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Reproductive performance, growth, and survival of selected and wild × selected channel catfish

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Summary. Wild (W) and selected (S) strains of channel catfish (*Ictalurus punctatus*) were crossed to attempt to introduce genes from wild stocks into a domesticated stock without loss of growth or survival performance. W strain broodfish were from the Kaskaskia River in Illinois and had no history of artificial selection. The S strain broodfish had undergone two generations of selection for multiple-traits since 1974 and had become adjusted to tank, cage, and pond culture conditions. Females and males from both strains were paired in individual spawning pens in all possible combinations and the 19 subsequent egg masses were artificially incubated. The 15 S♀ × S♂, 6 W♀ × S♂ and 9 S♀ × W♂ crosses produced 10, 3 and 6 egg masses, respectively. None of the 7 W♀ × W♂ pairs spawned. The fish density was standardized to two tanks of 500 in each full-sib family at 4 weeks of age and 200 in each at 12 weeks of age. Domesticated and crossbred fish did not differ in spawn characteristics or 4-week body weight but domesticated catfish grew progressively faster than crossbreds and were 55% heavier and 16% longer by 40 weeks of age. No survival differences were observed among the three genetic groups. A 9-week cage test which followed the tank culture also indicated that domesticated fish were superior to crossbreds in body weight, total length, condition factor, and carcass weight. These results indicated that a single W × S cross did not establish improved gene combinations without loss of growth performance.

Key words: Channel catfish – Wild × selected – Reproduction – Tank performance – Cage performance

Introduction

Many strains of channel catfish have been produced recently by artificial selection (Smitherman et al. 1978; Bondari 1982a). These strains were selected for characteristics (improved growth rate and fertility) that may be useful under intensive culture. In contrast, natural selection should have instilled into wild catfish characteristics (hardiness, and adaptability to a wide range of water temperatures) that should make them a practical source of genetic material for introduction to selected (domestic) strains. Crossbreeding might establish combinations of genes to produce more desirable individuals. Interest in crossing wild bison and domestic cattle is long standing (Boyd 1914). This interest was used to introduce the traits of hardiness and size of the bison without loss of the growth rate and carcass quality of beef cattle (Makobo et al. 1981). Crosses of wild with the highly selected channel catfish might result in transfer of desirable wild characteristics to create a better domestic stock.

Gall (1969) crossed wild and domesticated rainbow trout, Broussard and Stickney (1981) compared reproductive performance of wild, domestic, and wild × domestic crosses of channel catfish, and Bondari (1983a) compared growth and survival of domesticated and wild × domesticated channel catfish in two water temperatures. Crossing wild with domesticated fish has been proposed by Moav et al. (1978) for the genetic improvement of wild fish populations. Osman and Robertson (1968) introduced new genetic variation into the improved stock of *Drosophila melanogaster* by crossing with unimproved populations followed by further selection. Pelzman (1980) reported on genetic impact of Florida largemouth bass on five California populations of largemouth bass. Bondari (1983b) reported that one generation of selection improved 40-week body weight and total length of channel catfish by 21 and 9%, respectively.

The objective of this study was to determine if the growth and survival of channel catfish selected for a wide spectrum of performance capabilities in Georgia was further improved or eroded by crossing with a wild strain from Illinois.

Material and methods

Brood channel catfish (*Ictalurus punctatus*) were from an improved domestic strain (S) and a wild strain (W). The domesticated catfish were descended from six stocks obtained from five different hatcheries located in Georgia, Alabama, and Mississippi (Bondari 1983 b). They had undergone two generations of selection for multiple-traits (body weight, total length, food conversion, survival, and dressing percentage) since 1974 and were 5 years old when the experiment began. The fish were kept in a 0.1-ha earthen pond and fed a commercial trout ration (37.5% crude protein) ad libitum. The wild broodfish were collected from two Army Corps of Engineers' lakes, Carlyle (10,757-ha) and Shelbyville (4,492-ha) reservoirs built on the main stem of the Kaskaskia River in Illinois. A random sample of 40 wild broodfish was transferred to Tifton, Georgia on April 29, 1981.

Pairing was made randomly within each strain and between the two strains in mid-May, 1981. The four possible strain pairs were S♀ × S♂, S♀ × W♂, W♀ × S♂, and W♀ × W♂. Each pair was placed in one of the 40 chain link fenced spawning pens (182 × 152 cm) located in a single 0.1-ha earthen pond. A 38-l milk can was added to each pen for a spawning container. Cans were checked for spawns three times/week and egg masses were removed for artificial incubation. Egg weights were determined from two samples of 20 eggs/egg mass, one from the edge and the other from the center. The average of the two samples was used in statistical computations. Number of days required for eggs to hatch was determined as number of days between spawn collection and median hatching day (if hatched over a 2-day period, the earlier day was used). A score of 0 to 10 was used to quantify the hatchability property of each egg mass (0 = no eggs hatched, 1 and 2 = poor hatch, 3 and 4 = below average hatch, 5 and 6 = average hatch, 7 and 8 = good hatch, and 9 and 10 = excellent hatch). Factors used to determine hatchability scores were spawn size, portion of the spawn hatched, portion of eggs unfertilized and aborted, and sac-fry mortality first day. Swim-up interval was determined as number of days between median hatching day and the date swim-up began.

Tank culture

Density of the full-sib fry hatched from each egg mass was standardized to two rectangular tanks of 500 in each at 4 weeks of age. Each tank (30 × 122 × 51 cm) contained 130 l of water and was equipped with an aerating nozzle to supply a constant flow of water at the rate of 3.8 l/min. Water constantly exited through a standpipe so that the water turnover was once every 34 min/tank. Well water (22 °C) was heated to 28 °C during the first 12 weeks to promote rapid growth. Each egg mass was hatched in a separate tank. Larger egg masses were, however, split and divided among two or more tanks to hatch. Each sibling set was group-weighed to determine average 4-week weight/tank. Water temperature, flow rate, water depth, and aeration of the tanks were closely controlled throughout the 40-week tank culture.

At 12 weeks of age, a random sample of 200 fingerlings from each tank was transferred to a circular tank (122 cm in diameter). They were grown from 12–40 weeks of age in these tanks which contained 560 l of 22 °C well water only. An aerating nozzle supplied a constant flow of 11 l/min well water for each tank so that the water turnover rate was once every 143 min/tank. The fish were hand-fed (ad libitum) a commercial diet (40% crude protein) five times daily from hatching to 12 weeks and three times daily from 12–40 weeks. A random sample of 25 fish/tank was individually weighed and measured for total length at 12, 16 and 40 weeks of age.

Cage culture

A 9-week cage performance test including 15 full-sib families, 6 from S♀ × S♂, 6 from S♀ × W♂, and 3 from W♀ × S♂, was initiated at 40 weeks of age. Each full-sib family was represented by 40 randomly selected fish, 20/replication. Each replication involved one cage of 1.27 cm mesh Vexar® (76 × 117 × 122 cm) stocked with 300 heat-branded fish. The cages were placed in a 2-ha reservoir described by Bondari (1982 b). The water depth in each cage was about 90 cm. The fish were fed a commercial trout ration (37.5% crude protein) to satiation twice daily. Number of fish, sex, individual body weight, total length, carcass weight, and dressing percentage (clean weight × 100/carcass weight) were determined at the end of the 9-week test (April 20th–June 22nd). Each fish was heat-branded and individually weighed and measured for total length as an experimental unit. Condition factor was determined as weight × 10^5/(total length)^3, where weight was in g and total length in mm.

Statistical analysis

Statistical procedures involved least-squares analysis of variance, mean comparisons, variance components, and correlation coefficients (SAS 1979). Strain of the fish was the source of variation for parental body weight and total length. The source of variation for spawn data was genetic groups (S♀ × S♂, S♀ × W♂, and W♀ × S♂). Family within genetic group was added to the source of variation to analyze 12-, 26-, and 40-week tank data. The model used to analyze the cage data included replication, genetic groups, family within genetic group, sex, and all possible interactions. Cage data were also analyzed for each sex independently. All effects, except family within genetic group, were assumed fixed and the error term was used in all tests of significance except for genetic group which was tested over family within genetic group.

Results

At mating time, S♀ broodfish were 75% heavier (3,816 vs 2,181 g) and 15% longer (666 vs 578 mm) than W♀ broodfish. S♂ broodfish were 26% heavier (3,904 vs 3,104 g) than W♂ broodfish but their length difference (4%) was not significant (684 vs 658 mm). These differences represent a few among many diverse characteristics of the two strains since they were reared in two different environments. For this reason, there probably is a large environmental component in the strain differences measured on the adult broodfish. Straightbred and crossbred offspring were, however, reared in the same environmental conditions to be compared for genetic differences.

Tank culture

Of the 15 pairings made to produce straightbred (S♀ × S♂) and 15 to produce crossbred (S♀ × W♂ and W♀ × S♂) fry, 10 and 9 egg masses were produced, respectively (Table 1). Spawning success was therefore similar between the two groups, 67% for the straightbred and 60% for crossbreds. Reciprocal crosses differed in spawning success since 67% of the pairs involving S♀ but 50% of those involving W♀ succeeded in egg pro-

duction. None of the 7 W♀ × W♂ pairs spawned in captivity whereas both W♀ and W♂ responded favorably to spawning stimulants from the domesticated fish. Spawning success was the same (67%) for S♀ × S♂ and S♀ × W♂ and 16 of the 19 egg masses produced came from S♀ parent. Spawning success thus, is a trait largely influenced by domestic females.

S♀ × S♂ pairs did not differ ($P > 0.05$) from pooled S♀ × W♂ and W♀ × S♂ crosses in number of days required to spawn, spawn weight, egg weight, number of days required for eggs to hatch, hatchability score, or number of days required for fry to swim-up (Table 1). Reciprocals differed ($P < 0.05$) for average egg weight; thus, eggs by S♀ × W♂ were 33% heavier (36 vs 27 mg) than those by W♀ × S♂.

First generation straightbred and crossbred catfish (reciprocals pooled) were comparable in 4-week body weight but differed ($P < 0.05$) in 12, 26, and 40 week body weight and total length (Table 1). Straightbred fingerlings progressively grew faster than crossbreds and were 55% heavier and 16% longer by 40 weeks of age. W♀ × S♂ fingerlings were heavier ($P < 0.05$) and longer ($P < 0.05$) than those produced from their reciprocal crosses at 12 weeks of age but reciprocal differences diminished thereafter. The three genetic groups were comparable in 4–12 and 12–40 week survival rate (Table 1).

Table 1. Effects of parental matings (S = selected and W = wild channel catfish) on tank performance of the offspring

Item	Parental mating			CV[c] (%)
	S♀ × S♂	S♀ × W♂	W♀ × S♂	
No. of pairs	15	9	6	
No. of spawns	10	6	3	
No. of days to spawn	19.7[a]	14.7[a]	26.7[a]	48.6
Spawn wt (g)	992[a]	819[a]	752[a]	51.3
Egg wt (mg)	36[a]	36[a]	27[b]	13.1
No. of days to hatch	4.5[a]	4.5[a]	5.0[a]	15.4
Hatchability score	5.7[a]	5.3[a]	7.0[a]	45.9
No. of days to swim-up	5.8[a]	6.3[a]	5.7[a]	11.6
Body wt (g)				
4 weeks	0.29[a]	0.32[a]	0.29[a]	32.5
12 weeks	3.80[a]	3.13[b]	3.89[a]	23.7
26 weeks	14.74[a]	9.15[b]	10.13[b]	38.4
40 weeks	48.95[a]	32.56[b]	29.79[b]	45.1
Total length (mm)				
12 weeks	79.0[a]	74.1[b]	80.2[a]	7.6
26 weeks	125.9[a]	107.4[b]	110.8[b]	11.3
40 weeks	183.4[a]	158.9[b]	157.5[b]	12.7
Survival (%)				
4–12 weeks	94[a]	89[a]	96[a]	5.2
12–40 weeks	87[a]	86[a]	84[a]	9.6

[a, b] Means within each row with different superscripts differ ($P < 0.05$)
[c] Coefficient of variation

Variance components analysis indicated that family differences contributed 46.4 and 39.3% to the total phenotypic variation in 12-week body weight of straightbred and crossbred fingerlings, respectively. Corresponding values for the total length were 50.8 and 41.8%, respectively. Family component for body weight and total length of straightbred fish was reduced to 1.8 and 5.7% at 26 weeks and to 7.3 and 17.2% at 40 weeks, respectively. Corresponding values for crossbreds were 30.2 and 35.2% at 26 weeks and 33.6 and 39.7% at 40 weeks. These results indicated that genetic variation among families was strongly influenced by strain mating combinations. Variation among full-sib family means remained a major source of variation throughout the 40-week grow-out period in tanks for crossbreds but was unimportant for the straightbreds after 12 weeks of age.

Body weight and total length were positively correlated in both parents and offspring. Significant negative correlations were found for both straightbred and crossbreds between female weight and hatchability score, between egg weight and survival rate, and between spawn weight and number of days required for the eggs to hatch. These antagonisms are probably of maternal origin and may be partially responsible for the reciprocal differences in crossbreds.

Cage culture

Sex x strain mating combination interaction was significant for several traits at the end of the cage culture; thus, separate sex analyses are presented for the cage culture data (Table 2). Replication effect was not significant indicating that differences between genetic groups were due to strain mating combinations and were not confounded with cage effects. Straightbred females and males were superior to crossbreds in body weight, total length, condition factor, and carcass weight at the end of the 9-week cage experiment. The three groups were, however, comparable in dressing percentage (Table 2).

Within the crossbreds, male catfish produced from S♀ × W♂ grew faster than the male catfish produced from W♀ × S♂. The two groups were, however, comparable in carcass characteristics. No significant reciprocal effect was observed for the female offspring (Table 2). Reciprocal crossbreds were hatched from eggs different in weight (Table 1), but maternal effects through differences in egg size could not possibly be responsible for reciprocal differences in male catfish at the end of the cage test. No significant survival differences were observed at the end of the cage test since only 14 of the 600 fish were lost (2.3% mortality), mostly from branding and handling stress.

Relative variability, measured by coefficient of variation (Table 1) was greater for number of days required for pairs of broodfish to spawn, spawn weight, and

Table 2. Effects of parental mating (S = selected and W = wild channel catfish) on cage performance of the offspring

Parental mating	*N*	Weight (g)		Length (mm)		Condition		Carcass wt (g)		Dressing %	
		$\bar{X}$	%[d]	$\bar{X}$	%[d]	$\bar{X}$	%[d]	$\bar{X}$	%[d]	$\bar{X}$	%[d]
Female offspring											
S♀ × S♂	104	151[a]	100	260[a]	100	0.816[a]	100	80[a]	100	56.2[a]	100
S♀ × W♂	103	86[b]	57	220[b]	85	0.757[b]	93	54[b]	68	54.6[a]	97
W♀ × S♂	47	81[b]	54	220[b]	85	0.740[b]	91	56[b]	70	56.6[a]	101
Male offspring											
S♀ × S♂	131	203[a]	100	285[a]	100	0.828[a]	100	105[a]	100	54.1[a]	100
S♀ × W♂	137	118[b]	58	240[b]	84	0.776[b]	94	79[b]	75	56.6[a]	105
W♀ × S♂	64	96[c]	47	228[c]	80	0.751[c]	91	63[b]	60	55.5[a]	103

[a, b, c] Means ($\bar{x}$) of female or male offspring, within a column, with different superscripts differ ($P < 0.05$)
[d] Means ($\bar{x}$) of female or male offspring were expressed as percentages of the respective S♀ × S♂ mean

hatchability score than for egg weight, number of days required for eggs to hatch and number of days required for fry to swim-up. Survival rate and total length were less variable than body weight.

Discussion

Crosses between Wild and Selected channel catfish were successful in spawn production but the crossbred catfish did not perform as well as the straightbred domestic, suggesting limited use of crossbreds in catfish culture. Osman and Robertson (1968) point out that a potentially useful gene from the unimproved population may be only at a low frequency in the first cross. The main scope of this study, however, was the comparisons between straightbred and crossbred fish under tank and cage culture conditions. Thus, combining ability of the two strains for the production of crossbreds superior to the selected parental strain and not to the average of the two parental strains remained the focus of this study.

Although eggs from wild females (W♀ × S♂ cross) weighed significantly less than those produced by domestic females (S♀ × W♂), the fry hatched from these reciprocal crosses did not differ in 4-week body weight. These results indicated that fish size and environmental differences between wild and domestic fish have strongly contributed to differences in egg weight. Reciprocal crossbreds differed in weight and length at 12 weeks of age but were similar at the end of tank culture. Despite the different patterns of growth exhibited by two crossbred groups, one group did not prove superior over the other at the end of the 40-week tank test and both were inferior to straightbred fish.

As evidenced from body weight and total length measurements, breeding from domestic × domestic parents which had undergone two generations of selection resulted in genetic changes superior to that of crossing domestic × wild strains. Data of Gall (1969) also indicate that domestic rainbow trout were 60–72% heavier than first generation domestic × wild trout between the ages of 24–48 weeks. Thus, if the overall performance of channel catfish under culture conditions is to be genetically improved, a selective breeding approach is the strategy to follow. Bondari (1983) and Dunham and Smitherman (1983) have reported on effectiveness of selection for growth traits in channel catfish.

Improved gene combinations may also be established through: (1) selection of the wild fish before crossing to domestic fish since one-half of the selection gain is lost on crossing; and (2) intense selection of fish from inter se matings of wild × domestic crosses. From crossing a highly selected line of *Drosophila* to a line far inferior in performance, Osman and Robertson (1968) reported that: (1) the most rapid breakthrough of selection limits was achieved by crossing without preselection followed by intense selection immediately after crossing; and (2) the greatest final advance was achieved when selection before crossing had been most intense.

The principal findings of this study were influenced by sex and to some extent by maternal effects. The egg weight difference probably accounted for some of the maternal and strain influence since materials and nutrients deposited by the female in each egg provided a different developmental environment for the resulting fry. Since these materials and nutrients might vary in both quantity and quality, early life cycle of the fry could be influenced by these differences. A significant difference in sex response at the conclusion of the cage culture indicated reciprocal differences for growth traits of male catfish which was not thought to be directly connected with maternal effects. Maternal effects are usually more pronounced at the early growth stages and are expected to diminish in importance with increasing age of offspring.

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