A STUDY OF ABNORMAL CHARACTERISTICS OF CHANNEL CATFISH AND BLUE TILAPIA

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Abstract: Abnormal characteristics studied were taillessness, triple-tailed, crooked-back, albinism, and piebaldness in channel catfish (*Ictalurus punctatus*) and missing dorsal fin in blue tilapia (*Tilapia aurea*). Tailless catfish were divided into 2 groups: (1) totally tailless with the caudal fin completely missing and (2) partially tailless with the caudal fin reduced in size and modified in shape. Results indicated that the absence of the caudal fin in channel catfish severely reduced body weight and total length and should be selected against. Crooked back abnormality reduced body weight by 28 and 39% at 4 and 12 weeks of age, respectively. Triple-tailed catfish, however, were comparable in body weight to normal catfish at 4 and 12 weeks of age. Tailless, partially tailless, and normal catfish did not rank differently under different culture conditions indicating that multiple-environmental testing will not be required to determine relative growth of the 3 phenotypes. Albinism in channel catfish was determined to be inherited as a monogenic autosomal recessive trait. Both pied channnel catfish studied were female but differed in their color pattern and growth potential. Dorsal fin abnormality in blue tilapia was not sex influenced and had no detrimental effect on growth.

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Limited information reported on morphological abnormalities in channel catfish has been summarized by Smitherman et al. (1978). According to this report, the cause of such abnormalities as tailless, crooked backs, eyeless, and malformed mouth in channel catfish is speculated by a few authors to be environmentally (pesticides or incubation temperature) as well as genetically induced (inbreeding). However, most reports are merely comments on the capture of an aberrant specimen and give no detailed information on any of these abnormalities. Albinism in channel catfish has been studied in greater detail (Nelson 1958, Prather 1961, Brady et al. 1962, Allen 1968, Hill 1974, Page and Andrews 1975, Westerman and Birge 1978) but its mode of inheritance has not heretofore been determined. Also, the extent to which these abnormalities affect reproduction and growth traits is not determined.

No data are available on the effect of abnormalities on breeding or production characteristics of blue tilapia. Since our knowledge of the genetic mechanisms of abnormalities in channel catfish and tilapia is limited, abnormal phenotypes should be tested for mode of inheritance. The purpose of the present study was to report on abnormalities of fish observed in a domesticated population, to determine their influence on reproduction and growth traits, and to provide information which could lead to an understanding of the genetic bases for abnormal phenotypes.

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METHODS

Tailless, Triple-tailed, and Crooked Back Channel Catfish

Tailless, triple-tailed, and crooked back catfish were produced from apparently normal parents pair-mated in a 240 × 150 cm wire-fenced spawning pen located in a 0.1-ha pond. Eggs were collected in summers of 1980 and 1981 and were artificially incubated in 30.5 × 122 × 35.5 cm fiberglass tanks equipped with an aerating nozzle which supplied well water (27 C) at the rate of 3.8 l/min. All fry were kept for 4 weeks and then the full-sib family was reduced at random to 500 fry which remained in the same tank for 12 more weeks. The tail abnormality was noted at 4 weeks of age and a careful examination of about 100 full-sib families hatched in 1980 and 109 hatched in 1981 indicated that only 1 family from 1980 and 4 from 1981 were affected. Various degrees of taillessness were observed at 16 weeks of age when fingerlings were transferred to 122 cm diameter tanks (Fig. 1). The caudal fin was completely absent (Fig. 1-D) in some fish (totally tailless), reduced considerably in length and width in another group, and developed into a small knob in others (Fig. 1-C). No distinction was made between the latter 2 groups (partially tailless). Triple-tailed (Fig. 1-B) and crooked back (Fig. 2) fry were observed among those hatched in 1981. The affected phenotypes exhibited no swimming difficulties in tanks of various sizes and shapes. A random sample of 59 totally tailless, 14 partially tailless, and 84 normal catfish, hatched in 1980, was transferred to a 1.3 cm plastic mesh cage (76 × 117 × 122 cm) with a water depth of 91 cm. The cage was placed in a 2-ha reservoir to compare growth and survival in a different environment.

Albinism in Channel Catfish

Albino catfish were produced by the same procedures described for the tailless catfish. Initial crosses were made between the albinos and 5 other wild color stocks obtained from different hatcheries in 1974. Since this abnormality seemed to be transmitted genetically to the offspring, additional crosses were made in 1978 and 1979 to determine the mode of inheritance of albinism in channel catfish.

Piebaldness in Channel Catfish

Two pied female channel catfish were observed among many thousands of tank-cultured fingerlings hatched in 1979. The pied pattern varied considerably between the two (Fig. 3). Pigmentation of the smaller fish in Fig. 3 was asymmetrical. The left side showed more albino-like coloring (nonmelanic) with fewer black splotches than the right side. The left eye was also red in contrast to the normal black color of the right eye. The anal fin appeared albino-like with several black fin rays, while the caudal fin was mostly black with several albinic fin rays. This fish was produced from 1 generation of brother-sister mating and was kept with a random sample of 40 normally pigmented full-sib fish. Both parents were normal in color but had full-sib albinos.

The pigmentation of the larger pied fish (Fig. 3) was predominantly wild with black splotches (melanistic). The color pattern was symmetrical and no black

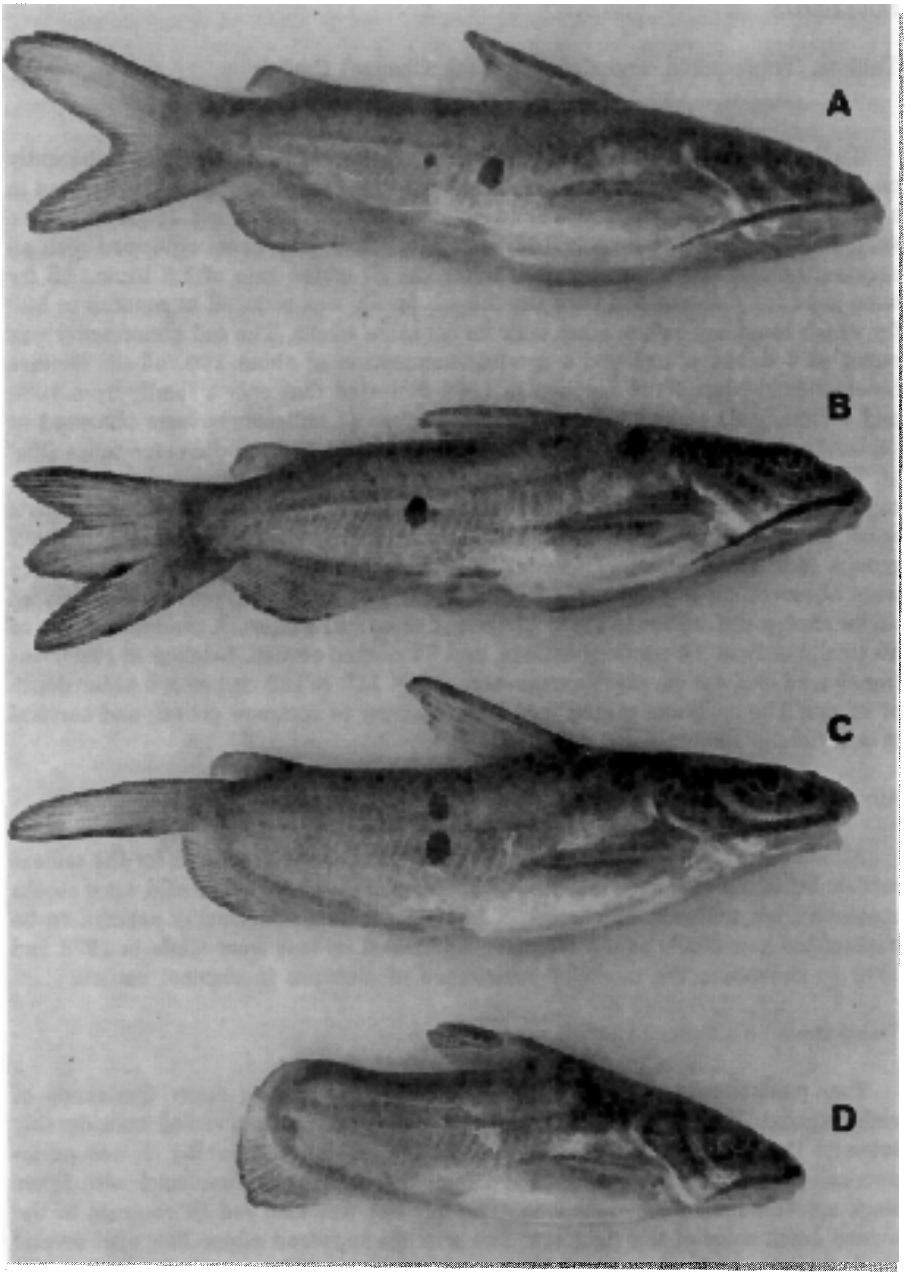

Fig. 1. Normal and abnormal caudal fin appearances in channel catfish. A indicates normal caudal fin, B triple-tailed, C partially tailless, and D totally tailless.

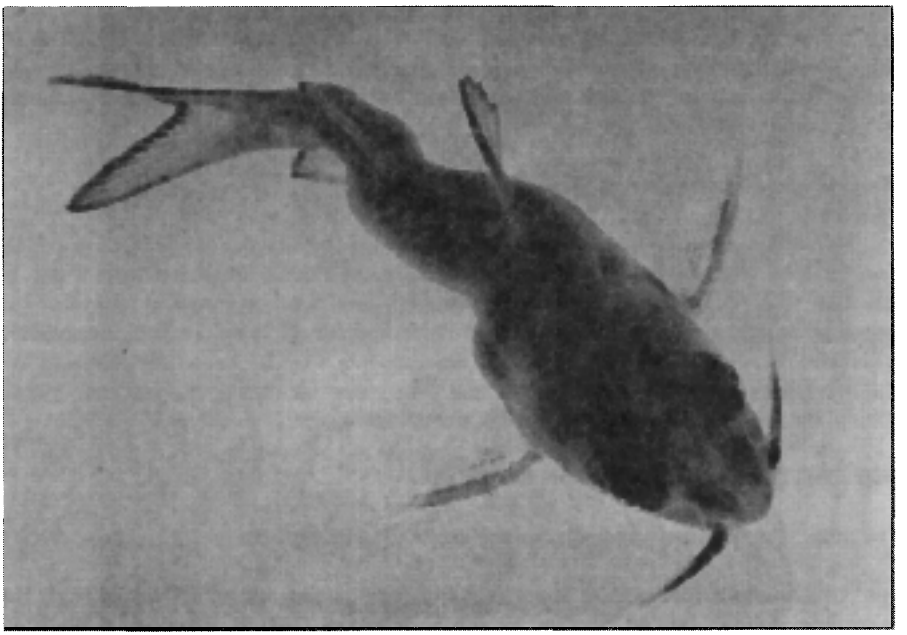

Fig. 2. A 10-week old crooked back channel catfish.

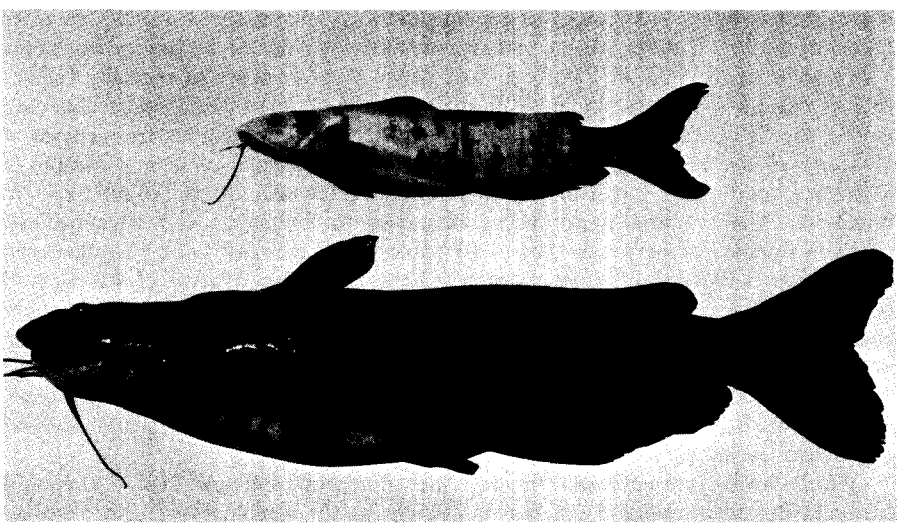

Fig. 3. Two pied channel catfish (females) of the same age (95 weeks old) but of different size. Eye color and piebald pattern of the right and left sides were different in the smaller catfish (top picture) but were the same in the larger one. The larger catfish shows melanistic pattern on both sides.

splotches were apparent on the head. This fish was also hatched in the summer of 1979 but not recognized as melanistic before being transferred to a 0.1-ha pond along with fish from other families. It was identified at the age of about 50 weeks when the pond was seined and was transferred to an indoor tank. No family pedigree was available for this fish.

Dorsal Fin Abnormality in Blue Tilapia

Dorsal fin absence was observed in 2-year-old foundation stock of blue tilapia kept in fiberglass tanks. The missing portion of the dorsal fin varied from 1 fish to another (Fig. 4), and both sexes were affected. Sex, total length, and length of the missing portion of the dorsal fin were determined for all individuals that exhibited this trait. One male also had a pectoral fin abnormality. The base population (500 - 600 fish) was grown in cages placed in a 2-ha reservoir during the summer before being transferred to indoor tanks for overwintering.

RESULTS AND DISCUSSION

Tailless, Triple-tailed, and Crooked Back Channel Catfish

A random sample of 200 fingerlings obtained at the age of 16 weeks from the abnormal full-sib family, hatched in 1980, indicated that 44, 45, and 11% of the fish were apparently normal, totally tailless, and partially tailless, respectively. The sex of the fish was not determined at this stage, but later observation showed that both sexes were equally affected. The frequency of occurrence of affected and normal phenotypes (Table 1) varied considerably among the 4 full-sib families hatched in 1981. Totally tailless catfish constituted about 2% of the fry in Family 3 as compared to 50% in Family 2. The range of occurrence of partially tailless catfish was 1.5 (Family 4) to 30.7% (Family 2). Triple-tailed catfish were observed among the fish in 2 of the 4 full-sib families (3 and 4) with relative frequencies of 52.4 and 26.5%, respectively. Only 6 crooked backs were observed in a sample of 500 fry from Family 1 (1.2%) but the number increased to 96 (about 32%) in Family 2. The crooked back catfish observed in Family 2 were also tailless, partially tailless, or normally tailed. No triple-tailed crooked back was observed among these fish. Mortality rate, from 4 to 12 weeks of age, of none of the affected phenotypes exceeded the normal phenotype. Number of fish and relative frequencies shown in Table 1, however, are based on the assumption of equal mortality rate for the 5 phenotypes prior to 4 weeks of age (12 weeks for Family 4). These catfish were not sexually mature so the mode of inheritance of caudal fin abnormality is unknown. However, data concerning the effects on growth and survival have been collected.

Within-family comparisons of normal and affected phentoypes (Table 2) should minimize the environmental differences influencing these phenotypes. Since catfish from each of the 4 full-sib families were group-weighed at 4 weeks of age, no statistical analyses were performed on these data. According to these results, totally tailless catfish weighed 13-25% less than normal but partially tailless and triple-tailed catfish were comparable in 4-week body weight to normal (Table 2). Crooked back fish were very few in number and weighed 28% less than normal fish.

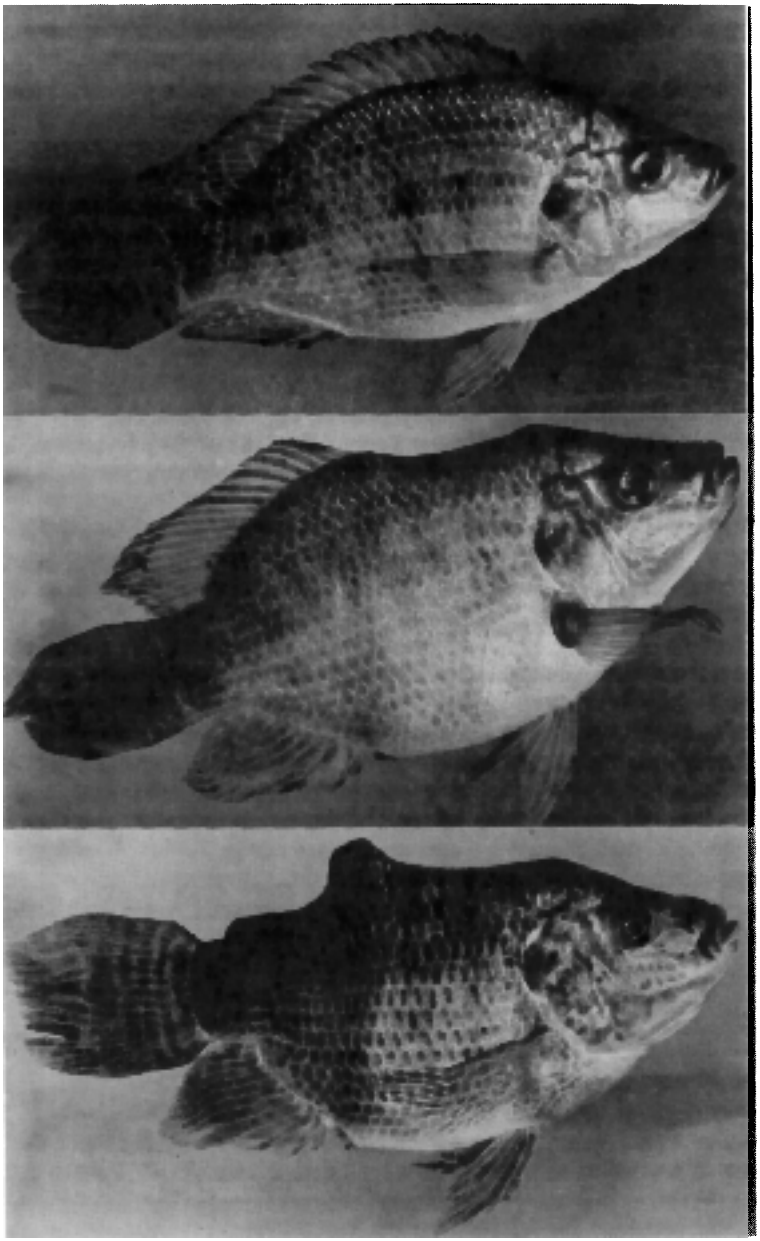

Fig. 4. Dorsal fin abnormality in 12-week-old blue tilapia. A indicates normal fin, B partially missing fin, and C totally missing fin. The missing portion of dorsal fin, expressed as percentages of total length, provided an index of variability for this quantitative trait.

Table 1. Frequency distribution of each phenotype in 4 full-sib families of channel catfish (1981-hatch).

Phenotype	Family 1[a]		Family 2		Family 3		Family 4	
	No. of fish	%	No. of fish	%	No. of fish	%	No. of fish	%
Totally tailless	26	5.2	151	49.8	18	1.8		
Partially tailless	88	17.6	93	30.7	92	9.2	7	1.5
Triple-tailed					524	52.4	122	26.5
Crooked back	6	1.2	96[b]	31.7				
Normal	380	76.0	59	19.5	366	36.6	332	72.0
Total	500	100.0	303	100.0	1,000	100.0	461	100.0

[a] Relative frequency of each phenotype was determined at 4 weeks of age for full-sib families 1, 2, and 3, and at 12 weeks of age for Family 4.

[b] Five of the crooked back fish were normally tailed, 67 totally tailless, and 24 partially tailless and were included in the number of fish for each of these phenotypes in Family 2.

Table 2. Four- and 12-week body weight (mg) and 12-week total length (mm) of totally tailless (TT), partially tailless (PT), triple-tailed (3T), crooked back (CB), and normal (N) channel catfish from 4 full-sib families (1981-hatch).

Trait	Age (wks)		Family 1 $\bar{X}$	Family 1 %[a]	Family 2 $\bar{X}$	Family 2 %[a]	Family 3 $\bar{X}$	Family 3 %[a]	Family 4 $\bar{X}$	Family 4 %[a]
Weight	4	TT	459	79	241	87	439	75		
		PT	559	97	258	93	631	108		
		3T					578	99		
		CB	417	72						
		N	576	100	276	100	583	100	585	100
Weight	12	TT	2,420D[b]	66	4,130C	71	4,290C	71		
		PT	3,200C	87	5,240B	90	4,670C	77	3,840B	83
		3T					5,610B	93	4,160B	89
		CB	2,210D	60	4,900BC	84				
		N	3,690B	100	5,820B	100	6,040B	100	4,650B	100
Length	12	TT	51D	67	53D	64	55E	67		
		PT	67C	88	74C	89	69D	84	67D	84
		3T					78C	95	74C	93
		CB	48D	63	69C	83				
		N	76B	100	83B	100	82B	100	80B	100

[a] As percentages of normal mean in each age group.

[b] Means for each trait, within the same column, followed by different letters differ ($P < 0.05$).

At 12 weeks of age, normal catfish were the heaviest and longest in all full-sib families. Partially tailless catfish from Families 2 and 4 and triple-tailed catfish were similar to normal in 12-week body weight but were significantly shorter ($P <$

0.05) in total length (Table 2). Partially tailless catfish from Families 1 and 3 weighed 13 and 23% less ($P < 0.05$) and were 12 and 16% shorter ($P < 0.05$) than normal catfish, respectively. Totally tailless catfish weighed 29 to 34% less ($P < 0.05$) and were 33 to 36% shorter ($P < 0.05$) than normal. Crooked back fish were very few in number and were comparable to totally tailess catfish in body weight and total length. These results indicated a downward trend in growth of totally and partially tailless catfish between the ages of 4 and 12 weeks. Differential phenotypic performances observed among families indicated that genetic differences among families have influenced the growth of normal and affected phenotypes differently.

Totally and partially tailless catfish (combined) weighed about half as much as the normal catfish at 40 weeks of age and were 35% shorter in length (Table 3). These differences were statistically significant ($P < 0.05$). At 45 weeks of age, totally and partially tailless catfish weighed 45 and 29% less ($P < 0.05$) than the normal catfish and were 37 and 18% shorter ($P < 0.05$) in length, respectively. Totally tailless catfish did not differ significantly from partially tailless catfish in 45-week body weight ($P > 0.05$) but were significantly ($P < 0.05$) shorter in length. These results indicate that the caudal fin absence during early life stages is detrimental to growth traits of channel catfish and should be selected against.

Table 3. Body weight (g) and total length (mm) of totally tailless (TT), partially tailless (PT), and normal (N) channel catfish at 40, 45, 54, and 69 weeks of age (1980-hatch).

Age	Tail	Tank-grown				Cage-grown			
		Weight		Length		Weight		Length	
(wks)		$\bar{X}$	%[a]	$\bar{X}$	%[a]	$\bar{X}$	%[a]	$\bar{X}$	%[a]
40	TT	31C[b]	51	121C	65				
	PT								
	N	61B	100	185B	100				
45	TT	41C	55	125D	63				
	PT	53C	71	164C	82				
	N	75B	100	200B	100				
54	TT	66D	46	149D	58	58D	43	143D	60
	PT	94C	66	211C	83	85C	63	195C	82
	N	143B	100	255B	100	136B	100	239B	100
69	TT	94D	41	160D	56	189D	46	202D	59
	PT	174C	75	247C	86	315C	76	294C	86
	N	232B	100	288B	100	413B	100	340B	100

[a] As percentages of normal mean in each age group.

[b] Means of each age group, within the same column, followed by different letters differ ($P < 0.05$).

The 3 phenotypes differed in relative growth under different culture conditions (Table 3). Totally and partially tailless catfish were significantly ($P < 0.05$) different in both tank and cage cultures (Table 3). Normal catfish were superior ($P < 0.05$) in body weight and total length to both totally and partially tailless groups when grown in tanks for 54 weeks or in a cage between 45 and 54 weeks of age. Results

obtained from 69-week data (Table 3) were consistent with those of 54 weeks under the 2 culture conditions. Totally and partially tailless catfish grew 59 and 25% less ($P < 0.05$) in weight and 44 and 14% less ($P < 0.05$) in total length than tank-grown normal catfish, respectively. Respective values for the 69-week cage-culture were 54 and 24% for body weight and 41 and 14% for total length (Table 3). Weekly gain and total length increase of the 3 phenotypes in cage-culture were 3 to 4 times greater than in tank-culture. These results indicate that (1) total or partial absence of the caudal fin is detrimental to growth of channel catfish and (2) differential ranking of the phenotypes was not observed in tank and cage culture and thus multiple-environmental testing will not be necessary to determine relative growth of the 3 phenotypes.

Albinism in Channel Catfish

To determine the genetic basis of albinism in channel catfish, 5 simultaneous parental crosses with different skin colors (Trial 1) were initiated in 1974 and were continued in 1978 (Table 4). Results of the 1st cross indicated that all of the F_1 fish were wild color. F_2 data from this cross were analyzed for goodness-of-fit to a 3:1 Mendelian ratio and the $\overline{X}^2$ was not significant at 0.05 level. Cross numbers 4 and 5 indicated that albino × albino crosses always produce albino catfish. Ten additional crosses of albino × albino made in 1981 (not listed here) all resulted in 100% albino offspring. These results (cross numbers 1, 4 and 5) are consistent with the hypothesis that the albino phenotype is inherited as a monogenic autosomal recessive "a." The wild type allele is represented by a "+." However, cross numbers 2 and 3 did not conform to this hypothesis since no albino offspring were produced in F_2. Differential results obtained from the 2 reciprocal crosses (1 and 3) suggest sex-linked inheritance. Since no obvious errors in these data were noted, further crosses were made in 1979 (Trial 2) and the results are shown in Table 5. These results conform to the hypothesis that albinism in catfish is inherited as an autosomal recessive trait. Cross numbers 2 and 3 (Table 5) indicated that albino fry may be less viable than normal fry. More research is needed to verify this hypothesis.

Piebaldness in Channel Catfish

Differential growth rates were apparent for the 2 pied catfish shown in Fig. 2. The smaller fish weighed 108 g at 81 weeks of age whereas the larger weighed 1036 g at the same age. Corresponding total lengths were 238 and 461 mm, respectively. Weights at 94 weeks of age were 171 and 1160 g, respectively, indicating that the smaller pied fish gained only 50% as much as the larger one during the 81st to the 94th week of age. The smaller pied fish, however, grew 23% more in length than did the larger pied fish (270 and 487 mm, total length at 94 weeks, respectively). Body weight and total length of the 22 full-sib females of the smaller pied fish at 94 weeks of age were 441 g and 356 mm. These data indicated that the smaller pied fish weighed only 39% as much as her normal sisters grown in the same tank. Her body length also was only 76% of the expected normal length. No comparable data on the full-sib basis were available for the larger pied fish. This fish was grown under environmental conditions different from the smaller

Table 4. Breeding data from channel catfish crosses involving albino and wild phenotypes (Trial 1).

Cross No.	Parental cross[b] (1974) ♀	Parental cross[b] (1974) ♂	F_1 Color[c]	F_1 cross (1978) Sex	F_1 cross (1978) Color[d]	Offspring (number and ratio) Albino	Wild	Ratio	$\overline{X}^2$
1.	Aub (+/+)	Alb (a/a)	Wild	♂ (+/a)	Wild	1,362	4,222	3:1	1.10
	Aub (+/+)	Alb (a/a)	Wild	♀ (+/a)	Wild				
2.	Alb (a/a)	Wild (+/+)	Wild	♂ (+/a)	Wild	None	100%	1:0	?[e]
	Alb (a/a)	Wild (+/+)	Wild	♀ (+/a)	Wild				
3.	Alb (a/a)	Aub (+/a)	Mixed	♂ (+/a)	Wild	None	100%	1:0	?
	Alb (a/a)	Aub (+/a)	Mixed	♀ (+/a)	Wild				
4.	Alb (a/a)	Alb (a/a)	Albino	♂ (a/a)	Albino	None	100%	1:0	
	Tift II (+/+)	Sk II (+/+)	Wild	♀ (+/+)	Wild				
5.	Alb (a/a)	Alb (a/a)	Albino	♂ (a/a)	Albino	None	100%	1:0	
	GK I (+/+)	Wild (+/+)	Wild	♀ (+/+)	Wild				

[b] Alb (albino), Aub, Sk II, Wild, Tift II, and GK I were original 6 stocks obtained from different hatcheries to establish a foundation breeding population.

[c] Mixed indicates the presence of both wild and albino colors in a full-sib family.

[d] Shows the color of male and female F_1 fish selected for breeding.

[e] Results are not as expected.

Table 5. Breeding data from channel catfish crosses involving albino and wild phenotypes (Trial 2).

Cross No.	Parental cross[b] (1974) ♀	Parental cross[b] (1974) ♂	F_1 Color[c]	F_1 cross (1978) Sex	F_1 cross (1978) Color[d]	Offspring (number and ratio) Albino	Wild	Ratio	$\bar{X}^2$
1.	Alb (a/a)	Aub (+/a)	Mixed	♂ (+/a)	Wild	4,233	13,112	3:1	3.26
	Aub (+/+)	Alb (a/a)	Wild	♀ (+/a)	Wild				
2.	Sk II (+/a)	Aub (+/a)	Mixed	♂ (a/a)	Albino	2,756	2,873	1:1	2.43
	Alb (a/a)	Wild (+/+)	Wild	♀ (+/a)	Wild				
3.	Alb (a/a)	Wild (+/+)	Wild	♂ (+/a)	Wild	635	720	1:1	5.33*
	Tift II (+/a)	Wild (+/a)	Mixed	♀ (a/a)	Albino				
4.	Tift II (+/a)	Wild (+/a)	Mixed	♂ (+/+)	Wild	None	100%	1:0	
	Alb (a/a)	Wild (+/+)	Wild	♀ (+/a)	Wild				
5.	Aub (+/+)	Alb (a/a)	Wild	♂ (+/a)	Wild	None	100%	1:0	
	GK I (+/+)	Wild (+/+)	Wild	♀ (+/+)	Wild				
6.	Alb (a/a)	Alb (a/a)	Albino	♂ (a/a)	Albino	None	100%	1:0	
	Wild (+/+)	Tift II (+/+)	Wild	♀ (+/+)	Wild				
7.	Tift II (+/+)	SK II (+/+)	Wild	♂ (+/+)	Wild	None	100%	1:0	
	Aub (+/+)	Alb (a/a)	Wild	♀ (+/a)	Wild				
8.	Wild (+/+)	Wild (+/+)	Wild	♂ (+/+)	Wild	None	100%	1:0	
	Aub (+/+)	Alb (a/a)	Wild	♀ (+/a)	Wild				
9.	Alb (a/a)	Aub (+/a)	Mixed	♂ (+/a)	Wild	None	100%	1:0	
	Tift II (+/+)	Sk II (+/+)	Wild	♀ (+/+)	Wild				
10.	Aub (+/+)	Alb (a/a)	Wild	♂ (+/a)	Wild	None	100%	1:0	
	Tift II (+/+)	Sk II (+/+)	Wild	♀ (+/+)	Wild				

[b] Alb (albino), Aub, Sk II, Wild, Tift II, and GK I were original 6 stocks obtained from different hatcheries to establish a foundation breeding population.

[c] Mixed indicates the presence of both wild and albino colors in a full-sib family.

[d] Shows the color of male and female F_1 fish selected for breeding.

* $P < 0.05$.

pied fish for the 50-week post-hatching period and the reasons for such great growth differences during this period are not known.

Body weight and total length of the small piebald catfish determined at the age of 121 weeks were 267 g and 317 mm, respectively. Average body weight and total length of the 21 females, grown in the same cage, were 890 g and 445 mm. The small piebald fish weighed only 30% of her normal full-sibs and was about 71% as long. The larger piebald fish which was grown in the same cage with the other full-sib family weighed 2730 g and was 601 mm long at the same age. This fish gained about 58 g/week weight and grew 4.2 mm/week in length from 94 to 121 weeks of age. Corresponding values for the smaller piebald were 3.6 g and 1.7 mm, respectively. Average weekly gain and length increase for the full-sib females kept in the same cage were 16.6 g and 3.3 mm. The larger piebald catfish has exhibited an outstanding growth record in this period and with no environmental differences between these fish, genetic potential for growth must be the main reason. The smaller piebald catfish has remained the smallest of the full-sibs and inferior in growth. These 2 fish were not bred so the mode of piebald inheritance in channel catfish was not determined. Most likely, the 2 female catfish are piebald for different genetic reasons.

Dorsal Fin Abnormality in Blue Tilapia

Length of the missing segment of the dorsal fin was expressed as a percentage of the total length of each fish since the missing portion varied from 1 fish to another and was thought to be influenced by the length of the fish. This trait provided an index of variability ranging from zero (normal fin) to 50% (completely missing). Of the 500 fish examined, approximately 4% exhibited dorsal fin abnormality. Affected females were twice as many as affected males but the missing portion of the dorsal fin when expressed as a percentage of total length was not influenced by sex. However, dorsal fin was 100% absent in 1 female but no male tilapia was so severely affected.

In general, length of the dorsal fin, expressed as a percentage of total length, in normal tilapia was not sex influenced and displayed very little variability. Means and standard deviations for this trait, determined from a sample of 10 normal males and 10 normal females, were 48 $\pm$ 2.5 and 49 $\pm$ 2.7, respectively.

The range of percent of the missing portion of the fin was 14.5 - 39.3 in males and 11.2 - 50.0 in females. The mean and standard deviation for the percent of missing fin were 29.2 and 9.2%, respectively for the 5 male tilapia possessing this trait. The respective values for the 11 affected females were 30.7 and 13.6%. These differences were not statistically significant indicating that the length of the missing portion of the dorsal fin was not affected by sex. Mean body weight and total length of a random sample of 25 normal male and 25 normal female tilapia at 100 weeks of age were 531 g and 292 mm and 274 g and 247 mm, respectively. Corresponding values for the affected males and females were 582 g and 291 mm and 270 g and 241 mm, respectively. These differences were not statistically significant. Thus, dorsal fin abnormality in blue tilapia is not detrimental to growth and should not be selected against. Missing dorsal fin in tilapia may be beneficial since these fish may be more efficient to process or may yield a greater dressed weight. Further research is needed to explore these possibilities. Furthermore,

missing fin, expressed as a percentage of total length is a quantitative trait and perhaps is controlled by many pairs of genes.

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