HANDBOOK ON THE ARTIFICIAL REPRODUCTION AND POND REARING OF THE AFRICAN CATFISH *CLARIAS GARIEPINUS* IN SUB-SAHARAN AFRICA

A handbook

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i

HANDBOOK ON THE ARTIFICIAL REPRODUCTION AND POND REARING OF THE AFRICAN CATFISH *CLARIAS GARIEPINUS* IN SUB-SAHARAN AFRICA

A Handbook

By

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ii

PREPARATION OF THIS DOCUMENT

The African catfish, *Clarias gariepinus* has been reared for almost 20 years in Africa with mixed success; the total farm production of this species being only 3,978 metric tonnes or 7.4% of the total farmed fish production of 69,434 mt in Africa in 1994. To a large extent the poor performance of this freshwater fish species in Africa has been due to the absence of reliable production techniques for the reproduction and rearing of the species under practical farming conditions

The document is based on the practical field experience of Gertjan de Graaf and Johannes Janssen on the artificial reproduction and rearing of the African catfish within FAO field projects in the Central African Republic, The Republic of Congo, Kenya and Nigeria. The manual has been written by the authors as a practical guide for the reproduction and pond rearing of the African catfish, based on methods which have proven to be successful and reliable in the field

The manual was edited by Dr. A.G.J. Tacon and Ms. M. Page of the FAO Inland Water Resources and Aquaculture Service and produced as part of the ongoing activities of the service to help to meet the needs of aquaculture workers of Member Countries for the development of suitable farming techniques for the sustainable expansion of aquaculture production

Distribution; FAO Fisheries Department; FAO Regional Fisheries Officers; FAO Aquaculture Projects; FAO Representatives; FAO Regional Fishery Commissions; Directors of Fisheries and Aquaculture

ABSTRACT

The manual is based on the practical field experience of Gertjan de Graaf and Johannes Janssen on the artificial reproduction and rearing of the African catfish within FAO field projects in the Central African Republic, The Republic of Congo, Kenya and Nigeria. The manual is divided into five major sections dealing with : 1) general biology, including feeding habits and reproduction; 2) artificial reproduction, including induced propagation without and through hormone injection; 3) fry nursing in earthen ponds, including pond preparation, fertilization, feeding and management; 4) monoculture, including feeding methods; and 5) poly culture with *Tilapia*. In addition, information is provided concerning the economics of different fingerling and grow-out farming practices in Africa, and concerning diseases and hybridisation.

TABLE OF CONTENTS

1.   INTRODUCTION

Pond culture is not a traditional farming practice in most parts of Africa. Introduced after the Second World War there was an initial spectacular development with about 300,000 ponds being operational, mainly rearing Tilapia spp, in about 20 African countries by the end of the fifties (Meschkat, 1967). Since then fish culture has not made much further progress and has in many cases even declined resulting in the abandonment of fish ponds by discouraged farmers. According to the authors this failure has been attributed to:

*   The harvesting of too many small stunted tilapia from over populated ponds because of the use of poor husbandry techniques

*   The dependency on subsidized extension services and fingerling distribution centres.

*   Misjudgement of the motivation of the rural fish farmers by policy makers, and the creation of the myth that the rural farmer will willingly take up fish farming for food security or as a source of protein for their family. This is most likely not the case, the primary motivation of rural fish farmer generally being **income generation**.

*   Failure to apply adequate resources (which may be naturally limiting) such as water and feed.

By the end of the sixties, a reorientation to increase aquaculture production was proposed that included;

*   A modification of the farming technique for Tilapia in which seed production and on-growing to marketable sized fish are separated and the introduction of monosex tilapia culture (Pruginin, 1967 and Shell, 1968).

*   Identification of new suitable species for aquaculture were identified (Lemasson and Bard, 1968).

It was soon recognized that the African catfish *Clarias gariepinus* (Burchell, 1822) was one of the most suitable species for aquaculture in Africa (CTFT, 1972; Micha, 1973.; Pham, 1975; Jocque, 1975; Kelleher and Vincke, 1976; Richter, 1979.; Hogendoorn, 1979) and since the 1970's it has been considered to hold great promise for fish farming in Africa; the African catfish having a high growth rate, being very resistant to handling and stress, and being very well appreciated in a wide number of African countries.

The development of a reliable method for the production of *Clarias gariepinus* fingerlings was one of the priorities of aquaculture research in Africa (Anonymous, 1987a). Hormone-induced reproduction of the African catfish using deoxycorticosterone acetate, human chorionic gonadotropin and common carp pituitaries has been carried out successfully (Hogendoorn and Wieme, 1976; Hogendoorn and Vismans, 1980; Micha, 1976; Kelleher and Vincke, 1976; El Bolock, 1976).

Hogendoorn (1980) and Hogendoorn and Vismans, (1980) successfully developed an intensive production system for African catfish fingerling production based on the use of *Artemia salina* nauplii and a commercial trout starter as feed. However the existence of technically feasible farming methods and manuals (Viveen *et al.*, 1985) did not guarantee a successful implementation, as the impact of local socio-economic and technical conditions are more

often than not always under-estimated (Anonymous, 1987b). The introduction of intensive rearing methods in the Central African Republic and the Ivory Coast encountered numerous technical and economic problems (Janssen, 1985a, 1985b and 1985c; de Graaf, 1989).

The main problem of fingerling production within ponds was fish survival rate which was unreliable and varied between 0 - 60 fingerlings/m^2/cycle (Micha, 1973, 1976; Hogendoorn, 1979; Hogendoorn and Wieme, 1976; Kelleher and Vincke, 1976). It has been suggested that the lack of appropriate feed and the presence of predators are likely causes of mortality. In the late 1980's a simple and reliable method was developed in Congo Brazzaville for the nursing of *Clarias gariepinus* within protected ponds (de Graaf *et al.*, 1995) and this study indicated that competition for feed and cannibalism were the major factors affecting pond nursing of *Clarias gariepinus*. The methodology as developed in Congo Brazzaville is now being used in many other African countries and an instruction video on this technique; ***"Anou is raising catfish"*** was produced by the FAO project (UNDP/FAO/PRC/88/007, Phase II) in Congo Brazzaville and can be obtained from FAO Headquarters in Rome or from the NEFISCO-foundation, Amsterdam, the Netherlands (see Annex I).

The last twenty years has seen considerable gains in our knowledge concerning the reproduction and rearing of *Clarias gariepinus*, and in particular through the activities of FAO projects in the Central African Republic, the Republic of Congo (Brazzaville) and Kenya; CTFT projects in the Ivory Coast; research programmes of the Department of Technology and Fisheries Science of the Rhodes University, South Africa and through basic research programmes carried out by the Department of Aquaculture and Inland Fisheries of

the Wageningen University in the Netherlands and other Universities and Institutes throughout the world.

In the present paper an attempt is made to compile and update available knowledge concerning the rearing of *Clarias gariepinus* with particular emphasis to African conditions.

A number of the illustrations used in this paper have been presented before in a publication of Viveen *et al.*, 1985 and permission given to use the illustrations in the present handbook is gratefully acknowledged.

2. THE AFRICAN CATFISH (Clarias gariepinus and Clarias anguillaris)

2.1. *Taxonomy*

Although more than 100 different species of the Genus *Clarias* have been described in Africa, a recent systematic revision based on morphological, anatomical and biographical studies has been carried out by Teugels (1982a, 1982b, 1984), who recognized 32 valid species. The large African species which are of interest for aquaculture belong to the subgenus *Clarias*. In earlier systematic studies on the large African catfish species Boulenger (1911) as well as David (1935) recognized five species of within this subgenus. Both authors used morphological criteria such as form of vomerine teeth, ratio of vomerine to premaxillary teeth band and the number of gill rakers. The five species were;

* Clarias anguilarus
* Clarias senegalensis
* Clarias lazera
* Clarias mossambicus
* Clarias gariepinus

In 1982 Teugels revised the subgenus *Clarias* and found only two species (*C. gariepinus* and *C. anguillaris*) if the number of gill rakers on the first branchial arch was considered; for *C. anguillaris* the number of gill rakers was rather low (14 to 40) while for *C. gariepinus* was relatively high (20 to 100, Figure 1.).
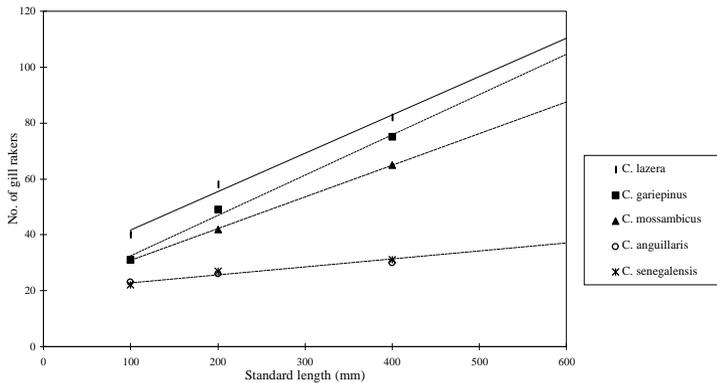
Figure 1: Regression lines showing the correlation between standard length and number of gill rakers on the first branchial arch for the catfish species of the subgenus *Clarias* recognized by Boulanger (1911) and David (1935). Source: Teugels, 1982b.

2.2.　　　　*Natural geographical distribution*

Clarias gariepinus, which is widely considered to be one of the most important tropical catfish species for aquaculture, has an almost Pan-African distribution, from the Nile to West Africa and from Algeria to Southern Africa. They also occur in Minor-Asia (Israel, Syria and South of Turkey). *Clarias anguillaris* has a more restricted distribution and is found in Mauritania, in most West African basins and in the Nile (Figure 2). In general *C. gariepinus* lives in most river basins sympatrically with *C. anguillaris*.
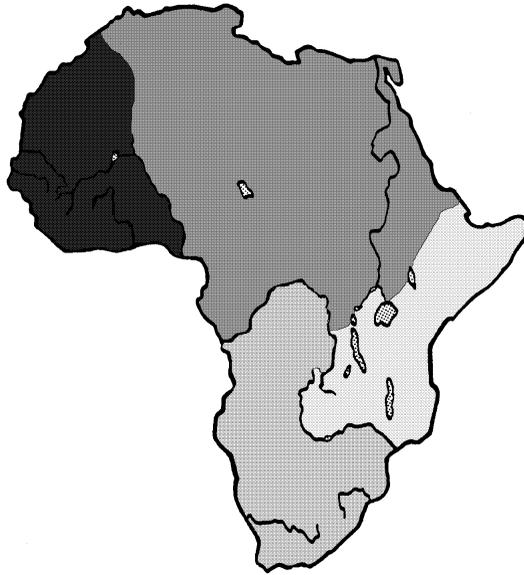
Clarias lazera
Clarias senegalensis & Clarias anguillaris
Clarias mossambicus
Clarias gariepinus

Figure 2:   Geographical distribution of the African catfish.

3.   BIOLOGY

3.1.   *Description of the genus and species*

The catfish genus can be defined as displaying an eel shape, having an elongated cylindrical body with dorsal and anal fins being extremely long (nearly reaching or reaching the caudal fin) both fins containing only soft fin rays (Figure 3). The outer pectoral ray is in the form of a spine and the pelvic fin normally has six soft trays. The head is flattened, highly ossified, the skull bones (above and on the sides) forming a casque and the body is covered with a smooth scaleless skin. The skin is generally darkly pigmented on the dorsal and lateral parts of the body. The colour is uniform marbled and changes from greyish olive to blackish according to the substrate. On exposure to light skin the colour generally becomes lighter

They have four pairs of unbranched barbels, one nasal, one maxillar (longest and most mobile) on the vomer and two mandibulars (inner and outer) on the jaw. Tooth plates are present on the jaws as well as on the vomer. The major function of the barbels is prey detection.

A supra-branchial or accessory respiratory organ, composed of a paired pear-shaped air-chamber containing two arborescent structures is generally present. These arborescent or cauliflower-like structures located on the secondhand forth branchial arcs, are supported by cartilage and covered by highly vascularised tissue which can absorb oxygen from atmospheric air (Moussa, 1956). The air-chamber communicates with the pharynx and with the gill-chamber. The accessory air breathing organ allows the fish to

survive for many hours out of the water or for many weeks in muddy marshes.
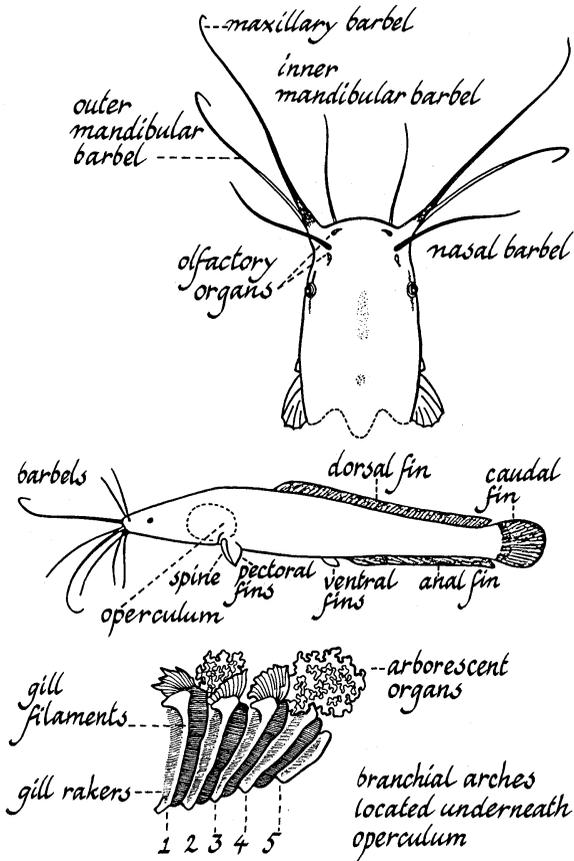
Figure 3: Morphological characteristics of *C. gariepinus*.

The male and females of *C. gariepinus* can be easily recognized as the male has a distinct sexual papilla, located just behind the anus. This sexual papilla is absent in females (Figure 4).
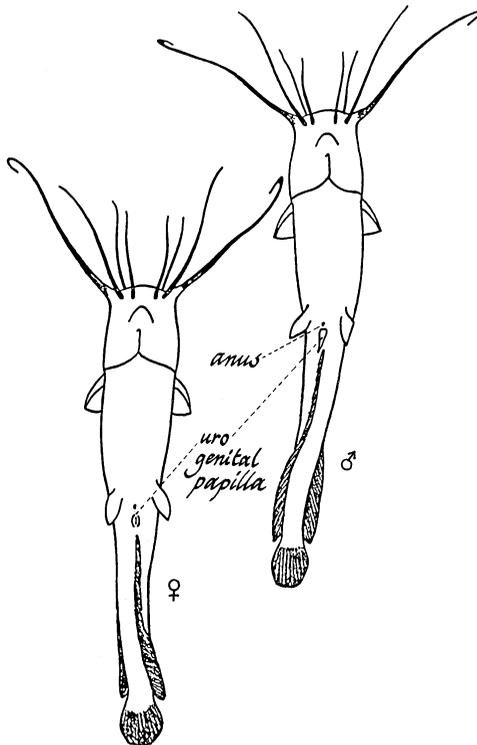
Figure 4: Sexual characteristics of *C. gariepinus*.

3.2.   Habitat

Clarias spp. inhabit calm waters from lakes, streams, rivers, swamps to floodplains, some of which are subject to seasonal drying. The most common habitats frequented are floodplain swamps and pools in which the catfish can survive during the dry seasons due to the presence of the accessory air breathing organs (Bruton, 1979a; Clay, 1979).

3.3.   Natural food and feeding

Although numerous studies on the food composition of C. gariepinus have been carried out, a consistent pattern has not emerged and they are generally classified as omnivores or predators. Micha (1973) examined catfishes from the river Ubangui (Central African Republic) and found that C. lazera (= C. gariepinus) fed mainly on aquatic insects, fish and debris of higher plants. They also feed on terrestrial insects, mollusc and fruits.

Similarly, Bruton (1979b) found that catfish in Lake Sibaya (South Africa) fed mainly on fish or crustacea, and that terrestrial and aquatic insects were an important part of the diet of juvenile and adult fish which inhabit shallow areas. However, molluscs, diatoms, arachnids, plant debris were the minor food items consumed in this lake.

Munro (1967) studied the feeding habits of C. gariepinus in Lake McIlwaine (Zimbabwe) and found that feed composition changes as fish became larger. Diptera, particularly chironomid pupae, predominate in the diet of the smallest group but become progressively less important with increasing size. Zooplankton became more important with increasing size and predominates in the diet of the largest

fish. Most of the minor food groups also showed a progressive increase or decrease in importance in relation to increasing size (Figure 5). The greater importance of zooplankton in the diet of large fish was believed to be due to the increased gape and number of gill rakers of the larger fish (Jubb, 1961; Groenewald, 1964); presumably resulting in a more efficient filter feeding.
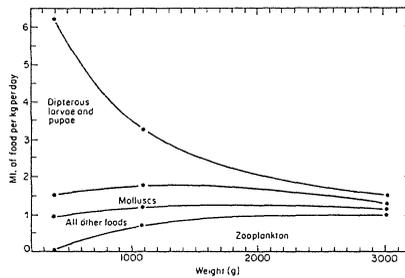
Figure 5: Apparent changes in the composition of the mean daily ration of *C. gariepinus* in relation to increasing size. Source: Munro, 1967.

Spataru *et al.* (1987) studied the feeding habits of *C. gariepinus* in Lake Kinneret (Israel) and found that preyed fish were the most abundant food component (81%) and constituted the highest biomass.

In conclusion, we can consider *C. gariepinus* as a slow moving omnivorous predatory fish which feeds on a variety of foods items from minute zooplankton to fish half of its own length or 10% of its own body weight.

In order to feed on this wide variety of organisms in different situations *C. gariepinus* is equipped with a wide array of anatomical adaptations for feeding under low visibility (Bruton, 1979b) including;

*   A wide mouth capable of considerable vertical displacement for engulfing large prey or large volumes of water during filter feeding.

*   A broad band of recurved teeth on the jaws and pharyngeal teeth preventing prey from escaping.

*   An abundant network of sensory organs on the body, head, lips and circumoral barbels. These barbels are extensively used for prey detection and fixation. Hecht and Applebaum (1988) found that *C. gariepinus* with barbels were 22.6% more efficient at catching prey than those without. This could indicate that tactile behaviour is important in the prey catching processes.

*   A wide, rounded caudal fin, typical for fish which ambush their prey.

*   Long gill rakers on the five branchial arches.

*   A short and dilatable oesophagus which opens into a distinct muscular stomach (mechanical digestion) and a simple thin walled intestine.

        Slow, methodical searching is the normal predatory tactic of *C. gariepinus*, with catfish grasping their prey by suction; a negative pressure (suction) being created by a sudden increase of the bucco-pharyngeal chamber.

        An important aspect of predation by *C. gariepinus* is their ability to switch feeding from one type of prey to another. In Lake Sibaya (South Africa), catfish ignore (or cannot catch) fish prey during daylight and feed mainly on invertebrates, which are abundant and relatively easy to catch. By contrast, at night, when fish prey become more vulnerable, they switch their feeding habits to fish prey (Bruton, 1979b). In general, fish prey provides far more

energy per unit weight than other prey items. However, switching feeding habits relies on the existence of at least two alternate abundant preys.

3.4. Natural reproduction

C. gariepinus shows a seasonal gonadal maturation which is usually associated with the rainy season. The maturation processes of *C. gariepinus* are influenced by annual changes in water temperature and photoperiodicity and the final triggering of spawning is caused by a raise in water level due to rainfall (de Graaf *et al.*, 1995).

An example of maturation and spawning of *C. gariepinus* in Lake Victoria (Kenya) is presented in Figure 6; reproduction starting in March just after the start of the first heavy rains as is indicated by the decrease in the Gonado Somatic Index[1] (G.S.I.). Natural reproduction is completed in July and the G.S.I. remains low till November, thereafter the oocytes start maturing gradually and become ripe again in March.

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[1]GSI = {weight ovary/total weight}*100
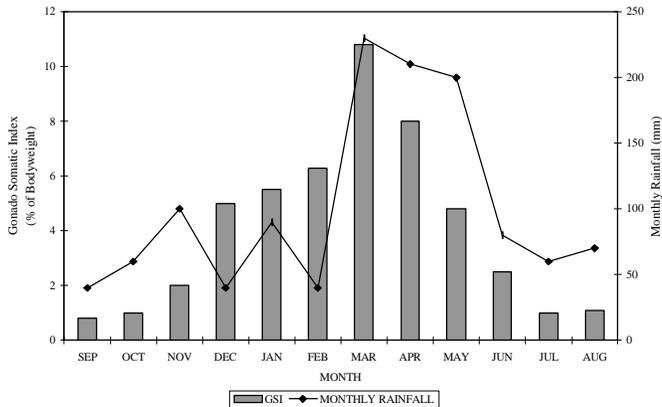
Figure 6:   The Gonado Somatic Index (% of body weight) of *C. mossambicus* (= *C. gariepinus*) and the monthly registered rainfall (mm), Nyanza Gulf, Lake Victoria, Kenya.**. After; Owiti and Dadzie, 1989**.

Spawning usually takes place at night in the shallow inundated areas of the rivers lakes and streams. Courtship is preceded by highly aggressive encounters between males. Courtship and mating takes place in shallow waters between isolated pairs of males and females. The mating posture, a form of amplexus (the male lies in a U-shape curved around the head of the female) is held for several seconds (see Figure 7). A batch of milt and eggs is released followed by a vigorous swish of the female's tail to distribute the eggs over a wide area. The pair usually rest after mating (from seconds up to several minutes) and then resume mating.
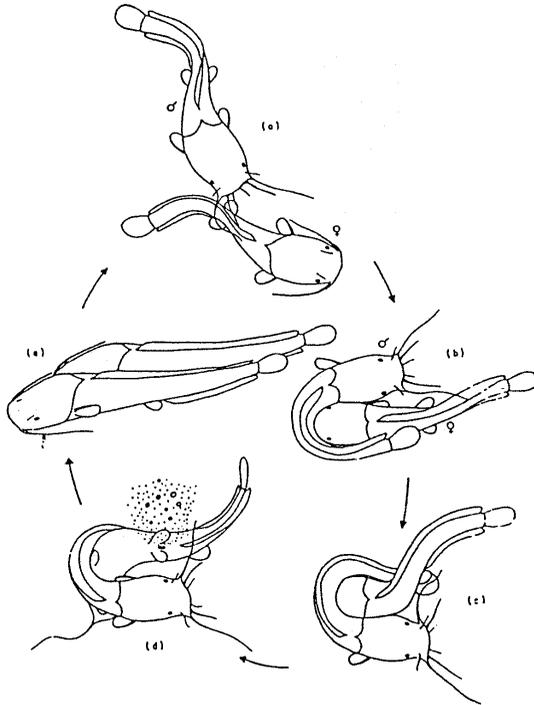
Figure 7:   The courtship ritual of *C. gariepinus*.. Source: Bruton, 1979a..

There is no parental care for ensuring the survival of the catfish offspring except by the careful choice of a suitable site. Development of eggs and larvae is rapid

and the larvae are capable of swimming within 48-72 hours after fertilization at 23-28 ^{o}C.

3.5.   *Oocyte development*.

The development of the oocytes of the African catfish is mostly related to temperature (as is common with a large number of fish species). Within the development of the oocyte six chronological stages[2] can be seen (Owiti and Dadzie, 1989, see Figure 8);

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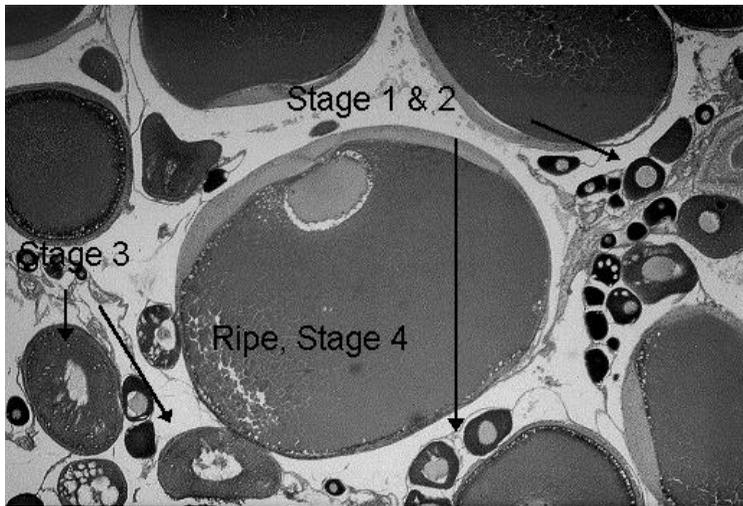
[2]   The photographs are provided by the Department of Inland Fisheries and Aquaculture, Wageningen University, Wageningen, the Netherlands.

Figure 8: Histological section of an ovary of *C. gariepinus,* with the different stages of oocyte development.

Stage 1, Immature virgin:

Macroscopic description; The ovary is colourless to translucent brown, lanceolate and lobular in appearance, occupying the posterior quarter of the body cavity. In fish larger than 10 cm the ovary can be distinguished from the testis due to its smoothness in contrast to serrated edges of the testis.

Histological description; **Pre-vitello genesis**[3] stage or primary oocytes. The oocyte are small (7-10 micron) and contain no yolk. The number of primary oocytes increases through mitotic division.

Stage 2, Developing virgin:

Macroscopic description; The ovary is translucent, brown in colour and occupies about one third of the length of the peritoneal cavity. Individual oocytes are visible with the naked eye as tiny specks.

Histological description; **Pre-vitello genesis** stage or primary oocytes. The oocyte are small (7-10 micron) and do not yet contain yolk. The number of primary oocytes increases through mitotic division and at the end of this stage the oocyte increase its size to approximately 200 micron.

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[3]   Vitellogenesis is the process of yolk formation.

Stage 3, Ripening:

Macroscopic description; The ovary is opaque, brownish-green in colour, occupying about one half the length of the ventral cavity. Eggs are visible as yellowish-green or brownish-yellow granules and blood capillaries visible around the ovary.

Histological description; **Endogenous vitello genesis** stage. Within this stage the yolk of the oocyte (the future reserve/feed for the hatched larvae) is formed. The origin of the yolk in this stage is the oocyte itself.

Stage 4, maturing or ripe:

Macroscopic description; The ovary is large, opaque, brown-green in colour. The eggs are yolk laden and clearly visible to the naked eye. Ovary occupies four fifth of the peritoneal cavity. A highly developed capillary net work is visible. Eggs ooze out freely with pressure on the belly.

Histological description; **Exogenous vitello genesis**. The oocyte increases to its final size of 1000-1200 micron (1-1.2 mm). During this phase yolk formation in the oocyte increases and the origin of the proteins needed for this process is outside the oocyte (the liver). A large nucleus (0.2 mm) is clearly visible a little outside of the centre of the oocyte (See figure 9). The oocytes in this stage are also called "ripe eggs". They remain in this stage until environmental factors (rainfall and water level rise or a hormonal injection) stimulate their ovulation.
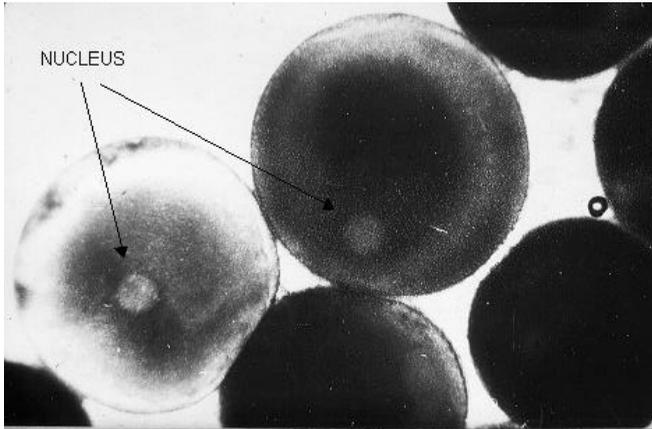
Figure 9: Ripe oocytes of *C. gariepinus* with a visible nucleus.

Stage 5, Running or spawning:

Macroscopic description; The eggs are translucent, flat, with cytoplasm concentrated at the animal pole and visible as a reddish brown spherical cap (figure 10). This aspect is quite distinct from the round eggs present in the ovaries before reproduction/hypophysation (figure 9).
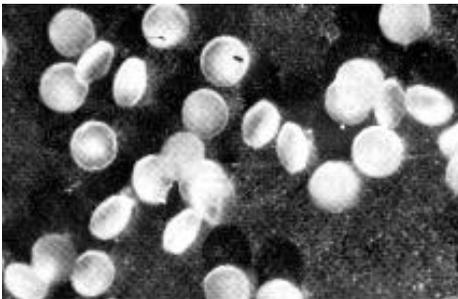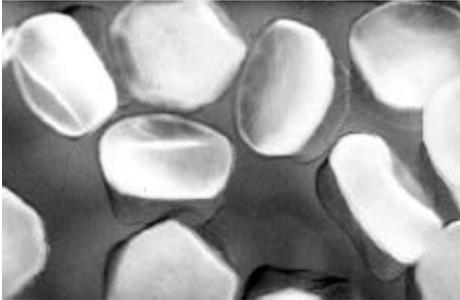
Figure 10: Ovulated eggs of *C. gariepinus* (Hogendoorn and Vismans, 1980)

Stage 6, Spent:

Macroscopic description; The ovary is flaccid, flabby and bloodshot with thick whitish tough walls. The genital aperture of the female looks inflamed. Some translucent and opaque (residual) eggs visible to the naked eye.

The development from stage 1 to stage 4 is related to temperature (and of course age when first maturation is considered). The development from stage 4 to stage 5 is triggered by environmental stimuli or can be provoked by hormonal injections (see Figure 11). This development process will take place once the water temperature is 20-22 ^{o}C or higher. After ovulation of the "ripe eggs" the majority of the oocytes found in the ovary consists again of stage 1 oocytes, the cycle is repeated and after approximately six weeks a new batch of "ripe eggs" is ready for ovulation.
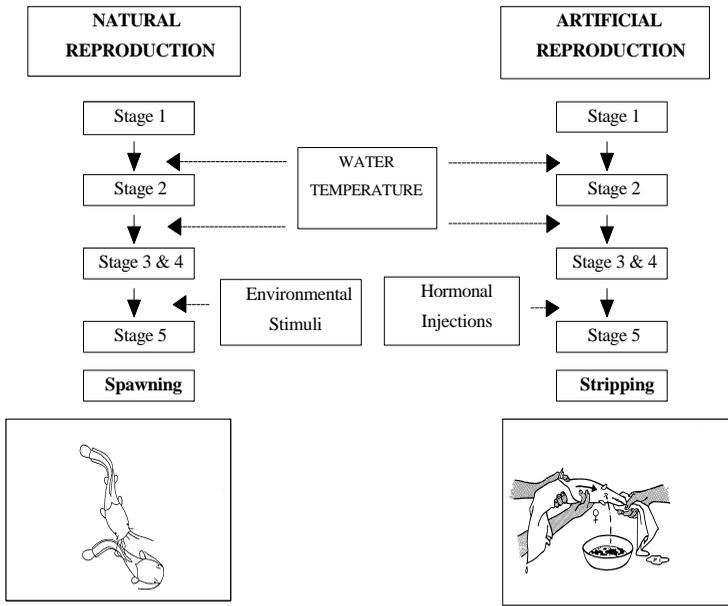
Figure 11: Pathway of oocyte development of *C. gariepinus*.

4. ARTIFICIAL REPRODUCTION.

4.1. Gonadal development in captivity.

The female African catfish has a fully developed ovary which contains "ripe" eggs the whole year through, if kept in ponds and once the water temperature remains above 22 ^{o}C. The eggs of a "ripe" female make up 15-20% of the body weight (i.e. a "ripe" female of 1 kg having about 150-200 gram of "ripe" eggs). The oocyte development decreases once the temperature drops below 22 ^{o}C as can be seen from the results obtained in Congo-Brazzaville (see figure 12).

In the dry season (June-July-August) the water temperature drops below 22 ^{o}C and we see that the ovary makes up approximately 5% of the body weight of the female. Artificial reproduction is still possible but the number of egg obtained is small and the quality of the eggs decreases as can be seen from the decreased hatching percentage.

In general the testis of a male is fully developed at an age 8-12 month once they reach a weight of approximately 200 g. In Congo Brazzaville sperm could be obtained the whole year through and no impacts of the temperature on the availability of sperm was found.
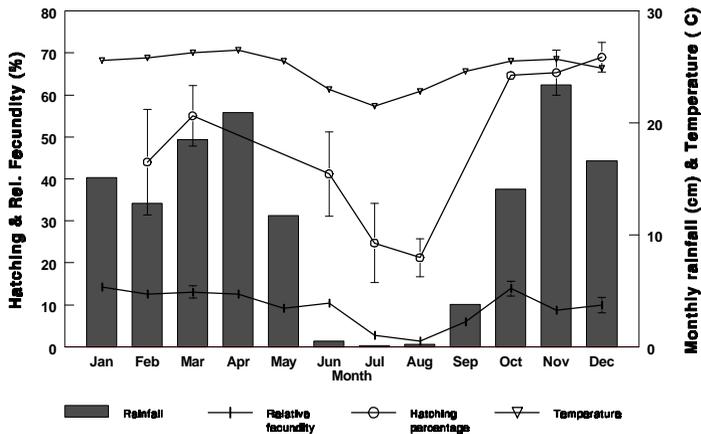
Figure 12:   The relative fecundity (% of total body weight)
hatching percentage (% of total eggs) of *C. gariepinus*,
average monthly rainfall (cm) and air temperature (^{o}C)
measured in Congo Brazzaville**.**, bars indicate s.e.m. Source:
de Graaf *et al.*, 1995.

In captivity the African Catfish does not spawn spontaneously
since the environmental factors such as the rise in water level
and inundation of shallow areas do not occur on the fish
farms. Since the early 1970's several techniques have been
developed (with or without hormone treatment) for the
artificial reproduction of the African catfish.

4.2. Induced propagation without hormone treatment.

Mature breeders can be reproduced artificially by simulating the events which will occur in during rainy season and which trigger the mating and spawning processes. Ponds of about 400 m^2 in size are filled with 25 cm of water and stocked with 6 mature females (average weight 300-500 g) and 4 males (average weight 200-500 g). A few hours later the water level is raised up to a level of 50-60 cm. Spawning will occur at night and the following morning the breeders can be removed.

Theoretically this techniques is artificial reproduction since some offspring are produced. However from a practical point of view it is not satisfactory as the number of fingerlings which can be harvested after 6-8 weeks is low (1-2 fingerlings/m^2). This technique of semi-natural reproduction has also been applied successfully using concrete tanks (C. Nugent, pers. com.).

4.3. Semi-artificial reproduction through hormone treatment.

For hormone induced reproduction (semi artificial or artificial) the following hormones are generally used;

* DOCA (Desoxycorticosteroid Acetate), 2.5-5 mg per 100 gram of female. A disadvantage of using this hormone is that it is mostly suspended in oil which causes severe ulcers on the injected female.

*   HCG (Human Chorionic Gonadotropin), 25 I.U. per 100 gram of female. This hormone works well but it is expensive.

*   Common carp (*cyprinus carpio*) pituitary gland material, 3-4 mg per kilogram of female or 1-2 whole pituitaries per female. In general the common carp pituitary gland material has to be imported from abroad which means that it is usually not accessible for small fish farms.

*   Pituitaries of the African catfish (*C. gariepinus*). A female catfish will respond once it injected with a pituitary of a catfish (male or female) of equal size.

*   Pituitaries of the Nile Tilapia (*Oreochromis niloticus*), 3-4 pituitaries of a Nile Tilapia (100-150 gram) per female catfish will induce ovulation.

*   Pituitaries of Nile perch (*Lates niloticus*). 1-2 pituitaries per female catfish will induce ovulation.

          Three techniques of semi-artificial reproduction have been developed;

4.3.1.　　Hormone induced reproduction in ponds

Mature females are injected with hormones in order to provoke the mating and spawning processes and then placed in completely filled ponds at a density of 2 females and 1 male per 100 m^2. Spawning usually takes place during the night after the hormone treatment and the breeders then removed the following morning. As for all nursing processes in ponds, the survival in the nursery ponds is a limiting factor for the mass production of fingerlings. This phenomena will be discussed in more detail in later in section 5.

4.3.2. Hormone induced reproduction in happa placed in a pond

A mature female is injected with hormones, so as to provoke ovulation, mating and the spawning processes. After injection the female and a non-injected male are placed together in a 2-3 m^3 happa (made from mosquito netting with a 0.5 mm mesh size) located within a pond (see Figure 13). Spawning usually takes place at night and the breeders then removed the following morning. One advantage of this method is that the eggs are concentrated within the happa where they eventually can be treated against fungal infections and the hatchlings easily collected after yolk sac absorption. It is essential that the happa be covered so as to prevent the breeders will jumping out.

Figure 13: Breeding happas placed within a fish pond in Congo Brazzaville.

4.3.3. Hormone induced reproduction in concrete tanks with a gravel substrate.

This was one of the first techniques developed for the hormone induced reproduction of *C. gariepinus* in Africa (Micha, 1973; van der Waal, 1974).

Mature females are injected in the afternoon with hormonal material (DOCA, HCG or pituitaries) and placed together with a male in a concrete tank. The bottom of the concrete tank is covered with a layer of stony gravel which functions as substrate for the released egg. The breeders spawn at night after the hormonal material is injected; the released fertilized eggs sticking to the gravel or

any other substrate provided or on the bottom of the tank if no substrate is available. The following morning the breeders are then removed from the tank. The fertilized eggs remain in the tank and hatching takes place after 24 hours (25-30 ^{o}C, see Table 2) and after 3-4 days approximately 3,000-5,000 larvae per female can be collected from the tank. However, the disadvantages of this method are that;

*   brood fish often injure each other, which sometimes may end in the death of one of the breeders;

*   the number of larvae obtained is relatively small as the ovulation is often partial. The quantity of eggs released is usually only 5-10% of the total body weight which is substantial less than the 15-20% which can be usually obtained through stripping.

4.4.   Artificial reproduction

4.4.1.   Introduction

Semi natural or hormone induced reproduction within ponds or concrete tanks as describe above can be used on small farms to produce their own larvae and fingerlings. However, the method has not proved to be a reliable method for <u>mass</u> production needed for larger fish farms or distribution centres of catfish fingerlings. Therefore artificial propagation under more controlled conditions including; stripping of eggs, collection of the sperm, followed by fertilization of eggs has been developed.

Artificial reproduction by induced breeding through hormone treatment followed by artificial fertilization and incubation of fertilized eggs and the subsequent rearing to fingerling size has several advantages (Woynarowich and Horvath, 1980) including:

*   Better rates of fertilization and hatching

*   Protection against enemies and unfavourable environmental conditions.

*   Better conditions for growth and survival.

The artificial reproduction of the African catfish, as for all finfishes, consists of a chain of activities which is more or less similar to that which occurs during the course of natural reproduction.

4.4.2. broodstock care and selection of ripe breeders

In most cases broodstock selected from nature or bought at a fish farm are kept in earthen ponds at a stocking density of 0.5-1/m^2 and fed regularly with agriculture waste products and sometimes with some trash fish. Egg development will take place and about six week after a female has been reproduced it can be used again. In some areas of Africa the water temperatures drops below 22 ^{o}C during the dry/winter season, which hampers the egg development and artificial reproduction (see Figure 12). In Congo-Brazzaville, this problem was overcome by careful planning i.e. catfish were reproduced artificially in the first month of the dry season and a double number of females were injected in order to guarantee a sufficient number of eggs and by this catfish fingerlings could be produced 11 months per year. Another method to overcome this problem is to keep the broodstock permanently indoors in a hatchery (de Graaf, 1989, Janssen, 1985a, Richter *et al.*, 1987). A complete breakdown of the natural annual reproductive cycle can be obtained after the broodstock is kept one year indoors and reproduction can be carried out throughout the year. This method is however not recommended by the authors as it depends on the availability of high quality composed feed and often encounters diseases such as crackhead and retarded growth in the breeders and an oedemic disease in the produced larvae.

Artificial reproduction starts with the selection of females from broodstock ponds afterwhich they are transferred to the holding tank within a hatchery. Ideally, broodfish weigh between **300-800 grams**, with larger fish being difficult to handle and often resulting in substantial egg

losses prior to stripping. In general mature females are selected according to the following criteria;

*   A well distended, swollen abdomen from which ripe eggs can be obtained by slightly pressing the abdomen toward the genital papilla. Ripe eggs are generally uniform in size and a experienced hatchery operator can see the nucleus as a small dark point in the centre of the egg (see Figure 9).

*   A swollen, sometimes reddish or rose coloured genital papilla.

Note: From a practical point of view it can be said that all females are "ripe" once some eggs can be pressed out and if the eggs are more or less uniform in size (just put some of the eggs onto the nail of your thumb and add a few drops of water and look).

For male broodstock there is only one criteria: they should be larger than 200 g and not less than 7 months old.

4.4.3.   Hormone injection

The most common technique employed to induce final maturation and ovulation in African catfish is to inject the female with hormones or pituitary gland material (the dosages and advantages and disadvantages have been discussed in paragraph 4.3).

The required quantity of powdered acetone dried pituitary material or the required number of whole pituitaries are pulverised in a porcelain mortar, mixed with the required quantity[4] of physiological salt solution (9 g of common salt/litre of water). A syringe is filled with the suspension and the injection can be given.

The most common method of administering the hormone solution, is by intra-muscular injection into the dorsal muscle (see Figure 14).
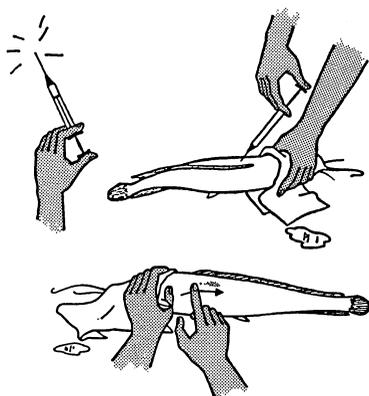
Figure 14:   Injection of the female breeders.

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[4] 1 ml per fish

> Note: Cover the head of the breeder with a wet towel in order to keep it quiet during the injection of hormones. In general most fish keep still if their eyes are covered.

> Note: fill the syringe, insert the needle on it and empty the syringe again into the mortar, when this is possible you can start to inject the fish. This procedure has to be followed always, as the needle often gets blocked if the pituitary material is not completely crushed and it is unpleasant for the fish and annoying for the operator to resolve this problem once the needle is inserted into the fish.

4.4.4. Maturation processes and stripping of the eggs

The process of final maturation (migration of the nucleus to the animal pole, fusion of the yolk, breakdown of the germinal vesicle followed by first meiotic division) and ovulation (rupture of the follicles and accumulation of the ripe eggs in the ovary cavity) cannot be stopped or reversed after administration of the correct hormone dosage. Once these processes start the eggs must either be spawned or stripped.

> Note: Normally the females are injected in the afternoon/evening and are kept (separated from the males) in holding facilities. The holding facility can be a concrete basin inside a hatchery, a happa in a pond or even a simple plastic bucket or a half oil drum will do. Of major importance is that the breeders can be caught easily the morning after injection so as to avoid spoilage of eggs.

The speed of the process is dependent upon water temperature, the higher the temperature the quicker the eggs ovulate. The relationship between water temperature and the time taken for eggs to ovulate is presented in Table 1.

Table 1:   The time interval between injection and stripping of female catfish relation to water temperature (source: Hogendoorn and Vismans, 1980)

WATER TEMPERATURE (^{o}C)	TIME BETWEEN INJECTION AND STRIPPING (HOURS)
20	21
21	18
22	15.5
23	13.5
24	12
25	11
26	10
27	9
28	8
29	7.5
30	7

> Note: Sometimes with fluctuating water temperatures, and in particular with higher temperatures during the day, it is difficult to establish the actual mean water temperature. This can result in eggs being stripped too early and consequently very low hatching rates (5-10%). Eggs which are stripped too early tend to have a treacly consistency. It is always much safer to strip eggs later than rather earlier. If you are too early you will lose all your eggs, if you are too late you will loose some eggs. The eggs ooze out very easily if stripped at the right time.

Stripping of the female spawners is carried out by gently pressing their abdomen with a thumb from the pectoral fin towards the genital papilla. Ovulated eggs will flow out easily in a thick jet from the genital vent and are usually collected into a dry plastic container (see Figure 15).
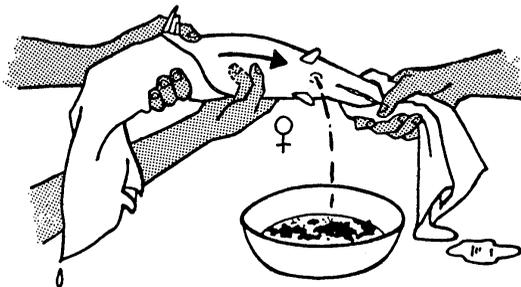
Figure 15:   Stripping a female African catfish.

The ovulated eggs are more or less transparent, flattened and one gram contains approximately 600[5] eggs. Under normal conditions a "ripe" female ovulates a quantity of eggs which equals to 15-20% of her own body weight (de Graaf *et al.*, 1995). If the fish is stripped too early the eggs come out with difficulty, whereas they have a "flushy" appearance if they are stripped too late.

The males of the African catfish cannot be stripped and consequently the sperm can only be obtained by sacrificing a male. The male is killed and the body surface thoroughly dried after which the testis is dissected and placed in a mortar or a teacup. The testis is rapidly cut into small pieces using a scissor and finally the milt is pressed out with a pestle or a teaspoon (see Figure 16).

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[5] This number is not consistent as reported by different authors therefore it is recommended that you determine this number yourself.
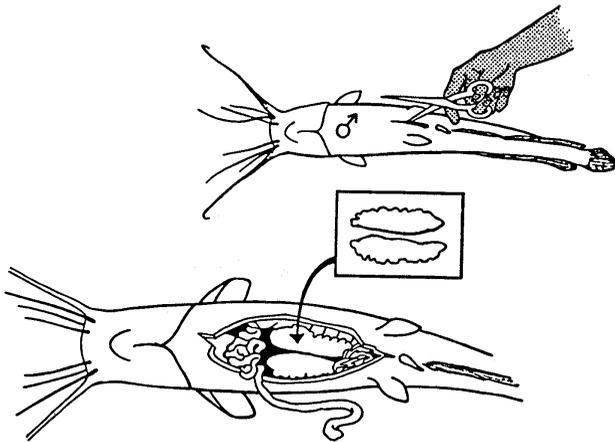
Figure 16:   Collection of milt from male African catfish.

Two different methods of fertilization are used in Africa;

*   In Congo-Brazzaville (de Graaf *et al.*, 1995) the females are first stripped, then a male killed and the milt then directly mixed with the stripped eggs. This was necessary as stripping was carried out outdoors under all weather conditions. It should be realized that one drop of water in the bottle with sperm will destroy the sperm completely while one drop of water in the bowl of eggs will only destroy some eggs. This method is very suitable if a limited number of females are stripped.

*   In Central Africa, Kenya and Ivory Coast (Janssen, 1985a, de Graaf, 1989) milt is taken from a male spawner and diluted with a physiological salt solution (9 gram of kitchen salt dissolved in one litre of boiled water) about half an hour before the females are stripped. This solution is then

later added to the stripped eggs. The advantage of this method is that eggs from a large number of females can be fertilized as one testis of a mature male can easily fertilize the eggs of 10-15 females.

The sperm (diluted or non-diluted) is added to the stripped eggs, and the eggs fertilized by adding an equal volume of clean water. The water and egg mass are then mixed by gently shaking of the bowl. Eggs must be stirred continuously until they are placed in the hatching tanks as the eggs become sticky and without stirring will stick together into one clump.

About 60 seconds after fertilization has taken place and the sperm has lost its activity, the fertilized egg are then ready for incubation in tanks or happa's.

4.4.5.   Incubation of fertilized eggs.

The development process from fertilized egg to hatching, like all other biological processes, is dependent upon water temperature; the higher the water temperature the faster the eggs hatch. The relation between water temperature and the incubation time of catfish eggs is shown in Table 2.

Table 2:   The time interval between fertilization and hatching of catfish eggs in relation to water temperature (Source; Hogendoorn and Vismans, 1980)

WATER TEMPERATURE (°C)	TIME BETWEEN FERTILIZATION AND HATCHING (HOURS)
20	57
21	46
22	38
23	33
24	29
25	27
26	25
27	23
28	22
29	21
30	20

A general principle of egg incubation is that water is renewed in order to provide oxygen and that after hatching the new born larvae are separated from the remaining egg-shells and dead eggs. The latter is of utmost importance in order to avoid fungal infections of hatchlings and consequent larval mortalities. The following incubation techniques are usually used;

*   The eggs are spread out on the bottom of a concrete basin. This method works well but it has the disadvantage that dead eggs/egg-shells are not separated from the hatchlings. Daily treatment with 0.1 ppm[6] malachite green is needed in order to prevent the outbreak of fungal infections.

*   The eggs are spread out on a screen (mesh size 1 mm) which is placed on the bottom of a concrete basin.

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[6]   ppm = parts per million or 1 mg/litre

This method works well as the hatchlings will pass through the screen and the dead eggs and shells remain on the screen. By removing the screen from the basin a separation between hatchlings and dead eggs is made.

*   The eggs are allowed to "stick" to the roots of floating water hyacinth (*Eichhornia crassipes*) placed within a happas made from mosquito netting (mesh size 0.5 mm) located within a concrete basin with running water or in a pond. This method was developed in Congo Brazzaville (de Graaf *et al.*, 1995). The investments are low and hatchlings easily separated from the dead eggs as long as the distance between the roots of the water hyacinth and the bottom of the happa is kept at 15-20 cm. After hatching the larvae sink to the bottom of the happa and the egg shells remain stuck to the roots of the water-hyacinth. The dead eggs are separated from the hatchlings once the water hyacinth is removed from the happa.

*   The eggs are allowed to "stick" to the roots of floating Nile cabbage/water lettuce (*Pistia stratiotus*) placed within a happa located in a concrete basin. The Nile cabbage works as well as the water hyacinth; floating well and having a well developed fine root system to which the eggs stick nicely. More importantly, Nile cabbage is not a "water pest", can be easily found and therefore more suitable than water hyacinth.

*   The eggs are allowed to "stick to a brush which floats inside a concrete basin or happa. This method works very well as the eggs are held completely under water, the only disadvantage being the price of the brush.

          It is also possible to incubate eggs and hatchlings in stagnant water, using oil drums/barrels, or inside a happa placed in a pond. However, low egg/hatchling

densities are essential and should not exceed 100-150 per litre (or 0.1 gram of eggs per litre).

The hatchlings (1-1.5 mg) can be kept in the incubators and do not have to be fed as they rely on the food resource within their yolk sac. Healthy larvae tend to stay in dark places and should not be exposed to direct sunlight. After three to four days the yolk sac will be absorbed and the hatchling is visibly developed into a small catfish. At this stage the hatchling must be fed on external food for its further development and survival, therefore, the hatchlings should be transferred out of incubation facilities to ponds or specialized hatchery facilities. This phase of rearing from first feeding larvae to fingerling size is usually carried out either in earthen ponds or in specialized hatcheries.

5.   FRY NURSING IN EARTHEN PONDS

Four factors are of great importance when nursing first feeding larvae within in earthen ponds;

*   The availability of large quantities of zooplankton;

*   The stocking density of the of the 3 day old larvae;

*   The duration of the rearing period;

*   Pond size, or the ratio dike length and pond surface

5.1.   *Pond preparation, fertilization and feeding rates.*

5.1.1.   Cleaning

Before the nursery pond is filled with water the banks of the dikes should be cleaned and monitored on weak points for leaks and repaired. Grasses should be cut and excess of silt from the pond bottom removed. The pond bottom should then be allowed to dry for a few days so as to kill potential fry predators (i.e. water insects, amphibian larvae and **catfish fingerlings from previous rearing)**, and to increase the mineralisation (oxidation) of nutrients in the pond bottom.

5.1.2.   Liming

Liming is an important part of nursery pond maintenance; having a favourable effect on the health of the fry and increasing the natural productivity of the ponds. Some of the beneficial effects of liming can be summarized as follows:

*   Disinfection of the pond bottom (only quick lime).

*   Increases the pH of water and pond bottom to an optimum level (pH 7-9) for plankton and fish production.

*   Increases the alkalinity of water; adequate alkalinity is required to ensure pH stability and neutralize harmful the effects of magnesium, sodium and potassium salts.

*   Increases pond productivity through increased biological activity and availability of minerals in the pond bottom.

The most commonly used liming compounds are quicklime (CaO), caustic lime also called slaked lime or hydrated lime ($Ca(OH)_2$), and agricultural lime. The required amount of lime depends upon acidity of water and soil and the alkalinity of the soil, and consequently varies from region to region and from pond to pond. In general heavy loam or clay soils require more liming than sandy soils and newly excavated ponds require more liming than used or old ponds. The quantity of liming required also depends also upon the type of lime used, since the neutralizing capacities of these compounds are different. The estimated quantity required depending on pH is:

Quick lime: 7 - 10 kg/100 m^2

Caustic lime: 7 - 13 kg/100 m^2

Agriculture lime 20 - 30 kg/100 m^2

5.1.3.   Fertilization

The most critical factor for the successful nursing of African catfish larvae is the ready availability of zooplankton during the first week after stocking, as they feed only on live food during this period (de Graaf *et al.*, 1995). A good zooplankton bloom can only be obtained if the ponds are well fertilized.

In general it is believed that both phosphorus (P) and nitrogen (N) are required in minimum quantities for optimum primary production in fish ponds. The favourable action of potassium (K) has not been clearly demonstrated. Since the required quantities of these minerals are not always available in ponds, it has become a necessity to add them in order to establish an optimum standing crop of zooplankton. This can be achieved by adding minerals either directly (chemical fertilizers) or indirectly (organic fertilizers).

Chemical fertilizers

In general the mineral composition of chemical fertilizers is expressed either as a percentage of equivalent N, P_2O_5 or K_2O. In practice, the main fertilizers used are: superphosphate (containing about 20% P_2O_5), triple

superphosphate (containing about 45% P_2O_5), urea (containing about 45% N) and NPK 15:15:15 (15% N, 15% P_2O_5, 15% K_2O).

Organic fertilizers

The most commonly used organic fertilizers are poultry manure, duck manure, pig dung, sheep dung and cow dung. In general, the fertilizing value of manure depends upon the C:N ratio in increasing order from cow and sheep manure followed by a grouping of pig, chicken and duck manure Schroeder, 1980).

The quantity of organic and inorganic fertilizers required varies from place to place and from pond to pond. In Congo Brazzaville the catfish nursing ponds were fertilized with dry chicken manure at a rate of 50 kg/100 m^2 one week prior to stocking. This resulted in a good phytoplankton bloom, the pond water containing about 1.5-2 ml of plankton per 100 litre of water and having a secchi disk reading of 20-25 cm (de Graaf, unpublished data).

By contrast, in the Central African Republic (Janssen, 1985c) the catfish nursing ponds are fertilized with;

10-20 kg manure/100 m^2

0.4-0.8 kg N/100 m^2

0.1-0.2 kg P_2O_5/100 m^2

It is preferable to dissolve the fertilizers, after which they are spread evenly over the surface. Dissolving fertilizers is of great importance especially for phosphorus containing fertilizers since this mineral, commercialized as

pellets, is easily absorbed by the pond bottom and thus lost for primary production. Alternatively, phosphorus fertilizers may be placed on a submerged platform or in a hanging bag, in order to promote gradual release of the minerals to the pond water.

5.1.4. Daily supplementary feeding

Daily supplementary feeding of the catfish must start immediately after stocking (100 larvae/m^2) and the feeding rate is 1-2 kg of rice/wheat bran per 100 m^2. However, before being used, the bran must be sieved through a 0.5 mm mesh. In addition to bran, the following feeding rates (six days a week in two equal portions) are recommended for the use of formulated feeds containing fish meal as animal protein source;

First week:	0.50 kg/100 m^2/day
Second week:	0.75 kg/100 m^2/day
Third week:	1.00 kg/100 m^2/day
Fourth week:	1.25 kg/100 m^2/day
Fifth week:	1.50 kg/100 m^2/day

In some cases not all the feed will be consumed completely by the hatchlings, and the remaining feed will serve as a fertilizer input and will help to maintain the plankton bloom within the pond.

5.2 Impact of tadpoles

A major problem frequently encountered is the presence of tadpoles. Tadpoles belonging to the species; *Rana occipitalis* (Gunther 1858), *Ptychadena pumilio* (Boulenger 1920) and *Xenopus tropicalis* (Gray 1864) seem to be phytophagous[7] and did not feed on the hatchlings stocked in ponds (de Graaf *et al.*, 1995).

However, their presence, is a nuisance because they compete for the same food resources within the pond. They feed on the phytoplankton which is needed for the development of zooplankton, which in turn is needed for the growth and development of the catfish larvae.

Typical results for the nursing of *C. gariepinus* in un-protected ponds are shown in Table 3 and average production figures of un-protected ponds in four different location in Africa are presented in Table 4.

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[7]However, Janssen (unpublished data) found that if tadpoles of Xenopus spp. were placed together with clarias larvae in a petri disk, that the clarias larvae disappeared within one hour.

Table 3:   Results of nursing of *C. gariepinus* within unprotected ponds in Congo Brazzaville and Kenya

CONGO BRAZZAVILLE (de Graaf *et al.,* 1995)					KENYA (Obuya *et al.,* 1995)		
No. of hatchlings stocked (No./m)	No. of fingerlings harvested (No./m^2)	Survival rate (%)	Rearing period (days)	Weight of fingerlings (g)	No. of hatchlings stocked (No./m)	No. of fingerlings harvested (No./m^2)	Rearing period (days)
29	8.4	28.7	36	2.8	15-45	0.6	29
30	1.9	6.3	38	4.1	15-45	10.1	18
32	1.2	3.6	34	12.8	15-45	4.1	29
34	0.0	0.0	37	-.-	15-45	21.6	33
53	0.0	0.0	45	-.-	15-45	11.7	24
68	0.0	0.0	45	-.-	15-45	5.1	23
68	1.3	1.9	37	5.5	15-45	11.1	28
71	0.6	0.9	37	8.2	15-45	5	35
71	0.7	1.0	45	22.4	15-45	6.4	36
75	2.1	2.8	39	15.5	15-45	0.7	36
87	0.9	1.1	37	2.9	15-45	0.8	37
100	27.1	27.2	45	2.9	15-45	6.3	18
100	26.5	26.5	45	1.4	15-45	5.6	42
100	0	0	45	-.-	15-45	1.9	44
100	1.2	1.2	44	16.9	15-45	2.6	40
100	0	0.0	37	-.-	15-45	6.9	38
					15-45	0.7	45
					15-45	4.3	21

Table 4: Average production figures for the nursing of *C. gariepinus* within un-protected ponds in different locations within Africa.

Country	No of fingerlings harvested (No./m^2 ± std)	Source
Congo Brazzaville	5.0 ± 13.9	de Graaf *et al.*, 1995
Kenya	5.8 ± 4.9	Obuya *et al.*, 1995
Cameroon	2.7 ± 1.6	Hogendoorn, 1979
Ivory Coast	6.8 ± 7.4	de Graaf, 1989

Although, fingerlings can be produced within un-protected ponds, the results are usually very variable and so the method is unreliable for the mass production of fingerlings. **Removal of tadpoles is essential** and there are two ways to solve this problem;

* Protect the pond against frogs and tadpoles. Surrounding the ponds with aluminium roof plates (80 cm high) proved to be very successful in Congo Brazzaville. In some countries the nursery ponds are surrounded by nylon netting (see Figure 17) but this proved has the disadvantage that the nets detoriated quickly, due to the effect UV radiation or sunlight.

* Remove the largest part of the tadpoles from the pond with a small mesh size seine net on the day the catfish larvae are stocked, as is routinely carried out in the Central African Republic.

The final choice to use either protected ponds or to remove the tadpoles manually depends on socio-

economic conditions such as; Investment of protected ponds, price of labour, the availability of skilled and reliable management, the site of the ponds as roofplates are easily removed at night in remote areas, etc.

Figure 17:   Nursery ponds for *C. gariepinus* surrounded with nylon nets.

5.3 Nursing of catfish larvae in protected ponds

A good plankton bloom is a crucial factor, therefore the protection of the ponds against tadpoles is essential for the successful nursing of *C. gariepinus* in ponds.

In Congo Brazzaville (de Graaf *et al.*, 1995) the nursing of *C. gariepinus* was successfully carried out in ponds which were surrounded with aluminium roof plates (80 cm). Three days after hatching, the larvae of *Clarias gariepinus* were stocked in earthen ponds (100-150 m^2, 0.8 m waterdepth) at densities varying between 70-100 larvae/m^2. The ponds were filled with water and fertilized with chicken dung (50 kg/100 m^2) one week before stocking. From the day of stocking, the fish were fed 6 days a week with wheat bran at a rate of 1 kg/100 m^2/day and thereafter this feeding rate was kept constant. The average production figures obtained from 24 nursery production cycles are presented in Table 5.

Table 5: Average production figures (± s.e.m) for the nursery rearing of *C. gariepinus* within protected ponds from 24 production cycles in Congo Brazzaville (de Graaf *et al.*, 1995).

Production parameter (means)	Results
Initial stocking density (No./m^2)	80±5.8
Rearing period (days)	48.3±4.6
Harvested fingerlings (No./m^2)	32.3±3.3
Survival rate (% of stocked total)	38.7±3.7
Weight at harvest (g)	3.1±0.5

Reliable fingerling productions can be obtained from protected ponds as plankton development is not hampered as in unprotected ponds. However, two factors are of importance for the successful nursing of *C. gariepinus* namely; stocking density and the length of the rearing period.

5.3.1. Stocking density of the catfish larvae

For years it has been believed (also by the authors) that the optimal stocking density for larval catfish was 100 per square meter; harvesting about 35-40 fingerlings/m^2 after 5 weeks, each fingerling weighing 2-3 gram each (de Graaf *et al.*, 1995). Increasing the initial stocking density did not increase the production and lower stocking densities resulted in less fingerlings but larger fingerlings being harvested.

However, recent developments in Kenya (Campbell *et al.*, 1995) have changed this picture, with higher stocking densities and more fingerlings per square meter being harvested as is shown in Table 6.

Table 6:   Results of nursing *C. gariepinus* within earthen ponds (10 x 10 x 1 m, water depth 30 cm) completely covered with a nylon net (mesh size 4 mm, Campbell *et al.*, 1995).

Parameter (mean)	Results ± s.e.m
Initial stocking density (No./m^2)	278±17.7
Rearing period (days)	18.4±1.2
Harvested fingerlings (No./m^2)	85±11.6
Survival rate (%)	32.2±3.9

Weight at harvest (g)	0.3±0.07

Stocking densities as high as 250 larvae/m^2 with an average production of 85 fingerlings/m^2 have only be obtained before in Africa by Janssen in Nigeria (unpublished data). In South Africa nursery ponds are repeatedly stocked at a rate of 2,000 fry/m^2 and about 500-800 fingerlings are harvested per square meter (Hecht *et al.*, 1988). However, these ponds are stocked with **10 day old fry** (20-30 mm) and so this cannot be directly compared with the stocking of hatchlings.

Although, these results are only preliminary, it is worthnoting that the larvae are reared in very small (10 m^2) shallow ponds which were well fertilized and completely covered with a nylon net (mesh 4 mm). The small size or the high dike-length/surface area ratio of these ponds could be of particular importance and is further studied in Kenya.

5.3.2.   Size and form of the nursing pond

In general the production and survival of *C. gariepinus* is higher with small ponds than in larger ponds; small ponds being easier to manage, to fertilize and develop a plankton bloom rapidly and so ensuring plentiful food the stocked hatchlings.

The hatchlings in Kenya are reared for only about 18 days their average weight is only about 0.3 gram. However the survival rate of 30-35% obtained, is comparable with that obtained within protected ponds in Brazzaville. It is

particularly, remarkable that the survival rate obtained after 14-15 days of rearing (29.8±11), did not differ from the survival rate obtained after 22-28 days of rearing (36.0±24.6). This indicates that major mortalities are occurring during the early period of the nursing phase. The critical factor is most probably the availability of plankton during the first days of the rearing cycle.

Another factor which could be of importance, and which is currently being studied by an FAO project in Kenya (Support to Small Scale Rural Aquaculture in Western Kenya, FAO/TCP/KEN/4551), is the form of the pond or the ratio between the dike length and the water surface area.

During the first days of the rearing period, the hatchlings can be seen wriggling in the water layer near the embankment. The hatchlings could be attracted by the shelter provided by the grass/weeds on the embankment or could possibly be attracted to more food being available in this area. In Table 7, the major production parameters of protected nursery ponds with different dike-length/surface ratios are compared.

Table 7: Production figures of protected nursery ponds with different dike/surface ratios

Production parameter (mean ± s.e.m)	Protected nursery ponds in Congo Brazzaville. Dike-length/surface area = 0.5 (de Graaf et al., 1995)	Protected nursery ponds in Kenya. Dike-length/surface area = 2.2 (Campbell et al., 1995)
Initial stocking density (No./m^2)	80 ± 5.8	278 ± 17.7
Rearing period (days)	48.3 ± 4.6	18.4 ± 1.2
Harvested fingerlings (No./m^2)	32.3 ± 3.3	85.0 ± 11.6
Survival rate (%)	38.7 ± 3.7	32.2 ± 3.9
Weight at harvest (g)	3.1 ± 0.5	0.3 ± 0.07
No. of fingerlings at harvest per cubic meter of pond water	40.3	283
Standing crop at harvest (kg/ha)	1250	850

It could be reasoned that the more embankment available, the better the results of the nursing phase, as the production is more as doubled in ponds with a high dike/surface ratio. The ponds with a lower dike/area ratio supports a higher standing crop at harvest, which is logical as supplementary feeding is the major food source during the last part of the nursing phase. The major benefit of a high dike-length/surface ratio will be during the first part of the nursing phase, when the hatchlings depend upon plankton as their main food source.

5.3.3. Duration of the rearing period and cannibalism among the catfish fingerlings.

A major factor which influences the success of the nursing phase is the length of the rearing period. In general four to five weeks after stocking two distinct size groups of catfish can be recognized within the pond (see Figure 18):

*   A large group (80-90% of the biomass) consisting of small sized fingerlings (2-3 g).

*   A small group of fingerlings (10-20% of the total biomass) consisting of large size fingerlings (8-10 g).

Cannibalism will occur (i.e. the large sized fish will eat the small ones) if the two groups are not separated and only a very small number of large fish will be harvested (see Table 3). For example, the results obtained in Congo Brazzaville showed very low survival rates (1-3%) if the weight of the fingerlings at harvest exceeded 15 g. However, under adequate management (i.e. harvesting before cannibalism starts), an average survival rate of 30-40% can be obtained.

Note: If 100 larvae are stocked per square meter it is essential to harvest your fingerlings 35-40 days after stocking otherwise the large fingerlings will predate on the smaller ones.
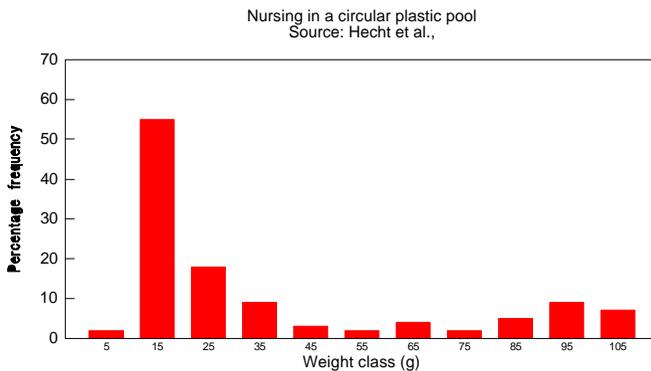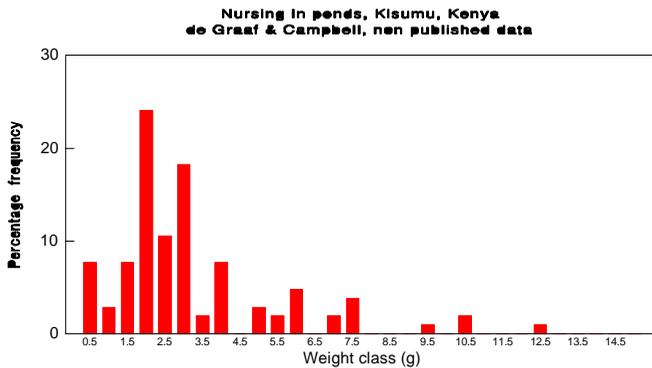
Figure 18: Frequency distribution of harvested *C. gariepinus* fingerlings nursed in an earthen pond (de Graaf and Campbell, unpublished data) or nursed in a 2,000 litre circular plastic pool (Hecht *et al.*, 1988).

5.3.4.　　Pond monitoring and predator control

Within un-protected ponds tadpoles must be seined out and removed prior to stocking. Aquatic insects such as water-scorpions, water-beetles, water-boatman and larvae of the dragon fly can be controlled with kerosene (0.5 l/100 m^2). The kerosene should be poured, in the early morning of the first rearing day, along the windward side. The breeze will carry the fuel across the water which will prevent the aquatic insects from taking air at the surface and they will soon die.

6 MONOCULTURE OF AFRICAN CATFISH

Monoculture of the African catfish can be carried out when suitable feed, with a high protein content is available.

6.1 Stocking rates

The results of Micha (1975) clearly indicated that the growth of *C. gariepinus* decreases with increased stocking rates while the standing crop remains more or less the same (Figure 19). Therefore the stocking rate depends upon the market size desired and varies from 2 to 10 fingerlings per square meter, which corresponds to a market size of approximately 500 and 200 g, respectively after a six month rearing period.

In the Central African Republic **static ponds** were stocked at a density of 10 fingerlings/m^2, and were harvested after 6 months when the standing biomass reached 10,000 kg/ha and the catfish attained an average weight of 200 g (Janssen, unpublished data, see also Table 13). Higher stocking densities were not used in the Central African Republic, because the adverse water conditions at the end of the production cycle are difficult to manage.

In South Africa and Zambia standing crops of 40,000-100,000 kg/ha are attained in ponds with a water exchange of 25%/day (Hecht *et al.*, 1988). This system is difficult to manage and it is recommended by these authors to stock the ponds at a maximum density of 10 fingerlings/m^2,

and to thin out the population at regular intervals in order to maintain a maximum standing crop of 40,000 kg/ha with a constant daily water exchange rate of 25 %. The latter is essential at these high standing crops because the accumulation waste (uneaten feed, excreta, etc.) will stress the fish and may provoke the outbreak of diseases.
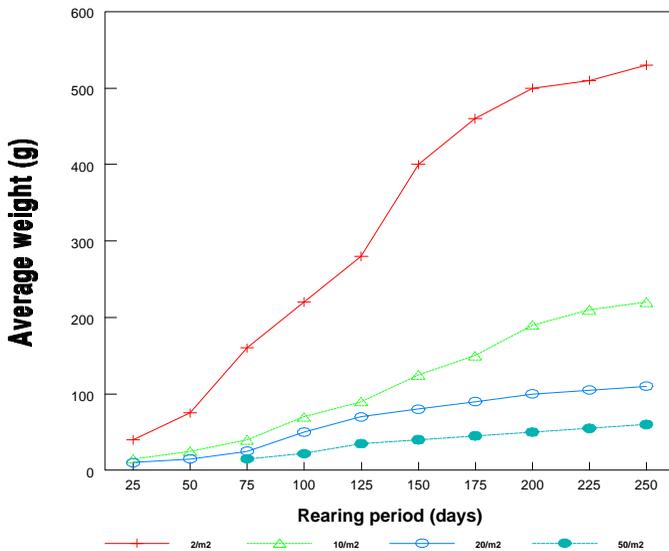
Figure 19: The relationship between stocking density and growth of *C. gariepinus* in earthen ponds in the Central African Republic (After Micha, 1976).

6.2 Feeding

C. gariepinus has a relatively high dietary protein requirement. Feeding with a formulated feed is a prerequisite for intensive monoculture of the African catfish. The best growth rates and food conversions are achieved with diets containing 35-42% crude protein and a calculated digestible energy level of 12 kJ g^{-1} (ADCP, 1983). Recommended dietary nutrient levels for *C. gariepinus* are presented in Table 8.

Table 8:   Recommended dietary nutrient levels for *C. gariepinus* (ADCP, 1983)

Nutrients (% of dry matter)	Fry and Fingerlings	Growers	Broodstock
Digestible protein	35-40	30-35	35-40
Digestible energy (kcal/g)	3.0-4.0	2.5-3.5	3.0-4.0
Ca (min-max)	0.8-1.5	0.5-1.8	0.8-1.5
P (min-max)	0.6-1.0	0.5-1.0	0.6-1.0
Methionine + Cystine (min)	1.2	0.9	1.0
Lysine (min)	2.0	1.6	1.8

Artificial formulated diets are generally composed of a mixture of vegetable and animal feedstuffs (usually agricultural and mill by-products) supplemented with vitamins and minerals. An example of a vitamin premix used in diets for *C. gariepinus* , based on levels used in commercial diets for channel catfish (Robinson, 1984) is given in Table 9.

Table 9:   Composition of a dietary vitamin premix for *C. gariepinus* diets (Hecht *et al.*, 1988).

Thiamin	11 g
Riboflavin	13 g
Pyridoxine	11 g
Pantothenic acid	35 g
Nicotinic acid	88 g
Folic acid	2.2 g
B12	0.09 g
Choline	550 g
Ascorbic acid	350 g
A (I.U.)	44,00 (I.U.) x 1000
D (I.U.)	22,00 (I.U.) x 1000
E (I.U.)	55 (I.U.) x 1000
K (I.U)	11 (I.U.) x 1000
Filler, maize meal	2 kg

One kilogram of this mixture is sufficient for one ton of pelletized feed (0.1%) or 500 kg of extrusion processed feed (0.2%)

It is not possible to give standard formulation for a balanced diet for catfish since the composition of artificial diets will depend upon the availability and prices of locally available feedstuffs which inturn vary considerably between countries. Least cost formulation methods are used within the feed manufacturing. Two examples of least cost formulations for *C. gariepinus* are given in Table 10 and 11.

Table 10: Least cost formulation for on-growing African catfish in the Central African Republic (Janssen, 1985).

Ingredients (kg)	Dry or moist pellets		Moist pellets			
	1	2	3	4	5	6
Wet brewers waste (25% dry matter)	-	-	78	60	61	44
Dried brewers waste	15	10	-	-	-	-
Wet brewers yeast (15% dry matter)	-	-	-	30	-	30
Rice bran/polishing	15	15	15	15	15	15
Maize	5.55	6.05	-	-	-	-
Cotton seed cake	25	25	25	25	25	25
Groundnut cake	25	25	25	25	25	25
Sesame cake	10	10	10	10	10	10
Blood meal	-	5	-	-	5	5
Vitamin/mineral premix[8]	0.25	0.25	0.25	0.25	0.25	0.25
Bone meal	2	2	2	2	2	2
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Palm oil	1	1	-	-	-	-
L-Lysine	0.5	0.2	0.5	0.3	0.2	-
D-Methionine	0.2	-	0.2	0.2	-	-
Gentian violet (g)	-	-	5	5	5	5
TOTAL	100	100	100	100	100	100
Calculated chemical composition						
Protein (%)	35.3	38.2	35.9	37.7	38.9	39.2
Digestible energy (kcal/g)	2.70	2.76	2.62	2.67	2.70	2.71
Methionine+Cystine (%)	1.0	1.1	1.0	1.0	1.1	1.1
Lysine (%)	1.6	1.6	1.6	1.6	1.6	1.6

[8]Commercial preparation used for poultry (layer) diets.

Costs FCFA per kg of feed	78	88	71	67	81	77

Table 11: Least cost diets for the on-growing (in ponds) of *C. gariepinus* used in South Africa, reported feed conversion ratios (FCR) and cost efficiency (Hecht *et al.*, 1988).

Diet No.	1	2	3	4	5	6	7	8	9	Control
Maize (%)	-	4.6	15.0	30.0	-	10.5	-	-	-	18.0
Wheat (%)	-	31.8	15.0	-	30.0	-	14.0	-	-	18.0
Cotton seed cake (%)	-	-	-	-	-	25.0	-	-	-	-
Soy bean cake (%)	10	-	-	-	-	10.0	10.0	-	-	-
Fishmeal (%)	24.7	16.0	10.0	10.0	10.0	20.0	10.0	10.0	-	43.5
Poultry by product meal (%)	10	10	-	10	10	9.0	10.0	26.0	35.2	-
Carcass meal (%)	10.5	27.6	50.2	39.5	31.4	-	22.7	-	-	10.0
Lucerne meal (%)	30.0	-	-	-	-	-	-	-	-	-
Tomato waste (%)	-	-	-	-	9.7	8.0	20.0	50.1	50.0	-
Fish acid oil (%)	6.8	-	-	2.5	0.9	7.5	3.3	5.9	6.8	2.5
Molasses powder (%)	8.0	10.0	9.8	8.0	8.0	10.0	10.0	8.0	8.0	8.0
TOTAL	100	100	100	100	100	100	100	100	100	100
Calculated chemical composition										
Crude protein (%)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0

Total lipid (%)	13.5	8.0	8.1	11.7	9.8	14.2	12.5	19.8	21.6	9.0
[9]Digestible energy (kJ/g)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Price/ton (R)	655	586	580	569	543	603	531	415	376	722
FCR	1.05	1.19	1.16	1.25	1.19	1.13	1.12	1.46	1.54	0.98
Feed cost to rear 1 kg of fish	0.69	0.70	0.67	0.71	0.65	0.68	0.59	0.61	0.58	0.71

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[9] Calculated on the basis of DE values for channel catfish Lovell, 1984).

In most African countries, raw materials containing high amounts of animal protein such as fish meal and blood meal are scarce and expensive. Hence, it is easier to meet the relatively high protein requirements for African catfish by using feedstuffs containing higher quantities of vegetable protein such as plant oilseed cakes and meals. These agricultural by-products are more common, cheaper and generally available in large quantities in the region. The use of unconventional ingredients such as tomato waste in feeds used in South African diets is a good example of this.

Since there is almost no large scale intensive aquaculture in most African countries, the present demand for raw materials comes mainly from domestic poultry and livestock industries. Consequently, there are generally no specific vitamin and mineral supplements for available for aquaculture species. At present these requirements can only be met using the premixes from the poultry industry.

The recommended feeding levels between 21 and 33 ^{o}C corresponding with maximum growth rates and optimum food conversion have been determined by Hogendoorn *et al.* (1983). These feeding levels have been calculated based on results of laboratory experiments in flow through systems, in which fish were fed with a commercial trout diet (crude protein 50%, gross energy 5,200 kcal/kg food) and are shown in Table 12.

Table 12: Recommended feeding levels (% of body weight/day) for *C. gariepinus* at different temperatures (Hogendoorn *et al.*, 1983).

Temperature (°C)	Body weight (g)					
	1	5	25	50	100	200
21	3.6	2.5	1.7	1.4	1.2	1
23	5.1	3.7	2.6	2.3	2.0	1.7
25	6.5	4.7	3.4	3.0	2.6	2.3
27	7.4	5.4	3.9	3.4	3.0	2.6
29	7.9	5.6	4.0	3.5	3.0	2.6
31	8.0	5.5	3.8	3.2	2.7	2.3
33	7.8	5.1	3.4	2.8		

In practice it has been found that slightly higher feeding levels may be applied during the first months of culture in order to acclimatize the fish to the feed and feeding place, while lower feeding levels should be applied during the last three months of culture due to the regressing water quality conditions in the static ponds (Janssen, unpublished results). Moreover, the quantity of feed distributed is generally calculated for a two week period and adjusted every four to six weeks after recording the average body weight of the fish. The latter is usually carried out by taking a sample with a cast net. The biomass of the catfish and the daily quantity of feed are then calculated according to the recorded average body weight and estimated survival rate. It is still difficult to predict growth rates and survival as they depend on many factors such as density, feed quality, temperature, predation by birds, etc. Despite this, some data on monoculture of African catfish is presented in Table 13.

Table 13: Biological data on monoculture of African catfish in the Central African Republic, (density 10 m^2, mean temperature 25-27 ^{o}C, Janssen, unpublished data).

Week	Mean body weight (g)	Survival (%)	Biomass (kg/100 m^2)	Feeding rate (%/biomass/day)	Feed (g/100 m^2/day)
0	1	100	1	10	100
2	5	70	3.5	7.5	250
4	10	65	6.5	4.5	300
6	18	60	10.8	4.0	400
8	27	60	10.2	3.3	525
10	36	60	21.6	3.0	650
12	52	55	28.6	2.7	775
14	65	55	35.7	2.6	900
16	79	55	43.4	2.4	1025
18	102	50	51.0	2.3	1150
20	130	50	65.0	2.1	1350
22	160	50	80.0	1.9	4500
24	200	50	100.0	1.8	Harvest

After about six months the pond can be harvested with a net production of 9-16 t/ha/year. The main problems encountered with intensive monoculture of the African catfish, have been related to water quality and predation

For example overfeeding leads to adverse environmental conditions, including low oxygen, high ammonia, high suspended solids, etc. Adverse water conditions often coincide with dense phytoplankton concentrations followed by the occurrence of a scum of phytoplankton at the surface of the pond. This in turn will cause low oxygen levels at night and pre-dawn. The only remedy for this is to reduce the dietary feeding level and start flushing the pond with fresh water. In turn, predation by birds and other animals is also another major problem often faced in intensive farming of the African catfish.

7. POLY CULTURE OF AFRICAN CATFISH WITH NILE TILAPIA

Nile tilapia (*Oreochromis niloticus*) is currently the most widely cultivated fish in Africa. A major disadvantage of this species and Tilapia in general is their excessive reproduction and at harvest up to 23% of the biomass may consists of fingerlings (Figure 20). The main problem with the existence of the fingerlings is that they compete for and consume the feed provided for the adult tilapia and consequently the growth rate of the adults is reduced (de Graaf *et al.*, in press).
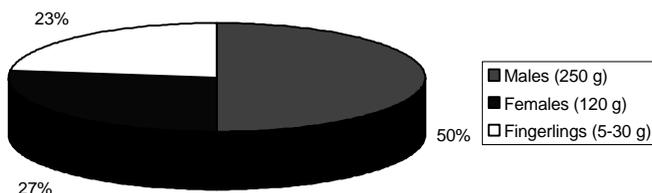
Figure 20: The percentage of the total harvest weight consisting of males, females and fingerlings of *Oreochromis niloticus* obtained in a mixed culture in Congo Brazzaville (stocking density 2.2 fingerlings/m^2, wheat bran as feed, production 7-8 t/ha/year, de Graaf *et al.*, in press).

Furthermore the same authors found that by reducing the number of fingerlings that the growth of adult fish was improved (Figure 21).
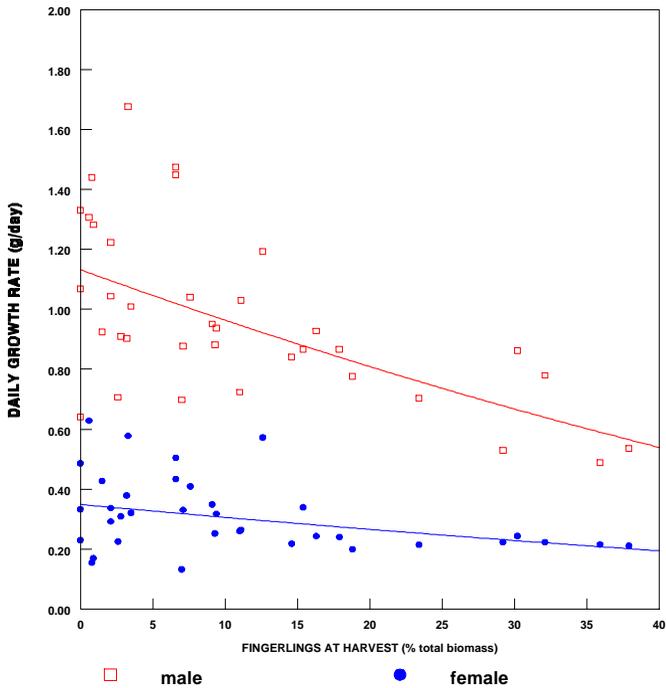
Figure 21:   Growth rate of pond reared male and female *O. niloticus* in relation to the presence of fingerlings in Congo Brazzaville (de Graaf, *et al.*, in press).

However, the number of tilapia fingerlings can be reduced by rearing tilapia in combination with a predator

fish. For example, the following predator fish have been successfully used in poly culture with Nile tilapia in Africa;

*   *Clarias gariepinus*: generally considered to be a "lazy" predator but works well as long as they are stocked in high densities (8,000-9000 fingerlings/ha).

*   *Ophiocephalus obscuris*: highly effective predator which is completely piscivorous and eliminates all the tilapia fingerlings if stocked at a density of 800-1,000/ha.

*   *Hemichromis fasciatus*: good predator but has a low market value and it is rather fragile with high mortalities often occurring at harvest.

*   *Lates niloticus*: good predator but it is difficult to obtain fingerlings.

Regarding the use of African catfish this species must be stocked at high densities in order to obtain a complete reduction of the Tilapia fingerlings, as it prefers to feed on the supplied feed. De Graaf *et al.* (in press) found a clear relation between the stocking density of *C. gariepinus* and the remaining quantity of Nile tilapia fingerlings at harvest (Figure 22).

Large catfish (6.8-130 g) were able to control the recruitment of Nile tilapia completely, with less than 0.15 % of fingerlings (as % of total harvested biomass) remaining at a stocking density of 8,300 catfish per ha.

However, small catfish (less than 3.6 g) were not able to completely control the recruitment of Nile tilapia (a fingerling percentage of 3.7 % persisting at the end of the culture period). The major reason for this is that small-sized catfish have a specific food preference for zooplankton and

probably shift to a more piscivorous behaviour once they reach a weight of 7-8 g. Consequently all of the Nile tilapia larvae hatched at the beginning of the rearing period escape usually predation. From a practical point of view this has the advantage that at harvest a small number of nicely calibrated tilapia fingerlings (30-35 gram) are usually obtained.
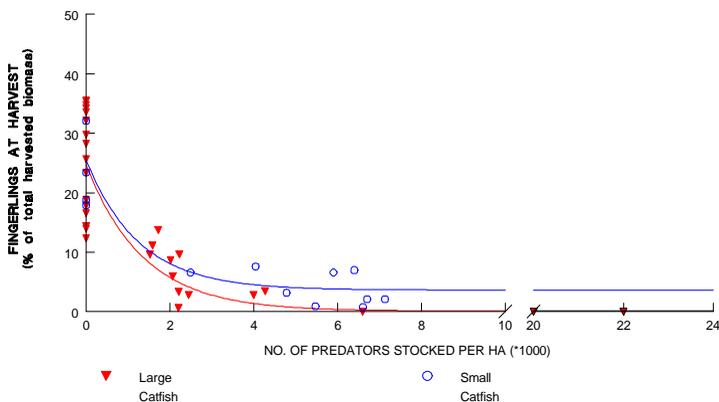
Figure 22:   The relationship between stocking density of *C. gariepinus* and the remaining quantity of fingerlings of Nile tilapia in polyculture (expressed as % of total harvested biomass).

Fish may be fed all kinds of available agriculture by products, including; rice bran, wheat bran, cotton seed cake, etc. However, the feeding rate must be adjusted to the presence and appetite of the catfish or they will be underfed. In practice, for the monthly adjustment of the feeding rate the weight of the catfish can be considered to be the same as the

weight of the tilapia. Some basic parameters for the polyculture Nile tilapia and African catfish are presented in Table 14.

Table 14:   Key parameters for the poly-culture of Nile tilapia with African catfish as obtained in large scale polyculture operations in Congo Brazzaville (de Graaf *et al.*, in press).

Parameter	
Stocking rate tilapia (20-30 g)	$2.2/m^2$
Stocking rate catfish (8-10 g)	$1/m^2$
Feed used	wheat bran
Feed Conversion Ratio	6.6
Rearing period	6 months
Weight of male Tilapia at harvest	200-250 g
Weight of female Tilapia at harvest	100-130 g
Weight of catfish at harvest	200-300 g
Net yield	7-8 t/ha/year

An advantage of rearing African catfish in polyculture with Nile tilapia is that the low valued tilapia fingerlings are replaced by a more or less equal quantity of the higher valued catfish[10]. Another advantage is that larger adult tilapia are obtained as the growth rate of the stocked adults increases (Figure 23).

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[10]   Provided the feeding level is adjusted for the stocking rate of *C. gariepinus*
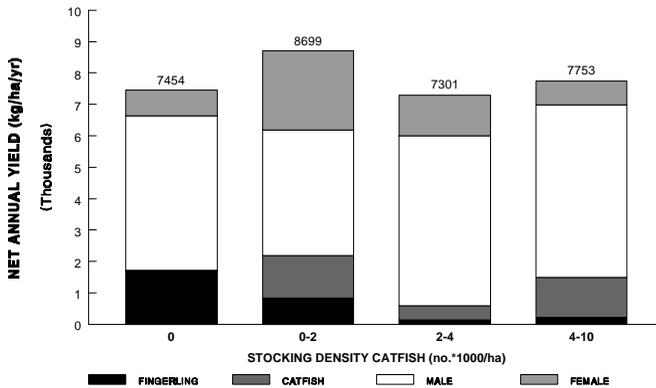
Figure 23: Relationship between the stocking density of *C. gariepinus* and net annual yield and division of yield into fingerling, male and female Nile tilapia and catfish for polyculture with *O. niloticus* (stocking density 2.2 fingerling/m$^{2)}$ in Congo Brazzaville (de Graaf *et al.*, in press).

8.   MISCELLANEOUS

8.1   Economics

Limited data is available on the economics of catfish rearing in Africa due to the fact that most of the work on catfish was oriented at the development and implementation of rearing techniques. In this chapter some economic data as obtained by the authors at large research stations in Congo Brazzaville (13 ha) and in the Central African Republic (3.5 ha) are presented.

8.1.1   Economics of fingerling production

In Congo Brazzaville the farm cost for the production of fingerlings in protected nursery ponds were 0.07 USD/fingerling. The production costs for a indoor hatchery in the Central African Republic, using nauplii of *Artemia salina* and composed feed were 0.14 USD/fingerling. A comparison of the costs of the two systems are presented in Table 15.

Table 15.   Division of the costs as percentage of the total costs of two African catfish production systems: Pond rearing and hatchery rearing using nauplli of *Artemia salina* and composed feeds.

	Pond rearing (% of total costs)	Indoor Hatchery rearing (% of total costs)
Labour	68.0	16.2
Operating costs	25.9	27.6
Depreciation of investments (15 year)	6.1	56.2

The production of fingerlings in ponds is labour intensive while the indoor production in hatchery is capital and technology intensive. Small scale, privately operated fingerling production units, based on nursing in protected ponds is at present the best option for the fingerling production in rural Africa. Investment costs for an unit for the annual production of 280,000 fingerlings are estimated at 12,000 USD[11] and is economic feasible with a Economic Rate of Return[12] of 58%, and a net cash flow of 9500 USD/year, details of the economic analysis are presented in Table 16.

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[11] Price level 1990, Congo Brazzaville
[12] ERR is calculated over a 30 year period

TABLE 16: ECONOMICS OF A POND BASED HATCHERY FOR *CLARIAS GARIEPINUS*

Production parameters

Production	35	Fingerlings/m2
No. of rearing cycles	8	Cycles/year
Average weight fingerling	3	g
Pond size	200	m2
Total pond area	1000	m2
Total fingerling Production	280000	fingerlings/year
Food conversion rice bran	7	

Inputs

Rice bran	5880	kg/year
Broodstock feed	800	kg/year
Labour	30	person-months
Material	1000	USD/year
Sundry	200	USD/year
Operation & Maintenance	10	%

Prices

Rice bran	0,25	USD/kg
Brood stock feed	0,8	USD/kg
Fingerlings	0,1	USD/piece
Labour	450	USD/month

Investments

			Percentage of Investments
5 ponds, 200 m2 each	6000	USD	50%
1 broodstock pond, 200 m2	900	USD	8%
Building with basins	3000	USD	25%
Store	2000	USD	17%
TOTAL	11900	USD	100%

Farmcost/'000 piece

			Percentage of Costs
Feed	7,5	USD/'000 piece	11%
Labour	48,2	USD/'000 piece	73%

Material	3,6	USD/'000 piece	5%
Sundry	0,7	USD/'000 piece	1%
O&M	6,0	USD/'000 piece	9%
TOTAL	66,0	USD/'000 piece	100%

Investments/'000 piece

Rearing ponds	21,4	USD/'000 piece
Broodstock pond	3,2	USD/'000 piece
Building	10,7	USD/'000 piece
Store	7,1	USD/'000 piece
TOTAL	42,5	USD/'000 piece

8.1.2 Economics of polyculture and monoculture

This chapter presents preliminary data on the economics of polyculture vs monoculture of the African catfish . It should however be realized that the analysis is made by a compilation of biological data for monoculture obtained in the Central African Republic (1984-1985), biological data for polyculture obtained in Congo Brazzaville (1986-1990) and prices from Congo-Brazzaville (1990, 1 USD=285 FCFA). Some economic parameters are summarized in Table 17 and details are given in Table 18 and Table 19.

Table 17: Economic parameters of monoculture of *C. gariepinus* and polyculture of *C. gariepinus* and *O. niloticus*.

Parameters	Monoculture	Polyculture
Production (kg/ha/crop)	10,000	6,500
Investments (FCFA/400 m2)	180,000	180,000
Farmcosts (FCFA/100 m2)	114,000	36,000
ERR (%)	35	56
Net Cashflow (FCFA/400 m2/year	118,000	120,000

Comparison of the data indicates that from an economic point of view polyculture is slightly better due to a higher Economic Rate of Return, the net cash flow for the farmer is however more or less the same. A major difference are the farmcosts which are much higher for monoculture because

composed feed is needed in order to cover the protein requirements at the given production level.

TABLE 18: ECONOMICS OF MONOCULTURE OF *CLARIAS GARIEPINUS*

Production parameters

Production level	100	kg/100 m2
No. of rearing cycles	1,8	Cycles/year
Stocking density	10	fingerlings/m2
Pond size	400	m2
Food conversion composed feed	3	
Total annual production	720	kg

Inputs

Fingerlings	7200	No./year
Composed feed	2160	kg/year
Fertilizers	270	kg/year
Labour	80	person-days/year
Sundry	20000	FCFA/year
Operation & Maintenance	10	%

Prices

Composed feed	140	FCFA/kg
Fertilizers	80	FCFA/kg
Catfish fingerlings	10	FCFA/piece
Labour	1000	FCFA/day
C. gariepinus (200 g)	800	FCFA/kg

Investments

1 pond (400 m2)	150000	FCFA
Equipment	30000	FCFA
TOTAL	180000	FCFA

Farmcost/100 m2			Percentage of costs
Feed	75600	FCFA/100 m2	66%
Fertilizers	5400	FCFA/100 m2	5%

Fingerlings	18000	FCFA/100 m2	16%
Sundry	5000	FCFA/100 m2	4%
O&M	10400	FCFA/100 m2	9%
TOTAL		FCFA/100 m2	100%
	114.400		

Investments/100 m2			Percentage of investments
Pond	37500	FCFA/100 m2	83%
Equipment	7500	FCFA/100 m2	17%
TOTAL	45000	FCFA/100 m2	100%

TABLE 19: ECONOMICS OF POLYCULTURE OF *CLARIAS GARIEPINUS* WITH *OREOCHROMIS NILOTICUS*

Production parameters

Production level	65	kg/100 m2	
No. of rearing cycles	1,8	Cycles/year	
Stocking density *O. Niloticus*	2,2	fingerlings/m2	
Stocking density *C. gariepinus*	0,8	fingerlings/m2	
Pond size	400	m2	
Food conversion rice bran	7		
Total annual production	468	kg	
Percentage male tilapia at harvest	65%	304	kg/year
Percentage female tilapia at harvest	15%	70	kg/year
Percentage tilapia fingerlings at harvest	3%	14	kg/year
Percentage catfish at harvest	17%	80	kg/year

Inputs

Tilapia fingerlings	1584	No./year
Catfish fingerlings	576	No./year
Feed	3276	kg/year

Labour	80	person-days/year
Sundry	20000	FCFA/year
Operation & Maintenance	10	%

Prices

Rice bran	30	FCFA/kg
Tilapia fingerling	6	FCFA/piece
Catfish fingerlings	10	FCFA/piece
Labour	1000	FCFA/day
Male Tilapia (200 g)	600	FCFA/kg
Female Tilapia (100 g)	250	FCFA/kg
African Catfish (200 g)	800	FCFA/kg

Investments

1 pond (400 m2)	150000	FCFA
Equipment	30000	FCFA
TOTAL	180000	FCFA

Farmcost/100 m2			Percentage of costs
Rice bran	24570	FCFA/100 m2	67%
Tilapia fingerlings	2376	FCFA/100 m2	6%
African catfish fingerlings	1440	FCFA/100 m2	4%
Sundry	5000	FCFA/100 m2	14%
O&M	3339	FCFA/100 m2	9%
TOTAL		FCFA/100 m2	100%
	36.725		

Investments/100 m2			Percentage of investments
Pond	37500	FCFA/100 m2	83%
Equipment	7500	FCFA/100 m2	17%
TOTAL	45000	FCFA/100 m2	100%

8.2 Diseases

In general diseases are not serious a problem in polyculture or monoculture of the African catfish at low densities, up to $5/m^2$. Some fungal, parasitic and bacterial diseases can occur but will not described here as diagnostics and treatment are well presented in several handbooks (Amlacher, 1970 and Reichenbach-Klinke and Elkan, 1965). More disease problems will be encountered at higher stocking densities (over $10/m^2$), the "Thai rearing system", as often the pond environment quickly detoriates. The specific problems encountered at high stocking densities are well described in two handbooks produced in Thailand (Anonymous, 1981, Tonguthai *et al.*, 1993). However, three diseases all encountered in intensive rearing systems and indoor hatcheries in Africa are describe below.

"Crack head" disease is an obvious catfish disease reported from intensive pond rearing and hatcheries upto present in Africa (de Graaf, 1989, Janssen, 1985). The cause of this disease is not fully understood. Adverse water quality due to overfeeding and Vitamin C deficiency are believed to be the main factor causing "crack head" disease. The clinical symptoms are: slightly distended abdomen due to septicaemia and haemorrhage and occasionally exophthalmus (pop-eyes). This disease can be detected in an early stage, affected fish show a reddish lateral line on the skull, between the two air chambers, parallel to the skull plate joints. In the final stage the skull will break laterally followed by death. As soon as the external symptoms of the disease (reddish lateral line) is observed in some fish during sampling, feeding should be substantially reduced, more vitamin C (ascorbic acid) must be added to the feed and pond

water should be replaced. Generally, the fish recovers after a few weeks, after which feeding can be increased little by little.

Infections by myxobacteria was a major problem in a hatchery in the Central African Republic and could cause heavy mortalities in several days. The major cause is bad management i.e. the fish are damaged by handling, water quality detoriates and the fish are stressed. The clinical symptoms are: fish remain in vertical position or exhibit a "waddling" swimming behaviour. White spots on the skin, especially on the fins are present. Proper hatchery management reduces the risk of myxobacteria and infected fish can be treated with a Furaltadone-bath at a dose of 50 ppm for one hour.

During the yolk-sac stage sometimes the larvae develop an oedema ventral from the cardiac cavity which can cause heavy mortalities (upto 90%). The major cause is a horizontal transmission (from the female broodstock) of an *Aeromonas* bacteria. Infected larvae can be treated with a bath of Oxytetracycline at a dose of 50 ppm. Oedema in yolk-sac hatchlings can be prevented by using healthy broodstock only, for example in Congo-Brazzaville where the broodstock was kept in ponds it never occurred, while in Ivory Coast, where the broodstock was kept indoor and had clinical signs of "crackhead" disease, oedema in the yolk sac larvae was endemic (de Graaf, 1989).

8.3   Hybridization

In Africa next to *Clarias gariepinus* another catfish, *Heterobranchus longifilus* is used for aquaculture. While in south-east Asia mostly catfish such as; *Clarias macrocephalus*, *Clarias batrachus*, and *Pangassius sutshi*

were used. In the early 80's *Clarias gariepinus* was introduced in south-east Asia and its culture was propagated due to its higher growth rate, if compared with the local catfish. The introduction was however not a complete success as socio-economic factors were neglected. For example in Vietnam the consumers refused to buy *Clarias gariepinus* at a reasonable price, because of its taste and its relatively large head (which can not be consumed).

Interspecific cross-breeding in fish may lead to hybrids with valuable characteristics for culture (sterility, monosex populations, heterosis for disease resistance or growth rate, etc.).

Hybridization among the Asiatic clarids involved *C. macrocephalus* and *C. Batrachus* (Boonbrahm *et al.*, 1977), C. batrachus or *C. macrocephalus* x *Pangasius sutshi* (Tarnchalanukit, 1986), and *C. batrachus* x *Heteropneustes fossilis* (Mukhopadathy and Dehadrai, 1987). In June 1988 the Department of Fisheries in Thailand succeeded in artificially cross breeding female *C. macrocephalus* with male *C. gariepinus*. This hybrid grows faster and has more resistance to diseases than other hybrids and the hybrid is rapidly replacing *C. macrocephalus* and *C. Batrachus* in the Thai fish markets (Tonguthai *et al.*, 1993). In Viet Nam this hybrid became also very popular and in Bangladesh a hybrid between *Pangasius sutshi* and *Clarias gariepinus* has recently been put on the market (de Graaf, unpublished data).

In Africa, hybridization between *C. gariepinus* and *Heterobranchus fossilis* has been carried out (Hecht and Lublinkhof, 1985 and Legendre *et al.*, 1992). Lengendre *et al.* (1992) found that the reciprocal hybrids were viable, their survival rates being similar to those found in the maternal species. Growth rate of *H. fossilis* and the hybrids were higher if compared with *C. gariepinus*. In the reciprocal hybrids,

female first sexual maturity was attained at 20-21 month, which is much later than for *C. gariepinus* (5-7 months) or for *H. fossilis* (12-14 month) .

The male and female hybrids are however not sterile, and viable fry can be obtained from F2 or backcross fertilization. Despite the eventual advantages from an production point of view it is the opinion of the authors that this hybrid should not be produced as the environmental risks are to high, escaping hybrids could contaminate the natural stocks.

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ANNEX I: ANOU IS RAISING CATFISH, A TRAINING FILM.

G.J. de Graaf , A. Schrover and L.E. Lyklema

A simple and reliable method for the mass production of fingerlings of the African catfish *Clarias gariepinus* (Burchell 1822) was developed within the UNDP/FAO project "The development of rural fish farming in Congo". Reproduction could be induced throughout the year by using carp pituitaries. The fertilized eggs were attached to the roots of water hyacinth and incubated in a cage made of mosquito netting. Three days old larvae were placed in ponds, surrounded by a wall of aluminium roof plates (0.8 m high). Fingerlings were harvested after 40 days in order to avoid cannibalism and an average productions of 33 fingerlings/m^2 was obtained. Details of this study are published in Aquaculture Research, 26 (2) 1995.

An instruction film (40 minutes, French) was made in order to propagate this production technique. The film follows Anou, a student who wants to learn how to produce fingerlings. Anou executes a complete rearing cycle and all steps in the production cycle are visualised and explained in detail.

The film has been made as part of the UNDP/FAO Fish Farming Development Project in the Republic of Congo and can be obtained on PAL or SECAM through the Development Support Department of the Food and Agriculture Organization of the United Nations, Rome, Italy or from the NEFISCO-foundation, Amsterdam, the Netherlands.

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