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Genetic basis of pectoral fin deformities in the African catfish *Clarias gariepinus* (Burchell,1822), *Heterobranchus longifilis* (Valenciennes 1840) and their hybrids

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Abstract

Morphological aberrations of the pectoral fins in nine mating combinations involving *Clarias gariepinus* (Burchell, 1822), *Heterobranchus longifilis* (Valenciennes, 1840) and their hybrids were investigated to determine the level and genetic basis of occurrence. The highest mean percentage survival in a *Clarias* × *Clarias* group was 75%, whereas the least mean percentage survival was 2% in the same group. The least mean percentage survival (40.3%) in the remaining three groups occurred in the cross of female hybrid (right pectoral fin absent) × male *C. gariepinus* (right pectoral fin absent). A maximum of nine types of aberrations was observed in the four mating groups – double dorsal fin, curved posterior dorsal fin, spineless right pectoral fin, right pectoral fin absent, left pectoral fin absent, rudimentary pectoral fin, both pectoral fins absent, double anal fin and curved anterior dorsal fin. These nine aberration types were recorded in the *Clarias* × *Clarias* group, with a total frequency ranging from 7.14% to 75.00%. The least number of aberrations was observed in the hybrid × *Clarias* group (double dorsal fin and both pectoral fins absent) with a frequency range of 1.47–5.55%. No aberration was observed in two crosses involving female hybrid (right or left pectoral fin absent) × female *C. gariepinus* (normal). The level of aberrations in some of these crosses indicates the involvement of genotype rather than the influence of environment.

Keywords: aberration, pectoral fin, *Clarias gariepinus*, *Heterobranchus longifilis*, hybrid

Introduction

The African clariid catfish, especially species of *Clarias* and *Heterobranchus*, are important candidates for commercial aquaculture in Africa. They are mostly used under controlled conditions in fish hatcheries. In addition, hatchery operators hardly have room for exchange of genes with collections from the wild or other hatcheries, thus encouraging morphological abnormalities in hatchery-bred catfish.

Communications describing the incidence and inheritance of morphological traits in commercially valuable fish are increasingly being documented. According to Kirpichnikov (1981), a lot of studies have been carried out among cyprinids, salmonids, catostomids, percids, silurids as well as in aquarium fish, such as the Cypridontidae and the Poecilidae. Aberrations commonly described include scaling pattern, fin shape and body colour differences. The ubiquitous goldfish *Carassius auratus* L. represents a principal example of variations in fin shape. The simplest fin shape genetics appear to be those observed in fancy platies of the genus *Xiphophorus*. In *Xiphophorus maculatus* Helleri, fancy forms with a very pronounced dorsal fin called 'top sail' or 'hifin' have been developed. Norton (1967a,b) described this characteristic to be inherited as a Mendelian

dominant, which made it easy to introduce sundry other colour forms.

Several types of abnormalities have been reported in channel catfish *Ictalurus punctatus* Walbaum, including stumpbody, partial taillessness and tail-lessness (Smitherman & Dunham 1985); eyeless-ness in *I. punctatus* (Green, Smitherman & Pardue 1979); albinos in *Ictalurus catus* (Linnaeus, 1758), (McLane 1950); and solid black and piebald in *I. punctatus* (Bondari 1981). Morphological abnorm-alities affecting pectoral and ventral fins have been reported in some second-generation backcross hybrids of *Clarias* and *Heterobranchus* species (Aluko 1998). Other aberrations that affect the dorsal, adipose, caudal and anal fins as well as the cephalic region and the shape of the abdominal region have been observed in hatchery-bred African catfish, clariid species (P. O. Aluko, unpublished). The genetic basis of the pectoral fin aberration of the African catfish has not been reported before in the literature.

This study was therefore designed to determine whether environmental or genetic factors are responsible for fish aberrations.

Materials and methods

Source of breeders

The *Clarias gariepinus* (Burchell, 1822) used were obtained from the Netherlands, *Heterobranchus longifilis* (Valenciennes, 1840) from south-eastern Nigeria, and the hybrids between *Clarias* and *Heterobranchus* used in this study were produced at the National Institute for Freshwater Fisheries Research (NIFFR), Nigeria. These collections had been reared and managed in the concrete tanks at NIFFR for about 2 years. Fish samples with pectoral fin abnormality as well as normal samples were selected as follows:

(1) female *C. gariepinus* with left pectoral fin absent [C.gar. (f)(LPA)];
(2) male *C. gariepinus* with right pectoral fin absent [C.gar. (m)(RPA)];
(3) female *C. gariepinus* with both right and left pectoral fins intact [C.gar. (f)(normal)];
(4) male *C. gariepinus* with both right and left pectoral fins intact [C.gar. (m)(normal)];
(5) female *H. longifilis* with both right and left pectoral fins intact [H.long. (f)(normal)];
(6) male *H. longifilis* with both right and left pectoral fins intact [H.long. (m)(normal)];
(7) female hybrid with left pectoral fin absent [Hb. (f)(LPA)];
(8) female hybrid with right pectoral fin absent [Hb. (f)(RPA)].

Male breeders were easily recognized by pointed genitals, whereas the genitals of females were roundish.

Hormonal injection

Both male and female breeders were injected with $0.5\,mL\,kg^{-1}$ fish body weight of ovaprim hormones at a latency period of about 10 h for *C. gariepinus* and about 15 h for *H. longifilis* and the hybrids. *H. longifilis* and the hybrids were injected with hormones 5 h before the injection of *C. gariepinus.* At the end of latency, the males were dissected to expose the testes. The testes were carefully removed and wiped clean of blood, put in Petri dishes and covered for about 2 min before use. Slight pressure was applied to the abdomen of the female to release the eggs into another Petri dish.

Fertilization procedure

The testes were cut open with a razor blade, and the spermatozoa were first diluted with 0.9% physiolo-gical saline before mixing with eggs to effect fertilization. Mixing of eggs and sperm was aided by a clean dry feather.

Experimental crosses

The following crosses were carried out in duplicate using the sperm from the same male for the duplicates:

(1) [C.gar. (f)(normal)] × [C.gar. (m)(RPA)];
(2) [C.gar. (m)(LPA)] × [C.gar. (m)(normal)];
(3) [C.gar. (f)(normal)] × [C.gar. (m)(normal)];
(4) [H.long. (f)(normal)] × [H.long. (m)(normal)];
(5) [C.gar. (f)(normal)] × [H.long. (m)(normal)];
(6) [Hb. (f)(LPA)] × [C.gar. (m)(RPA)];
(7) [Hb. (f)(RPA)] × [C.gar. (m)(RPA)];
(8) [Hb. (f)(LPA)] × [C.gar. (m)(normal)];
(9) [Hb. (f)(RPA)] × [C.gar. (m)(normal)].

Incubation procedure

Kakabans (egg collectors) were placed in indoor aquaria filled to the one-third level with water at a pH of about 7, dissolved oxygen (DO_2) of

5 mg L^{-1} and temperature of 26 °C. Fertilized eggs from each cross were poured into separate aquaria. After about 24 h, the hatchlings were observed swimming around the base of the aquaria.

Larval rearing

Two hundred hatchlings from each cross were put in each aquarium. Survivors were counted daily, and dead fry were removed daily for a period of 22 days. Water in the aquaria was changed once a week. At the beginning of the fourth day, the fry were fed with live zooplankton, mainly *Moina micrura*, Kurz, 1874. The percentage survival for each day was obtained by pooling all the fish specimens in each genetic group together and dividing by the initial stocking number.

Outdoor rearing of post-fry

Survivors of the indoor aquaria larval rearing were transferred to 2 × 2 × 1 m^3 concrete tanks. The post-fry were fed with finely powdered 40% crude protein artificial diet. After about 1 month of outdoor fry rearing, spot samples were taken with fry nets to determine the level of aberrations in each cross. Final observations of aberrations were done at the end of 3 months of outdoor rearing by total sampling of each concrete tank.

Results

Figure 1 and Table 1 show the mean survival of fry for each day for nine genetic groups involving crosses of *Clarias* × *Clarias*, *Heterobranchus* × *Heterobranchus*, *Clarias* × *Heterobranchus* hybrid and hybrid × *Clarias* under indoor aquaria conditions. Among the *Clarias* × *Clarias* group, 2% of the fish in the cross involving female *C. gariepinus* (normal) × male *C. gariepinus* (RPA) (cross 1) survived for 24 h after hatching in the aquaria. The cross involving female *C. gariepinus* (LPA) × male *C. gariepinus* (normal) (cross 2) presented a different picture of mortality 24 h after hatching. The mean percentage survival (96.25%) was recorded in this cross. At the end of 22 days of indoor management of the fry, the mean percentage survival of this cross was 72.5% (Table 1). The cross involving [C.gar. (f) (normal)] × [C.gar. (m)(normal)] (cross 3) gave 75% survival after 22 days of rearing indoors. The percentage survival in *H. longifilis* (normal male × normal female) (cross 4) gave 68.5% survival in 22 days. This high percentage survival was only comparable with the cross of [C.gar. (f)(LPA)] × [C.gar. (m)(normal)] (72.5%), but significantly higher ($P < 0.05$) than the survival in crosses 6–9 involving either aberrant or normal *C. gariepinus* × aberrant hybrid. The cross involving [C.gar. (f)(normal)] × [H.long. (m)(normal)] (cross 5) gave 66.5% survival after 22 days of indoor rearing. Figure 1 and Table 1 also show four types of crosses involving hybrid × *Clarias.* In the cross of female hybrid(LPA) × male

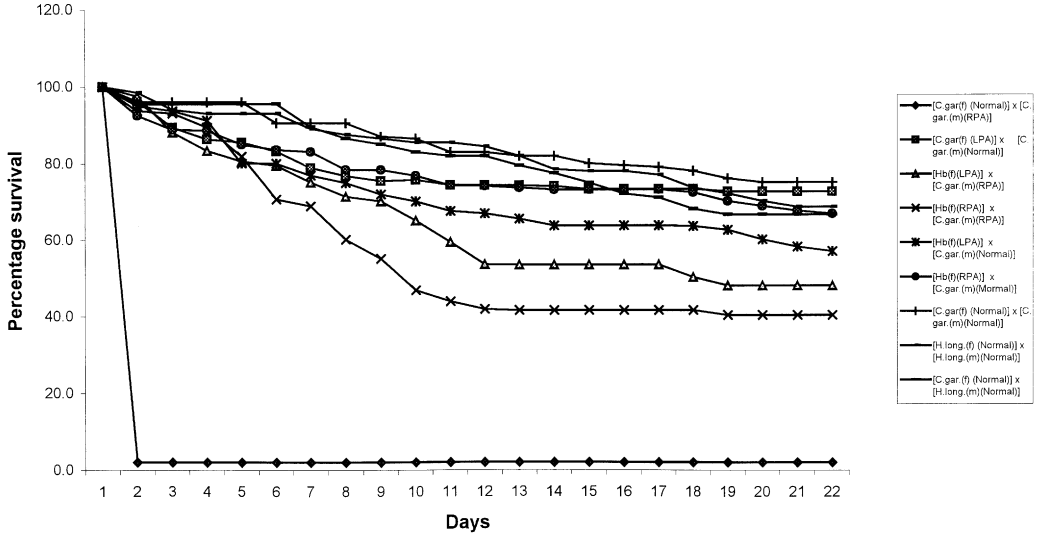

Figure 1 Mean percentage survival of fry for each day for nine genetic groups involving crosses of *Clarias* × *Clarias*, *Heterobranchus* × *Heterobranchus*, *Clarias* × *Heterobranchus* and hybrid × *Clarias* under an aquaria system.

Genetic groups (crosses)	Percentage survival* after: 24 h	22 days
A. *Clarias* × *Clarias*		
1. [C.gar.(f)(normal)] × [C.gar. (m)(RPA)]	2.00	2.00
2. [C.gar. (f)(LPA)] × [C.gar. (m)(normal)]	96.25	72.50
3. [C.gar. (f)(normal)] × [C.gar(m)(normal)]	97.36	75.00
B. *Heterobranchus* × *Heterobranchus*		
4. [H.long. (f)(normal)] × [H.long. (m)(normal)]	96.81	68.50
C. *Clarias* × *Heterobranchus*		
5. [C.gar. (f)(normal)] × [H.long. (m)(normal)]	97.43	66.50
D. Hybrid × *Clarias*		
6. [Hb (f)(LPA)] × [C.gar. (m)(RPA)]	96.50	48.00
7. [Hb (f)(RPA)] × [C.gar. (m)(RPA)]	94.81	40.30
8. [Hb (f)(LPA)] × [C.gar. (m)(normal)]	94.92	56.90
9. [Hb (f)(RPA)] × [C.gar. (m)(normal)]	98.14	66.80

Table 1 Percentage survival for the different crosses after 24 h and 22 days in the fry of *Clarias* × *Clarias*; *Heterobranchus* × *Heterobranchus*; *Clarias* × *Heterobranchus* and hybrid × *Clarias* under aquaria systems

*Number of survivors/initial number of fish stocked.
RPA, right pectoral fin absent; LPA, left pectoral fin absent; C.gar, *Clarias gariepinus*; H.long, *Heterobranchus longifilis*; Hb, hybrid.

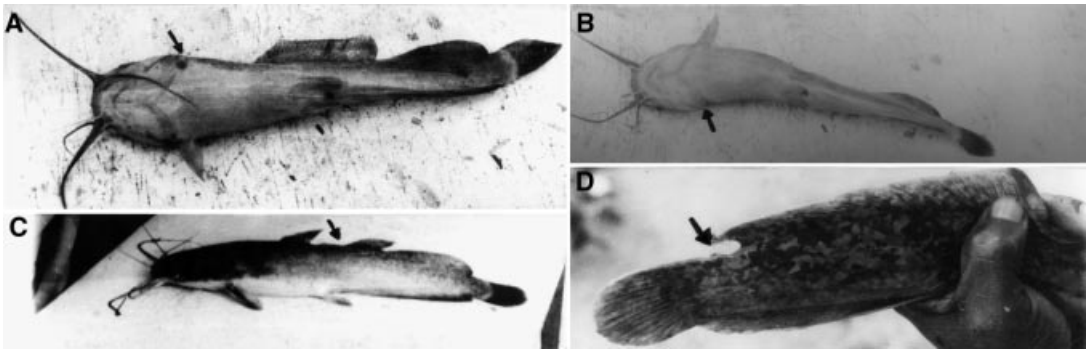

Figure 2 Morphological aberration in *Heterobranchus longifilis* and *Clarias gariepinus*. (A) Absence of left pectoral fin in *H. longifilis* (arrowed). (B) Absence of right pectoral fin in *H. longifilis*(arrowed). (C) Double dorsal fins (arrow indicates gap between two dorsal fins) in *H. longifilis*. (D) Curved posterior end of dorsal fin in *C. gariepinus* (arrowed).

C. gariepinus (RPA) (cross 6), the percentage survival at the end of indoor management was 48%, whereas the cross involving female hybrid(RPA) × male *C. gariepinus* (RPA) (cross 7) gave 40.3% survival after 22 days of indoor management. The percentage survival after 22 days of indoor management for female hybrid(LPA) (56.90%) or RPA (66.80%) crossed with a normal *C. gariepinus* male (crosses 8 and 9 respectively) shows higher survival than the two crosses involving aberrant hybrid × aberrant *C. gariepinus* (crosses 6 and 7), which was between 40% and 48%.

Table 2 shows the types of aberrations observed in nine genetic groups of mating *Clarias* × *Clarias*, *Heterobranchus* × *Heterobranchus*, *Clarias* × *Heterobranchus* and hybrid × *Clarias* reared under outdoor concrete tank conditions. Among the *Clarias* × *Clarias* crosses, the cross involving [C.gar. (f)(normal)] × [C.gar. (m)(RPA)] (cross 1) had 50% of the surviving progeny with aberrations of the pectoral fins, including 25% BPA and 25% RPA. An aberration not involving the pectoral fin (curvature of the anterior dorsal fin) (CAD = 25%; Fig. 2D) was also observed in this cross. Total percentage

Table 2 Types of aberration observed in mating aberrant and normal *Clarias* × *Clarias*, *Heterobranchus* × *Heterobranchus*, *Clarias* × *Heterobranchus* and hybrid × *Clarias*

Genetic group (cross)	Total no. of survivors after 22 days	Type of aberration									Total frequency of aberrant specimens
		DD (%)	CPD (%)	SRP (%)	RPA (%)	LPA (%)	RP (%)	BPA (%)	DA (%)	CAD (%)	
1 [C.gar. (f)(normal)] × [C.gar. (m)(RPA)]	4	0 (0.00)	0 (0.00)	0 (0.00)	1* (25.00)†	0 (0.00)	0 (0.00)	1 (25.00)	0 (0.00)	1 (25.00)	75.00
2 [C.gar. (f)(LPA)] × [C.gar. (m)(normal)]	145	0 (0.00)	1 (0.73)	1 (0.73)	2 (1.46)	2 (1.46)	1 (0.73)	5 (3.65)	1 (0.73)	1 (0.73)	10.22
3 [C.gar. (f)(normal)] × [C.gar. (m)(normal)]	150	1 (2.38)	1 (2.38)	0 (0.00)	0 (0.00)	1 (2.38)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	7.14
4 [H.long(f)(normal)] × [H.long. (m)(normal)]	137	1 (1.47)	0.00 (0.00)	3 (4.41)	2 (2.94)	2 (2.94)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	11.76
5 [C.gar(f)(normal)] × [H.long. (m)(normal)]	133	0 (0.00)	3 (1.21)	0 (0.00)	1 (0.81)	1 (0.40)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2.42
6 [Hb (f)(LPA)] × [C.gar. (m)(RPA)]	96	1 (1.47)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1.47
7 [Hb (f)(RPA)] × [C.gar. (m)(RPA)]	86	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (5.55)	0 (0.00)	0 (0.00)	5.55
8 [Hb (f)(LPA)] × [C.gar. (m)(normal)]	114	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.00
9 [Hb (f)(RPA)] × [C.gar. (m)(normal)]	134	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.00

CPD, curved posterior dorsal fin; DD, double dorsal fin; SRP, spineless right pectoral fin; RPA, right pectoral fin absent; LPA, left pectoral fin absent; RP, rudimentary pectoral fin; BPA, both pectoral fins absent; DA, double anal fin; CAD, curved anterior dorsal fin; C.gar, *Clarias gariepinus*; Hb, hybrid; H.long, *Heterobranchus longifilis*.

*Absolute number of aberrant specimens.

†Percentage of aberrant specimens.

aberration in this cross was 75%. Eight different types of aberration were recorded in cross 2 [C.gar. (f)(LPA)] × [C.gar. (m)(normal)]. These aberrations include RPA (1.46%), BPA (3.65%), CPD (0.73%), SRP (0.73%), LPA (1.46%), RP (0.73%), DA (0.73%) and CAD (0.73%). The overall frequency of aberration in this cross was 10.22%. The cross involving normal *C. gariepinus* (female × male) recorded three types of aberrations: LPA (2.38%), DD (2.38%) and CPD (2.38%) (cross 3 in Table 1 and Fig. 2D). This gives a total frequency of 7.14%. The cross (cross 4) involving normal *H. longifilis* (female × male) gave four types of aberrations: DD (1.47%) (Fig. 2C), SRP (4.41%), RPA (2.94%) (Fig. 2B) and LPA (2.94%) (Fig. 2A) (cross 4). The overall frequency of aberrant fish in this cross was 11.76%. Three types of aberrations – CPD (1.21%), RPA (0.81%) and LPA (0.40%) – were recorded in the cross involving female *C. gariepinus* (normal) × male *H. longifilis* (normal). Thus, the overall frequency of aberration in this cross is 2.42% (cross 5). Among the hybrid × *Clarias* group, the two crosses involving female hybrids (with either RPA or LPA) × male *C. gariepinus* (with either RPA or LPA) recorded one aberration each (Table 2). These aberrations include DD (1.47%) in female hybrid (LPA) × male *C. gariepinus* (RPA) (cross 6), as well as BPA (5.55%) in female hybrid (RPA) × male *C. gariepinus* (RPA) (cross 7). No aberration was recorded in the two crosses involving female hybrid (with either RPA or LPA) × male *C. gariepinus* (normal) (crosses 8 and 9).

Discussion

When compared with mortality patterns in other mating combinations in this study, mortality in the cross involving female *C. gariepinus* (normal) × *C. gariepinus* (RPA) was extremely high, with 98% of hatchlings dying within 24 h after hatching. There are no comparable data available from other fish species on this kind of massive mortality known to the authors. The underlying genetic mechanism responsible for the high incidence of mortality in this cross is not fully known. Even the exceptionally high mortality (level not stated) in the laboratory crosses involving pelvisless and normal Brook stickleback, *Culaea inconstans* (Kirtland, 1841) reported by Nelson (1977) cannot be compared with this result, in that the mortality reported by Nelson (1977) lasted over a few weeks when the young attained at least 20 mm standard length. However, the level of mortality reported in this cross compares with that reported by Nelson (1977) in the area of totally altering phenotypic ratios. In addition, the embryonic mortality of about 25% reported by Kirpichnikov (1981) in the offspring of many plants and animals for certain combinations of parents is far from the 98% level recorded in this study. All four crosses involving hybrid × *Clarias* had lower survival values, suggesting that mating combinations in F_2 and backcross generations often have viability problems.

The proportions of fin abnormalities varied considerably among the mating groups. For instance, the *Clarias* × *Clarias* group had 7.14–75.00% fin abnormalities. The other groups, *Heterobranchus* × *Heterobranchus*, *Clarias* × *Heterobranchus* and hybrid × *Clarias*, had 11.76%, 2.42% and 1.47–5.55% fin abnormalities respectively. It was also clear that the proportions of fin abnormalities were not equal within the groups. For example, the two hybrid × aberrant *Clarias* crosses recorded a maximum of 5.55% fin abnormalities, whereas none was recorded for the two hybrid × normal *Clarias* crosses. The variation in these fin abnormalities was therefore not randomly distributed, and this suggests that these fin abnormalities were genetically controlled. The similarity of offspring to their parental phenotypes in this study agrees with the findings of Nelson (1977) in pelvisless Brook stickleback *C. inconstans*. Nelson (1977) clearly demonstrated that the similarity of offspring to their parental phenotypes in laboratory and field crosses was an indication that a genetic component was involved in determining the presence or absence of the pelvic skeleton. The maximum percentage (75%) reported for the *Clarias* × *Clarias* mating group in this study is comparable with the 65% severe fin deformities reported in the larvae of Razorback sucker (family: Casostomidae) *Xyrauchen texanus* (Abbot, 1861) by Severson, Tyus & Haines (1992).

According to Berra & Au (1981), anomalies caused by genetic alterations result from mutations or recombinations on the DNA, and these alterations are heritable unless they are lethal. The absence of fin abnormalities in the two crosses involving hybrid × normal *Clarias* could result from some degree of relaxation of the factors favouring the expression of these fin abnormalities. This probably accounts for the variation in the frequency of fin abnormalities in the *Clarias* × *Clarias* and hybrid × *Clarias* mating groups. Apart from the

cross involving *C. gariepinus* female (normal) × *C. gariepinus* male (RPA) (cross 1), in which there is a high percentage of fin abnormalities (owing to high mortality in this cross), other crosses with abnormalities show a prevalence range of 1.47–11.14% (with a low mortality rate), which suggests the non-lethal characteristic of the fin abnormalities. There is no reported case of the level of incidence of fin abnormalities in the wild for these species, even though specimens with abnormal phenotypes like the ones reported in this study are encountered occasionally.

It is very unlikely that the cause of fin abnormalities in these species is environmental. For example, in an earlier experiment conducted by Dunham & Smitherman (1987) at Auburn University (USA), in which tailless catfish *Ictalurus punctatus* were mated with each other, all the progeny were normal. These authors judged these traits to be environmentally induced.

Full description of these traits and other aberrations should be encouraged in Nigerian fish hatcheries. The inheritance pattern of these aberrants as well as their impact on growth, disease resistance and viability need further vigorous investigation. Furthermore, the impact of these aberrations on productivity and profits as well as control mechanisms still need to be evaluated.

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