Growth of Mixed-Sex Young-of-the-year Blue Tilapia (*Tilapia aurea*) in Polyculture with Channel Catfish (*Ictalurus punctatus*)[1]

Les Torrans, *Department of Agriculture, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601*

Fran Lowell, *Department of Agriculture, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601*

Abstract: Young-of-the-year mixed-sex blue tilapia (*Tilapia aurea*) averaging 6.1 g were stocked on 30 June 1982, at a rate of 5,000/ha in 3 0.1-ha ponds containing 10,000 channel catfish/ha. Male and female tilapia were not significantly different in weight after 55 days, averaging 111.6 g and 106.4 g respectively. After 118 days, males were significantly larger than females, averaging 248.9 g vs 211.3 g for the females. Male growth during this period averaged 2.06 g/day vs 1.72 g/day for the females. The tilapia ranged in weight from 164 g to 351 g at harvest on 17 November. Average tilapia production was 1,020 kg/ha, with an average survival of 91.7%. Total production, including catfish, averaged 3,971 kg/ha, with an average food conversion rate of 1.4:1. Less than 10 kg/ha of tilapia offspring were recovered from 1 pond and none were present in the other replicates when the ponds were harvested. The major constraints to commercial tilapia production in the southern United States appear to be the seasonal production and harvesting problems.

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Tilapia have potential as commercial culture fish in the southern United States (Dupree and Huner 1984, Suffern 1980). They are valuable as food fish, grow well in polyculture with other commercial pond fishes, and are easy to produce (Dupree and Huner 1984). In the tropics where tilapia are important aquaculture species, the major constraint to their culture is stunting caused by reproduction of the original stock before they reach a marketable size (Bardach et al. 1972, Hepher and Pruginin 1982). Various techniques have been developed to minimize or eliminate unwanted tilapia reproduction in food fish production systems. Some of the more popular methods include hybridization (Hickling 1960), polyculture with predators (Dunseth and Bayne 1978), cage culture (Pagán-Font 1975), raceway culture (Maruyama

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and Nagashima 1978), sex-reversal (Anderson and Smitherman 1978), high density culture (Allison et al. 1976) and selecting all-male fingerlings for grow-out to market size (Lovshin and Da Silva 1975).

The relative complexity of some of these techniques may pose a practical constraint to the production of tilapia in the United States. Four farmers in Arkansas are currently producing tilapia as baitfish, and several others have expressed interest. However, commercial fish farmers would be reluctant to raise tilapia as a food fish if they had to invest time and money on complicated techniques, such as hybridization or sex-reversal, or if tilapia did not fit well with their existing management operation.

An additional constraint to tilapia culture in temperate zones such as the southern United States is that tilapia die in the winter, limiting the growing season to 4 to 7 months (Dupree and Huner 1984). If the fish do not reach a marketable size in that period, the entire crop must be held in heated water over the winter for final grow-out the following season. This would probably not be economical for food fish production.

Commercial tilapia food fish production in the United States may therefore develop only if it is not complicated, if tilapia can be produced as a single-season crop, and if tilapia can be easily incorporated into existing channel catfish operations.

One of the simplest management plans to produce tilapia as foodfish in the southern United States would involve overwintering tilapia broodstock indoors, spawning them in small earthen ponds in the spring (Torrans and Lowell 1985), then transferring mixed-sex tilapia fingerlings into production ponds for grow-out in a single season (Hepher and Pruginin 1982). Polyculture with channel catfish may be preferred in order to fully utilize existing commercial facilities. However, this would be efficient only if the female tilapia, as well as the males, reached a marketable size in a single season. An insufficient growing season, slower female tilapia growth, or stunting caused by tilapia reproduction are some of the factors that could limit the practical application of this technique.

The purpose of this study was to determine the relative growth rates of young-of-the-year male and female blue tilapia (*Tilapia aurea*) when the sexes were reared together in polyculture with channel catfish (*Ictalurus punctatus*). We wanted to determine if, under typical Arkansas management practices, 1 or both sexes of tilapia would reach a marketable size in a single season. We also wanted to determine the magnitude of tilapia reproduction resulting from this single-season production technique.

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Methods

This study was conducted at the University of Arkansas at Pine Bluff Agricultural Experiment Station, in southeast Arkansas. The 3 earthen ponds used were

approximately 25m wide 40 m long (0.1 ha) and averaged 1 m deep. Ponds were filled with well water prior to stocking and additional water added thereafter only to compensate for evaporation and seepage. Chlorophyll *a* and zooplankton dry weight were determined weekly for all ponds using standard techniques (Am. Public Health Assoc. et al. 1980). Condition factors were calculated for male and female tilapia at harvest from the formula $K_n = 10^5 W/TL^3$, where W is weight in grams and TL is total length in millimeters. Statistical analyses were conducted using ANOVA and *t*-test (Barr et al. 1979).

Three ponds were stocked in March 1982 with channel catfish at the rate of 10,000 fish/ha. Catfish averaged 164 g and ranged in weight from 5 g to 600 g. Catfish density and size range were chosen to simulate the production methods currently used in Arkansas. Average catfish density maintained by Arkansas fish farmers is around 10,000 fish/ha. Farmers attempt to maintain that density by periodically "topping off" larger fish during the growing season and re-stocking with smaller fish once or twice a year. Thus, there is a wide size range of fish in a production pond at all times.

The 3 study ponds were also stocked on 30 June with 5,000 mixed-sex blue tilapia/ha, averaging 6.1 g. Tilapia fingerlings had been produced in a separate spawning pond and were estimated to be 6 to 7 weeks old when stocked in the study ponds.

Fish were fed 32% protein floating pelleted feed 6 day/week. When water temperatures were low (10° to 20° C) in March and April, fish were fed the quantity consumed in a 15-minute period. As surface feeding activity increased in relation to increasing water temperatures, the quantity fed was increased accordingly up to a management-imposed limit of 45 kg/ha/day. This is considered a relatively safe limit for production ponds managed without continuous aeration. Surface feeding activity decreased in late October as water temperatures declined, and the amount fed was reduced accordingly. Surface feeding activity ceased completely in early November prior to the final harvest.

Catfish were partially harvested or "topped off" several times during the growing season by seining the ponds and removing all catfish longer than 40 cm (approximately 600 g). Samples of tilapia captured during these partial harvests were sexed (beginning with the partial harvest in August), individually weighed and measured, and returned to their respective ponds. All ponds were drained and completely harvested on 17 November 1982, approximately 2 weeks before the lower lethal temperature for tilapia was reached.

Samples of tilapia from the final harvest were given to 2 retail fish markets in Pine Bluff. Retailers were asked to market the fish. While this was in no way intended to be definitive market survey, we felt the limited information obtained would be helpful in interpreting the other results of our study.

Results and Discussion

Ponds received an average feed input of 1,930 kg/ha prior to the stocking of tilapia on 30 June. Partially as a result of this feeding, dense phytoplankton blooms were already present when the tilapia were stocked, and remained at a high level throughout the study. Chlorophyll *a* averaged 33.7 μ/liter from July through October, and zooplankton dry weight averaged 1.74 mg/liter.

Tilapia aggressively attacked pellets during feeding periods, but were too small to ingest whole pellets, and therefore unable to compete to a great extent with the catfish for feed, until August. Prior to August they were only able to eat "fines," nibble on the few water-softened pellets that the catfish missed, and graze on natural food in the pond.

Although the catfish ranged up to 600 g in weight, catfish predation on tilapia was apparently minor. Tilapia survival averaged 91.7% for the 3 replicates (Table 1). The net production of tilapia alone averaged 1,020 kg/ha, and the total fish production averaged 3,971 kg/ha, with a food conversion ratio (FCR) of 1.4:1. This compares to a net catfish production of 3,190 kg/ha and an FCR of 1.6:1 obtained in a concurrent study with catfish reared in monoculture but otherwise under identical management (Torrans and Lowell 1986).

Male tilapia were significantly larger than females at the final harvest in November (ANOVA, $P \leq 0.05$). However, at that time there were no significant differences in either male or female average weights among the three replicates (Table 2). Therefore, data from the 3 replicate ponds were pooled for each sampling date to simplify further discussion of tilapia growth and size distributions.

Tilapia average 34.0 g when sampled on 20 July (Table 3). They were not differentiated by sex at that time, but were in subsequent samples. On 24 August after 55 days, male and female tilapia averaged 111.6 g and 106.4 g, respectively; however, this difference was not significant. A significant difference in weight between the sexes was first seen on 24 September, after 86 days (*t*-test, $P \leq 0.01$). Males at this time averaged 179.9 g, and the females averaged 149.5 g.

Growth of both sexes continued in a linear fashion through the fourth sample on 26 October (Table 3). Males gained 2.06 g/day from stocking through the October sample, while females grew at a rate of 1.72 g/day, or 17.5% slower.

Male and female tilapia showed striking growth differences during the last 22

Table 1. Tilapia survival and production, total production, and food conversion ratios in 3 replicate tilapia/catfish polyculture ponds.

Pond number	Tilapia survival (%)	Tilapia net production (kg/ha)	Total net production (kg/ha)	F.C.R.
1	92.4	1,017	4,195	1.5:1
2	93.0	1,052	3,814	1.3:1
3	89.6	992	3,906	1.5:1
Mean	91.7	1,020	3,971	1.4:1

Table 2. Mean weights of young-of-the-year male and female blue tilapia from three replicate ponds at harvest on 17 November 1982.

Sex	Pond number	*N*	Mean wt. (g) ± SE[a]	
Male	1	25	253.6 ± 8.4	
Male	2	25	262.0 ± 4.2	
Male	3	25	257.7 ± 6.7	
Male	sum	75	257.8 ± 3.8	a
Female	1	25	211.3 ± 5.2	
Female	2	25	204.8 ± 5.1	
Female	3	25	209.5 ± 4.7	
Female	sum	75	208.5 ± 2.9	b

[a]Means followed by different letters are significantly different at the $P \leq 0.05$ level, ANOVA. Neither male nor female weights varied significantly among ponds.

Table 3. Mean weights of young-of-the-year male, female, and unsexed blue tilapia at stocking, on 4 sample dates and at final harvest.

Date	Days growing	Male weight,[a] mean (g) ± SE (*N*)	Female weight,[a] mean (g) ± SE (*N*)	Unsexed weight, mean (g) ± SE (*N*)
30 Jun	0	—	—	6.1 (1500)[b]
20 Jul	20	—	—	34.0 ± 0.7 (122)
24 Aug	55	111.6 ± 2.2 (56)	106.4 ± 1.6 (55)	—
24 Sep	86	179.9 ± 4.6 (42)	**149.5 ± 4.8 (27)	—
26 Oct	118	248.9 ± 4.3 (47)	**211.4 ± 4.3 (43)	—
17 Nov	140	257.8 ± 3.8 (75)	**208.5 ± 2.9 (75)	—

[a]Asterisks indicate significant differences (*t*-test) of $*P < 0.05$ and $**P \leq 0.01$.
[b]Individual weights not determined at stocking.

days of the study. While males continued to grow slowly (at a rate of 0.40 g/day) from the October sample to the final harvest in November, the average female weight actually decreased 2.9 g (or −0.13 g/day) during this 22-day period (Table 3). No suitable explanation has been found for this difference in growth patterns. Water temperatures during this period were well below the lower limit for reproduction (Torrans and Lowell 1985), so spawning itself could not be a factor.

While the males were significantly larger than the females at the end of the study, both sexes had excellent body conformation, with small heads and deep bodies. Mean male and female condition factors at this time were not significantly different, averaging 2.24 ± 0.02 and 2.22 ± 0.02 respectively. While we did not determine the dress-off percentage, we have no reason to believe that there was any sex-related difference.

Less than 1 kg of 3–5 cm TL tilapia fingerlings were recovered from 1 replicate pond during the final harvest in November, indicating that 1 or more females had matured and spawned before falling water temperatures limited further reproduction. Size of fingerlings recovered at harvest indicated that they had hatched in the latter half of September, at which time the females were slightly over 4 months

Table 4. Size distributions of young-of-the-year male and female blue tilapia from final harvest. The distributions are based on a sample of 75 males and 75 females (25 of each sex from each replicate pond).

Size (g)	% males larger	% females larger	% of total harvest larger
150	100	100	100
175	100	96	98
200	96	57	76
225	92	21	56
250	53	5	29
275	28	3	16
300	11	0	6

old and averaged approximately 150 g. Yashouv (1958) also noted spawning of 4- to 5-month-old blue tilapia with an estimated weight of 120 g. Stickney et al. (1979) reared blue tilapia fry to as much as 218 g in 110 days (at which time the fish were approximately 4 months old, including prior incubation time) with no reproduction reported. These results indicate that some female blue tilapia become sexually mature at between 4 to 5 months of age, with size playing a relatively minor role in determining sexual maturity.

The 2 retail fish markets which were given tilapia indicated that all of the tilapia produced in this study were sold. The tilapia were sold "in the round" at the fish markets for $3.30/kg, a price comparable to bluegill (*Lepomis macrochirus*). The size distribution of tilapia produced in this study (Table 4) indicates that the slightly slower growth of young-of-the-year female tilapia would not be significant to a producer, in a practical sense, unless the minimum acceptable market size was 200 g or more.

The major limitation to tilapia food fish production on large catfish farms in the southern United States does not appear to be the growth rate or prolific reproduction of tilapia, but rather the seasonal production, and the difficulty in harvest. Processing and mass-marketing may not be possible if tilapia are only available in the fall, since retailers are unlikely to handle a new item that is only seasonally available. Even if mass markets for tilapia develop, harvesting tilapia from a polyculture pond is difficult without draining the pond and hand-sorting the fish, 2 practices rarely seen on large catfish farms.

Literature Cited

American Public Health Association, American Water Works Association and Water Pollution Control Federation. 1980. Standard Methods for the Examination of Water and Wastewater, 15th Edition. Am. Public Health Assoc., New York. 1,134pp.

Allison, R., R. O. Smitherman and J. Cabrero. 1976. Effects of high density culture on reproduction and yield of *Tilapia aurea*. FAO Technical Conference on Aquaculture, Kyoto, Japan, 26 May–2 June, FAO/Rome, FIR:AQ/Conf/76/E.47:3 pages.

Anderson, C. E., and R. O. Smitherman. 1978. Production of normal male and androgen sex-reversed *Tilapia aurea* and *Tilapia nilotica* fed a commercial catfish diet in ponds. Pages 34–42 *in* R. O. Smitherman, W. L. Shelton and J. H. Grover, eds. Symposium on the Culture of Exotic Fishes, Fish Culture Section, Am. Fish. Soc., Bethesda, Md.

Bardach, J. E., J. H. Ryther and W. O. McLarney. 1972. Aquaculture, the farming and husbandry of freshwater and marine organisms. Wiley-Interscience, New York. 868pp.

Barr, A. J., J. H. Goodnight, J. P. Sall, W. H. Blair and D. M. Chilko. 1979. SAS User's Guide. SAS Inst., Raleigh, N.C. 494pp.

Dunseth, D. R. and D. R. Bayne. 1978. Recruitment control and production of *Tilapia aurea* (Steindachner) with the predator, *Cichlasoma managuense* (Gunther). Aquaculture, 14:383–390.

Dupree, H. K. and J. V. Huner, eds. 1984. Third report to the fish farmers: the status of warmwater fish farming and progress in fish farming research. U.S. Fish and Wildlife Service, Washington, D.C. 270pp.

Hepher, B. and Y. Pruginin. 1982. Tilapia culture in ponds under controlled conditions. Pages 185–203 *in* R. S. V. Pullin and R. H. Lowe-McConnell, eds. The biology and culture of tilapias. Internat. Ctr. Living Aquat. Resour. Mangt., Metro Manila, Philippines.

Hickling, C. F. 1960. The Malacca tilapia hybrids. J. Genet. 57:1–10.

Lovshin, L. L. and A. B. Da Silva. 1975. Culture of monosex and hybrid tilapias. Pages 549–564 *in* Symposium on Aquaculture in Africa, Accra, Ghana 30 September to 6 October. FAO/Rome CIFA Tech. Paper (4), Suppl. 1.

Maruyama, T. and K. Nagashima. 1978. Effect of water current on growth and spawning activity of *Tilapia nilotica*. Bul. Freshwater Fish. Res. Lab. 28:201–210.

Pagán-Font, F. A. 1975. Cage culture as a mechanical method for controlling reproduction of *Tilapia aurea* (Steindachner). Aquaculture, 6:243–247.

Stickney, R. R., J. H. Hesby, R. McGeachin and W. A. Isbell. 1979. Growth of *Tilapia nilotica* in ponds with differing histories of organic fertilization. Aquaculture. 17:189–194.

Suffern, J. S. 1980. The potential of tilapia in United States aquaculture. Aquac. Mag. 6(6):14–18.

Torrans, E. L. and F. Lowell. 1985. Spawning season of blue tilapia in Arkansas. Ark. Farm Res. J. 34(1):3.

——— and ———. 1986. Potential control of off-flavor in channel catfish through polyculture with blue tilapia. (Abstract) Aquaculture 1986, Am. Fish. Soc., Fish. Cult. Sect., January 19–23, 1986, Reno, Nev.

Yashouv, A. 1958. Biological data on *Tilapia galilaea* and *Tilapia nilotica* in the fish ponds. Bamidgeh, 3 (10):47–52.