	32.5^{a}	27.5^{b}	28.0^{b}	27.7^{b}
Size of egg, length (mm)	2.2^{a}	2.2^{a}	2.3^{a}	2.2^{a}
width (mm)	1.5^{a}	1.5^{a}	1.6^{a}	1.5^{a}

Discussion

Water temperature was optimum for gonad maturation and spawning. The water was quite hard and salinity was 1.6 ppt. Other water quality parameters were within optimum range for tilapia growth and reproduction (Stickney 1979).

The pattern of maturation and depletion of gonads, changes in gonadosomatic index and size frequency distribution of intra-ovarian oocytes were almost the same in hybrid tilapia stocked at four densities. No significant effect of stocking rates was found on size of fish at first maturity, though growth of fish significantly decreased with increasing density. Fast-growing fish matured earlier than the slow growers and, in each treatment, no fish below 8.5 cm in length was found to have mature gonads. The mean size of mature fish was larger than the mean size of all fish in bi-weekly samples.

The fecundity per female significantly decreased at the highest stocking density, though the amount of food available to each fish was proportionate to body weight. At this density the mean percentage of mature fish was also lower than at other stocking densities, and no significant difference in the size and weight of eggs was found in fish of different treatments.

Fish reproduction has been found to be influenced by several density-independent chemo-physical factors and density-dependent biotic factors. The reproductive potential of tilapia has been reported to be influenced by photoperiod (Chimits 1955; Goldstein 1970; Balarin and Hatton 1979), temperature (Hyder 1970), salinity (Chervinski 1982; Jalabert and Zohar 1982), food (Bagenal 1969; Miranova 1977), dietary protein level (De Silva and Radampola 1990; Gunasekera et al. 1995), space (Lowe-McConnel 1982), population density and social factors (Fryer and Iles 1972; Lauenstein 1978; Allison et al. 1979; De Silva and Chandrasoma 1980; De Silva 1986) and the presence of a hormone-like excretion (pheromone) in the water (Swingle 1953).

Fecundity is positively related to the size of fish (Lowe-McConnel 1975; Bagenal 1967), and as the growth of fish decreased with increasing density of fish, it appears that social interaction and social stress were responsible for inefficient food utilization, poor growth and consequently low fecundity at the highest stocking density. Tilapia are territorial and need space for nest building and spawning; at high densities there is competition for space which increases social interaction, and causes social stress and possibly thereby affecting reproductive efficiency. However, reduced aggressive behavior and a breakdown in territorial behavior of tilapia at high density has been reported (Balarin and Haller 1982). In the present study, among females at the lowest density with reduced competition for space, the best reproductive strategy was to maximize the rate of natural increase by increasing fecundity; while at the highest density where there is intense competition for space, the best strategy was to reduce the number of ova and number of spawners to control population.

Stocking rates showed significant effect on mean final weight and FCR. Males were heavier than females at the time of stocking and grew faster than females. The divergence in growth of males and females had occurred earlier than the stocking size of 3.77 g. In different strains of *O. niloticus*, the size at divergence of growth of males and females was found variable and ranged from 4 to 18 g (Palada-de Vera and Eknath 1993).

An inverse correlation between growth rate and population density, as found in the present study, has been reported in *Salmo trutta* (Le Cren 1962), *Ictalurus punctatus* (Walker and Carlander 1970), *Tilapia zillii* (Schulze-Wiehenbrauch 1977), *O. mossambicus* (De Silva 1986) and *O. niloticus* (Siddiqui et al. 1989). It appears that the space factor as suggested by Chen and Prowse (1964) and Meske (1985) is operative in inhibiting growth of fish. Aeration of water may eliminate the space factor affecting feed utilization and growth of tilapia up to a stocking density of 5-20 fish·m^{-2} (Allison et al. 1979), but at higher densities, as in the present study, aeration was probably not effective in eliminating the effects of space factor.

The present study indicates that inhibition of reproductive processes at higher densities leading to population control also inhibit growth of fish. Therefore, all these interactive factors — stocking density, growth and reproductive processes — should be considered in tilapia culture.

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