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Effects of Blue Tilapia/Channel Catfish Polyculture on Production, Food Conversion, Water Quality and Channel Catfish Off-flavor

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EFFECTS OF BLUE TILAPIA/CHANNEL CATFISH POLYCULTURE ON PRODUCTION, FOOD CONVERSION, WATER QUALITY AND CHANNEL CATFISH OFF-FLAVOR

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ABSTRACT

Channel catfish *(Ictalurus punctatus)* monoculture ponds stocked with 10,000/ha of mixed-size catfish were compared to ponds stocked additionally with blue tilapia *(Tilapia aurea)*. Ponds stocked with 5000/ha young-of-the-year blue tilapia produced 236 kg/ha less catfish, but tilapia biomass increased by 1020 kg/ha, averaging 233 g/fish. Ponds stocked with sexually mature tilapia in April to provide forage to the catfish had increased catfish production but a poorer food conversion radio. Ponds stocked with sexually mature tilapia in June or July had catfish production and FCR's similar to the controls. Dissolved oxygen was significantly lower than the controls in all polyculture treatments. Zooplankton biomass and secchi disc visbility were significantly lower than the controls in three of four polyculture treatments. Chlorophyll *a* was slightly, but not significantly, less than the controls. The major benefit of tilapia/catfish polyculture was the reduction of channel catfish off-flavor. Catfish in polyculture treatments were off-flavor 8.3% of the times sampled, compared to 62.5% for catfish reared in monoculture. The addition of tilapia to catfish ponds is a practical, effective means of reducing the incidence of off-flavor in channel catfish.

INTRODUCTION

Commercial catfish farmers were facing difficult times in 1982. Feed prices and energy costs were extremely high, and pond-bank prices for channel catfish averaged only $0.55/pound, compared to the previous five year average of $0.61/pound (USDA National Agricultural Statistics Service, 1986). Many Arkansas catfish farmers were searching for additional fish species and/or production methods that could increase their net income.

Polyculture, the rearing of two or more aquatic species together in a pond, is a production technique used to increase overall fish production and profits (Dupree and Huner, 1984). Fish species that feed low on the food chain, such as plankton feeders or detritivores, are especially suitable as companion species with channel catfish in that they do not compete directly with catfish for feed. They consume the plankton bloom and bottom sediments, normally unusable and unwanted by-products of intensive catfish culture. The result of polyculture is an increase in net fish production without a proportional increase in production costs (Dunseth and Smitherman, 1977; Torrans and Clemens, 1981).

Unfortunately, most secondary foodfish species that are suitable in polyculture for biological reasons, such as bigmouth buffalo *(Ictiobus cyprinellus)*, silver carp *(Hypophthalmichthys molitrix)* or bighead carp *(Aristichthys nobilis)*, are unsuitable for practical reasons — they have a comparatively low market value and require more than one year to reach market size. It is difficult to incorporate species such as these into an applied polyculture system with channel catfish, given the management normally practiced on commercial catfish farms. Most catfish farmers currently maintain a stock of mixed-size channel catfish, periodically "top off" the larger marketable catfish during the growing season, and restock smaller fingerlings (Dupree and Huner, 1984). A secondary species would therefore have to be separated by hand from the catfish at each partial harvest once it became too large to pass through the grading seine. This makes polyculture impractical on large commercial farms with existing management. However, polyculture could be economical if the secondary species reached market size in a single season (eliminating numerous hand-sortings) and/or had a high value (justifying the expense of extra labor).

A fish species that reduced channel catfish production costs or risks would also increase the net income of catfish farmers. A catfish food conversion ratio improved by the addition of forage fish, or better water quality (higher dissolved oxygen levels, for example) resulting from the addition of a secondary species would mean more profits for the farmer.

We felt that blue tilapia *(Tilapia aurea)*, an exotic Cichlid (Suffern, 1980) could be used in several ways to improve the economics of fish farming in Arkansas. They are an excellent foodfish with high value (Crawford *et al.*, 1978; Anon., 1986) that do well in polyculture with channel catfish (Dunseth and Smitherman, 1977; Williamson and Smitherman, 1975). What was not previously known was how large tilapia could grow in a single season in Arkansas. If tilapia could grow to market size in one season, hand-sorting during numerous partial harvests would not be a major problem. The tilapia would be large enough to be held in a grading seine only during the last partial harvest of the growing season, by which time they would be marketable. The value of the tilapia at that time could be high enough to justify the labor of separating them from the catfish (Anon., 1986).

Tilapia could also be an excellent forage fish for channel catfish. The ideal forage species has been defined as a species that is 1) prolific, 2) stable in abundance, 3) trophically efficient, 4) vulnerable to predation, 5) non-emigrating, and 6) innocuous to other species (Ney, 1981). Although blue tilapia have not been previously studied as a forage fish in catfish ponds, they appear to meet all of the criteria. In addition, since they are a tropical species that die when the water temperature falls below 7 °C, it is easy to control their distribution, both on and off the fish farm.

Finally, tilapia are facultative filter-feeders (Drenner *et al.*, 1984; McBay, 1961), as well as bottom grazers (McBay, 1961; Williamson and Smitherman, 1975; Spataru and Zorn, 1976), and could improve the water quality in catfish ponds. The use of so-called "sanitary fish"

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to improve water quality in commercial culture ponds and water reservoirs is practiced in Israel (Dupree and Huner, 1984). *Tilapia aurea* have been credited with reducing organic matter in Israeli reservoir bottom sediments, and also reducing objectionable taste and odor in water (Leventer, 1981). While objectionable taste and/or odor of the water is not itself a problem in channel catfish ponds in the United States, the absorption of odorous compounds by channel catfish is a serious problem.

The frequency and severity of "off-flavor" in pond-raised channel catfish has increased dramatically in recent years, and is generally related to increased feeding rates (Brown and Boyd, 1982). It is estimated that over 50% of the commercial catfish ponds in Mississippi and Alabama contain catfish that are "off-flavor" during the growing season (Armstrong *et al.*, 1986). Off-flavor is currently the most serious economic problem faced by the catfish industry. The annual economic impact of off-flavor in Mississippi alone is $25-75 million (Anon., 1987).

Geosmin is produced by actinomycetes and blue-green algae (Medsker *et al.*, 1968; Safferman *et al.*, 1967), and has been shown to be a major cause of off-flavor in channel catfish (Lovell and Sackey, 1973). Since tilapia consume and digest blue-green algae (Moriarty, 1973), and also forage on the sediment surface where actinomycetes grow, there is reason to believe that tilapia raised in polyculture could be effective in reducing off-flavor in channel catfish.

The purpose of this study was to evaluate blue tilapia as both a secondary food fish and as a forage fish in channel catfish ponds. We expected that this polyculture combination would result in increased net fish production, improved food conversion ratios, and better water quality, as reflected by dissolved oxygen, the plankton biomass and the incidence of channel catfish off-flavor.

MATERIALS AND METHODS

Nine 0.1 ha earthern ponds at the University of Arkansas at Pine Bluff Agricultural Experiment Station were stocked in March 1982 with mixed-size channel catfish, *Ictalurus punctatus,* averaging 164 g (5 g to 600 g) at the rate of 10,000 fish/ha. Three of the ponds served as catfish monoculture controls. Three of the ponds were also stocked with 5000 young-of-the-year blue tilapia/ha averaging 6.1 g on June 30, to evaluate the foodfish potential of blue tilapia. The last three ponds were stocked on April 25 with sexually mature (approximately one-year-old) blue tilapia at a rate of 30 females and 30 males per hectare. It was anticipated that these adult tilapia would begin spawning in May and continue to spawn throughout the summer. This could provide a large biomass forage-size tilapia for the catfish, perhaps improving the catfish food conversion ratio (FCR).

Nine ponds were similarly stocked in April 1983 with 10,000 mixed-size channel catfish/ha that averaged 194 g (5 g to 600 g range). As in 1982, three of the ponds were maintained as catfish monoculture controls. Three of the ponds were stocked on June 1 with sexually mature blue tilapia at a rate of 30 females and 30 males per hectare. Three of the ponds were stocked on July 6 with sexually mature blue tilapia at a rate of 90 females and 30 males per hectare. Different stocking rates and/or dates of adult tilapia were used in the two forage treatments this year as a result of what was learned the previous year.

Zooplankton dry weight, chlorophyll *a* (an estimate of phytoplankton density), dissolved oxygen concentration (at dawn), and secchi disc visibility were determined weekly for all ponds in 1982 using standard techniques (American Public Health Association *et al.*, 1980). Zooplankton biomass and secchi disc visibility were determined weekly in 1983, and dissolved oxygen was determined daily.

The fish were fed a 32% protein floating pelleted feed six days/week both years. The feeding rate was adjusted in a manner normally used on commercial catfish farms. When water temperatures were low (10° to 20°C) in the spring, fish were fed as much as they would eat in a 15-minute period. As fish metabolism and surface feeding activity increased in relation to rising water temperatures, the quantity fed was increased accordingly up to a management-imposed limit of 45 kg/ha/day. This limit on maximum daily feeding rate was established to minimize the need for emergency aeration (Cole and Boyd, 1986; Tucker *et al.*, 1979). Feed consumption decreased in late October as water temperatures declined, and ceased completely in early November.

Larger catfish were partially harvested or "topped off" from all ponds five times both years by seining and removing all catfish longer than 40 cm (approximately 600 g). This was done to simulate the harvesting practices on commercial catfish farms (Dupree and Huner, 1984) where the standing crop of catfish is periodically reduced to the level where maintenance and growth requirements of the standing crop are met by the management-imposed limit on feeding rate. All ponds were drained and completely harvested each year after feeding ceased in November.

One food-size catfish was randomly chosen from each partial harvest and "taste-tested". An unseasoned filet was cooked in a microwave oven, and each cooked sample was smelled, tasted and rated as to flavor by a minimum of three experienced tasters. Samples were categorized as "off-flavor" if they had an objectionable odor or taste, or "on-flavor" if there was no objectionable odor or taste.

Statistical analyses were conducted using ANOVA, Duncan's multiple range test and T-Test (Barr *et al.*, 1979).

RESULTS AND DISCUSSION

Net Production and FCR

The net catfish production over the two-year study ranged from 2916 kg/ha to 3991 kg/ha (Table 1). This was higher than the average reported fish production from commercial catfish farms in Arkansas of 2524 kg/ha (Arkansas Crop and Livestock Reporting Service, 1986). The lowest catfish yield and poorest catfish food conversion ratio (FCR) occurred when tilapia fingerlings were stocked in 1982 to produce a secondary foodfish crop (tilapia foodfish treatment, Table 1). Although the net catfish production was not significantly lower than the catfish monoculture treatment that year, the FCR was significantly poorer when only the catfish net yield was considered. However, an additional 1020 kg/ha of tilapia foodfish averaging 233 g were also produced in this treatment. When the tilapia foodfish production was added to the catfish produced, both the total yield of marketable fish (3936 kg/ha) and the FCR (1.40:1) were significantly better than the control treatment (ANOVA, $P < 0.05$). Assuming the catfish in this polyculture treatment converted feed as well as the controls (1.60:1), the 1020 kg/ha of tilapia produced consumed only 935 kg/ha of feed, for an FCR of 0.92:1. While tilapia grew to a marketable size in a single season, and the economics of this polyculture system appear favorable, we believe that there are a number of practical constraints to the successful application of this technology. Tilapia are difficult to harvest by seining alone, and a complete harvest would (and did) require total pond draining in the fall. Even if farmers found this acceptable, the entire tilapia crop would have

Table 1. Stocking, net catfish yields and incidence of catfish off-flavor of catfish monoculture and catfish/tilapia polyculture ponds in 1982 and 1983 (means of three replicate ponds per treatment).

Year	Treatment	Date tilapia stocked	Number tilapia stocked/ha	Amount fed (kg/ha)	Net yield (kg/ha)	FCR	Percent of samples off-flavor (N)
1982	Catfish Monoculture	-	-	5037 b[1]	3152 ab	1.60 b	67 (12)
1982	Tilapia Forage	April 25	30F+30M[3]	6451 a	3476 a	1.86 a	0 (12)
1982	Tilapia Foodfish	June 30	5000[2]	5601 ab	2916 b	1.92 a	0 (12)
1983	Catfish Monoculture	-	-	6237 a	3990 a	1.57 a	58 (14)
1983	Tilapia Forage	June 1	30F+30M[3]	6519 a	3991 a	1.64 a	13 (15)
1983	Tilapia Forage	July 6	90F+30M[3]	6117 a	3655 a	1.68 a	20 (15)

[1] Values in the same column followed by different letters are significantly different at the p=0.05 level. Data analyzed by year.
[2] Six- to seven-week old fingerlings averaging 6.1 g.
[3] Approximately one-year-old, sexually mature fish.

to be marketed in a relatively short time period. Few restaurants would be willing to introduce a new menu item that is only available seasonally (Pers. comm., Larry Joiner, Farm Fresh Farms, Inc.). Since the major constraint to tilapia foodfish production appeared to be marketing, not production, further research on tilapia foodfish/catfish polyculture was not conducted in 1983.

The ponds stocked with sexually mature tilapia in 1982 (tilapia forage treatment, Table 1) had a slightly higher net catfish production, but a significantly poorer FCR than the control treatment. Since the adult tilapia had been stocked in late April, they were able to begin spawning as early as May (Torrans and Lowell, 1985). Fry produced early in the year were large enough to eat whole pellets by late July, and thus competed directly with the catfish for feed for approximately three months. By the time the water was cold enough for the catfish to effectively catch and eat the tilapia (October), tilapia from the early spawns were too large (approximately 150 g to 200 g) to be consumed by the catfish. Thus, significantly more feed was given to the forage treatment over the growing season, little forage benefit was returned to the catfish, and a significantly poorer FCR resulted (Table 1). While these results were not all positive, we felt that further research on the forage benefit of tilapia was warranted. We believed that an increased stocking rate of adult tilapia and/or a later stocking date would result in an improved FCR.

Neither of the forage treatments in 1983 differed significantly from the catfish monoculture control with respect to either net catfish production or FCR (Table 1). We believe that the poorer FCR of the 1982 forage treatment was largely due to the date that the adult tilapia were stocked that year. The earlier (April 25) stocking of mature tilapia in the 1982 forage treatment, and the subsequent large size attained by the tilapia offspring, resulted in the significantly poorer FCR (1.86:1) seen in the forage treatment that year.

Overall catfish production in 1983 averaged 3879 kg/ha. Since the FCR of the catfish monoculture control treatments were nearly identical both years (1.60:1 and 1.57:1 in 1982 and 1983, respectively), we believe that the higher overall production in 1983 may be due to the greater average weight of the catfish stocked in 1983 (194 g average in 1983 versus 164 g in 1982). The greater initial fish biomass would have resulted in more feed being fed early in the season, prior to reaching the management-imposed limit on the feeding rate.

Water Quality

There were no significant differences in chlorophyll *a* between the polyculture and monoculture treatments in 1982 (Table 2). *Tilapia aurea* are size-selective phytoplankton grazers which selectively feed on particles larger than 25 µm (Drenner *et al.*, 1984). A selection pressure such as this on the phytoplankton community can result in a shift in the species composition to smaller, more rapidly reproducing species, rather than a reduction in overall phytoplankton biomass. In fact, heavy fish predation on the zooplankton has been shown to result in an overall increase in chlorophyll *a* (Burke and Bayne, 1986; Smith, 1985).

While differences in phytoplankton biomass were not detected, the zooplankton biomass was significantly lower than the control in both polyculture treatments in 1982. Both 1983 polyculture treatments had a reduced zooplankton biomass, however the difference was significant only in the treatment stocked with tilapia on June 1 (Table 2). A reduced zooplankton biomass in the polyculture ponds was expected, and at least partially accounts for the low (0.92:1) apparent FCR of tilapia. *Tilapia aurea* are escape-selective zooplankton predators that suppress populations of zooplankton with limited escape abilities (Drenner *et al.*, 1984). Other species with similar feeding strategies have also been shown to reduce the zooplankton biomass when raised in polyculture with channel catfish (Burke and Bayne, 1986; Torrans and Clemens, 1981).

The secchi disc visibility (a measure of water clarity) was less than the controls in all four polyculture treatments, and this difference was significant in three of the four treatments (Table 2). Since the reduced water clarity cannot be explained by increased zooplankton or phytoplankton biomass, we believe that it may be due to increased turbidity resulting from the tilapia foraging on the sediment surface for

Table 2. Comparison of four water quality parameters between catfish monoculture (control) ponds and catfish/tilapia polyculture ponds during 1982 and 1983. Values given are means ± SE (N) for the time period after the tilapia were stocked. Treatment means were compared to the control by sample date (Paired T-Test). Asterisks mark values that are significantly different from zero (*P<0.05; **P<0.01).

Year	Treatment	Zooplankton dry weight (mg/L)	Chlorophyll a (µg/L)	Oxygen (mg/L)	Secchi disc visibility (cm)
1982	Control[1] (From April 25)	3.16±0.46 (55)	47.2±7.8 (86)	4.97±0.26 (86)	11.6±0.6 (85)
		**	N.S.	*	*
	Tilapia forage (Stocked April 25)	1.46±0.41 (57)	40.0±4.3 (87)	4.30±0.22 (87)	9.6±0.4 (87)
	Control[1] (From June 30)	3.08±0.46 (52)	34.4±3.3 (60)	4.87±0.30 (60)	13.0±0.6 (60)
		**	N.S.	**	**
	Tilapia foodfish (Stocked June 30)	1.53±0.30 (54)	32.1±3.5 (58)	3.45±0.29 (59)	11.2±0.5 (60)
1983	Control (From June 1)	2.92±0.42 (47)	-	3.96±0.11 (313)	10.4±0.4 (48)
		*		**	N.S.
	Tilapia forage (Stocked June 1)	1.74±0.19 (46)	-	3.54±0.10 (315)	9.5±0.5 (48)
	Control (From July 6)	2.91±0.56 (35)	-	3.90±0.13 (250)	10.6±0.5 (39)
		N.S		*	**
	Tilapia forage (Stocked July 6)	1.91±0.25 (36)	-	3.13±0.11 (251)	8.2±0.3 (39)

[1] Two mean values are given for the control treatment each year since different time periods are being compared.

organic detritus and benthic invertebrates (McBay, 1961; Williamson and Smitherman, 1975).

Dissolved oxygen, perhaps the most important water quality parameter from a commercial production standpoint, was significantly lower in all polyculture treatments when compared to the controls (Table 2). The dissolved oxygen concentration measured at dawn averaged 0.4 mg/L to 1.4 mg/L less in the polyculture treatments. This was unexpected and certainly undesirable from a production standpoint, although production and FCR's were apparently unaffected by it. The reduced oxygen concentrations may have been due in part to the increased turbidity, which could reduce photosynthesis, or to the respiration of the increased fish biomass.

Off-flavor of Channel Catfish

The most important finding of this study was the reduced incidence of off-flavor in channel catfish reared in polyculture with blue tilapia. None of the catfish from the polyculture treatments were off-flavor in 1982 (Table 1), compared to a 67% incidence of off-flavor in the catfish monoculture ponds. Catfish fromt he two 1983 polyculture treatments were off-flavor 13% and 20% of the time (Table 1), compared to 58% for the catfish reared in monoculture that year. Overall, the incidence of catfish off-flavor averaged 8.3% for the tilapia/catfish polyculture treatments, versus 62.5% for the catfish monoculture controls. To our knowledge, this represents the first management technique shown to be effective in reducing the incidence of off-flavor in pond-raised channel catfish.

The dynamics of off-flavor in channel catfish are poorly understood. A variety of "off-flavors" have been detected in channel catfish, including "sewage", "stale", "rancid", "metallic", "mouldy", "petroleum", "weedy", and "musty-muddy". Only the "musty-muddy" flavor has been tied to specific compounds, namely geosmin (trans, 1, 10,-dimethyl-trans-9-decalol) and 2-methylisoborneol (Lovell, 1983).

Geosmin and methylisoborneol are produced by actinomycetes and certain blue-green algae (Medsker *et al.*, 1968; Safferman *et al.*, 1967; Silvey, 1966). However, a simple correlation between the presence of specific organisms in the water and catfish off-flavor has not been established (Armstrong *et al.*, 1986). It is likely that the production of odorous compounds results from only certain combinations of interactions of organisms and environment (Silvey, 1966).

With this in mind, it is impossible to say with certainty exactly what caused the reduced incidence of catfish off-flavor observed in our study. The tilapia may have directly reduced the blue-green algae populations by filter-feeding, or affected the actinomycetes by foraging on the sediment for detritus and benthic invertebrates. They may have indirectly influenced the system by consuming "fines" or feed normally wasted by the catfish, or by increasing the turbidity of the water.

Our data indicate that tilapia/catfish polyculture is effective in reducing the incidence of off-flavor in pond-raised channel catfish. If these findings are consistent across a large geographical area, it could result in multi-million dollar savings to the industry.

CONCLUSIONS

1) The production of tilapia foodfish in polyculture with channel catfish could be economical if tilapia can be marketed. Major constraints are that tilapia are difficult to harvest by seining, and they would have to be marketed in a relatively short time period in the fall.

2) Tilapia produced as forage for catfish had no affect on overall catfish production and FCR when the adult tilapia were stocked no earlier than June 1. Earlier stocking resulted in increased catfish production but a poorer FCR.

3) All polyculture treatments had significantly lower dissolved oxygen concentrations than the controls. While this had no observable effect on catfish food conversion, it may increase the overall risk of fish losses due to oxygen depletion. The polyculture treatments had a reduced zooplankton biomass and were more turbid, but had similar chlorophyll *a* concentrations to the controls.

4) Catfish raised in polyculture with tilapia had a significantly lower incidence of off-flavor than did catfish raised in monoculture. This management practice could provide a significant economic benefit to the catfish farming industry.

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