Production studies with the red and normal varieties of the sharptooth catfish *Clarias gariepinus* (Burchell) using a mixture of minced fish, bakery-floor sweepings and a formulated pelleted diet

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Abstract

A red and a normal variety of the catfish *Clarias gariepinus* (Burchell) were stocked in equal numbers at a density of 15 000 fish per hectare and reared on a mixture of minced fish, bakery-floor sweepings and an 18% protein formulated pelleted diet. The growth period was 140 d with a total yield of 7,641 t of fish per hectare. Problems were experienced with accumulated wastes in the ponds, which seriously affected the water quality. Flushing of the ponds with fresh water rectified the situation. The black normal strain showed a slightly superior growth over that of the red variety.

Introduction

With the reclassification of *Clarias lazera* (C and V) as a junior synonym of the African sharptooth catfish *Clarias gariepinus* (Burchell) by Teugels, (1982a; b), a vast amount of data of possible relevance, which previously applied to *C. lazera*, and which cover the aquaculture potential of that species, also became applicable to *C. gariepinus*.

Much of the work on the artificial reproduction, growth, health control and constraints concerning the aquaculture potential of *C. lazera* (= *C. gariepinus*) and conducted by the Department of Fish Culture and Fisheries at the Agricultural University of Wageningen and by the Department of Experimental Zoology of the University of Utrecht in the Netherlands, is summarised by Huisman and Richter (1987). In South Africa, published records on the reproduction, larval rearing and feeding of this fish species include work done by Schoonbee *et al.* (1980), Hecht (1981; 1982), Hecht *et al.* (1982), Steyn *et al.* (1985), Uys and Hecht (1985; 1987), Van der Waal (1985), Britz and Hecht (1987), Uys *et al.* (1987), Polling *et al.* (1987; 1988) and Prinsloo *et al.* (1989b).

Clarias gariepinus farming in the Netherlands is based largely on indoor recirculation production systems because of the climate. According to Huisman and Richter (1987), there are presently in the Netherlands 30 to 40 such African catfish production units with yields varying between 1 to 50 t of fish per year. In South Africa at least two sharptooth catfish farms exist, one at Kimberley in the Cape and one near Hoedspruit in the eastern Transvaal. Indications are that *Clarias gariepinus* may well develop into one of the major aquaculture fish species in South Africa and that the stage has been reached where more attention should be paid to its intensive production in mono and polyculture systems adapted for local environmental conditions. Information on its pond culture in South Africa includes the work by Van der Waal (1978), Bok and Jongbloed (1984), Prinsloo and Schoonbee (1987), and Prinsloo *et al.* (1989a). With the large-scale spawning and larval rearing of a red mutant of the sharptooth catfish (Prinsloo *et al.*, 1989b) it became necessary to investigate the production potential of this variety in comparison with that of the normal dark strain. In this study, a mixture of minced small tilapia spawned and grown naturally in sewage maturation ponds, bakery-floor sweepings and a formulated pelleted 18% protein feed was used as diet in the intensive production of the two varieties stocked together in ponds.

Materials and methods

Ponds used

Two 450 m^2 earthen ponds, provided with monks and with a mean water depth of 1,5 m, were used in this investigation. To compensate for evaporation and loss of water through seepage, water to the ponds was gravity-fed from the nearby Turfloop Dam, which also supplies water to the Turfloop Fish Breeding and Research Station. At the point of entry into the ponds screens were used to prevent wild fish and predators, such as the clawed frog *Xenopus laevis*, from entering the ponds. Evaporation and seepage water were replenished on a regular basis to maintain the same water levels throughout the period of investigation. On one occasion, halfway through the investigation, it became necessary to flush the accumulated wastes responsible for increased ammonia concentrations and a sharp reduction in oxygen levels in the water of the ponds, using the inflow of fresh water from the Turfloop Dam for a period of four days. Approximately four times the volume of water held by the ponds was replaced by fresh water during the flushing period.

Physical and chemical analysis of water

A Thies hydrothermograph was installed in one of the ponds to provide continuous recordings of temperature fluctuations in the pond water throughout the period of investigation. Selected physical and chemical parameters analysed for, according to APHA (1980), included: dissolved oxygen, conductivity, pH, ammonia, nitrite, nitrate, soluble reactive phosphate, alkalinity, calcium and total hardness. An analysis was made once a week on samples collected at 09h00.

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Fish used

Both varieties of the sharptooth catfish were spawned in the Mobil Laboratory of the Aquaculture Research Unit of the University of the North according to locally-developed procedures (Schoonbee *et al.*, 1980; Polling *et al.*, 1988). Larvae were reared in 500 ℓ PVC containers, using a recirculation water system supplied with heater elements and a biological filter system. Feed used during the indoor larval rearing period of four weeks consisted of screened live food, made up of rotifers (*Brachionus* spp.) and the cladoceran *Moina* spp., applied according to procedures described by Polling *et al.* (1988). Juveniles were transferred to outside earthen grow-out ponds where they were also overwintered. During the grow-out phase of the juveniles, a 38% protein formulated dry feed was used as a supplementary feed. Once a week, jumper fish, which could pose a danger of cannibalism to the rest of the population of pond fish, were removed during routine seining inspections of the juveniles. Fish were overwintered in the earthen ponds.

Because of the higher density at which juveniles of the red strain were stocked in grow-out ponds, compared to that of the black normal strain, the growth rate of the red strain was comparatively slower. As a result, the mean individual mass of the red strain at the time of stocking in the production ponds fluctuated between 81,4 g and 81,7 g compared to 121,1 g and 121,4 g for the normal variety respectively. The two varieties were stocked in two experimental ponds in equal numbers and at a density of 15 000 fish ha^{-1}. As only two production ponds were used, the results were not suitable for detailed statistical evaluation and were considered together in the evaluation of the growth results.

Feeding program

Feed used consisted of a mixture of minced tilapia (25%) grown in final maturation pond effluent water at the Seshego fish farm of the Lebowa Government, bakery-floor sweepings (37,5%), and an 18% protein formulated pelleted chicken feed (37,5%). A daily quantity of American catfish vitamin premix at a ratio of 2 kg t^{-1} final feed mixture was added to the food mixture. By using these constituents, the total cost of formulated feed component purchased, including the chicken feed, amounted to approximately R0,20 kg^{-1} of food mixture. After seining, small wild spawn of tilapia used as food were thoroughly washed in clean water before being macerated in an industrial mincer. Minced fish meat was then frozen in predetermined quantities, ready for use.

Immediately before application, the measured quantities of the above-mentioned constituents were thoroughly mixed before the food was handspread over the pond's surface. Feed was applied for six days a week in quantities, calculated as dry mass, at 4% of the estimated total fish mass in the ponds. Because of the composition of the food mixture, feed was applied at a higher ratio than that recommended by Hoogendoorn *et al.* (1983), where a well-balanced formulated feed was used. This was adjusted fortnightly on estimates of fish growth done on samples of fish seined from the ponds, varying between 15 and 25% of the total numbers of fish initially stocked in the ponds. During the first two months, application of food was made twice daily at 10h00 and 15h00. During the last phase of the experiment food was applied three times per day at 10h00, 12h00 and 15h00. This procedure was considered necessary to prevent the undue wastage and accumulation of food at feeding times, especially during the latter part of the investigation when the standing crop of fish in both ponds exceeded 5 t ha^{-1}. The investigation lasted for 140 d during the summer season of 1987-1988. At the end of the production period, both ponds were completely drained and all fish removed, counted and individually weighed to assess survival and production for both varieties of catfish.

Results

Pond water chemistry

Although the lowest water temperature of the fish-ponds was 14°C during the period of investigation, mean values for the consecutive fortnightly periods never declined below 19°C (October 1987, Table 2). With the exception of two periods, water temperatures averaged more than 20°C. Maximum temperatures for the pond water exceeded 26°C. It should be pointed out that these temperatures are well below the preferred and optimal growth temperatures for *C. gariepinus* (Britz and Hecht, 1987).

From Table 1 it can be seen that parameters such as dissolved oxygen, ammonia, nitrite, nitrate and phosphate were most subject to variation. Although the mean value for dissolved oxygen of 6,5 mg ℓ^{-1} indicates well-oxygenated conditions in the ponds at most times, a minimum value of 1,7 mg ℓ^{-1} points towards periodic severe declines in this parameter in the pond water dur-

TABLE 1
SUMMARY OF RESULTS OBTAINED ON CERTAIN PHYSICAL AND CHEMICAL CONDITIONS OF FISH POND WATER ANALYSED DURING THE PERIOD 6 OCTOBER 1987 TO 2 FEBRUARY 1988

Analysis	N	$\bar{x}$	Min	Max	SD	CV
Dissolved oxygen (mg ℓ^{-1})	32	6,5	1,7	8,3	1,19	18,42
pH	36		7,49	9,14	0,34	4,18
Conductivity (μS cm^{-1})	36	623	445	741	60,58	9,72
Alkalinity as $CaCO_3$ (mg ℓ^{-1})	30	270	219	326	22,06	8,18
Calcium hardness as $CaCO_3$ (mg ℓ^{-1})	32	71	60	81	2,46	3,48
Total hardness as $CaCO_3$ (mg ℓ^{-1})	32	143	105	167	8,58	5,99
Ammonia (NH_4) (mg ℓ^{-1})	34	0,935	0,268	4,087	0,380	40,66
Nitrite (NO_2) (mg ℓ^{-1})	34	0,017	0,003	0,076	0,010	59,73
Nitrate (NO_3) (mg ℓ^{-1})	34	1,15	tr	2,64	0,65	56,29
Orthophosphate (PO_4) (mg ℓ^{-1})	34	0,953	0,29	1,90	0,355	37,26

SD: Standard deviation
CV: Coefficient of variability
tr: traces

ing the period of investigation.

Occasionally pH values rose above 9, creating a situation where the danger existed of ammonia becoming toxic. In fact, the highest value recorded for ammonia exceeded 4 mg ℓ^{-1}, with a mean value of 0,935 mg ℓ^{-1}. Apart from the high densities of fish in the ponds, which may have been responsible for the release of substantial quantities of nitrogenous metabolic wastes into the pond water and which must have contributed much towards the high concentrations of ammonia recorded, breakdown in the water of the minced fish applied as food might have been another contribution towards the comparatively high ammonia loads recorded.

With the mean phosphate loads of 0,593 mg ℓ^{-1} and high concentrations of nitrogen in the water, algal development in the ponds could also have contributed further towards the wide fluctuation in dissolved oxygen recorded.

Fish production

The results on the mean standing crop, cumulative mass increment and separate and total yields of the two catfish varieties are listed in Tables 2 and 3 and in Fig. 1. Although the mean initial individual mass of the two catfish varieties in the ponds amounted to 101,6 g, the discrepancy in mean individual mass between the red catfish ($\bar{x}$: 81,5 g) and black catfish ($\bar{x}$: 121,7 g) was 40,2 g at the start of the production investigation (compare Tables 2 and 3). Both varieties together contributed to an initial standing crop of 1,524 t ha^{-1} when the fish-feeding programme commenced. Expressed as a percentage, the individual mass contribution of the red catfish at the onset of the experiment was 67% of that of the black catfish (Table 4).

After 140 d the mean fish standing crop for the two ponds stood at 9,171 t ha^{-1} with a total yield of 7,647 t ha^{-1} (Table 2).

TABLE 2
RESULTS ON THE MEAN GROWTH AND PRODUCTION OF THE RED AND BLACK VARIETIES OF THE SHARPTOOTH CATFISH STOCKED TOGETHER, AND RECEIVING A MIXTURE OF MINCED FISH, BAKERY-FLOOR SWEEPINGS AND 18% PROTEIN FORMULATED DIET OVER A PERIOD OF 140 D

Period	Days	Date	Mean and extreme pond water temperatures for each 14-d period (°C)	Stocking(S) and final (F) densities (Fish ha^{-1})	Mean individual mass of fish (g)	Standing crop (kg ha^{-1})	Yield increment (kg ha^{-1})	Production (kg ha^{-1} d^{-1})	Minced fish and formulated food mixture dosage quantity (kg ha^{-1})	FCR*
0	0	6.10.87		15 000 (S)	101,6	1 524,0				
1	14	6.10-19.10	19,0 14,0-24,0		131,3	1 770,7	246,7	17,6	413,1	1,7
2	28	20.10- 2.11	19,9 16,0-23,5		167,3	2 255,5	484,8	34,6	619,9	1,3
3	42	3.11-16.11	21,1 16,0-24,5		213,8	2 882,3	626,8	44,8	687,9	1,1
4	56	17.11-30.11	22,2 16,5-25,5		296,9	4 003,1	1 120,8	80,1	1 050,0	0,9
5	70	1.12-14.12	22,7 20,0-26,0		391,0	5 272,2	1 269,1	90,6	1 445,9	1,1
6	84	15.12-28.12	23,4 21,0-25,5		435,3	5 869,8	597,6	42,7	1 463,8	2,4
7	98	29.12-11.1	22,7 19,5-26,0		498,0	6 714,8	845,0	60,4	1 803,4	2,1
8	112	12.1 -25.1	23,8 20,5-26,5		594,0	8 009,5	1 294,7	92,5	2 059,1	1,6
9	126	26.1-8.2	22,8 20,0-25,5		656,7	8 854,1	844,6	60,3	2 447,0	2,9
10	140	9.2-22.2	22,0 19,5-24,5	13 483 (F)	680,2	9 171,0	316,9	22,6	2 704,3	8,5
	Total and mean values						7 647,0	$\bar{x}$ = 54,6	14 694,4	$\bar{x}$ = 1,9

*FCR: Feed conversion ratio expressed as dry feed mass gain
(This figure does not consider the contribution by the natural pond productivity).

TABLE 3
INDIVIDUAL CONTRIBUTION OF THE RED AND BLACK VARIETIES OF THE SHARPTOOTH CATFISH TOWARDS THE YIELD OBTAINED OVER A PRODUCTION PERIOD OF 140 D

Varieties	Mean density (fish ha^{-1})	Mean initial individual mass of fish at stocking (g)	Mean initial fish biomass (kg ha^{-1})	% contribution to total mass at time of stocking	Final numbers of fish harvested (fish ha^{-1})	Mean final biomass (kg ha^{-1})	% contribution at the time of cropping	Mean final individual mass of fish (g)	Fish yield (kg ha^{-1})	% contribution to final yield
Black variety	7 500	121,7	912,7	59,9	7 246	5 227,3	57,0	721,4	4 314,6	56,4
Red variety	7 500	81,5	611,3	40,1	6 237	3 943,7	43,0	632,3	3 332,4	43,6
Total	15 000		1 524,0	100,0	13 483	9 171,0	100,0		7 647,0	100,0

TABLE 4
COMPARISON OF THE INITIAL, INTERMEDIATE (CALCULATED) AND FINAL (EMPIRICAL) MEAN INDIVIDUAL MASS OF THE TWO VARIETIES OF *C. GARIEPINUS* STOCKED TOGETHER IN A 140 D PRODUCTION INVESTIGATION, WITH AN INDICATION OF THE COMPARATIVE IMPROVEMENT OVER TIME (%) IN THE MASS OF THE RED VARIETY.

Period	Days	Mean estimated* and final empirical individual mass (in g) of the black variety of the sharptooth catfish	Mean estimated* and final empirical individual mass (in g) of the red variety of the sharptooth catfish	Progressive proportionate increase in the mean individual mass of the red variety of the sharptooth catfish compared to that of the black variety over a production period of 140 d
0	0	121,7	81,5	67,0
1	14	161,7	100,9	62,4
2	28	200,6	133,9	66,7
3	42	258,0	169,5	65,7
4	56	356,7	237,1	66,4
5	70	447,9	334,1	74,6
6	84	493,1	377,6	76,6
7	98	574,2	421,8	73,4
8	112	672,5	515,6	76,7
9	126	728,3	585,1	80,3
10	140	721,4	632,3	87,6

*Based on capture data

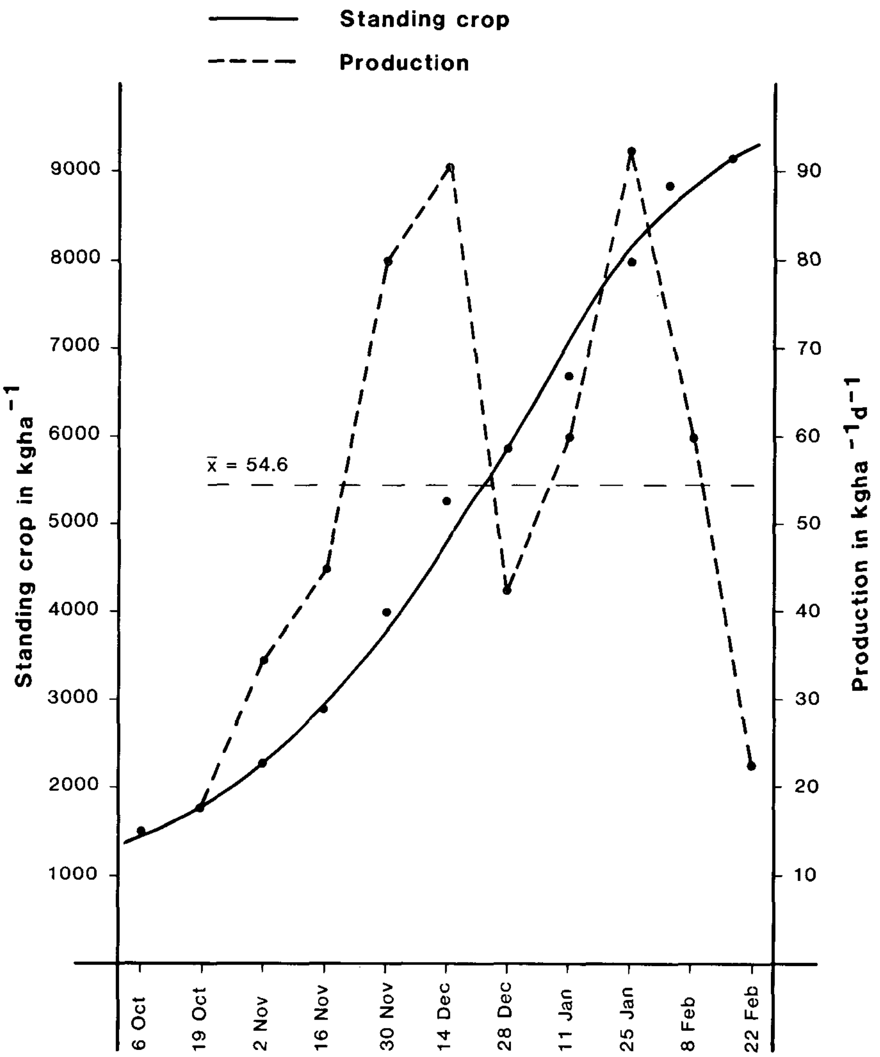

Figure 1
Standing crop (kg ha^{-1}) and production (kg ha^{-1} d^{-1}) of the two varieties of the sharptooth catfish stocked together at a density of ± 15 000 fish per hectare, over a period of 140 d.

Of this, the black catfish contributed 4,315 t ha^{-1} (56,4%) and the red catfish 3,332 t ha^{-1} (43,6%). This implies that had there been no mortalities, the red catfish would have improved its percentage contribution in the ponds by 3,5% (Table 3). It must, however, be taken into account that the higher mortalities of the red catfish, caused largely by predation of fish-eating water birds during the early stages of the production period (Prinsloo and Schoonbee, 1989c), resulted in an 83,1% survival of the red catfish, compared to a considerably higher 96,6% for the black catfish. The mean individual mass of the red catfish cropped after 140 d was 632,3 g compared to 721,4 g for the black catfish.

There was a consistent increase in the daily production of the fish in the ponds during the first 70 d, with yield increments for the different fortnightly periods reaching a peak of 1 269,1 kg ha^{-1} between day 56 and 70 (Table 2). Massive waste accumulation in the ponds led to a dramatic decline in the daily production of the fish: from a maximum of 90,6 kg ha^{-1} d^{-1} to 42,7 kg ha^{-1} d^{-1} between days 70 and 84. This phenomenon is clearly reflected in the yield increment data (Table 2) and daily production pattern (Fig. 1). The flushing of the ponds with fresh water for four days during the first week in January led to a rapid recovery in fish growth and a maximum production of 92,4 kg ha^{-1} d^{-1} between days 89 and 112. The deterioration of pond water conditions (see above) also had a negative effect on the feed conversion ratio (FCR) of the fish, which deteriorated to more than 2 between day 70 and day 98 (Table 2). A further rapid decline in production occurred towards the end of the growth period when the investigation was terminated, at a time when all the fish had already reached a marketable size. This further deterioration in pond conditions again seriously affected the feed conversion pattern of the fish, which averaged 1,9 over the total production period of 140 d (Table 2).

Discussion

As mentioned earlier, very little information exists on the pond production of the sharptooth catfish, *C. gariepinus*, under local conditions. Van der Waal (1978) obtained a production figure of 23,5 kg to 59,3 kg ha^{-1} for *C. gariepinus* in fertilised and unfertilised ponds. Where food was given, more than 3 t ha^{-1} were obtained over a growth period of 150 d. In the latter case stocking densities ranged between 54 000 and 170 000 fish ha^{-1} but with mortalities, ascribed to cannibalism, ranging between 73% and 90%. The feed conversion factor for this latter investigation varied between 5,1 and 7,1 (Van der Waal, 1978).

Using organically-fertilised ponds, with poultry manure as nutrient and providing no supplementary feed, Bok and Jongbloed (1984) obtained a production figure of 500 to 1 500 kg ha^{-1} for *C. gariepinus* where it was reared in monoculture over a period of 113 d. When stocked together with the common carp, these authors found the catfish production to diminish. Where macerated chicken offal was used as food for *C. gariepinus* in ponds at a density of 5 875 fish ha^{-1} using fish of an average mass of 406,5 g, a yield of more than 2 t ha^{-1} was obtained by Prinsloo and Schoonbee (1987) over a summer growing period of 75 d. Prinsloo *et al.* (1989a) used *C. gariepinus* and the European common carp *C. carpio* in polyculture in final maturation pond effluent water at a total stocking density of 11 045 fish ha^{-1}. Equal numbers of both species were stocked. Mean initial stocking mass was 166,4 g for the catfish and 124,0 g for the common carp. A total yield of 4,55 t ha^{-1} was obtained over a period of 100 d using a low-cost 18% protein formulated chicken broiler pelleted feed. Of this yield 46% was contributed by the sharptooth catfish.

Even though two sharptooth catfish varieties were used in the present production trial, the present investigation can essentially be considered as a *C. gariepinus* monoculture production effort. The final yield of 7,647 t ha^{-1} can certainly be bettered if pond-water quality and the diet of the fish can be improved. This then would make the present production effort the best published information of its kind for *C. gariepinus* under local environmental conditions, especially if it is taken into account that waste material formed the bulk of the food used, and that the average water temperature during the production period fluctuated around 20°C. The composition and lack of binding properties of the food given, definitively posed a serious threat to the oxygen regime in the ponds. Furthermore, the release of nitrogenous substances, such as ammonia, from the decomposing waste food must have affected the yields (Table 3) and also the eventual feed conversion obtained (Table 2). It is therefore recommended that, where waste food is incorporated into the diet of this omnivorous fish, the food be processed into a kind of dough which would not dissolve as easily in the water and which could be converted into strands before providing it to the catfish. An almost similar situation was observed in the Republic of China where shreds of a dough-like food were given to black bass in intensive culture systems (Schoonbee, personal observation).

The necessity of removing the accumulated organic wastes from ponds, a practice which is common nowadays at major fish farms in the Republic of China and Israel, is again demonstrated by the rapid recovery in the production capacity of the fish in the present investigation, following the flushing of the pond water in January 1988 (Fig. 1). It is therefore important that in designing production ponds for intensive African catfish farming and in fact also for other fish species produced under high density conditions, earthen ponds be constructed to enable the rapid and easy removal of the accumulated wastes from the pond bottom without completely emptying the ponds. This approach need not require an expensively designed and constructed pond system.

The present results on the growth of the red variety of the sharptooth catfish which originated at the Turfloop Dam (Prinsloo *et al.*, 1989b) clearly point towards a somewhat inferior growth of this strain when compared to that of the normal black variety. Although pointing towards a good growth ability, it does not appear to match that of the normal dark strain when reared together in the same pond. Because of its attractive colour at marketable size, it may fetch a better price than the normal variety. This certainly merits further investigations into the production potential of the red strain of *C. gariepinus* in monoculture and in polyculture.

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