The use of a red strain of the sharptooth catfish *Clarias gariepinus* (Burchell) in the evaluation of cannibalism amongst juveniles of this species

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Abstract

A red variety and a normal, mottled dark-coloured variety of the catfish *Clarias gariepinus* were used to demonstrate the possible effects of cannibalism amongst 14 to 24 day-old early juveniles of this species. The results suggest that at this particular developmental stage, size difference rather than colour, density, or even food supply, might be an important factor which influences cannibalism amongst juveniles of this fish.

Introduction

It is a well-known fact that cannibalism occurs during all the developmental stages of *Clarias gariepinus* under natural conditions and in captivity (Groenewald, 1961, 1964; Van der Waal, 1978), and that serious problems in this regard are already encountered from the early larval and juvenile developmental stages (Van der Waal, 1978; Hecht and Appelbaum, 1987).

An accurate assessment of the extent of cannibalism amongst *C. gariepinus* larvae of similar size under high density conditions in the hatchery proved to be impossible, especially amongst larvae and juveniles of similar age and size. Where attempts had been made by the present authors to study cannibalism amongst differentially grown groups of larvae and early juveniles of this species of the same colour and age, it was found impossible either to determine the actual daily or even hourly losses of the smaller larvae because of the high density and rapid movement of the specimens in the experimental containers. It was also not possible to distinguish between the larger specimens from the group of smaller juveniles and the smaller specimens from the group of larger juveniles after a few days, because of the rapid and differential growth rate which occurred amongst the two groups of juveniles used. Furthermore, the potentially stressful effects of handling the specimens when taken from the tanks for mass determinations, might have increased the tendency towards predation by the other juveniles of the handled fish.

In this study early juveniles of a red strain of *C. gariepinus* and juveniles of the normal dark mottled coloured (black) strain (Fig. 1) were used to establish the actual occurrence and extent of cannibalism in the laboratory amongst 14 to 24 day-old juveniles of both strains of this species over periods of 6 to 10 d.

Since it has been shown conclusively by a number of research workers such as Hoogendoorn (1980), Bryant and Matty (1981), Msiska (1981), Vanhaecke and Sorgeloos (1983), Dabrowski (1984), Prinsloo and Schoonbee (1986) and Polling *et al.* (1988), that live food is an extremely important component in the diet for the rearing and survival of larvae and juveniles of a number of fish species, including *C. gariepinus*, it was decided not to include any dry feed in the diets of the experimental fish as it might have introduced an unnecessary constraint affecting the survival rate of the larvae and juveniles, especially during the primary nursing phase, which might then erroneously be ascribed to the effects of cannibalism only.

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Origin of the red strain of *Clarias gariepinus*

During the summer of 1984, naturally dark coloured (black) catfish brood-stock from the Turfloop Dam were used in induced spawning programmes during which time several red coloured larvae were obtained (Van der Walt, 1988). From these, one female and three male catfish were reared to maturity and were used to produce the first offspring of red *C. gariepinus* during November, 1986. These larvae were transferred to grow-out ponds at the Turfloop fish-breeding and research station. A small number of these were kept as brood-stock whilst the rest were used in production studies (Prinsloo *et al.*, 1989).

Materials and methods

Both the red and the normal coloured black *C. gariepinus* were spawned simultaneously at the Turfloop fish-breeding station following the procedures described by Polling *et al.* (1987), but with the exception that only pituitary gland homogenate (PGE) was used. After hatching, larvae of exactly the same age were transferred to 1 000 ℓ holding tanks, connected to a water recirculating system which maintained a constant water temperature of 27°C. Both the red and black larvae were subdivided into two groups each at different densities, and were grown under these conditions for a period of 14 d. During this period of differential growth, fish juveniles in all the containers were provided with live food (*Moina* spp.) developed in earthen ponds at the hatchery.

Mass determination of the juveniles of red and normally dark, mottled coloured *C. gariepinus*

After 14 d, specific numbers of early juveniles of each size group, from both the red and black varieties, were carefully scooped from the holding tanks with the aid of fine mesh sieves, counted, and transferred to randomly selected experimental tanks at the laboratory. In this way equal numbers of both red and black juveniles were transferred to eight randomly selected tanks to

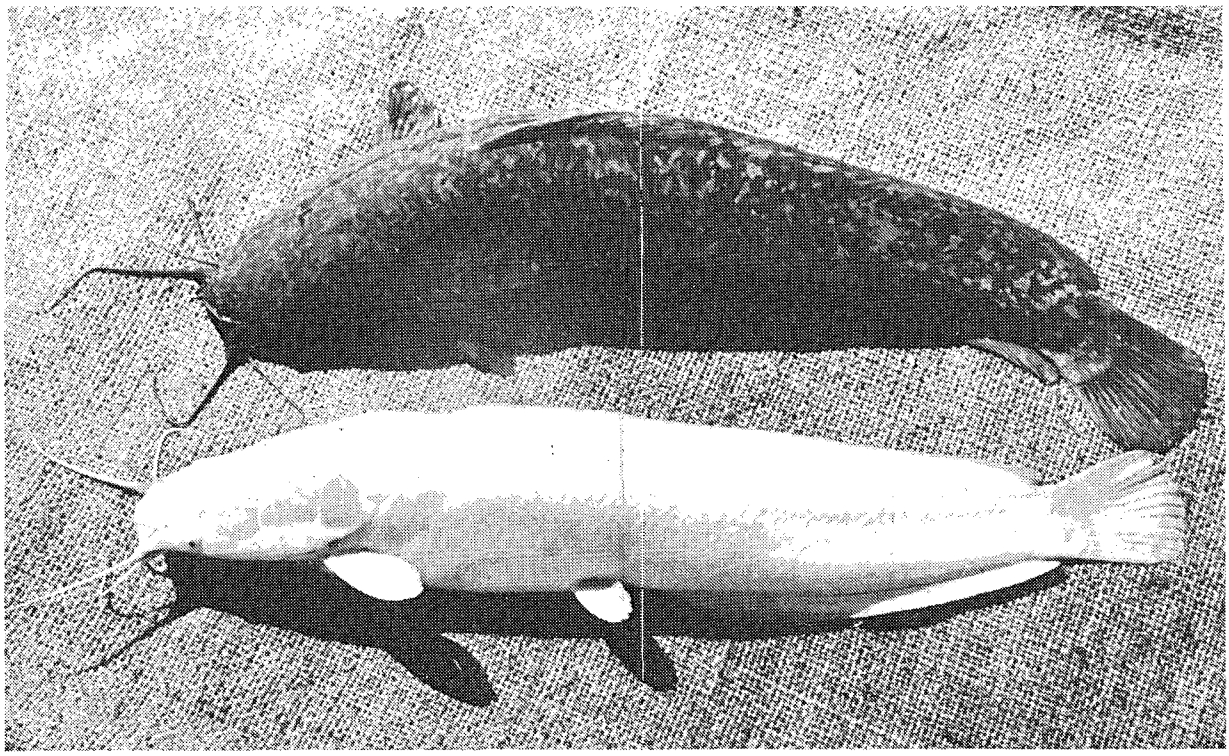

Figure 1
The red and black mottled varieties of the sharptooth catfish Clarias gariepinus *of which larvae were used in the present investigation.*

TABLE 1
PHYSICAL AND CHEMICAL CONDITIONS IN THE WATER RECIRCULATING BIOLOGICAL FILTER SYSTEM AND IN THE EXPERIMENTAL TANKS OVER A PERIOD OF 10 D

	Day 1			Day 5			Day 10		
	Inlet	Outlets		Inlet	Outlets		Inlet	Outlets	
Analysis	Mean	Mean	Range	Mean	Mean	Range	Mean	Mean	Range
Oxygen mg ℓ^{-1}	6,5	5,9	5,7 - 6,1	6,3	6,0	5,9 - 6,0	6,5	5,9	5,9 - 6,0
pH	8,11		7,72 - 7,64	7,93		7,65 - 7,72	7,91		7,57 - 7,69
Conductivity μS cm^{-1}	80	79	78 - 80	105	105	104 - 105	119	116	114 - 117
Ammonia (NH_3) mg ℓ^{-1}	0,073	0,087	0,079 - 0,092	0,061	0,077	0,073 - 0,085	0,037	0,057	0,049 - 0,061
Nitrite (NO_2) mg ℓ^{-1}	0,010	0,012	0,010 - 0,013	0,010	0,012	0,009 - 0,013	0,010	0,035	0,013 - 0,059
Nitrate (NO_3) mg ℓ^{-1}	3,96	4,18	3,96 - 4,40	7,92	7,92	7,92	11,88	11,58	11,44 - 11,88
Orthophosphate (PO_4) mg ℓ^{-1}	0,350	0,210	0,150 - 0,310	0,280	0,280	0,275 - 0,290	0,310	0,330	0,310 - 0,370
Alkalinity as $CaCO_3$ mg ℓ^{-1}	35	35	33 - 36	41	39	38 - 39	43	40	37 - 43
Total hardness as $CaCO_3$ mg ℓ^{-1}	42	42	39 - 45	48	47	46 - 47	55	55	54 - 56

make up total densities of 10 specimens per litre of water (Tables 2 and 3). In one tank, however, only large black juveniles were used at a density of 15 specimens per litre (Table 3). Insufficient numbers of large red juveniles prevented a similar set-up for the red *Clarias* variety.

Recirculation and purification of water in fish holding tanks

The experimental tanks were all connected to a 6 000 ℓ water recirculation system provided with a gravel biological filter and aeration. Water temperatures were maintained at 27 °C ± 1 °C. The water replacement in each tank was continuous at a rate of approximately 2 ℓ min^{-1}. A 118 μm nylon screen was mounted in a perspex framework around the top of each tank to permit the maximum flow of water through the tanks. To cope with the large quantities of waste material associated with the high dosage levels of live food, each tank was also provided with an Eheim filter system fitted with a banjo-type filter with a screen of 63 μm mesh size. This continuously removed the smaller colloidal particles emanating from waste material released into the tanks by the larvae. These filters were replaced six times per day with clean, sterilised filters. This step ensured that the water in each tank was practically free from suspended waste material or any dead material accumulating at the bottoms of the tanks during the entire 10-d period. Such an accumulation of waste material often occurs in feeding experiments of this nature (Hecht and Appelbaum, 1987).

Combinations of larvae stocked in tanks

In order to eliminate any bias in favour of either red or dark juveniles, the following combinations were made in the experimental set-up: A set of two tanks was prepared for each of combinations of juveniles to accommodate two levels of feed application (Tables 2 and 3). The combinations were:

Large red x small black
Small red x large black
Large red x large black
Small red x small black

Application of food to the tanks

Live food, derived from pond cultured material (Polling *et al.*, 1988) and consisting of the cladoceran *Moina* and some brachionid rotifers, was applied daily to all the tanks. The juveniles in one of each of the above-mentioned sets of tanks received food equivalent to 10%, calculated as dry mass, of their total estimated wet mass. The juveniles in the other tank of each set received only 2% live food, calculated on a similar basis as for the 10% food application. Adjustment in the food dosage levels was made twice during the experimental period of 10 d according to the adjusted calculated juvenile mass in each tank at those times. Food was applied to each tank four times daily: at 09h00, 11h00, 14h00 and 16h00. In this way the daily dosage quantities could be staggered to prevent undue accumulation of the feed organisms in the tanks and against the screens of the tanks' water outlets.

Collection and weighing of juveniles

Thirty juveniles of both the red and dark coloured strains of *C. gariepinus* were randomly collected from the different rearing tanks for the initial day 0 mass determinations. These juveniles were immediately killed and preserved in 5% formalin. Excess moisture was removed from each specimen before weighing, using blotting paper. Mass determinations were made on a Mettler Model AE160 balance, accurate to 0,1 mg . The mass determinations of juveniles in the experimental tanks were made on ten randomly selected specimens on days 0, 4 and 8. On day 10, at the end of the experiment, all larvae were killed and preserved in 5% formalin, counted and individually weighed. In this way an accurate assessment was made of the actual survival of the larvae in each of the experimental tanks.

Observations on mortalities and cannibalism occurring in the tanks

Observations on the survival of juveniles of both strains in the various experimental set-ups (Tables 2 and 3) were made at 24 h intervals. Due to the low mortalities which occurred in the experimental tanks of similar sized specimens of the two strains, difficulties were experienced in counting the surviving number at each stage, except for the last count at the end of the experiment when all the specimens were killed and counted. However, where large juveniles of one colour were kept together with small juveniles of the other colour, the reduction in numbers of the smaller juveniles, irrespective of the colour, was so dramatic that accurate counts could already be made of the surviving numbers of the smaller juveniles, from day 1 until all of them had been eaten.

Water chemistry

Selected water chemical parameters were determined at the main inlet to the tank system and at the three major communal outlets from the tanks. The analysis of the water quality in the tank and the water recirculating system was made on days 1, 5 and 10 according to APHA (1980). Parameters analysed for included: oxygen (mgℓ^{-1}), pH, conductivity (μS cm^{-1}), ammonia (NH_3) mgℓ^{-1}, alkalinity as $CaCO_3$ (mgℓ^{-1}) and total hardness as $CaCO_3$ (mgℓ^{-1}), nitrite (NO_2) mgℓ^{-1}, nitrate (NO_3) mgℓ^{-1}, and orthophosphate (PO_4) mgℓ^{-1}.

Results

Water chemistry

As previously mentioned, the water temperature was maintained at 27 °C ± 1 °C throughout the period of investigation. The introduction of the Eheim filter systems, in addition to the main recirculating biological filter system, largely contributed towards the satisfactory oxygen levels recorded in all the systems throughout the period of investigation (Table 1). With the exception of day 1, when the pH exceeded 8 at the water inlet to the tanks, all pH values recorded remained below 8, indicating the effective functioning of the biological filter system. The conductivities in the water recirculating system increased from approximately 80 μS cm^{-1} on day 1 to 119 μS cm^{-1} on day 10. This tendency in conductivity can be ascribed to the accumulation of inorganic solutes in the water over the 10-d experimental period.

The fact that there was no serious build-up of ammonia or phosphates in the system, despite the large quantities of food applied to the tanks, also reflected the efficiency of the removal of these and other metabolic wastes by the biological filter system. The increase in nitrates, from less than 5 mgℓ^{-1} (day 1) to almost 12 mgℓ^{-1} (day 10), is a normal occurrence in recirculating systems where there is a general absence of algae which could otherwise utilise this nutrient.

TABLE 2

INITIAL STOCKING DENSITIES, FEED DOSAGE LEVELS AND SURVIVAL OF THE RED AND BLACK *C. GARIEPINUS* JUVENILES STOCKED IN DIFFERENT COMBINATIONS WITH INDICATIONS OF THE RAPID REDUCTION OF THE SMALLER JUVENILES THROUGH CANNIBALISM AND THEIR EVENTUAL DISAPPEARANCE FROM THE TANKS WITHIN 5 D OF THE COMMENCEMENT OF THE EXPERIMENT

Combinations of red and black juveniles with initial mean mass (g ± SD*) for each group	Initial juvenile densities per litre water	Daily dosage quantities of food as % or total mass	Initial total numbers of juveniles per group	Number and percentage survival of small juveniles during the first 6 d of the experiment. Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Mean individual mass (± SD) of remaining large juveniles after 10 days	Percentage survival of large juveniles after 10 d
Large red x small black 0,1859 0,0172 ± 0,0729 ± 0,0056	5 + 5	10	269 + 269	2 0,7%	1 0,4%	0 0	– –	– –	– –	1,2200 ± 0,4377	91,2
Large red x small black 0,1859 0,0172 ± 0,0729 ± 0,0056	5 + 5	2	269 + 269	4 1,5%	0 0	– –	– –	– –	– –	0,3598 ± 0,0733	74,8
Large black x small red 0,1887 0,0265 ± 0,0601 ± 0,0064	5 + 5	10	269 + 269	30 11,2%	12 4,5%	3 1,1%	3 1,1%	2 0,7%	0 0	1,0010 ± 0,4080	91,9
Large black x small red 0,1887 0,0265 ± 0,0601 ± 0,0064	5 + 5	2	269 + 269	11 4,1%	1 0,4%	0 0	– –	– –	– –	0,2451 ± 0,0606	83,0

* SD = Standard deviation

TABLE 3

THE POSSIBLE EFFECTS OF CANNIBALISM ON THE SURVIVAL OF SIMILAR SIZED RED AND BLACK *C. GARIEPINUS* JUVENILES STOCKED TOGETHER AT DENSITIES OF 10 JUVENILES ℓ^{-1} AT 10% AND 2% FEEDING LEVELS EXPRESSED AS DRY MASS OF THE TOTAL MASS OF JUVENILES IN THE EXPERIMENTAL TANKS.

Combinations of red and black juveniles with initial mean mass (g ± SD*) for each group	Initial juvenile densities per litre water	Daily dosage quantities of food as % of total mass	Initial total numbers of juveniles per group	Mean individual juvenile mass (g ± SD) after 10 d Red	Black	Percentage survival of juveniles after 10 d Red	Black
Large red x large black 0,1859 0,1887 ± 0,0729 ± 0,0601	5 + 5	10	269 + 269	1,0097 ± 0,3343	0,7744 ± 0,2274	87,9	89,4
Large red x large black 0,1859 0,1887 ± 0,0729 ± 0,0601	5 + 5	2	269 + 269	0,2195 ± 0,0467	0,2232 ± 0,0531	72,2	87,5
Small red x small black 0,0265 0,0172 ± 0,0064 ± 0,0056	5 + 5	10	269 + 269	0,3836 ± 0,1013	0,2205 ± 0,0596	94,5	92,3
Small red x small black 0,0265 0,1887 ± 0,0064 ± 0,0601	5 + 5	2	269 + 269	0,0408 ± 0,0103	0,0289 ± 0,0096	87,9	90,5
Large black 0,0827 ± 0,0538	15	10	750		0,3693 ± 0,1317		97,0

* SD = Standard deviation

Mortalities due to cannibalism

The different combinations of the groups of large and small juveniles of the red and the dark coloured varieties of the juveniles of *C. gariepinus* fed at two different levels of live food, and the extent of cannibalism in some of these combinations, are recorded in Tables 2 and 3. From Table 2 it is evident that, no matter which colour the smaller juveniles are, they are preyed upon by the larger ones at a very rapid rate, irrespective of feed dosage level. It is also clear from Table 2 that there was a slightly longer period of survival for the smaller juveniles at the higher feed application levels. Even so, in three of the four experimental tanks, more than 90% of the smaller juveniles were already eaten by the larger ones before the end of day 1. After day 3, only one tank (large black x small red juveniles) (Table 2) still contained a small number (1,1%) of the red juveniles. In all the other tanks the smaller groups of juveniles were, however, eaten by the larger groups of juveniles by day 3.

The survival of the larger groups of juveniles in all four tanks was exceptionally good after day 10, exceeding 91% in two cases. The lowest survival of 74,8% and 83,0%, respectively, occurred at the lower feed dosage levels, indicating a possibly higher degree of cannibalism amongst the larger juveniles. Although not indicated in this table a small component of fast growing jumper juveniles (less than 1%), more than 10 times the mean mass of the rest of the surviving juveniles, was present after ten days. Where large red and large black juveniles, as well as small red and small black juveniles, were stocked together at the 10% and 2% feed dosage levels (Table 3), the survival of both varieties after 10 d was still exceptionally good.

In all the cases except one (small red x small black) the survival of the black juveniles was slightly better than that of the red juveniles. In the experimental tanks where only large black juveniles were stocked at 15 juveniles per litre, and at a live feed dosage level of 10% expressed as dry mass, a survival of 97% was still achieved after 10 d.

Discussion

By using different juvenile sizes of red and normal strains of *C. gariepinus*, the considerable impact of cannibalism amongst juveniles differing from each other by between 7 to 10 times in mass is clearly demonstrated by the present investigation. The results also showed that a red or dark colour in itself was not an important factor concerning this phenomenon amongs juveniles of *C. gariepinus*, as equally severe cannibalism can take place irrespective of colour. Where red and black juveniles of equal size were reared together, exceptionally good survival rates were constantly recorded for both strains (Table 3).

One of the major factors responsible for the high survival rate recorded must be ascribed to the availability of adequate food supplies of a good quality, in this case live food, and the carefully controlled hygienic conditions and continuous removal of waste material from tanks without placing undue stress on the juveniles.

It is sometimes erroneously stated by some research workers that the larvae of *C. gariepinus* only commence active feeding approximately four days after hatching. This was found not to be so by Polling *et al.* (1988) and by the present authors, who observed the larvae commencing exogenous feeding one day after hatching. This implies that if food of the correct size and quality is available after hatching, it may lead to stronger and larger larvae than those which begin to take food four days after hatching. This procedure of providing live food such as rotifers from day one, may also play an important role in size uniformity within larval and juvenile populations of this fish.

The maintenance of a fairly uniform size within a population of sharptooth catfish larvae and juveniles is closely linked to the adequate provision of good quality food which, to a large extent, inhibits the tendency towards cannibalism amongst the larvae and juveniles of this fish species in particular. This is clearly demonstrated by the present results obtained, especially in the case where the juveniles were kept at a density of 15 specimens per litre of water and where the survival rate after 10 d was 97% (Table 3). Even so, when the experiment was terminated, there were a few juveniles present in some of the tanks which were more than 10 times the average size of the rest of the population. This created a condition where cannibalism by a relatively small number of large individuals might have seriously affected the eventual survival rate within such a population. A method will have to be devised to eliminate or screen off such large individuals from the rest without undue stress being placed on the others. The design of variable sized mechanical screens might be an option to be considered in the separation of the specimens into specific size groups.

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