

**A COMPARATIVE STUDY OF THE REPRODUCTIVE AND EARLY LIFE GROWTH
PERFORMANCE OF THREE STOCKS OF THE AFRICAN CATFISH, *CLARIAS*
GARIEPINUS, (BURCHELL, 1822) IN GHANA.**

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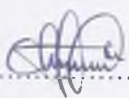
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DECLARATION

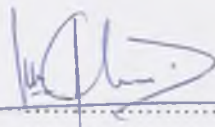
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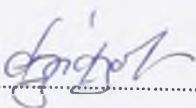
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DEDICATION

I dedicate this work to my lovely family.

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ABSTRACT

A comparative study was carried out into the reproductive and early life growth performance of three stocks of the African catfish, *Clarias gariepinus* (Burchell 1822) in Ghana under pond culture system at Aquaculture Research and Development Center (ARDEC) in Akosombo in the Eastern Region from January, 2009 to October, 2009. Broodstocks of *C. gariepinus* were collected from Kumah Farms in Kumasi (Ashanti Region), the Pacific Farms in Ashaiman (Greater Accra Region) and ARDEC at Akosombo (Eastern Region). The broodstocks were used for artificial propagation under more controlled conditions including; stripping of eggs, collection of the sperm, followed by fertilization and incubation of eggs. The fries were stocked at 2000 fries per 200 m² pond (10 fries per 1m²) in six fenced experimental ponds at an average weight of 0.003 g and harvested at an average weight of 3.304 g after six weeks pond culture for five consecutive times. Differences in fecundity ($P = 0.592$) and gonado-somatic index ($P = 0.114$) as well as specific growth rate ($P = 0.163$), condition factor ($P = 0.345$) and survival rates ($P = 0.601$) among the three stocks were all not statistically significant. Temperature, Dissolved Oxygen and pH ranges from 30.88 ± 0.75 to 31.15 ± 0.87 , 4.28 ± 2.34 to 4.99 ± 2.45 and 6.18 ± 0.15 to 6.98 ± 0.61 respectively. These water quality parameters taken were all within the conducive ranges for the culture of the fish species. No statistical difference was found among the mean weight of ARDEC stock (3.496 g), Pacific farms stock (3.304 g) and Kumah farms stock (3.256 g) indicating that *C. gariepinus* grows at approximately the same rate regardless of its geographical location. This implies that fish farmers can reduce cost and save time and resources as they rely on the nearest fish seed (fingerlings) for stocking.



CHAPTER ONE

1.0 INTRODUCTION

In recent years the culture of species of the catfish belonging to the family Clariidae is fast gaining global attention. *C. gariepinus* is probably the most widely distributed freshwater fish in Africa (Skelton, 1993). The major species of catfish that are of commercial interest and cultured in Africa include *C. gariepinus*, *Heterobranchus* spp and their hybrids. However, comparison of growth rates according to Skelton (1993) indicate that *C. gariepinus* performs better in terms of growth rates and feed conversion than other species of the genus *Clarias*. FAO (2005) emphasized that aquaculture in Ghana focusses mainly on Nile tilapia, *O. niloticus* and *C. gariepinus*.

Out of the cultured fish species worldwide, *C. gariepinus* is highly favoured owing to the following qualities: high growth rate, hardy and resistant to handling and stress, disease resistant, highly valued predominant food fish, much appreciated in a wide number of African countries, highly fecund and easily spawned under captive conditions, amenability to high density culture, related to their air-breathing habits, it is omnivorous and used as a population control check for Tilapias in a polyculture system (Huisman and Richter, 1987; Haylor, 1993; De Graaf and Janssen, 1996).

C. gariepinus has almost Pan-African distribution, ranging from the Nile to West Africa and from Algeria to Southern Africa and widespread in the tropics. Having evolved in the

Pliocene epoch (upper Tertiary period) some 7-10 million years BP, it can tolerate salinities up to 2.2 ppt (Clay, 1977).

Aquaculture potential of *C. gariepinus* in Africa was first realized by Douglas Hey at the Jonkershoek Fish Hatchery in the Western Cape Province in South Africa in 1941 (Richter, 1979). It has since been considered to be a fish of great promise for fish farming in Africa. This fish species was later confirmed as one of the most suitable species for aquaculture in Africa (CTFT, 1972; Micha, 1973; Jocque, 1975; Pham, 1975; Hogendoorn, 1979; Richter, 1979).

C. gariepinus, is also of a well-grounded position in European fish culture (Huisman and Richter, 1987; Kuczyński *et al.*, 1999), such experiments were carried out by numerous authors (among others by Eding *et al.*, 1982; De Leeuw *et al.*, 1985; Richter *et al.*, 1985, 1987; Goos *et al.*, 1987; Kouřil *et al.*, 1992; Inyang and Hettiarchichi, 1994). It is also valuable for aquaculture worldwide (Khwanjai Hengsawat *et al.*, 1997).

C. gariepinus spawn naturally in floodplains during the rainy season, and this spawning is induced by rise in water levels (Pillay, 1990). However, seed collection from the wild is unreliable and limited to the rainy season. In captivity the African Catfish does not spawn spontaneously since environmental factors such as the rise in water level and inundation of shallow areas do not occur on the fish farms (De Graaf and Janseen, 1996). A combination of physical, chemical and biological factors, such as changes in water level, pH, water temperature, clarity and flow rate, flooding of marginal plants,

associated chemical changes, and access to suitable spawning sites, are responsible for triggering the spawning of catfish which hardly reproduces in captivity (Howerton, 2001).

C. 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 (De Graaf and Janseen, 1996).

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

Since the early 1970's several techniques have been developed (with or without hormone treatment) for the artificial reproduction of the African catfish. Semi natural or hormone induced reproduction within ponds or concrete tanks 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 mass production needed for larger fish farms or distribution centers of catfish fingerlings (De Graaf *et al.*, 1995)

Artificial propagation of *C. gariepinus* under more controlled conditions including stripping of eggs, collection of the sperm, followed by fertilization of eggs is now carried out in hatcheries with hormonal induction. 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 as compared to the natural reproduction (Woynarowich and Horvath, 1980).

These advantages include better rates of fertilization and hatching, protection against predators and unfavourable environmental conditions and better conditions for growth and survival. 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 as feed.

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/m²/cycle (Micha, 1973, 1976; Hogendoorn and Wieme, 1976; Hogendoorn, 1979) or between 0 and 90 % (Micha, 1975; Janssen, 1985a).

In the late 1980's, a simple and reliable method developed by De Graaf *et al.* (1995) in Congo-Brazzaville for the nursing of *C. gariepinus* within protected ponds revealed that competition for feed and cannibalism were the major factors affecting pond nursing.

1.1 JUSTIFICATION

Despite the popularity of *C. gariepinus* as a species for culture and its great market potentials, production is still basically at subsistence level due largely to inadequate availability of seed for stocking and feed problems. In Ghana, the fingerlings supplied from both the government and privately owned hatcheries are not enough to meet the catfish farmers' fingerling demands as such its market demands far exceeds supply. There is therefore an urgent need to increase the supply of seed through the development of simple and efficient seed production and management protocols that are easy to adopt by small-scale fish farmers themselves.

In fish reproduction under controlled conditions attempts are made to obtain eggs of the highest weight possible and of the best quality, and hence to produce the highest possible numbers of good quality hatch. Up till now, there is lack of adequate scientific information on the reproductive and early life growth performances of different stocks of *C. gariepinus* in Ghana.

This study was therefore geared towards comparing the reproductive and early life growth performance of three stocks of *C. gariepinus* in Ghana as baseline information that will be employed to genetically improve the fish species in Ghana.

1.2 OBJECTIVES

The main objectives of this study were to determine and compare the reproductive capacity of broodstocks of *C. gariepinus* from three different populations and the early life growth performance of their fries in Ghana.

The specific objectives were to:

- compare the fecundity, hatchability and gonado-somatic index of the broodstocks from Kumah farms (Kumasi), Pacific farms (Ashaiman) and ARDEC (Akosombo).
- compare the growth rate, survival rate, condition factor and specific growth rate of the fries of the broodstocks from Kumah farms (Kumasi), Pacific farms (Ashaiman) and ARDEC (Akosombo).
- assess the ambient water quality environment for culture of the fries of the broodstocks from Kumah farms (Kumasi), Pacific farms (Ashaiman) and ARDEC (Akosombo).



1.3 RESEARCH HYPOTHESIS

- H_0 : Growth rate of the fries of the broodstocks of *C. gariepinus* from Kumah farms (Kumasi), Pacific farms (Ashaiman) and ARDEC (Akosombo) in pond culture system in Ghana is not significantly different.
- H_1 : Growth rate of the fries of the broodstocks of *C. gariepinus* from Kumah farms (Kumasi), Pacific farms (Ashaiman) and ARDEC (Akosombo) in pond culture system in Ghana is significantly different.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Taxonomy and Morphology

C. gariepinus belongs to the Kingdom Animalia, Phylum Chordata, Subphylum Vertebrata, Order Siluriformes, Family Clariidae, Genus *Clarias*, Species *gariepinus*, Scientific name: *Clarias gariepinus*. Based on morphological, anatomical and biographical studies carried out by Teugels (1982a, 1982b, 1984), six species were identified in the freshwaters of Ghana as follows: *C. gariepinus* (Burchell, 1822), *C. anguillaris* (Linnaeus, 1758), *C. laeviceps* (Gill, 1863), *C. camerunensis* (Lonnberg, 1922), *C. ebriensis* (Pellegrin, 1922), *C. agboyiensis* (Sydenham, 1980).

The *Clarias* genus can be described 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. The outer pectoral ray is in the form of a spine and the pelvic fin normally has six soft rays. 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 (De Graaf *et al.*, 1995).

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, the skin 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 (De Graaf *et al.*, 1995).

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. *Clarias spp.* inhabits 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, 1979; Clay, 1979).

2.2 Reproduction of *C. gariepinus*

Information on the reproduction of *C. gariepinus* has been given by several researchers in Africa (Mulder, 1971; Willoughby and Tweddle, 1978; Bruton, 1979; Clay, 1979; Micha, 1976; Richter, 1979; Clay, 1981; Nawar and Yoakim, 1984; Quick and Bruton, 1984).

Many *Clarias* species undertake lateral migrations from the larger water bodies in which they feed and mature, according to Legendre and Jalabert (1988) at about the age of two years under natural conditions (but sometimes 7-8 months in captivity), to temporarily flooded marginal areas to breed (Seegers, 1996).

These reproductive migrations typically take place shortly after the onset of the rainy season(s). Predictive cues for gonadal maturation include increasing temperature, photoperiod and electrical conductivity, while proximate cues for final maturation are associated with rising water levels (De Graaf and Janssen 1996; Legendre and Jalabert 1988).

The adult female *C. gariepinus* has a fully developed ovary which contains "ripe" eggs the whole year through and is capable of reproduction if kept in ponds at water temperature above 22 °C. The oocyte development decreases once the temperature drops below 22 °C (Young and Fast, 1990).

Under ideal conditions, the ovary of a mature female constitutes 15-20% of the fish's body weight, with about 600 ova per gram of ovulated eggs (De Graaf and Janssen, 1996). Willoughby and Tweddle (1978) stated that the mature ovaries contained between 600 and 1,400 eggs per gram wet weight for *C. gariepinus* living in the Shire Valley, Malawi.

In the dry season (June-July-August) the water temperature drops below 22 °C and the ovary makes up approximately 5% of the body weight of the female. Artificial reproduction is still possible but the number of eggs obtained is small and the quality of the eggs decreases (De Graaf and Janssen, 1996).

In general, the testis of a male is fully developed at an age of 8-12 months once the males 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 (De Graaf and Janssen, 1996). Wootton (1992) stated that the fish reach sexual maturity at an unusually small size (in length and weight) in stunted populations. Some factors, such as pollution, uncontrolled hunting and other physical and chemical factors, may stunt the *C. gariepinus* population.

Ovarian anatomy in *Clarias* is typical for teleostians. The testes, on the other hand are peculiar, being divided into two parts: an anterior functional testes and a posterior cluster of seminal vesicles, the role of which is not precisely understood but which may contribute to sperm longevity and motility (Legendre and Jalabert, 1988). In terms of gonadal activity, males appear to be less sensitive to temperature fluctuations than females (De Graaf and Janssen, 1996).

Prior to mating, males have been reported to compete aggressively for females with which they mate in single pairs, with the female swishing her tail vigorously to mix the eggs and sperm and distribute the fertilized eggs. The adhesive eggs stick to submerged



vegetation, hatch in 20-60 hours, depending upon temperature (De Graaf and Janssen, 1996).

The yolk sac is absorbed within 3-4 days (De Graaf and Janssen, 1996) and the stomach is fully functional within 5-6 days after onset of exogenous feeding (Hecht, 1996). Sexual differentiation begins between 10-15 days after hatching (Legendre and Jalabert, 1988). The female is the heterogametic sex (Volckaert and Agnèse, 1996).

Larvae feed on phytoplankton and grow rapidly in the warm, nutrient-rich floodplain, reaching a size of 3-7 grams within 30 days (De Graaf *et al.*, 1995). As flooded marginal areas dry up with the end of the rains, juveniles and adults make their way back to deeper water. In areas with two rainy seasons, there are usually two reproductive peaks during the year, corresponding in intensity to the magnitude of the rains (Young and Fast, 1990).

Egg and larval fish can be mainly divided into 5 stages: (1) Egg phase (Incubation period); (2) Prolarval stage (yolk sac stage); (3) Larval stage (absorbed yolk sac but incomplete organs); (4) Postlarval stage (absorbed yolk sac and complete organs) and after that they will develop to (5) juvenile stage (fry and fingerling). In this stage they are similar to adult fish but smaller and reproductive organs are not matured (De Graaf and Janssen, 1996).

The use of high quality gametes from captive fish broodstock is of great importance for ensuring the production of viable larvae (Kjorsvik *et al.*, 1990). The fish farming industry

has been more focused on the quality of eggs or larvae rather than that of sperm, even though the quality of both gametes may affect fertilization success and larval survival (Bozkurt *et al.*, 2006). It is well known that the size of eggs of fish shows considerable intra- and inter- specific variation. Even parental fish of the same strain, weight and length have eggs that are in different sizes (Bagenal, 1971).

Egg size is primarily determined by the genotype of parents of fish and it is also known to be affected by other factors including age and size of the female parent. Gall (1974) has shown in studies of hatchery-reared trout that older and heavier females produce larger eggs than younger and smaller fish. The availability of food also affects egg size (Springate *et al.*, 1985). Alterations in egg size also occur in batch-spawning fish as the season progresses (Bagenal, 1971) and in synchronous spawners as a result of photoperiodic modifications of maturation (Bromage *et al.*, 1984).

Sperm quality data are required for successful fertilization. Viable sperm is an essential component in any successful animal production operation and the success of reproductive process is dependent on a supply of high quality gametes (Cruz-Casallas *et al.*, 2005). In addition, sperm quality is a measure of the ability of sperm to successfully fertilize an egg. Any quantifiable physical parameter that directly correlates with the fertilization capacity of sperm could be potentially used as a measure of sperm quality. Optimal sperm quality is important for effective broodstock management and should be a criterion in the selection of male broodstock (Bozkurt *et al.*, 2006).

In commercial hatcheries, sperm is often inadequate both in terms of quantity and quality and it does not always give successful fertilization in the artificial insemination procedures commonly used for aquaculture species. Spermatozoa motility is the most reliable indicator used to evaluate semen quality. However, investigations of the relationship between spermatozoa motility and fertility have given conflicting results or were of little value in predicting fertilization potential (Bozkurt, 2006).

Subjective estimation of motility requires considerable experience and this indicator is being used in the selection of sperm for insemination and preservation. Spermatozoa motility varies in vigor and duration not only among males but also within an individual male depending on its ripeness (Graham *et al.*, 1978). The highest motility of the spermatozoa is observed at the peak of the breeding season (Terner, 1986). Studies on most fish species recorded that motility of spermatozoa may show seasonal variation (Benau and Terner, 1980).

Fecundity which is the number of ripening eggs found in the female prior to the spawning act (Bagenal, 1978) varies greatly in individuals of one species of the same weight, length and age, but in many species it increases in proportion to the size of fish (Lowe-McConnell, 1975). Fecundity is known to be affected by stress and nutritional deficiency (Hogendoorn and Vismans, 1980).

Most studies of reproduction tend to consider fecundity and egg size as separate indicators of reproductive performance. It is generally accepted that there is an inverse

relationship between fecundity and egg size in which fish produce either more eggs of a smaller size or fewer eggs of a larger size (Springate *et al.*, 1985; Bromage *et al.*, 1992).

Egg size is more important than fecundity for the fertilization success. During incubation, the eggs should be well oxygenated for maximum hatching to occur (Hogedoorn, 1980; Viveen *et al.*, 1985; De Graaf and Jansen, 1996). Moreover, the poor survival of eggs and larvae is mainly the result of inadequate nutrition during the nursing phase and careless nursery management practices. Successful hatching of fish eggs and careful feeding of larvae during the early stages of their development is essential for better survival of larvae.

There is strong evidence that the degree of stress; the feeling of pain and fear (Broom, 1998) in female affect the quality of eggs in induced spawning (Pickering *et al.*, 1995). In fish, stress response to different stimuli is well documented (Barton and Iwama, 1991; Iwama *et al.*, 1997; Wendelaar-Bonga, 1997; Iwama *et al.*, 1999; Ruane, 2002). Wendelaar-Bonga (1997) stated that stress is a condition in which the dynamic equilibrium of animal organisms, called homeostasis, is threatened or disturbed as a result of the actions of intrinsic or extrinsic stimuli, commonly defined as stressors.

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 °C. The development of the oocytes of the African catfish is mostly related to temperature (as is

common with a large number of fish species). According to Owiti and Dadzie, (1989), six chronological stages can be seen within the development of oocyte (Appendix 1).

For hormone induced reproduction (semi artificial or artificial) the following hormones are generally used (De Graaf *et al.*, 1995):

- 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 extract, 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 *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.

2.3. Early growth performance of *C. gariepinus*

Growth of fish larvae, postlarvae, fry and fingerling reared in pond, hapa (mosquito netting) and tank varies according to species and within species depending on factors such as stocking rate, water temperature, feed and feeding, intensity of light. Growth in *Clarias* species is relatively rapid, with most species approaching their maximum size within a couple of years.

Most *Clarias* species are relatively r-selected (altricial) with medium to high resilience (population doubling time of 15-30 months) and rapid growth to relatively early sexual maturity, high fecundity and a (anticipated) short lifespan (Hecht, 1996). The author further stated that first year growth in the larger, k-selected species (e.g., *C. gariepinus*) is nearly linear resulting in the large initial jump in size (Merona *et al.*, 1988).

Length and weight relationships are of great importance in fisheries research because they provide information on population parameters (Garcia *et al.*, 1989; Krause *et al.*, 1998; Haimovici and Velasco; 2000; Øvredal and Totland; 2002). Length and weight measurements in conjunction with age data can give information on the stock composition, age at maturity, life span, mortality, growth and production (Beyer, 1987; Bolger and Connolly, 1989; King, 1996a and b; Diaz *et al.*, 2000).

First, a change in length and weight tells the age and year classes of fishes, which is important in fishery and Pisciculture. Secondly, the data can be used to estimate the mortality rate, and thirdly they can be used to assess the sustaining power of the fishery

stock. In addition, the data on length and weight can also provide important clues to climatic and environmental changes, and the change in human subsistence practices (Luff and Bailey, 2000).

However, the size attained by the individual fish may also vary because of variations in food supply, and these in turn may reflect variations in climatic parameters and in the supply of nutrients or in the degree of competition for food. Thus, a change in average size through a certain period of time may indicate a change in average age resulting from those factors (Pauly, 1985). Environmental deterioration, for example, may reduce growth rates and may cause a decrease in the average age of the fish. In reality, the interactions between environmental changes and growth rates for instance are believed to be complex and difficult to explain (Hecht and Uys, 1997).

Growth is density dependent; the higher the rearing density of larvae, the lower their growth rate. Stocking density of *C. gariepinus* is considered the most important factor affecting cannibalism and aggression. It is known to have a strong influence on growth, survival and behaviour of fish (Hecht and Appelbaum, 1988). Increasing the number of fish per culture unit is one of the most common practices under farm conditions to increase production. Multiple sorting is essential owing to the cannibalistic nature of *C. gariepinus* (Kaiser *et al.*, 1995).

Feeds and feeding of the larvae, fry and fingerlings of the catfishes have been most studied and shown to influence the growth and survival of the fish. Studies have revealed

that live zooplankton is the preferred larval food. Many smallholdings merely rear larvae to fingerling size in organically fertilized ponds at a density of between 30-1000 larvae/m². Fingerlings are stocked into rearing ponds at a rate of 50-75 fish/m³ under good management (Olaleye, 2005).

Davy and Chouinard (1980) noted that the most critical area of fish fry production and the major critical period is immediately before and during the initiation of first feeding. If food is not immediately available to fish hatchlings the fry may become weak and become predisposed to predation in natural rearing systems (Rana, 1990). Availability of zooplankton during the first week after stocking is essential for the successful nursing of the catfish larvae.

If the initial feeding of *C. gariepinus* fry is delayed beyond 4 - 5 days, more than 50% of the fish may die (Owodeinde *et al.*, 2004). Huisman *et al.*, (1976) considered the lack of suitable food as the main cause of mortality in most fishes at this stage, emphasizing the importance of, not only, of the quantity and quality, but also the feed size.

Live food such as *Artemia*, *Daphnia*, rotifers, and copepods are the most satisfactory "first food" for fry (Bard *et al.*, 1976). After this transition period of two weeks the fry can detect and eat artificial food (Madu *et al.*, 1993). Consumption of live food during the first four days of feeding ensures adequate survival of *C. gariepinus* fry (Adeyemo *et al.*, 1992). Micha (1973) analyzed the stomach contents of 15-day-old *C. gariepinus* fry and

reported that the entire food contents was zooplankton, and that beyond that age the contents changed to larvae of aquatic insects and eventually artificial feed.

In general after four to five weeks after stocking, two main size groups of catfish can be recognized within the pond (De Graaf *et al.*, 1995):

- 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.

According to De Graaf *et al.*, (1995), three factors are probably influencing fingerling production in ponds;

- The presence of amphibian predators like adult frogs which can cause mortality of 10% due to predation.
- A competition for food resources. Phytoplankton levels, in the unprotected ponds, are reduced by the presence of phytophagous frog larvae, consequently leading to a reduction in availability of zooplankton, needed by the catfish larvae. This effect is critical during the first days of exogenous feeding of the larvae and determines the limits of the nursery system which is dependent on natural food production. Production levels up to 800 fingerlings/m² are reported by Hecht *et al.* (1988), the nursing ponds however are stocked with 10 day old larvae which



passed the critical moment before which live food or a real “baby” diet (Verreth *et al.*, 1991) is essential for survival and production.

- Sibling cannibalism has been observed earlier among fry of *C. gariepinus* in hatcheries (Janssen, 1985) and has been studied in detail by Hecht *et al.* (1988). Within aquarium experiments two types of cannibalism can be distinguished; type 1 or tail first cannibalism, where predator and prey size are almost equal, occurring in a weight range of 0.006 g – 0.9 g and Type 2 or head first cannibalism, where predator size exceeds prey size, occurring in a weight range of 0.9 g – 4.6 g. Once the weight of the fish exceeds 4.6 g, cannibalism ceased to exist in these aquarium experiments due to the fact that the mouth width of the largest fish in the sibling population is smaller than the head width of the smallest fish. In ponds, two main groups of fingerlings can be distinguished 40 days after stocking: a small group (0–3%) with an weight ranging between 8–12 g, and a large group ($\pm$ 97%) of fingerlings weighing 0.5 –3 g. It is most likely that type 2 cannibalism continues to be of importance due to its higher size variation as compared with the experiments of Hecht *et al.*, (1988). This phenomenon explains why after a long rearing period the number of fry harvested is low and their average weight is high.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area:

The study was conducted in Akosombo (Fig. 3.1) at the Aquaculture Research and Development Centre (ARDEC) of the Water Research Institute (WRI) of Council for Scientific and Industrial Research (CSIR) in the Eastern Region of Ghana from January, 2009 to October, 2009. Akosombo lies at latitudes 06°13'N and longitude 00°04'E. ARDEC has aquaculture facilities such as twenty (20) 0.2 ha ponds, twenty (20) 200 m² experimental ponds (out of which six (6) were used to conduct the study: plates 1 and 2), twenty (20) 50 m² ponds, a pumping machine that pumps water from the Volta Lake to the ponds, a Laboratory where the analyses of the water quality parameters were done, feed formulation machine among others.

3.2 Collection of fish Samples.

Broodstock (gravid females and matured males) of the African Catfish, *Clarias gariepinus*, were collected from three populations namely Kumah Farms Complex in Kumasi (Ashanti Region), the Pacific Farms in Ashaiman (Greater Accra Region) and the Aquaculture Research and Development Centre (ARDEC) at Akosombo (Eastern Region). The Kumah Farms Complex population had its source (the fingerlings) from

River Tano in Techiman whereas the populations from Pacific Farms and ARDEC had their sources from a stream in Ashaiman and the Volta Lake in Dzemeni respectively.

3.2.1 Broodstock Management

The broodstocks collected from the fish farms were kept for two months in three separate earthen experimental ponds of sizes 200 m² each and fed twice a day at 9.00 GMT and 15.00 GMT with formulated pelleted feed of 40% crude protein constituting 40% fish meal, 35% wheat brown and 25% maize. After the two months' culture period, the matured females of average size 950 g were 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
- A swollen, sometimes reddish or rose coloured genital papilla.

Matured male broodstocks of average size 887 g were also identified using their distinct sexual papilla located just behind the anus (Plate 3).

3.3 Artificial Reproduction (Hypophysation)

Broodstocks (Plate 4) from the three Stocks were taken from the ponds every two months for five consecutive times. For each time, the broodstocks were held in 1 m² happas (one fish in one happa) fixed in round concrete tanks (Plate 5) to condition them for three days.

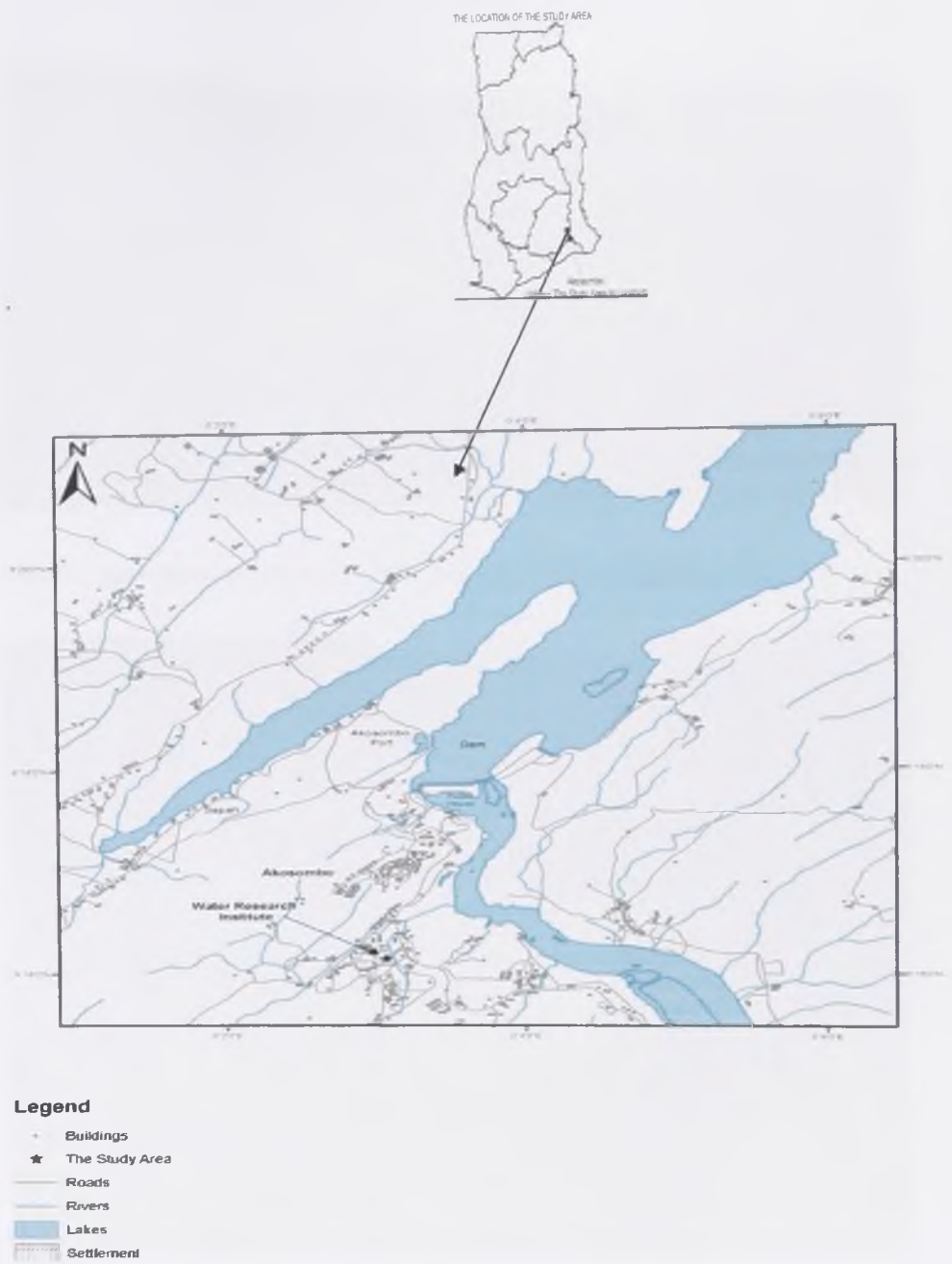


Fig. 3.1 The study area, ARDEC, Akosombo.



Plate 1: Experimental ponds used for the study at ARDEC, Akosombo.



Plate 2: Feeding of fries stocked in pond.



Plate 3: Sexing of *C. gariepinus*



Plate 4: Some of the Broodstock used



Plate 5: Concrete tank used to hold fish



Plate 6: Removal of pituitary gland



Plate 7: Injection of Female broodstock



Plate 8: Testes of a male broodstock



Plate 9: Stripping of eggs of the injected female



Plate 10: Eggs in Hatchery bowls



Plate 11: Fry kept in bowls



Plate 12: Some fingerlings harvested

3.3.1 Hormone injection

After the conditioning period, males of approximately the same weight as the females from the three Stocks were weighed with an Electronic Scale of Model KERN 572 and sacrificed using a sharp knife to cut off the head whilst covering the head with a dry towel. The pituitary glands extracted from the dissected heads (Plate 6) were ground in a portable mortar with a pistil and mixed with a physiological saline solution (9.0 g of common salt/litre of water). The testes (milt) of the sacrificed males were preserved in the physiological saline solution.

A syringe was filled with 5ml of the suspension of the ground pituitary gland and injected intra-muscularly at about 21.00 GMT into the dorsal muscle just below the tail peduncle of the female broodstocks (Plate 7) following the method described in De Graaf and Janssen (1996) and Viveen *et al.*, (1985). The head of the breeders were covered with a towel in order to keep them quiet during the injection of the pituitary hormone. All the injected females were returned to the separate hapas fixed in different concrete tanks filled with water to enable the breeders to be caught easily the morning after injection so as to avoid spoilage of eggs.

The pituitary gland extract triggered the maturation of the eggs of the gravid females. The time of injection until the time of ovulation is temperature dependent (De Graaf and Janssen, 1996). The maturation processes of the eggs were completed within 6 to 12



hours (a clock was used to monitor the time) at a temperature of within 26 to 28°C (using a thermometer).

3.3.2 Maturation processes, stripping and incubation of fertilized 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. The speed of the process is dependent upon water temperature, the higher the temperature the quicker the eggs ovulate.

The males of the African catfish could not be stripped and consequently the sperm was only obtained by sacrificing a male. The male was killed and the body surface thoroughly dried after which the testis was dissected and placed in a mortar. The testes (Plate 8) of the sacrificed males were rapidly cut into small pieces using a pair of scissors. The milt was then pressed out of the testes with both hands (Janssen, 1985, De Graaf, 1989) into dry plates. The eggs (Plate 9) of the injected females were stripped out into separate dry plastic containers by gently pressing their abdomen with a thumb from the pectoral fin towards the genital papilla. This was done to avoid direct contact between the eggs and water since the latter renders the eggs infertile.

Eggs stripped after 6 hours of injection flowed out easily in a thick jet from the genital vent. The ovulated eggs were more or less transparent and flattened. The milt of the males was sprinkled on the stripped eggs and stirred in order to prevent the eggs from sticking together into one clump. The eggs mixed with clean water stored in reservoir tanks were stirred continuously for about 60 seconds and then left for about 120 seconds before spreading it at the bottom of the hatchery bowls (Plate 10) with a constant flow of water in order to provide enough oxygen.

After hatching, the larvae (hatchlings) swam to the surface of the hatchery bowl where they were siphoned from the remaining egg-shells and dead eggs into bigger bowls (Plate 11) with clean water from the reservoir tanks in order to avoid fungal infections of hatchlings and consequent larval mortalities. This water was changed every 12 hours to enable the fry have enough oxygen at all times. The eggs that could not hatch turned whitish which is an indication of its unviability.

The hatchlings were not exposed to direct sunlight since healthy larvae tend to stay in dark places in the wild (De Graaf *et al.*, 1995). They were not fed for the first three days as they relied on the food resource within their yolk sac. After the three days, the yolk sacs were absorbed and the hatchling visibly developed into a fry.

In order to enhance further development and survival of the fry at this stage, they were fed with live food namely *Artemia nauplii* for three days after which they were fed alternatively with both *Artemia nauplii* and powdered feed for two days and finally with

only powdered feed for additional two days before stocking them in the ponds. This was done to introduce them to the powdered feed that they would be fed with during the pond culture period.

3.4 Fry nursing in earthen ponds

3.4.1. Pond preparation and Stocking

Six fenced 200 m² experimental ponds (three stocks with two replicates each) stocked at 2000 fry per pond with an average fry weight of 0.003 g were used for the nursing period of fry for five consecutive times at a duration of six weeks (42 days) each. Before water was pumped from the Volta Lake near ARDEC into the nursery ponds using the Hidel pump, grasses were cut and excess silt from the pond bottom removed. The pond bottoms were then allowed to dry for 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.

Quicklime (CaO) of about 3 kg weight was used to lime each nursing pond before stocking for the culture period. This was done to disinfect the pond bottom, increase the pH of water and pond bottom to an optimum level (pH 7-9) for plankton and fish production and also increase the alkalinity of water.

3.4.2 Daily supplementary feeding

Daily supplementary feeding of the fry started a day after stocking with formulated powdered feed of 40% crude protein consisting 60% fish meal, 35% wheat brown and 5% maize. The feed was ground and sieved with a mosquito net to much smaller size that could be consumed by the fry. Feed was broadcast on the surface of each pond three (3) times daily within every 4 hours (8:00 GMT, 12 GMT and 4:00 GMT) at a rate of 200 g per day.

3.4.3 Sampling of fry

Sampling of the fry was done after every six weeks culture period. Data on Standard Length (SL) was taken to the nearest ± 0.1 mm using Measuring Board and the Weight (W) to the nearest ± 1.0 g using an Electronic Scale of Model KERN 572.

3.5 Reproductive and Growth Parameters

3.5.1 Fecundity

The stripped eggs for each female were weighed with an electronic scale of model KERN 572. Samples (0.5 g) of eggs was taken in three replicates for each female and counted. The total number of eggs was estimated from the averages taken as follows:

Fecundity = (Weight of eggs counted / Total weight of eggs stripped) $\times$ Average number of eggs counted (Ricker, 1975).

3.5.2 Gonado-Somatic Index (GSI)

The Gonado-Somatic Index of both males and females were calculated by the formula:

$$\text{GSI} = (\text{Gonad weight} / \text{fish body weight}) \times 100\% \text{ (Ricker, 1975).}$$

3.5.3 Hatchability

After the hatching period, samples of both eggs that did not hatch and the hatched fry were taken in three replicates from the hatchery bowls. The fry was separated from the eggs that did not hatch and both counted. The hatching rates were then calculated by the formula:

$$\text{Hatching Rate (\%)} = (\text{Average number of fry counted} / \text{Total number of both fry and eggs}) \times 100\% \text{ (Ricker, 1975)}$$

3.5.4 Survival Rate

Survival rate of the fry (now fingerlings) was determined after every final harvesting of the fingerlings (Plate 12). The total number harvested was counted. The survival rate was then computed as:

$$\text{Survival Rate (\%)} = (\text{Number of survivals at the end of the experiment} / \text{number stocked}) \times 100\% \text{ (Ricker, 1975).}$$

3.5.5 Specific Growth Rate (SGR)

Specific Growth rate which is the increase in cell mass of the fry per unit time is expressed as the per cent daily fish body weight gain throughout the culture period. Both the final and initial weights of the fry were taken using an electronic scale of model KERN 572. The average specific growth rate for each Stock was then calculated as follows:

Specific Growth rate (SGR) in %/day = $100 (\ln W_2 - \ln W_1) / \text{change in time (t)}$ (Ricker, 1975).

Where:

- $\ln W_1$ and $\ln W_2$ are natural logarithm of the initial and final weights (in grams) of the fish respectively.
- Change in time is the culture period (in days) for which fish has grown from W_1 to W_2 .

3.5.6 Weight gain

After every culture period of fry, 200 fish were sampled from each Stock. The average weight in grammes was used to calculate the Mean Weight Gain as well as the Mean Daily Weight Gains as follows:

Mean Weight Gain = final weight (g) – initial weight (g) (Ricker, 1975).

Mean Daily Weight Gain (MDWG) = $(W_2 - W_1) / (W_2 - W_1) \times 0.5t$ (Ricker, 1975).

Where:

- W_1 and W_2 are initial and final weights (in grams) of the fish respectively.

- t = culture period (in days) for which fish has grown from W_1 to W_2 .
- 0.5 = constant

3.5.7 Condition Factor

The condition factor (K) is a quantitative parameter of the well-being state of the fish and reflects recent feeding conditions. The total lengths in cm and weights in grams of 200 sampled fish from each Stock after every culture period were taken and used to calculate condition factor as follows:

Condition Factor: $K = (W / L^b) \times 100\%$ (Ricker, 1975).

Where:

- W = weight in grams
- L = total length in (cm)
- b = regression co-efficient (slope) of weight / length plots

3.6 Water Quality Parameters

The water quality parameters (physicochemical parameters) of the culture medium were taken every two weeks.

3.6.1 Temperature, Dissolved Oxygen and pH

The temperature ($^{\circ}\text{C}$), dissolved oxygen (mg/l) and pH of the pond water for the three stocks were measured *in situ* using the WTM Inolab Oxi Level 2 Oxygen metre for both temperature and dissolved oxygen and then Suntex model SP-701 pH meter for pH. For all the three parameters, the probes of the measuring instruments were immersed into the ponds at a depth of about 10 cm at the middle of the ponds and the readings taken from the meters when equilibrium was attained.

3.6.2 Turbidity.

About 5 ml of water samples from each pond was poured into a cuvette and inserted into the cell holder and the value read from the already calibrated Turbidity metre in Nephelometric Turbidity Units (NTU).

3.6.3 Ammonia ($\text{NH}_3\text{-N}$)

The Direct Nesslerization Method was used to determine Ammonia. A 50 ml of each water sample was measured into a conical flask. 1 drop (0.05 ml) ethylenediaminetetra acetic acid (EDTA) reagent was added and mixed well; 2 ml Nessler Reagent was then added and well mixed. A 50 ml zero blank and a 50 ml standard of 1.00 mg/l $\text{NH}_3\text{-N}$ were also treated the same way. A reaction process of at least 10 minutes was allowed with the Nessler Reagent. Ammonia-nitrogen's presence was indicated by the yellow colouration. The Comspec M201 visible spectrophotometer at a wavelength of 420 nm



with a 1 cm light path cell or cuvette was used to standardize the zero blank and standard. Ammonia concentration in samples was measured in mg/l to 2 decimal places.

3.6.4 Nitrite ($\text{NO}_2\text{-N}$).

Diazotization Method was used in the determination of nitrite in samples. A 10 ml of each sample of water was measured into a test tube and 1 ml of 0.3 M sodium hydroxide solution added. A 1 ml colouring reagent was also added to each sample. A zero blank and standard of 0.1 mg/l $\text{NO}_2\text{-N}$ was used to standardize the visible spectrophotometer at a wavelength of 543 nm. The concentration of $\text{NO}_2\text{-N}$ in mg/l was read with a 1 cm light path cell after 10 minutes of colour development. The presence of a pink colouration indicated nitrite-nitrogen.

3.6.5 Nitrate ($\text{NO}_3\text{-N}$).

Nitrates were determined using the Hydrazine Reduction Method. A 10 ml of each sample of water was measured into a test tube and 1 ml 0.3M NaOH (Sodium Hydroxide) solution added. A 1 ml reducing mixture was also added. The mixture was then heated for 10 minutes at 60 °C and cooled. 1 ml of colouring reagent was added and 10 minutes reaction period was allowed. A zero blank and standard of 1.00 mg/l $\text{NO}_3\text{-N}$ mixture were used to standardize the visible spectrophotometer at a wavelength of 543 nm with a 1 cm light path cell. Nitrate concentration in samples was measured in as $\text{NO}_3\text{-N}$ to 2 decimal places

3.7 Data Analysis

The data on both the growth characteristics and the water quality parameters were statistically analyzed using GraphPad INSTAT software program (GraphPad Software, 1993) and presented graphically using Microsoft excel programme. A One-Way Statistical Analysis of Variance (ANOVA) was done for the Female Broodstock weight, Male Broodstock weight, Male gonad weight, Egg weight, Fecundity, Gonadosomatic Index, Fingerlings weight gained, Specific growth rate, Condition factor and Survival rate of the fish from the three stocks using MINITAB. This was to determine whether the observed differences were significant.

Data on the fecundity and fish weight, fecundity and gonad weight and length and weight of fish from the three stocks were subjected to Regression and Correlation Analysis at a ($P < 0.05$) significance level in order to determine the relationship between them. The standard deviation in each growth parameter was calculated and expressed as means $\pm$ SD.

CHAPTER FOUR

4.0 RESULTS

4.1: Reproductive Characteristics of *C. gariepinus*.

The average weights of brood fishes, gonad weights and fecundity recorded in Table 4.1 reveals that Pacific Farms Stock (P) recorded the highest average weight of female brood fish (1110 ± 364.7 g) followed by ARDEC Stock (A): (1060 ± 251.00 g) and then Kumah Farms Stock (K): (1020 ± 148.32 g). For the average egg weights, Stock P brood females had the highest (156 ± 53.8 g) followed by Stock K (124.7 ± 62.67 g) and then Stock A (90.68 ± 39.24). The gonado-somatic indexes of the female broodstocks were 8.69%, 12.23% and 14.14% for stock A, stock K and stock P respectively. The average fecundity for Stock P, Stock K and then Stock A are 8.57×10^4 eggs, 7.06×10^4 eggs and 6.43×10^4 eggs respectively. Stock P recorded an average total number of 58471 eggs hatched representing 68.25%, followed by stock K with 53256 eggs hatched (75.48%) and stock A had 46644 eggs hatched (72.54%).

For the males, the highest average weight was recorded by Stock K (975.0 ± 244.58 g) followed by Stock P (887.5 ± 252.98 g) with Stock A (581.30 ± 151.00 g) recording the least. Stock P males recorded the highest gonad weight (4.17 ± 3.75 g). This was followed by Stock K (2.92 ± 2.15 g) and the least by Stock A (2.03 ± 1.21 g). The gonado-somatic

index for stock K (0.09%), stock A (0.34%) and stock P (0.47%) were all less than 1% of the male broods fish body weight.

Upon subjecting the data to one-way analysis of variance (Appendix 2), it was realized that there were no significant relationship between the female broodstocks weights ($F=0.14$, $P=0.871$), egg weights ($F=1.95$, $P=0.184$), gonad weights ($F=1.70$, $P=0.207$) as well as fecundity ($F=0.55$, $P=0.592$) whereas a highly significant relationship existed between the male broodstocks weights ($F=8.64$, $P=0.002$).

The locality, number of eggs per female of *C. gariepinus* and the Authors (table 4.2) were compared. Mulder (1971) had the highest eggs per female: 293 - 446 ($\times 10^3$) in Transvaal, South Africa followed by Micha (1973): 3 - 328 ($\times 10^3$) in Ubangui River, West Africa, Nawar and Yoakim (1984): 13.9 - 164.8 ($\times 10^3$) in River Nile, North Africa, Bruton (1979): 52 - 163 ($\times 10^3$) in Lake Sibaya, South Africa, Richter (1976): 10 - 120 ($\times 10^3$) and the least of 64 - 85 ($\times 10^3$) from Kumah farms, Pacific farms and ARDEC.

Table 4.1: The stock, sex, average fish weight, average gonad weight, average number of eggs, hatchability and the Gonado-Somatic Index of *C. gariepinus*.

STOCK	SEX	TOTAL NO	AVERAGE	AVERAGE GONAD	AVERAGE	HATCHABILITY		GSI
		OF FISH	FISH WT(g)	WT (g)	NO OF EGGS	TOTAL NO	PERCEN	
						OF EGGS	TAGE (%)	
ARDEC	FEMALES	5	1060.00±	90.68±	64301±	46644	72.54	8.69
(A)			251.00	39.24	30686			
	MALES	8	581.30±	2.03±	-	-	-	0.34
			151.00	1.21				
	FEMALES	5	1110.00±	156.00±	85672±	58471	68.25	14.14
PACIFIC			364.7	53.80	30281			
(P)	MALES	8	887.50±	4.17±	-	-	-	0.47
			252.98	3.75				
	FEMALES	5	1020.00±	124.7±	70556±	53256	75.48	12.23
KUMAH			148.32	62.67	33566.28			
(K)	MALES	8	975.00±	2.92±	-	-	-	0.09
			244.58	2.15				

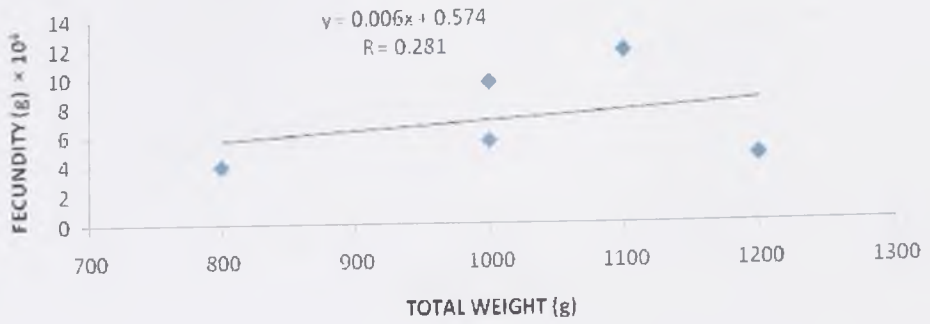
Table 4.2: The locality, number of eggs per female of *C. gariepinus* and the Authors

LOCALITY	NO. OF EGGS PER FEMALE($\times 10^3$)	AUTHORS
Transvaal, South Africa	293 - 446	Mulder (1971)
Ubangui River, West Africa	3 - 328	Micha (1973)
Central and West Africa	10 - 120	Richter (1976)
Lake Sibaya, South Africa	52 - 163	Bruton (1979)
River Nile, North Africa	13.9 - 164.8	Nawar and Yoakim (1984)
Kumah farms, Pacific farms and ARDEC	64 - 85	Thesis (current study)

4.1.1 Relationship between fecundity, gonad weight and fish body weight

Stocks P, A and K according to Fig. 4.1 show a correlation of ($r = 0.809$), ($r = 0.434$) and ($r = 0.281$) respectively between the fecundity and the fish body weight. The Stock K had the strongest correlation among the three followed by Stock A and then Stock K. The fecundity also correlates with gonad weight for the three Stocks. For Stock P ($r = 0.999$), Stock K ($r = 0.975$) and Stock A ($r = 0.974$) (Fig. 4.2).

KUMAH FARMS



PACIFIC FARMS



ARDEC

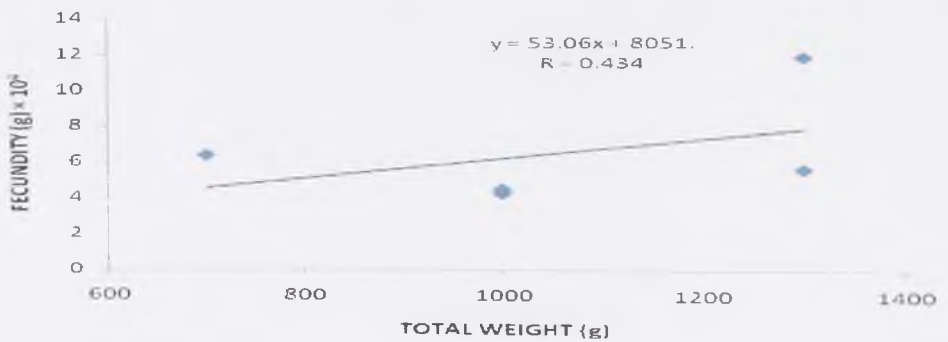
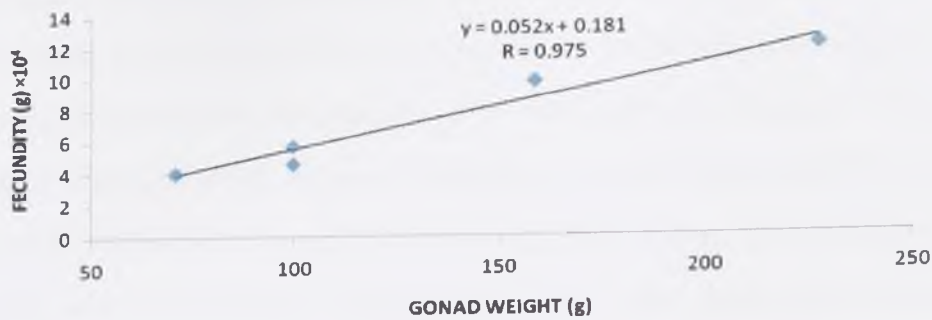


Fig.4.1: Relationship between fecundity and fish body weights of the three stocks of *C. gariepinus*.



KUMAH FARMS



PACIFIC FARMS



ARDEC



Fig.4.2: Relationship between fecundity and gonad weights of the three stocks of *C. gariepinus*.

4.2 Growth Parameters

Table 4.3 shows the mean relative growth and survival of the three stocks of *C. gariepinus*. Initial mean body weight of the stocked fry for stock A, stock K and stock P were 0.00300 g, 0.00325 g and 0.00313 g respectively. The highest mean weight of fingerlings at the end of the experiment was 3.496 g (Stock A) and lowest was 3.256 g (Stock K). Mean daily growth rate ranged between 0.0832 g/d for stock A and 0.0776 g/d for stock K. Survival rate of the fishes were all below 50%. It ranges between 37.23% (Stock A) and 40.92% (Stock P). Stock A recorded the highest Specific growth rate (16.81) whereas Stock K recorded the lowest (16.50).

Table 4.3: Mean Relative growth and survival of three stocks of *C. gariepinus*.

Parameter	Stock A	Stock P	Stock K
Culture period(days)	42	42	42
No of times Cultured	5	5	5
Stocking density(m ²)	10	10	10
Mean Body W ₁ (g)	0.003 ± 0.00014	0.00325 ± 0.00035	0.00313± 0.00010
Mean Body W ₂ (g)	3.496 ± 0.32020	3.304 ± 0.29870	3.256 ± 0.41680
Mean daily growth rate (g/d)	0.0832	0.0787	0.0776
Survival rate (%)	37.23	39.67	40.92
Specific growth rate(%/d)	16.81	16.54	16.50

4.2.1 Condition Factor

Table 4.4 shows the trends in Condition Factor of *C. gariepinus* for the three Stocks. The Condition Factor of Culture I for Stock A was 1.01. This increased to 1.18 for Culture II and then 1.28 for Culture III. It however decreased to 1.23 for Culture IV and then to 1.2 for Culture V. There was an increment from 1.06 in Culture I to 1.27 in Culture II in the Condition Factor for Stock K. This declined to 1.25 in Culture III but increased again to 1.34 in Culture IV and further reduced to 1.24 in Culture V. Stock K recorded an increase in Condition Factor from 1.03 in Culture I to 1.20 in Culture II. This declined to 1.19 in Culture III but increased again to 1.3 in Culture IV and declined further to 1.25 at the end of the study.

Table 4.4: Condition factor for Stocks A, K and P for the five culture times

CULTURE	CONDITION FACTOR		
	STOCK A	STOCK K	STOCK P
I	1.01	1.06	1.03
II	1.18	1.27	1.20
III	1.28	1.25	1.19
IV	1.23	1.34	1.3
V	1.2	1.24	1.25
MEAN	1.18	1.23	1.19

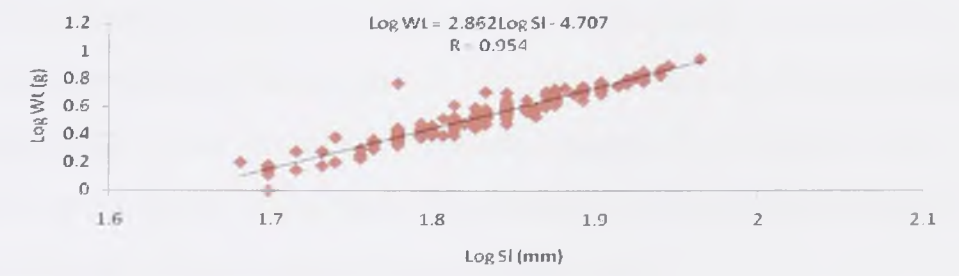
4.2.2 Body Length-Weight relationship

The Body Length-Weight relationship indicates a positive correlation between Stocks A ($r = 0.954$), P ($r = 0.936$) and K ($r = 0.939$). The growth pattern determinant which is the 'b' value for ARDEC stock (2.8629), Pacific farms stock (2.6076) and Kumah farms stock (2.7843) were all closer to 3 which suggests that the growth of the fishes was

isometric, a type of growth that occurs at the same rate for all parts of an organism so that its shape is consistent throughout development.

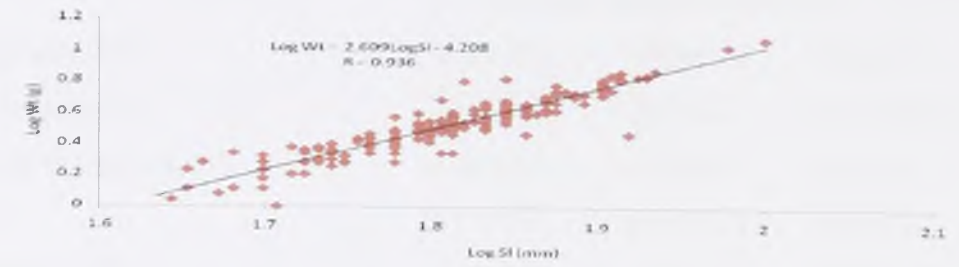
ARDEC

Sample size =200



PACIFIC FARMS

Sample size =200



K UMAH FARMS

Sample size =200

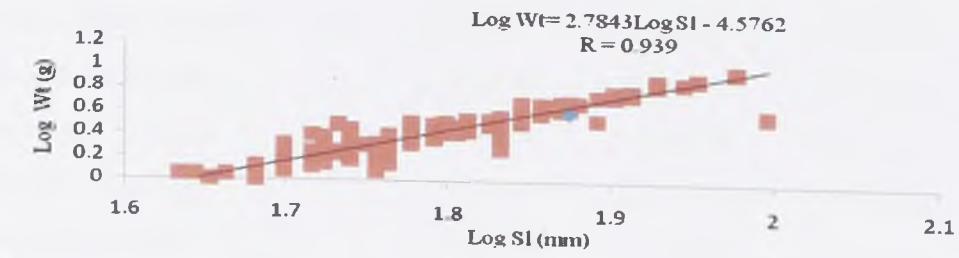


Fig.4.3 Logarithmic Length-Weight relationships of ARDEC stock, Pacific stock and Kumah stock.

4.3 Water quality Parameters

Table 4.3 presents the mean water quality parameters taken throughout the culture period. All the water quality parameters recorded during the study period indicate that the medium of culture was conducive for the growth of the fish species since all were within the ranges reported by De Graaf and Janssen (1996). Temperature, Dissolved Oxygen and pH ranges from 30.88 ± 0.75 (stock A) to 31.15 ± 0.87 (stock P), 4.28 ± 2.34 (stock A) to 4.99 ± 2.45 (stock K) and 6.18 ± 0.15 (stock P) to 6.98 ± 0.61 (stock A) respectively. Turbidity was between 11.00 ± 4.43 (stock P) and 13.83 ± 4.12 (stock K), Total Suspended Solids (20.33 ± 8.43 to 27.83 ± 10.12), Ammonia (0.12 ± 0.06 to 0.43 ± 0.37), Nitrite (0.01 ± 0.02 to 0.02 ± 0.02), Nitrate (0.05 ± 0.04 to 0.08 ± 0.04), Total Alkalinity (39.00 ± 5.97 to 46.33 ± 9.03) and Total Hardness (33.50 ± 5.99 to 41.83 ± 8.75).

Table 4.4: Mean water quality parameters for stocks A, P and K

PARAMETER	AVERAGE SAMPLE VALUES		
	STOCK A	STOCK K	STOCK P
Temperature (°C)	30.88 ± 0.75	30.92 ± 0.6	31.15 ± 0.87
Dissolved Oxygen (mg/l)	4.28 ± 2.34	4.99 ± 2.45	4.40 ± 1.48
pH	6.98 ± 0.61	6.367 ± 0.18	6.18 ± 0.15
Turbidity (NTU)	11.67 ± 2.88	13.83 ± 4.12	11.00 ± 4.43
Total Suspended solids (mg/l)	27.83 ± 10.12	20.33 ± 5.32	20.33 ± 8.43
Ammonia (NH ₃ -N) (mg/l)	0.12 ± 0.06	0.43 ± 0.37	0.13 ± 0.03
Nitrite (NO ₂ -N) (mg/l)	0.01 ± 0.02	0.02 ± 0.02	0.01 ± 0.04
Nitrate (NO ₃ -N) (mg/l)	0.05 ± 0.04	0.08 ± 0.04	0.05 ± 0.03
Total Alkalinity (mg/l)	39.00 ± 5.97	39.75 ± 8.43	46.33 ± 9.03
Total Hardness (mg/l)	33.50 ± 5.99	35.00 ± 6.42	41.83 ± 8.75

CHAPTER FIVE

5.0 DISCUSSION

Fecundity which is the number of ripening eggs found in the female prior to the spawning act (Bagenal, 1978) varies greatly in individuals of one species of the same weight, length and age, but in many species it increases in proportion to the size of fish (Lowe-McConnell, 1975). Fecundity in this study revealed that an average *C. gariepinus* brood female of weight ranging from 1020 g to 1110 g from Kumah farms, Pacific farms and ARDEC produce an average number of within 6.4×10^4 to 8.5×10^4 eggs weighing between 90.68 g to 156.00 g. Differences in weights of female broodstocks ($F = 0.14$, $P = 0.871$), egg weights ($F = 1.95$, $P = 0.184$) and fecundity ($F = 0.55$, $P = 0.592$) among the three stocks were not statistically significant which implies that females from these stocks produce approximately the same number of eggs. The weights of the *C. gariepinus* broodstocks used for the artificial breeding were within 300 g and 2000 g as established by Olaleye (2005). The fecundity of the females from the three Stocks after the study fell within the ranges given by other Authors as indicated in Table 4.2.

The results shown in Fig. 4.1 indicate that Pacific farms stock showed a strong positive correlation ($r = 0.809$) between the fecundity and fish body weights followed by ARDEC stock ($r = 0.434$) and then Kumah farms stock ($r = 0.281$). This implies that an increase in fish body weight of a female brood corresponds with an increase in fecundity for all the three stocks and this finding agrees with De Graaf *et al.*, (1995) who reported that heavier females yielded eggs of higher number and weight expressed in grams.

Strong correlation (Fig. 4.2) between fecundity and its weight was recorded by Pacific farms ($r = 0.999$) followed by Kumah farms ($r = 0.975$), and then ARDEC ($r = 0.974$). This shows that an increase in gonad weight also corresponds with an increase in the number of eggs in all the three stocks.

The data obtained in Table 4.1 show that the treatment with the pituitary hormone preparation of the African catfish gave satisfactory hatching rates of eggs for Kumah farms (75.48%), ARDEC (72.54%) and Pacific farms (68.25%). Differences in hatching rates among the three stocks were not statistically significant. This is satisfactory because in fish reproduction under controlled conditions, attempts are made to obtain eggs of the highest weight possible and of the best quality, and hence to produce the highest possible numbers of good quality hatch all year round. These hatching rates fell within the 50 to 80% hatching rates established by De Graaf *et al.*, (1995) in well-managed hatcheries and this was as a result of the appropriate average temperature (29°C) and Dissolved Oxygen (4.5mg/l) recorded during incubation of the eggs at the hatchery. De Graaf and Jansen (1996); Hogedoom (1980) and Viveen *et al.* (1985) confirmed this by stating that during incubation, the eggs should be well oxygenated for maximum hatching to occur. Bruton (1979) also buttressed on the fact that the principal requirement for successful incubation and hatching of *Clarias* eggs is oxygenated, silt-free water at the correct temperature (19 to 30°C) as these findings corresponds to the environmental temperature during the period of natural reproduction.



The highest Gonado-Somatic Index of the female broods from the three stocks calculated was 14.14% and fell within the 12 to 20% reported by De Graaf and Janssen (1996). This proves that all the female broods used for the study were in good condition (gravid) for artificial reproduction of the fish species. No significant statistical difference ($F = 2.62$, $P = 0.114$) however existed among all the Gonado-Somatic Indexes of the three stocks.

The highest final mean weight gain (3.496 g) according to Table 4.2 was observed in ARDEC stock and the lowest mean weight gain (3.256 g) was observed in the Kumah farms stock but no significant difference ($F=0.66$, $P = 0.533$) was observed within the three stocks (Appendix 2). This indicates that the fries from all the three stocks grew at approximately the same rate. Growth is density dependent; the higher the rearing density of larvae, the lower their growth rate. Stocking density of *C. gariepinus* is considered the most important factor affecting cannibalism and aggression. It is known to have a strong influence on growth, survival and behaviour of fish (Hecht and Appelbaum, 1988). Micha (1976) indicated that protected ponds could be stocked within 10 to 100 fries per 1 m² but the lower the stocking rate, the higher the growth rate of *C. gariepinus*. In this study however, the stocking density of 10 fries per 1 m² contributed to the high growth rate of the three stocks of *C. gariepinus*. It also enhanced the survival rate since the fries had enough space to feed and also escape from their predators.

The condition factor is used to compare the “condition”, “fatness” or wellbeing of fish and it is based on the hypothesis that heavier fish of a particular length are in a better

physiological condition (Bagenal, 1978). It represents how fairly deep bodied or robust fishes are (Reynold, 1968). The trends in condition factor of the fingerlings from all the three stocks after the various culture times in this study as shown in Table 4.3 was relatively high (above 1) and stable. No significant difference ($F=1.16$, $P = 0.345$) existed among the stocks. This underscore the fact that all the fishes harvested after the study were in good condition.

The Length-Weight relationship (Fig. 4.3) shows a strong correlation between the length and weight of all the three stocks with ARDEC stock ($r = 0.954$) recording the highest followed by Kumah farms stock ($r = 0.939$) and then Pacific farms stock ($r = 0.936$). This reveals that an increase in length of *C. gariepinus* corresponds with an increase in body weight of the fish species for all the three stocks. The growth pattern determinant which is the 'b' value for ARDEC stock (2.862), Pacific farms stock (2.609) and Kumah farms stock (2.784) were all closer to 3 which suggests that the growth of the fishes was isometric, a type of growth that occurs at the same rate for all parts of an organism so that its shape is consistent throughout development.

Survival rate of the three stocks of fishes (Table 4.3) were all below 50%. It ranges between 37.23 (Stock A) and 40.92 (Stock P). This survival though below 50%, is commendable since survival rate in the fish species as indicated by De Graaf *et al.*, (1995) could fall as low as 5% or even 0% (100% Mortality). De Graaf *et al.*, (1995) further stressed that the successful hatching of fish eggs and careful feeding of larvae

during the early stages of their development is essential for better survival of larvae. No significant difference ($F=0.55$, $P = 0.601$) existed among all the three stocks. This survival rate is attributed to the fertilization of the ponds with organic manure (poultry droppings) prior to stocking thereby producing enough phytoplankton for the fish to consume since this is the most critical factor for the successful nursing of the catfish larvae during the first week after stocking of the fry.

According to De Graaf *et al.*, (1995), factors influencing fry production in ponds include the presence of amphibian predators like adult frogs which can cause mortality of 10% due to predation and competition for food resources. Phytoplankton levels, in the unprotected ponds, are reduced by the presence of phytophagous frog larvae, consequently leading to a reduction in availability of zooplankton, needed by the catfish larvae. Hogendoorn, (1979), Hogendoorn *et al.*, (1976) and Micha, (1976) also realized that the production of *C. gariepinus* in unprotected ponds is highly variable and that the production in protected ponds proved to be reliable and is about 8 times higher than in unprotected ponds. Therefore the fencing of the study ponds with a mosquito net mesh size happas prevented predatory frogs from preying on the fry and this contributed to the moderate survival rates.

De Graaf and Janseen (1996) reported that differential sizes that exist in fry after stocking is very high after the first six weeks of stocking and this promotes high cannibalism among the fry leading low survival rates. Micha, (1976) also stated that harvesting fry

after 35–40 days is considered to be optimal. The harvest of fry at the end of every six weeks in this study contributed to the high survival rate of fry since predominant sibling cannibalism that exist in culture ponds after six weeks of culture as observed by Janssen (1985) and Hecht *et al.* (1988) was prevented.

All the water quality parameters recorded during the study period according to Table 4.3 indicate that the medium of culture was conducive for the growth of the fish species since all the physico-chemical factors were within the ranges reported by De Graaf and Janssen (1996). These researchers stated that the abiotic factors (physico-chemical factors) of the water environment affect the behavior, biology and growth and this determines the fishes' abundance and distribution in the water.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The study shows that the artificial reproduction and mass rearing of *C. gariepinus* throughout the year is technically possible under tropical conditions by using 'low cost' adapted methods. An increase in both fish body weight and gonad weight of a female brood corresponds with an increase in fecundity for all the three stocks and this finding agrees with De Graaf *et al.*, (1995) who reported that heavier females yielded eggs of higher number and weight expressed in grams. The hatching of the eggs was successful as hatching rates for the broodstocks from all the three stocks fell within the 50 to 80% recommended hatching rates in well-managed hatcheries (De Graaf *et al.*, 1995). The survival rate of the fries from all the three stocks though below 50% (between 37.23% and 40.92%), is commendable since survival rates in the *C. gariepinus* fries as indicated by De Graaf *et al.*, (1995) could fall as low as 5% or even 0% (100% Mortality).

All the water quality parameters recorded during the study period according to Table 4.3 indicate that the medium of culture was conducive for the growth of the fish species since all the physico-chemical factors were within the ranges reported by De Graaf and Janssen (1996). The growth pattern determinant which is the 'b' value for ARDEC stock (2.862), Pacific farms stock (2.609) and Kumah farms stock (2.784) were all closer to 3 which suggests that the growth of the fishes was isometric, a type of growth that occurs at the

same rate for all parts of an organism so that its shape is consistent throughout development.

No statistical difference was found among the mean growth rates of ARDEC stock (3.496 g), Pacific farms stock (3.304 g) and Kumah farms stock (3.256 g) indicating that *C. gariepinus* grows at approximately the same rate in pond culture system regardless of its geographical location. This implies that fish farmers can reduce cost and save time and resources as they can rely on the nearest fish seed (fingerlings) for stocking.

6.2 RECOMMENDATIONS

The main limitation on the expansion of catfish culture in Ghana is the inadequate supply of high-quality seed, especially at the right time and place, for stocking purposes. It is totally dependent on the government, NGOs and research institutes to produce and supply the fish seed. One way to overcome this constraint is to develop and promote low-input systems with local materials that are quite simple and easily transferable to rural fish farmers as done in this study.

Further studies are therefore needed to increase the viability, survival and development of larvae used in farming conditions. Fries of *C. gariepinus* should therefore be cultured in concrete tanks and hapas fixed in ponds in order to compare the early life growth and survival rates of the fish species from the three stocks to the pond culture of the fry undertaken in this study.

Stress in broodstocks should be minimal to guarantee optimal gamete quality production in fish. External factors such as confinement, starvation, transportation and dryness result into predictable pattern of physiological changes which among other things attributed to weight loss and poor gamete quality of stressed broodstock of *C. gariepinus*

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APPENDICES:

Appendix 1: Six chronological stages seen within the development of *C. gariepinus* oocyte (Owiti and Dadzie, 1989).

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** 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. 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, brownish-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. 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.

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

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. This development process will take place once the water temperature is 20-22 °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.

Appendix 2: Analysis of Variance (ANOVA) of Reproductive and Growth Performance
at 95% confidence level.

Parameter	F	P-value	Remarks
Fish Weight (Female Brood)	0.14	0.871	> 0.05, not significant
Fish Weight (Male Brood)	8.64	0.002	highly significant
Male gonad weight	1.70	0.207	> 0.05, not significant
Egg weight	1.95	0.184	> 0.05, not significant
Fecundity	0.55	0.592	> 0.05, not significant
GSI	2.62	0.114	> 0.05, not significant
Weight gain	0.66	0.533	> 0.05, not significant
Specific Growth Rate	1.95	0.163	> 0.05, not significant
Condition factor	1.16	0.345	> 0.05, not significant
Survival rate	0.55	0.601	> 0.05, not significant

