Perspectives on clariid catfish culture in Africa

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Abstract

The African catfish *Clarias gariepinus* is undoubtedly the most suitable species for aquaculture throughout its distributional range. The reasons for this, which relate principally to the biology and ecology of the species, are briefly reviewed and commented upon. The species is currently farmed on a commercial and subsistence basis in over 12 African countries, the most important of which in terms of tonnage produced are Nigeria, South Africa, Zambia and Ghana. The scientific and technological foundation for the farming of African catfish is sound, and has been developed mainly in The Netherlands, South Africa, Belgium and the Central African Republic. Most of the important culture parameters, inclusive of spawning, incubation, larval nutrition and rearing, production and feed formulation have received adequate attention for the successful farming of the species in Africa. Production levels, depending on the type of operation, range from <1 to 40 t/ha per year, and exceed 800 kg/m^3/year under ultra-high density commercial culture conditions. Food conversion ratios vary between 1:6 using agricultural waste, to 1:1.1 using formulated, least-cost feeds. Significant progress has also been made in the development of the technology for the farming of a related species, *Heterobranchus longifilis* and the hybrid of this species with *Clarias gariepinus*. Despite the technological kow-hnow, total recorded production of clariid catfish in Africa in 1993 was a mere ca. 4500 tonnes. Despite the fact that there may be a considerable margin of error in the reported production figures the farming of catfish in Africa is a marginal activity. The reasons for this are manifold and can be primarily pinned on market forces, inadequate regional infrastructures, production costs, the socio-economics of fish farming and the philosophy upon which aquaculture development in Africa is largely based. Nevertheless the future potential for the farming of clariid catfish throughout their distributional ranges is immense.

Keywords: *Clarias*, Clariidae, Africa, farming technology, production, yields, nutrition.

Perspectives sur l'élevage des poissons-chats en Afrique.

Résumé

Le poisson-chat africain *Clarias gariepinus* est sans aucun doute l'espèce la plus adaptée à l'aquaculture au travers de sa vaste répartition géographique. Les principales raisons, liées à la biologie et à l'écologie de l'espèce, sont brièvement passées en revue et commentées. Cette espèce est couramment mise en élevage à des fins commerciales et de subsistance dans plus de 12 pays d'Afrique; les plus importants d'entre eux, en termes de tonnage, sont le Nigéria, l'Afrique du Sud, la Zambie et le Ghana. Les bases scientifiques et techniques de l'élevage du poisson-chat africain ont été principalement développées aux Pays-Bas, en Afrique du Sud, en Belgique et en République Centre-Africaine. Les paramètres importants concernant l'élevage telles que la ponte, l'incubation, la nutrition larvaire, la production et la formulation d'aliments ont été étudiés avec toute l'attention nécessaire pour le succès de l'élevage de cette espèce en Afrique. Les niveaux de production, en fonction du type d'opération, sont compris entre 1 et 40 t. ha^{-1}.an^{-1}, et excède 800 kg.m^{-3}.an^{-1} lors de cultures commerciales intensives. Les taux de conversion nutritionnels varient de 1 pour 6 en utilisant des déchets d'agriculture à 1 pour 1,1 avec des aliments à prix de revient moindre. Des progrès significatifs ont été également faits dans la technique d'élevage d'une espèce proche, *Heterobranchus longifilis* et l'hybride de cette espèce avec *Clarias gariepinus*. En dépit de la technique du savoir-faire, la production totale enregistrée pour les poissons-chats clariidés en Afrique est de 4500 t en 1993 et en dépit du fait qu'une marge considérable d'erreurs existe dans les chiffres de production rapportés, l'élevage du poisson-chat en Afrique est une activité marginale. Les raisons sont multiples et assujetties aux lois du marché, à l'inadéquation des infrastructures régionales, aux coûts de production, aux aspects socio-économiques de l'équaculture et à la philosophie sur laquelle le développement de l'aquaculture est largement basé en Afrique. Néanmoins, le potentiel futur pour l'élevage de clariidés est immense.

Mots-clés : *Clarias*, Clariidae, Afrique, techniques d'élevage, production, rendement, nutrition.

INTRODUCTION

Biologically the African catfish, *Clarias gariepinus* is undoubtedly the most ideal aquaculture species. It is widely distributed, thrives in diverse environments (temperate to tropical), is hardy and adaptable principally as a consequence of its airbreathing ability, feeds on a wide array of natural prey under diverse conditions, is able to withstand adverse environmental conditions, is highly fecund and easily spawned under captive conditions. It has a wide tolerance of relatively poor water quality and possibly the most exciting feature of the species is its potential for highly intensive culture without prerequisite pond aeration or high water exchange rates (Hecht *et al.*, 1988; Haylor, 1992*a*; Hecht, in press). Recent work in Rwanda has also shown that strains of the species can also be grown successfully at lower temperatures and at high altitude.

Contrary to the development of the American channel catfish industry where the research was, and still is, to a large extent needs driven, the research on the development of clariid catfish farming has largely been driven by science and technology. While the technologies for the farming of the species have now been developed, to varying degrees of sophistication depending on location, there is still a great need to convince farmers to adopt the technology and to farm the species on a large scale. The aquaculture potential of *Clarias gariepinus* in Africa was first realised by Hey (1941). Until the mid 1970s the research effort was of a relatively low key nature and was revived principally by the papers of De Kimpe and Micha (1974) and Richter (1976). Since the mid 1970s the research on African catfish culture has mushroomed and has been undertaken mainly in the Netherlands, South Africa, Belgium, Central African Republic and Ivory Coast. These largely independent but parallel research initiatives resulted in the rapid development of the technology throughout Africa. For example, in southern Africa the research and development phase lasted a mere six years before the results were translated into commercial practice (Hecht and Britz, 1990).

Clarias species, particularly *C. batrachus*, *C. fuscus* and *C. macrocephalus* are farmed widely in Asian countries such as Thailand (Areerat, 1987), the Philippines (Carreon *et al.*, 1976), Indonesia, India (FAO, 1992). China (Zheng *et al.*, 1988) and to a limited extent in Taiwan. The African catfish, *Clarias gariepinus* is farmed mainly in Africa and Europe, although it is now also receiving attention in India, China and some East European countries, and has also recently been introduced into Brazil. In Europe it is farmed in the Netherlands and in Belgium (Huisman and Richter, 1987), and in Africa it is farmed at varying levels in Burundi, Cameroon, Central African Republic, Egypt, Gabon, Ghana, Ivory Coast, Kenya, Lesotho, Nigeria, Rwanda, South Africa, Swaziland, Zaire, Zambia and Zimbabwe (Anon., 1989; Hecht and Britz, 1990; FAO, 1992).

Several other clariid catfish species are also currently being considered for aquaculture in Africa. These include *Clarias isheriensis* (Fagbenro, 1990) and *Heterobranchus longifilis* (Kerdchuen and Legendre, 1992). *H. longifilis* and its hybrid cross with *C. gariepinus*, in particular, has received considerable attention (Hecht and Lublinkhof, 1985; Legendre, 1986; Legendre *et al.*, 1992). *C. gariepinus* has also been hybridized with *H. bidorsalis* in Nigeria (Salami *et al.*, 1993), and with *C. fuscus* in China (Zheng *et al.*, 1988).

PRESENT STATUS

The global production of *Clarias* species for 1990 is summarized in *table* 1. Data were obtained from FAO (1992) and other sources. No production figures could be obtained for China, although it is known that *C. fuscus*, *C. macrocephalus* and *C. batrachus* are farmed profitably and on a relatively large scale (Zheng *et al.*, 1988). The production figures, particularly those for Africa, presented in *table* 1 should, however, be regarded with great circumspection. Aquaculture in Africa is predominantly rural, and orientated principally to the immediate needs of the farmers and their families (Anon., 1989). In many instances the fish are consumed directly (*e.g.* as much as 50% of the harvest in Kenya, Ivory Coast and Rwanda). Consequently the production figures are not always reported or recorded. More

Table 1. – World production of *Clarias* species in 1990 (FAO, 1992 and other sources).

Country	Species	Production (tonnes)
Asia		
India	*Clarias* sp.	39 260
Thailand	*C. batrachus, C. macrocephalus*	12 400
Indonesia	*Clarias* sp.	3 880
Cambodia	*C. batrachus*	216
Malaysia	*C. batrachus*	197
Hong Kong	*C. fuscus*	120
Philippines	*Clarias* sp.	100
Guam	*C. batrachus*	10
Europe		
Netherlands	*C. gariepinus*	300
Africa		
Nigeria	*C. gariepinus*	1 533
South Africa	*C. gariepinus*	438
Ghana	*C. gariepinus*	150
Ivory coast	*C. gariepinus & H. longifilis*	100
Cameroon	*C. gariepinus*	10
Malawi	*C. gariepinus*	10
Central African Rep.	*C. gariepinus*	5
Lesotho	*C. gariepinus*	3
Mali	*C. gariepinus*	3
Africa total for 1990		3 211
World total for 1990 (excluding China)		59 697

recent information (1992-1994) was obtained from the scientific literature, aquaculture and agriculture magazines and in unpublished research reports of research stations on the continent and through personal contacts of the authors. Using this information and assuming a considerable measure of under-reporting and non-recording the total production of clariid species for 1993 in Africa was estimated to be ca. 4 500 tonnes.

The status of *C. gariepinus* farming in Africa is considered further in terms of spawning and fry production, grow-out, systems, yields, nutrition, processing and marketing. In all aspects the technologies range widely in their level of sophistication, from subsistence level farming, simple processing and marketing channels, to high density tank culture and highly sophisticated product development and export.

Spawning and fry production

Many different hormonal preparations have been successfully used to induce spawning in *C. gariepinus*. Some of these include HCG, DOCA, Carp Pituitary Suspension, Progestagen, Pimozide, and LH-RHa (De Kimpe and Micha, 1974; Hogendoorn, 1977; Schoonbee *et al.*, 1980; Hecht *et al.*, 1982; Richter and van den Hurk, 1982; De Leeuw *et al.*, 1985; Richter, 1985). However, the clariid farming community in Africa is now using mainly a homoplastic pituitary gland suspension to induce spawning (Britz, 1991). The method has been found to be highly reliable and, in comparison to synthetic hormone analogs, the technique is cheap and practical. This is of particular importance in African countries where sophisticated chemicals are often difficult, if not impossible, to obtain.

The whole pituitaries are removed from sexually mature adult catfish during the spawning season and are either used immediately or are stored in absolute ethanol or acetone, or stored dry after acetone or alcohol impregnation for up to 18 months with no loss of efficacy. The pituitaries are simply homogenised in sterile water or pure rainwater and injected into the females. The dose is calculated on a 1.5:1 (donor: recipient weight basis). Females with suitably developed eggs can usually be stripped 12 hours after receiving a single dose at a temperature of 28°C, or 20 hours at a temperature of 22°C. Broodstock females usually vary between 1 and 2 kg in weight. Owing to high levels of aggression, broodstock females after injection are usually separated from each other in the holding tanks by way of sturdy screens. A simple and completely reliable method of testing the readiness of the eggs for fertilization is by holding the females in a head-up vertical position. If the eggs begin to run freely from the genital pore they are ready to be fertilised.

To increase genetic variability a minimum of two males are used to fertilise batches of eggs. To obtain adequate quantities of sperm males are sacrificed. Fertilisation is best effected by first diluting the sperm in physiological saline whereafter the solution is mixed with the eggs.

The fertilised eggs become sticky on contact with water and in commercial and demonstration hatcheries are spread onto mosquito screens, which are suspended slightly off the vertical axis in hatching troughs. If screens are not available the eggs can also be adhered to the roots of floating aquatic plants (such as water hyacinth) during the incubation period. Development time is temperature-dependent. Once hatching occurs the free embryos fall to the bottom of the tank while the egg envelope remains adhered to the screen. All commercial catfish hatcheries in southern Africa work at 28°C at which the larvae hatch after 16-18 hours. After swim-up they flow into rearing tanks. Larval rearing is restricted to a 10-15 day period during which the fish are kept indoors under optimal conditions and fed on a complete dry feed every two hours. During the first 3-5 days they receive a supplement of *Artemia* nauplii three times a day. Several studies have also shown that clariid larvae can be reared successfully without *Artemia* or other zooplankton supplementation (Hecht, 1982, Uys and Hecht, 1985; Appelbaum and van Damme, 1988; Kerdchuen and Legendre, 1994).

After a 10-15 day intensive hatchery period they are transferred to nursery ponds (fertilised and filled two days prior to transfer), at a density of 2000 fry.m $^{-2}$. During the following 3 weeks the juvenile fish are graded into three size classes at least two times. The smallest size class is usually discarded each time. The fry are fed every 4 hours, with a 38% protein diet. A water exchange rate of 0.5 l.min $^{-1}$.m $^{-2}$ is maintained throughout the nursery pond phase. At an average weight of 4-5 g they are either sold to producers or put into the farms own production ponds. Average total survival rate from the time of hatching to the end of the nursery phase is 40%.

In less sophisticated hatcheries the procedures are markedly different. After yolk sac absorption, the larvae are fed on live zooplankton, usually caught from production ponds and are transferred to nursery ponds as early as two days after yolk sac absorption (approximately 5 days old) at an average weight of 5 mg. The rearing of the larvae to fingerling size under small-scale/subsistence conditions is usually achieved in organically fertilised ponds, filled two days prior to stocking, at a stocking density of 30 to 100 larvae.m $^{-2}$. In some instances ponds are equipped with compost enclosures covering 10 to 25% of the surface area. The larval fish are fed on a supplementary basis with substances such as sun-dried brewery waste, rice and wheat bran or other agricultural by-products, if available. Fingerlings are harvested six weeks later at an average weight of 3 to 5 g. In aquaculture development programmes the production of fingerlings and their transport to outlying rural farms is a bottleneck. To overcome this problem extension officers sell the fish to farmers directly after yolk-sac absorption at which time they can be transported in greater numbers with relative ease.

During the late 1970s and early 1980s government and or donor funded demonstration hatcheries for *C. gariepinus* were built in Cameroon, Central African Republic, Ivory Coast and Nigeria, but only those in the Ivory Coast and Central African Republic were still in operation in 1989 (Anon., 1989). In 1989 a hatchery was developed in Rwanda, and more recently in Malawi (Haylor, 1992*b*; Dickson, 1993).

The establishment of hatcheries in those countries which lack sophisticated infrastructure requires ingenuity, and some remarkable successes have been achieved. The production from these hatcheries is however low and would not satisfy the needs of large scale operations. Claims have often been made as to the potential of government or donor funded hatcheries but none have yet lived up to expectation. In South Africa direct comparisons can be made between private hatcheries and government hatcheries. In effect, most government hatcheries were totally inefficient and all but a few have been privatised in the least decade. Since privatisation they have all become successful and economically viable.

In all operations in Africa the original broodstock is collected from the wild, whereafter selected farm-grown fish are used as broodstock. This practise is not necessarily a good one, as inbreeding can lead to a decrease in fitness of the farmed fish, which is noticeable after only a few generations (van der Walt *et al.*, 1992). On the other hand, controlled inbreeding of "shooters" (particularly fast growing individuals) may lead to a strain of fast growing fish, although these show a greater propensity towards cannibalism (Hecht and Pienaar, 1993). To overcome these problems catfish farmers in South Africa usually bring a small number of wild fish onto the farm each year.

Systems, yields and nutrition

Two types of systems are used for catfish farming in Africa, viz. ponds and concrete tanks. Ponds are mainly used in small and large-scale extensive and semi-intensive farming operations, while tanks are used mainly for the high density culture of catfish (under either through-flow or recirculating conditions). Some work has also been undertaken on the utilisation of concrete grow-out systems for home based catfish production.

The size of production ponds is highly variable and range from 36 m ^{2} (low input homestead concrete ponds - Egwui, 1986), to 100 m ^{2} under subsistence pond farming conditions to 1 ha in size under extensive commercial pond culture conditions. On semi-intensive commercial farms the average pond size is 1 000 m ^{2} (*table* 2). The average depth of all ponds is approximately one metre.

In southern Africa most of the commercial farms are monoculture semi-intensive to intensive, and are based on the guidelines set out by Hecht *et al.* (1988). The production ponds on commercial farms are relatively small (in comparison to channel catfish ponds) and on average do not exceed 1 000 m ^{2} (0.1 ha) in size. Ponds of this size are optimal in terms of management, feed utilisation and production (Uys and Hecht, 1988). Experienced farmers stock fingerlings into the production ponds at an initial density of 100 000 ha $^{-1}$. After six weeks the density is reduced and the fish are graded for size. Under optimal conditions the fish are grown to an average market size of 700 to 800 g in 8 months at average yields of 40 t.ha $^{-1}$. Food conversion ratios (FCR) under optimal conditions range from 1:1.1 to 1:1.4. In those regions where water temperature drops below 22°C in winter the production cycle includes two summers. The feeding rate is adjusted every 10 days. During the production period the fish are graded for size every 2 months. A flow rate of 2-6 l.s $^{-1}$.ha $^{-1}$ is necessary to produce 40 t of catfish.ha $^{-1}$.production period $^{-1}$.

Production of food-size fish by small-scale rural farmers is achieved mainly under polyculture conditions with mixed sex tilapia, in extensive to semi-intensive systems (if supplemental food is available). In Rwanda maximum production under these conditions is achieved when catfish are stocked

Table 2. – Examples of extensive, semi-intensive and intensive catfish farms in Africa.

Country	Pond/tank size (area m²)	Pond type	Exchange rate	Reference
Extensive				
E. Cape, South Africa	200	earthen	stagnant	Bok and Jongbloed, 1984
Nigeria	5 000	barrage	stagnant	Fagbenro, 1990
Semi-intensive				
Nigeria	36	concrete	stagnant	Egwui, 1986
Nigeria	38	concrete	9 days	Salami *et al.*, 1993
Nigeria	180	earthen	topped up	Fagbenro and Sydenham, 1990
Malawi	200	earthen	topped up	Brooks, 1994
Zambia	800	earthen	10 days	Hecht (pers. obs.)
Egypt	926	earthen	stagnant	El Bolock, 1975
N. Tvl, South Africa	300-1 400	earthen	sporadic flushing	van der Waal, 1978
N. Tvl, South Africa	840-972	earthen	14 days	Prinsloo *et al.*, 1989
N. Tvl, South Africa	1 000	earthen	10 days	Hecht *et al.*, 1988
N. Cape, South Africa	4 210	earthen	rate not noted	Kenmuir, 1993
Intensive	Volume (m³)			
N. Tvl, South Africa	3	concrete	120 min	Hecht (pers. obs.)
N. Tvl, South Africa	2	concrete	60 min	Hecht (pers. obs.)
E. Cape, South Africa	1	concrete	45 min	Hecht, 1994

(25-35% by numbers) with tilapia at a total stocking density of 1 fish.m^{-2}. Catfish and tilapia are stocked at equal size. Production in rural polyculture ponds with mixed sex tilapia varies from 2 to 3,5 t.ha^{-1}.yr^{-1}. Marketable size for both species is normally reached at the same time (120-150 g for tilapia and 250-450 g for catfish) after 10-12 months. *Heterobranchus* species are also often used in polyculture with tilapia (Copin and Oswald, 1993). Monoculture of catfish under conditions where the fish are dependent on natural pond productivity does not produce equivalent yields.

Some examples of final densities and yields under different conditions of farming intensity are presented in *table* 3. Under pond culture conditions catfish have been reared at densities from 0.1 kg.m^{-2} (Bok and Jongbloed, 1984) using only manure, to 4 kg.m^{-2} using formulated feeds (Hecht *et al.*, 1988). Under polyculture conditions catfish have been reared together with carp (1.6 kg.m^{-2} catfish plus 2.9 kg.m^{-2} carp) (Prinsloo *et al.*, 1989) or with mixed sex tilapia in Rwanda at a ratio of 1:6 (catfish:tilapia) at a final density of 0.3 kg.m^{-2}.

C. gariepinus has also been used in polyculture with other tilapiine species, particularly with *Tilapia guineensis* (Salami *et al.*, 1993), *Tilapia rendalli* and *Oreochromis karangae* (Brooks, 1994) and *Oreochromis niloticus* (Lazard, 1986; Copin and Oswald, 1993). In most of these studies African catfish are used as predators to control tilapia densities to prevent precocious breeding and stunting.

Bovendeur *et al.* (1987) held African catfish at a density of 436 kg.m^{-3} in a recirculating system. The consequent possibility of ultra-high density catfish farming was pursued by South African catfish farmers. Although this is the common way of farming African catfish in the Netherlands, there are only two commercial farms using this method of production in Africa. Both of these are situated in the Northern Transvaal Province in South Africa. On these farms catfish are grown at 250-350 kg.m^{-3} water in 2-3 m³ concrete tanks (*table* 4). Water in the tanks is exchanged every 1-2 hours and feed conversion ratios range from 1.2 to 1.3. The highly concentrated nature of the operation, plus reduced labour costs, and higher yields per m³ of water more than adequately compensable for the slightly higher FCR and the

Table 3. – A comparison of pond size, threshold density and yield in semi-intensive catfish farms.

Pond size (m²)	Final density (kg.m^{-2})	Yield (kg.ha^{-1} × months)	Reference
200	0.1	1 069/5 mths (E)	Bok and Jongbloed, 1984
300-1 400	0.3	3 135/7 mths (A)	van der Waal, 1978
200	0.4	3 820/6 mths (E)	Brooks, 1994
926	0.5	5 388/6 mths (A)	El Bolock, 1975
840-972	0.6	1 633/3 mths (A)	Prinsloo *et al.*, 1978
4 210	0.9	5 625/6 mths (E)	Kenmuir, 1993
320	1.3	12 786/12 mths (E)	Hastings, 1973
36	1.7	13 367/10 mths (E)	Egwui, 1986
38	2.1	19 600/3 mths (E)	Salami *et al.*, 1993
1 000	4.0	40 000/10 mths (A)	Hecht *et al.*, 1988

E = Extrapolated yield.
A = Actual yield.

Table 4. – A comparison of pond size, threshold density and yield in intensive catfish farms.

Pond size (m^3)	Final density ($kg.m^{-3}$)	Yield ($kg.m^{-3}$ × months)	Reference
1.1	13.9	9.8/3 mths	Diana and Fast, 1989
3.0	250-350	350/10 mths	Hecht (pers. obs.)
0.9	360	180/2 mths	Huisman and Richter, 1987
0.8	436	336/3 mths	Bovendeur *et al.*, 1987
1.0	450-650	Not reported	Hecht, 1994
1.0	900	881/4 mths	Hecht and Oellermann (pers. obs.)

capital expenditure in comparison to earthen pond culture.

The potential of ultra-high density farming has since been investigated in detail at the Rhodes University experimental fish farm, using *C. gariepinus* and the *C. gariepinus* × *H. longifilis* hybrid. The fish have been successfully reared at densities of 850 $kg.m^{-3}$ (water volume) in this fully recirculating system. The fish were grown in 1 m^3 concrete tanks with just over one water exchange per hour to 850 g in 8-9 months at FCRs of between 1.2 and 1.3. A density of 950 $kg.m^{-3}$ appears to be the upper threshold limit.

Feeding and nutrition

Several types of feed are used to rear catfish in Africa, and include various kinds of pellets (chicken grower pellets, trout pellets and formulated catfish pellets), ranging in protein content from 18% (Prinsloo *et al.*, 1989), 25% (Fagbenro and Sydenham, 1990), 35% (Kerdchuen and Legendre, 1992), 38% (Hecht *et al.*, 1988), 40% (Salami *et al.*, 1993) to 45% (Legendre *et al.*, 1992). Non-pelletised feeds utilising conventional and unconventional ingredients such as maize bran (Brooks, 1994), chicken offal (Prinsloo and Schoonbee, 1987), cocoa pod husk (Fagbenzo, 1992), maize brewery waste, heat treated and cooked soya beans, condemned wheat, palm kernel cake, wheat bran, groundnut cake, blood, bran, bone meal, and poultry by-product meal have also been used to rear catfish. Some production trials have also been undertaken in fertilised ponds with no supplemental feeding (Bok and Jongbloed, 1984; Fagbenro, 1990). Success has been achieved with all these diets albeit to varying degrees. Nevertheless it illustrates the dietary versatility of the species.

Pellets have also been made using combinations of ingredients such as ground nut cake, palm kernel cake, cotton seed cake, rice bran, blood meal, maize, soya bean, fish meal, bone meal and brewers waste (Egwui, 1986; Balogum and Ologhobo, 1989; Haylor, 1990). In South Africa a formulated catfish pellet has been developed and is used by all commercial farmers. These pellets, which yield the best growth rates at least-cost, have a protein content of 38% and a digestible energy value of 12 $kJ.g^{-1}$ (Hecht *et al.*, 1988; Uys, 1989).

Feed conversion ratios (FCRs) are as varied as the feeds (*table* 5) and vary between 1:6 (van der Waal, 1978) and 1:1.1 under pond culture conditions using the formulated feed (Uys, 1989) and 1:1.2 under ultra-high density culture conditions.

A lipid content of 8-10% is recommended for African catfish (Uys, 1989), however this must be adjusted in order to attain the required energy level of 12 $kJ.g^{-1}$ DE.

No information is available on the dietary vitamin and mineral requirements of *C. gariepinus*. The levels of inclusion recommended by Robinson (1984) for channel catfish are commonly used. It is also recommended that mineral supplements only be added to such diets which contain less than 20% ingredients of animal origin (*e.g.* fish meal or carcass meal) (Uys, 1989).

From an age of six weeks the dietary requirements of *C. gariepinus* do not seem to change (Uys and hecht, 1988), except that the required daily ration decreases with size. As the fish grow, their relative food consumption rates decrease from approximately

Table 5. – Feed types, protein content and feed conversion ratio (FCR) on catfish farms in Africa.

Reference	Protein (%)	Feed	FCR
van der Waal, 1978	38.0	Trout pellets	6.1
Balogun and Ologhobo, 1989	40.0	Groundnut cake, cooked soyabeans, fish & bone meal, veg. oil, brewers waste	5.0
Legendre *et al.*, 1992	45.0	Formulated pellets	3.9
El Bolock, 1975	–	Chicken offal, blood, bran	3.2
Degani *et al.*, 1989	40-45	Fish/poultry/soyabean meal, wheat meal,	0.9-4.3
Salami *et al.*, 1993	42.5	Palm kernel cake, fish meal, wheat bran	–
Brooks, 1994	–	Maize bran + tilapia (polyculture)	–
Egwui, 1986	27.0	Pellets, groundnut cake, palm kernel	2.7
Prinsloo *et al.*, 1989	18.0	Chicken broiler finisher pellet	1.7
Hecht, 1985	–	Brewery waste	1.7
Oellermann (unpubl.)	42.0	Trout pellets	1.3
Hecht *et al.*, 1988	38.0	Formulated catfish pellets	1.2

10% body weight.day^{-1} (4 weeks old) to 2% of body weight.day^{-1} (10 weeks and older). Similarly, growth rates decrease from 14% to 2% of body weight.day^{-1} and feed conversion ratios increase from 0.7 to 1.2. Hogendoorn *et al.* (1983) proposed a size and temperature related model for the estimation of daily ration for *C. gariepinus*, a modified version of which is generally used by all commercial farmers in South Africa.

The processing and marketing of catfish in Africa is highly variable and ranges from selling fish alive from the farm, whole or gutted, gutted and smoked whole, as skinned fillets to value added products such as vacuum packed smoked fillets or other ready to cook and eat products. In rural Africa it is essential that the abdominal fat bodies are not removed when the fish is sold in a gutted state.

PERSPECTIVES ON FISH FARMING IN AFRICA

Despite its many and loudly acclaimed virtues and the potential of clariid catfish for aquaculture the production figures presented in *table* 1 tell a different table. Overall the production of catfish in Africa over the last decade has been disappointing. An attempt is made here to explain the relatively poor showing of African catfish farming in particular, and of aquaculture on the continent in general.

In considering this question a distinction had to be made between large scale commercial farming of catfish (either intensive or semi-intensive) on the one hand and small scale commercial or subsistence farming on the other hand.

In terms of large scale commercial farming the catfish industry in South Africa serves as a model to explain why the commercial farming of *Clarias gariepinus* has not lived up to expectations. As a premise the following ground rule for any commercial venture needs to be born in mind. All animal husbandry ventures are at the mercy of feed prices on the one hand and market demand (which determines the price) for the product on the other. An adverse shift in either of these factors can have serious implications.

The first 10 tonnes of African catfish were produced in South Africa in 1987. By 1990 production had increased to 1 400 tonnes, but fell back to some 350 tonnes in 1993 and to less than 120 tonnes in 1994. The decline in production has principally been a consequence of poor consumer demand and acceptance of the fish and increasing feed cost, which resulted in reduced profit margins. Initially farmers found themselves in a situation in which the product could not be promoted owing to the lack of fish. By 1989 production had increased to ca. 400 tonnes. Given the cost of feed at the time all the fish produced was sold at a highly acceptable margin, whereupon the farmers increased production. At the same time feed producers increased the price of feed, which since 1991 increased disproportionately with the gate price of the fish. This trend, coupled with the generally protracted nature of a marketing compaign has resulted in farmers changing to other more profitable species, resulting in the near collapse of the catfish industry. Currently there are indications that the marketing campaign is beginning to yield dividends. Moreover, given the steady rise in the price of marine fish in South Africa it is estimated that within a period of five to seven years the balance in terms of production cost and price per unit weight will have swung in favour of farmed freshwater fish. Depending on the success of the marketing campaign and movements within the market the industry has the capacity to increase production to approximately 10 000 tonnes.yr^{-1} within three years. Should this not be the case then catfish farming in South Africa will remain a marginal industry. It is highly probable that similar factors, and a preference for tilapiine fishes, have also been responsible for the slow growth of commercial catfish farming elsewhere in Africa.

The reasons for the slow progress of small-scale or small-holder fish farming (including catfish) on the African continent are different to those for commercial fish farming. Given the research and extension efforts and the funds allocated for aquaculture development on the continent and on viewing these in the context of production statistics (FAO 1992) small-scale aquaculture development has not been successful. In purely economic terms it has been a dismal failure, although it is perhaps not quite fair to assess small-holder fishfarming on the same basis as large scale commercial farming. It would probably be better and more realistic to assess small scale fishfarming on a socio-economic basis, rather than on a purely economic basis.

However, except for the work undertaken by the FAO Aquaculture for Local Community Development Programme (ALCOM) in southern Africa, particularly in Zambia, Malawi and Zimbabwe, very little is known about the socio-economic benefits of aquaculture throughout the continent. Recent studies have clearly shown that there is a significant informal trade in farmed fish and fish products (Sen, 1995) and that the FAO aquaculture production figures cannot be used to assess the development of aquaculture in the region. These figures for Africa are in fact widely recognised as being unreliable at best and misleading at worst (Anon., 1993). There exists a dire need to undertake proper socio-economic studies more widely in Africa and to use these data for a realistic assessment of aquaculture on the continent.

Nevertheless the fact remains that the development of aquaculture in Africa has not been the success it had been anticipated to be. The "multi-million dollar donor agency funded African aquaculture experiment" to develop small-scale subsistence fish farming in Africa has been severely questioned and criticised by Huisman (1985) and by Hecht (in press) at the World

Fisheries Congress in 1992. Hecht (op. cit.) concluded that aquaculture in Africa would only progress if there was a fundamental change in the underlying philosophy from attempting to improve nutrition at the family level to its commercialisation on a small or large scale. Fortunately, there now seems to be a wider acceptance of the idea to move away from subsistence aquaculture towards developing small-scale rural aquaculture into cash income generating ventures (Andreasson, 1993; Anon., 1994; Jensen and Haight, 1994).

New (1991) made a strong call for donor organisations to continue aquaculture funding in the developing world, including Africa. Such assistance should however only be made available on condition that the aim is to develop small-scale commercial ventures, leading to the economic empowerment of people. Great care should also be exercised to not create false hopes. For example, Brummett (1995) projects that 2,5 million tonnes of fish could be produced on only 1% of the available, GIS determined, area suitable for aquaculture in the SADC countries, excluding South Africa. Such projections are unrealistic and create false expectations and could once again lead to a spiral of unprofitable and unsuccessful investment by donor countries. Nevertheless there is a very real need to develop small and large scale commercial aquaculture, either on an integrated or dedicated basis, to satisfy the ever increasing need and demand for protein in Africa.

A small-scale commercial fish farming model has been developed in South Africa on a private ornamental fish farm, which might have applicability further afield in Africa. In essence the model (Britz, 1994) entails the following. Prospective small holder fish farmers gain experience by working on the farm. Once they have gained sufficient experience (minimum of 5 years) they obtain a loan from the Small Business Development Corporation (or other lender), which is guaranteed by the commercial farm. The farm also provides a package which includes access to the farm complex and infrastructure, technical back-up and marketing of all fish. The overall goal of this model, which has been successfully implemented, is the creation of additional employment opportunities and wealth. Fifteen ex fishfarm workers are now independent small holder farmers. Of relevance here is that this arrangement is not based on benevolence, it is in essence a win-win situation for both parties. The lesson to be learnt from this model is perhaps that donor agencies should consider all available expertise in a country and how that expertise can be utilised for the benefit of communities or the country as a whole. Perhaps the time has come not be too squeamish to whom the money is made available. The rapid development and progress of aquaculture, on an accountable basis, for the good of a community or the country is what should be of relevance.

While the infrastructural differences between countries in Africa are widely disparate, we are nevertheless convinced that there is sufficient expertise, know-how and entrepreneurial skills in most countries to make aquaculture successful on the continent in the future.

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REFERENCES

Andreasson A. 1993. A case for small-scale fish farming. *ALCOM News* **11**, 2-3.

Anonymous 1989. Aquaculture in Africa. *Fish Farmer* **3**, 28-29.

Anonymous 1993. Aquaculture production Africa. *ALCOM News* **11**, 3-4.

Anonymous 1994. Aquaculture into the 21st century in southern Africa. *ALCOM News* **16**, 2-4.

Appelbaum S., P. van Damme 1988. The feasibility of using exclusively artificial dry feed for the rearing of Israel *Clarias gariepinus* (Burchell, 1822) larvae and fry. *J. Appl. Ichtyol.* **4**, 105-110.

Areerat S. 1987. *Clarias* culture in Thailand. *Aquaculture* **63**, 355-362.

Balogun A. M., A. D. Ologhobo 1989. Growth performance and nutrient utilization of fingerling *Clarias gariepinus* (Burchell) fed raw and cooked soybean diets. *Aquaculture* **76**, 119-126.

Bok A. H., H. Jongbloed 1984. Growth and production of sharptooth catfish, *Clarias gariepinus* (Pisces: Clariidae), in organically fertilized ponds in the Cape Province, South Africa. *Aquaculture* **36**, 141-155.

Bovendeur J., E. H. Eding, A. M. Henken 1987. Design and performance of a water recirculation system for high-density culture of the African catfish, *Clarias gariepinus* (Burchell, 1822). *Aquaculture* **63**, 329-353.

Britz P. J. 1991. The utility of homoplastic pituitary glands for spawning induction of the African catfish (*Clarias gariepinus*) in commercial aquaculture in Africa. *Water S.A.* **17**, 237-241.

Britz P. J. 1994. Tropical fish create wealth in KwaZulu. *S.A. Commer. Mar.* **3**, 8-9.

Brooks A. 1994. Polyculture works well in Malawi. *Fish Farmer* **8**, 4-5.

Brummett R. 1995. In praise of integrated aquaculture, its prospects in the SADC region. *ALCOM News* **15**, 10-11.

Carreon J. A., F. A. Estocapio, E. M. Enderez 1976. Recommended procedures for induced spawning and fingerling production of *Clarias macrocephalus* Gunther. *Aquaculture* **8**, 269-281.

Copin Y., M. Oswald 1993. Orientation des techniques d'élevage de la pisciculture artisanale dans le Centre-Ouest de la Côte d'Ivoire. *Europ. Aquac. Soc. Spec. Publ.* **18**, 407-419.

De Kimpe P., J.-C. Micha 1974. First guidelines for the culture of *Clarias lazera* in Africa. *Aquaculture* **4**, 227-248.

De Leeuw R., H. J. Th. Goos, C. J. J. Richter, E. H. Eding 1985. Pimozide-LHRHa-induced breeding of the African catfish *Clarias gariepinus* (Burchell). *Aquaculture* **44**, 295-302.

Degani G., Y. Ben-Zvi, D. Levanon 1989. The effect of different dietary protein sources and temperatures on growth and feed utilization of African catfish, *Clarias gariepinus* (Burchell). *Isr. J. Aquac. Bamidgeh* **40**, 113-117.

Diana J. S., A. W. Fast 1989. The effects of water exchange rate and density on yield of the walking catfish, *Clarias fuscus*. *Aquaculture* **78**, 267-276.

Dickson M. 1993. Update on the Malawi central and northern regions fish farming project. *Aquaculture News* **15**, 5 p.

Egwui P. C. 1986. Yields of the African catfish, *Clarias gariepinus* (Burchell) from a low input, homestead, concrete pond. *Aquaculture* **55**, 87-91.

El Bolock A. R. 1975. Studies on the biology and culture of *Clarias lazera* in Egyptian ponds. PhD thesis. Cairo University, Egypt.

Fagbenro O. A. 1990. Food composition and digestive enzymes in the gut of pond-cultured *Clarias isheriensis* (Sydenham, 1980), (Siluriformes: Clariidae). *J. Appl. Ichthyol.* **6**, 91-98.

Fagbenro O. A. 1992. Utilization of cocoa pod husk in low-cost diets by the clariid catfish, *Clarias isheriensis* Sydenham. *Aquac. Fish. Manag.* **23**, 175-182.

Fagbenro O. A., D. H. Sydenham 1990. Studies on the use of *Clarias isheriensis* Sydenham (Clariidae) as a predator in *Tilapia guinensis* Dumeril (Cichlidae) ponds. *J. Appl. Ichthyol.* **6**, 99-106.

FAO 1992. Aquaculture production 1984-1990. *FAO/FIDI/C815 (Rev. 4)*, 206 p.

Hastings W. H. 1973. Experiences relatives à la préparation d'aliments des poissons et à leur alimentation. *FAO/FIDP/RAF/66/054/1*, 24 p.

Haylor G. 1990. African catfish shows promise as a farmed species. *Fish Farmer* (July-August), 36 p.

Haylor G. S. 1992*a*. Some aspects of the biology and culture of the African catfish, *Clarias gariepinus* with particular reference to developing African countries. In: Recent Advances in Aquaculture vol. IV, R.J. Roberts, J.F. Muir eds. Blackwell Scientific Publications, Oxford.

Haylor G. S. 1992*b*. Catfish hatchery gives Malawians a fresh option. *Fish Farmer* **6** (Jan/Feb), 15 p.

Hecht T. 1982. Intensive rearing of *Clarias gariepinus* larvae (Clariidae: Pisces). *S. Afr. J. Widl. Res.* **12**, 101-105.

Hecht T. 1985. Recent developments in aquaculture in South Africa: the sharptooth catfish, *Clarias gariepinus*. *Ecosyst. Progr. Occ. Rep. (CSIR, Pretoria)* **1**, 33-47.

Hecht T. 1994. Aquaculture in South Africa: Where is it now? Where is it going? *ALCOM News* **16**, 5-10.

Hecht T. (in press). The culture of *Clarias gariepinus* in southern Africa, with comments on the relative futility of subsistence aquaculture in Africa. *Proc. World Fish. Congress.* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Hecht T., J. E. Saayman, L. Polling 1982. Further observations on the induced spawning of the sharptooth catfish *Clarias gariepinus* (Clariidae: Pisces). *Water S.A.* **8**, 101-107.

Hecht T., W. Lublinkhof 1985. *Clarias gariepinus* × *Heterobranchus longifilis* (Clariidae: Pisces): a new hybrid for aquaculture. *S. Afr. J. Sci.* **81**, 620-621.

Hecht T., W. Uys, P. J. Britz eds. 1988. The culture of sharptooth catfish, *Clarias gariepinus* in southern Africa. *S. Afr. Nat. Sci. Progr. rep.* **153**, 133 p.

Hecht T., P. J. Britz 1990. Aquaculture in South Africa: History, status and prospects. Aquaculture Association of southern Africa. Lynnwood Ridge, 53 p.

Hecht T., A. G. Pienaar 1993. A review of cannibalism and its implications in fish larviculture. *J. World Aquac. Soc.* **24**, 246-261.

Hey D. 1941. Practical freshwater fish culture. Department of Nature Conservation. Cape Town, 118 p.

Hoogendoorn H. 1977. Progress in the controlled propagation of *Clarias lazera* (Cuvier and Valenciennes). Actes de Colloques du CNEXO **4**, 123-130.

Hogendoorn H., J. A. J. Janssen, W. J. Koops, M. A. M. Machiels, P. H. van Ewijk, J. P. van Hees 1983. Growth and production of the African catfish, *Clarias lazera*. II. Effects of body weight, temperature and feeding level in intensive tank culture. *Aquaculture* **34**, 265-285.

Huisman E. A. ed. 1985. Aquaculture research in the Africa region. Pudoc, Wageningen, 274 p.

Huisman E. A., C. J. J. Richter 1987. Reproduction, growth, health control and aquaculture potential of the African catfish, *Clarias gariepinus* (Burchell, 1822). *Aquaculture* **63**, 1-14.

Jensen A., B. Haight 1994. Towards sustainable small-scale aquaculture. *ALCOM News* **16**, 13-15.

Kenmuir D. 1993. Along the Orange. *Effective Farming* (March) 170-174.

Kerdchuen N., M. Legendre 1992. Effet favorable des fortes densités pour l'adaptation d'un silure africain, *Heterobranchus longifilis* (Pisches, Clariidae), en bacs de petit volume. *Rev. Hydrobiol. Trop.* **25**, 63-67.

Kerdchuen N., M. Legendre 1994. Larval rearing of an African catfish, *Heterobranchus longifilis* (Teleostei, Clariidae): a comparison between natural and artificial diets. *Aquat. Living Resour.* **7**, 247-253.

Lazard J. 1986. Practical aspects of the prolificity in Tilapia species in pond culture for African rural aquaculture. Reproduction in fish - Basic and applied aspects of endocrinology and genetics. Les Colloques de l'INRA, **44**, 155-159.

Legendre M. 1986. Seasonal changes in sexual maturity and fecundity, and HGC-induced breeding of the catfish *Heterobranchus longifilis* Val. (Clariidae), reared in Ebrie lagoon (Ivory Coast). *Aquaculture* **55**, 201-213.

Legendre M., G. G. Teugels, C. Cauty, B. Jalabert 1992. A comparative study of the growth rate and reproduction of *Clarias gariepinus* (Burchell, 1822), *Heterobranchus longifilis* Valenciennes, 1840, and their reciprocal hybrids (Pisces, Clariidae). *J. Fish. Biol.* **40**, 59-79.

New M. B. 1991. Turn of the millenium aquaculture: navigating troubled waters or riding the crest of the wave. *World Aquac.* **22**, 28-49.

Prinsloo J. F., H. J. Schoonbee 1987. Utilization of chicken offal in the production of the African sharptooth catfish *Clarias gariepinus* in the Transkei. *Water S.A.* **13**, 129-132.

Prinsloo J. F., H. J. Schoonbee, I. H. van der Walt, M. Pretorius 1989. Production of the sharptooth catfish *Clarias gariepinus* (Burchell) and the European common carp *Cyprinus carpio* with artificial feeding in polyculture in maturation ponds at Seshego, Lebowa. *Water S.A.* **15**, 43-47.

Richter C. J. J. 1976. The African ctafish, *Clarias lazera*, a new possibility for fish culture in tropical regions? *Misc. Pap. Lanbouwhogeschole, Wageningen* **13**, 51-74.

Richter C. J. J. 1985. 17-hydroxy-progesterone induced breeding of the African catfish, *Clarias gariepinus* (Burchell), without priming with gonadotropin. *Aquaculture* **44**, 285-293.

Richter C. J. J., R. van den Hurk 1982. Effect of 11-deoxycorticosterone and carp pituitary suspension on follicle maturation in the ovaries of the African catfish, *Clarias lazera* (C. & V.). *Aquaculture* **29**, 53-66.

Robinson E. A. 1984. Vitamen requirements. In: Nutrition and feeding of channel catfish (revised). E.H. Robinson, R.T. Lovell eds. *Southern Cooperative Ser. Bull.* **295**, 21-25.

Salami A. A., O. A. Fagbenro, D. H. J. Sydenham 1993. The production and growth of clariid catfish hybrids in concrete tanks. *Isr. J. Aquac. Bamidgeh* **45**, 18-25.

Schoonbee H. J., T. Hecht, L. Polling 1980. Induced spawning of and hatchery procedures with the sharptooth catfish, *Clarias gariepinus* (Pisces: Clariidae). *S. Afr. J. Sci.* **76**, 364-367.

Sen S. 1995. The market for fish and fish products in Zimbabwe. *ALCOM News* **17**, 8-9.

Uys W. 1989. Aspects of the nutritional physiology and dietary requirements of juvenile and adult sharptooth catfish, *Clarias gariepinus* (Pisces: Clariidae). PhD Thesis, Rhodes Univ. Grahamstown, South Africa.

Uys W., T. Hecht 1985. Evaluation and preparation of an optimal dry feed for the primary nursing of *Clarias gariepinus* larvae (Pisces: Clariidae). *Aquaculture* **47**, 173-183.

Uys W., T. Hecht 1988. Production and grow-out. In: The culture of sharptooth catfish in southern Africa. T. Hecht, W. Uys, P.J. Britz eds. *S. Afr. Nat. Sci. Prog. Rep.* **153**, 62-72.

Van der Waal B. C. W. 1978. Some breeding and production experiments with *Clarias gariepinus* (Burchell) in the Transvaal. *S. Afr. J. Wildl. Res.* **8**, 13-19.

Van der Walt L. D., F. H. Van der Bank, G. J. Steyn 1992. Genetic selection of the African catfish (*Clarias gariepinus*). *Proc. Aquac. Assoc. S. Afr.* **1**, 135-136.

Zheng W. B., J. H. Pan, W. S. Liu 1988. Culture of catfish in China. *Aquaculture* **75**, 35-44.