UNIVERSITY OF CAPE COAST

STUDIES ON ASPECTS OF THE BIOLOGY OF *CLARIAS GARIEPINUS* AND *HETEROBRANCHUS LONGIFILIS* FROM RIVER OFFIN: TOWARDS THEIR CULTURE DEVELOPMENT IN GHANA.

BY

WILLIAM DOGAH

Thesis submitted to the Department of Fisheries and Aquatic Sciences of the School of Biological Sciences, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Aquaculture

FEBRUARY 2020

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature ………………………… Date ..………………

Name: William Dogah

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature ……………………… Date ………………..

Name: Prof Edward Adzesiwor Obodai

Co-Supervisor's Signature ……………………………… Date ………………..

Name: Dr George Darpaah

ABSTRACT

This study examined some aspects of the biology of *Clarias gariepinus* and *Heterobranchus longifilis* as a contribution towards their culture development in Ghana. Samples of the two fish species were obtained monthly from September 2017 to August 2018 from River Offin at Dunkwa-on-Offin. Physico-chemical parameters of their habitat were measured. Morphometric characteristics, sex, gonads and stomach contents of the fishes were examined in the laboratory. Data were analysed using Minitab 16 and Microsoft Excel 2016. Average temperature, dissolved oxygen, pH and turbidity of the water were recorded as 28.02±1.04 ℃, 2.55±1.52 mg/L, 7.39±0.38 and 715.11±159.09 NTU respectively. *C. gariepinus* were more abundant and bigger in size than *H. longifilis*. The two species were below average condition (< 1), however, *H. longifilis* had a better condition factor of 0.96 relative to 0.75 for *C. gariepinus*. Length-weight analysis revealed negative allometric growth in both species. Both species explored similar food items with plants dominating their diets. Sex ratio of *C. gariepinus* was found to be 1:1 and 1.5:1 for *H. longifilis*. The two species exhibited variable fecundity but *C. gariepinus* was more fecund (1,750 - 88,930) than *H. longifilis* (39,170 - 53,891). Fecundity increased with fish size and gonad weight in *C. gariepinus* but these relationships could not be determined for *H. longifilis* due to insufficient samples. The rainy season, from April to July marked the major spawning period for *C. gariepinus* but could extend to August. This is suspected to be same for *H. longifilis*. Females consistently have higher GSI values than males. *H. longifilis* should thus be considered for aquaculture in addition to *C. gariepinus*.

KEY WORDS

Clarias gariepinus

Heterobranchus longifilis

River Offin

Biology

Aquaculture

Ghana

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DEDICATION

I dedicate this work to the Ecclesia family.

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CHAPTER ONE

INTRODUCTION

1.0 Background to the Study

Capture fisheries productions (both inland and marine) have stabilised over the past two decades, and the increasing human population is adding up pressure on the demand for fish of which capture productions are currently unable to meet (FAO, 2018). The Food and Agriculture Organisation (FAO) also stated that aquaculture has been identified as the remedy to the declining capture fisheries. Globally, the contribution of aquaculture to supplies of fish and other aquatic organisms have been on the increase over the past few years. This is significant such that, increases in fish productions over the past decade have been attributed to the contribution from aquaculture. The story is not different for Ghana in fish production from the global trend.

In Ghana for instance, fish is regarded as the most prominent source of animal protein hence the fishery sector plays an important role, in the nutrition of the country (Coastal Resources Center, 2018). Additionally, it also supports livelihoods and economic growth of the country. Increases in fish production in recent years in Ghana have been accredited to aquaculture and culture-based fisheries (Asiedu, Nunoo, & Iddrisu, 2017). According to the FAO (2005), aquaculture in Ghana is predominantly Nile tilapia, *Oreochromis niloticus* and the African catfish, *Clarias gariepinus.* Hiheglo (2008) agrees to this assertion and indicated that tilapia forms about 80% of aquaculture production in Ghana. Asamoah, Nunoo, Osei-Asare, Addo and Sumaila (2012) further confirmed this assertion that the Nile tilapia is the single most predominant species cultured in Ghana. Meanwhile, Ghana's freshwater fish fauna includes an estimated 28 families, 73 genera and 157 species, from which *Clarias gariepinus* (Burchell, 1822) and *Heterobranchus longifilis*, (Valenciennes, 1840) have been identified as having potential for aquaculture development. (Dankwa, Abban & Teugels, 1999).

Clariid catfishes constitute one of the main fish families of economic value as food fish. Their economic importance have been demonstrated in most Asian and African countries (Legendre, as cited in Fagbenro, 1992). Of importance in this family are two genera, namely *Clarias* and *Heterobranchus,* of which the species of the genus *Heterobranchus* are found to be endemic to Africa (Fagbenro, 1992).

Clarias gariepinus has been identified as an air-breathing catfish which is scale-less and bony. The body is elongated with long dorsal and anal fins, and a helmet like head (Skelton, 2001). A maximum recorded length of 170 cm has been reported for the species (International Game Fish Association - IGFA, 2001). It is a commercially important fish species in Africa and very much sort after because it attains the biggest known size among the *Clarias* species, very tasty and therefore fetches high market value (Eyo & Mgbenka, 1992). As a candidate for aquaculture, *C. gariepinus* is favoured as a food fish because the flesh is known to have relatively less intra-muscular bones, compared to most aquaculture fish candidates (Admassu, Abera, & Tadesse, 2015).

The feral catfish, *Heterobranchus longifilis*, though from the same family as *C. gariepinus*, is not as widely distributed and said to be endemic to Africa. Its limited distribution has been reported (Skelton, 1993). In West Africa, it is reported to be found from the Gambia, Niger, Benue, Cross and Volta Rivers, Lake Chad, as well as coastal basins from Guinea to Nigeria, including the Niger delta (Teugels, 2003). This species is reported to be an uncommon fish which inhabits large rivers (Eccles, 1992), and said to be the largest freshwater species found in southern Africa (Skelton, 1993). *H. longifilis* is also known to be a popular food fish in West Africa and has been hinted as an excellent candidate for intensive aquaculture due to its omnivorous feeding, fast growth and high fecundity (Atse, Konan, Alla, & Pangini, 2009). Similarly, reports by Opeh, Eyo and Udo (2018) indicated that the species possesses characteristics suitable for culture purposes such as fast growth, disease resistance, hardiness and high market value.

Though *C. gariepinus* is widely cultured in Africa, the culture of *H. longifilis* is under developed (Kerdchuen & Legendre, 1994). The authors also reported on the demonstration of the culture potential of *H. longifilis* in Côte-d'Ivoire. Other authors have also reported on *H. longifilis* as a suitable species for aquaculture in West Africa (Otémé, Hem and Legendre as cited in Erondu, Bekibele, & Gbulubo, 2006).

1.1 Problem Statement and Justification

Although much work have been done in developing the culture of *C. gariepinus* as well as *H. longifilis* in terms of their biology in some parts of

Africa, relatively little has been done on any of these species in Ghana, despite their culture potential. Whereas the aquaculture sector in Ghana is heavily dominated by the culture of *Oreochromis niloticus*, there is the need for the development of other species for the expansion of the sector. *C. gariepinus* is common in Ghanaian inland waters, but *H. longifilis* is relatively scarce. These two species are easy to handle and considered hardy, making them suitable candidates to be considered for aquaculture.

The successful development of the culture of any aquatic organism requires an in-depth understanding of the biology of the organism in the natural habitat. The study of dietary habits based on stomach content analysis is widely used in fish biology and ecology (Fagbenro, 1992) and important in formulating feed for aquaculture purposes. Studies on the reproductive biology of aquaculture species are important for successful hatchery production of seed for stocking.

This study was undertaken to ascertain the potential of culturing *C. gariepinus* and *H. longifilis* in Ghana, by studying aspects of their growth and reproductive biology. It is envisaged that this will provide requisite information as a move towards their culture development in Ghana.

1.2 Objectives

The main objective of this study is to provide information on aspects of the biology of *C. gariepinus* and *H. longifilis* from River Offin.

1.2.1 Specific objectives

The specific objectives of this study are to:

- assess some physico-chemical parameters of the natural habitat of the two species.
- assess the growth and condition factors of *C. gariepinus* and *H. longifilis*.
- determine the food and feeding habits of *C. gariepinus* and *H. longifilis*.
- ascertain the sex ratio of *C. gariepinus* and *H. longifilis*.
- determine the fecundity and gonadosomatic indices of *C. gariepinus* and *H. longifilis*.
- conduct a reciprocal *in vitro* fertilization in both species.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter analyses works done by other authors on the various subject matter under consideration. The taxonomy, geographical distribution, environmental adaptation, morphometric characteristics, food and feeding habits and reproductive biology from other studies were all discussed.

2.1 Geographical Distribution and Environmental Adaptation

The African Catfish, *Clarias gariepinus* from the family Clariidae, is a widely distributed species within the freshwater systems in Africa and elsewhere, occurring in several river systems in Africa (Admassu et al., 2015). Though considered a freshwater species, it is reported to be widely tolerant of many different habitats, including estuaries (Skelton 2001). For culture purposes, it is reported to be hardy and able to tolerate adverse environmental conditions (Eyo, Ekanem, & Ajom, 2016). This is due to the fish's ability to tolerate hypoxia by making use of its arborescent organ to utilise atmospheric oxygen.

The Clariid *Heterobranchus longifilis* is reported to be able to adapt in freshwater and brackish environment with the ability of tolerating up to 7 g/L of salinity. It was however indicated that, spawning is affected at salinities as high as above 5 g/L (Legendre, 1983). In a culture experiment, a pH of 6.5 to 7.5 was successfully used for brood stock of *H. longifilis* (Legendre, 1986). *H. longifilis* has also been identified to have high resistance to disease, fast growth rate and hardy, and also possess the ability to tolerate poor environmental conditions, (Offem, Ayotunde, & Ikpi, 2008).

2.2 Growth Pattern of Catfishes

Length-weight relationship analysis is used to determine how a particular fish is growing - that is whether the fish is growing plump or slender. This analysis is also used as the basis for determining the condition factor of fish. Fishes normally increase in weight to the cube of their respective length. Hence, if the regression coefficient, "b" is found to be 3, the fish is said to be growing isometrically, whiles any significant deviation from 3 implies an allometric growth (Dalu, Nhiwatiwa, & Clegg, 2013). Allometric growth implies fishes change shape during growth and thus no longer obey the cubic law. Values significantly less than 3 means negative allometric growth and higher than 3 implies positive allometric growth (Dalu et al., 2013). The work of Ayo-Olalusi (2014) showed positive allometric growth in *C. gariepinus* reared in flow-through system tanks. In that study, the researcher indicated that the females grew faster in weight than the males.

Anibeze (2000) reported a total length range of 12.6 to 64.0 cm for males and 12.3 to 93.6 cm for females of *H. longifilis* from the Idodo river of Nigeria. He however indicated that, the males were significantly larger than the females on average, but both sexes were found to exhibit negative allometric growth.

2.3 Condition Factor

For every increase in length, there is an expected weight gain for the fish. This has been hypothesised that, a unit of weight gain accompanies a cubic of length increase. This is based on the length-weight relationship in fish. This hypothesis forms the basis for determining the condition factor index of fish. Condition factor therefore gives an indication of the physiological state of the fish or degree of wellbeing and as well as providing necessary information for comparing two populations living in different conditions. It is also an important factor in understanding the life cycle of any species of fish (Dalu et al., 2013; Eke, Odo, Agwu, & Anya, 2017). Based on the underlying hypothesis, fish of a particular length which is relatively heavier is said to be in a better physiological state. The sex and size of fish, gonad development, season and environmental factors such as temperature and fluctuations in water level have all been reported to influence condition factor in fish (Dalu et al., 2013).

In a study on six species of fish (including *C. gariepinus*) in the Malilangwe Reservoir in Zimbabwe, the authors found that high condition factor values corresponded to the breeding season of the fishes which is accompanied by abundant food reserves. It was thus concluded that condition factor is related to breeding activities and food availability (Dalu et al., 2013). Ayo-Olalusi (2014) reporting on condition factor of *C. gariepinus* in a culture experiment, gave values ranging from 0.50 to 1.42 for the fish, with mean values of 0.80 and 0.79 for males and females respectively.

From the Idodo river in Nigeria, Anibeze (2000) found females of *H. longifilis* to have higher condition factor than males. He further reported that the values were generally higher for both sexes during the rainy season as compared to the dry season. The author attributed this observation to availability of food and gonadal development during the rainy season.

2.4 Food and Feeding Habits

Fish like all other animals, require energy to sustain life and the source of this energy is food. Studies on the natural feeding of fish provides useful information on the trophic relationships in aquatic ecosystems, which could be used in formulating management strategies and as well as formulating feed for culture purposes (Abdel-Aziz & Gharib, 2007). Pius and Benedicta (2002) reported the use of stomach content in reducing intra and inter specific competition for ecological niche.

Clarias gariepinus is generally regarded to be an omnivore, that scavenges and predates (Bruton, 1979). Merron (1993) reported that the species is very efficient in predation and hunting even in groups. Thus, several forms of feeding, which include solitary feeding, social hunting, coordinated pack-hunting and feeding migrations have been documented on the species (Bruton, 1979, Merron, 1993). Yalçın, Akyurt, and Solak (2001) described the species as benthopelagic and reported to be voracious with a wide range of diet. Dadebo (2009) also observed that the species is an opportunistic and indiscriminate feeder. Several authors have reported on the wide range of food items consumed by *C. gariepinus*, ranging from fish (both fin and shellfish), aquatic vertebrates and invertebrates, mammals, insects, macrophytes, plankton and plants in general (Dadebo, 2000; Skelton, 2001; Yalçın et al., 2001).

A lot of studies have been carried out on the food composition of *C. gariepinus*, but researchers have not been able to establish a clear-cut pattern of feeding for the fish. So the fish is largely classified as omnivorous or predatory. Willoughby and Tweddle (1978) observed that larger individuals of *C. gariepinus* show a specific dietary shift towards fish as they grow bigger. Bruton (1979) also observed inactive foods to be a target for the fish which they utilise by the help of their sensory barbells and array of fine teeth. This implies that the fish feed on non-living things also.

Findings by Micha (1973) from a study on catfishes from the Central African Republic, revealed that insects (aquatic and terrestrial), fish and higher plant fruits and debris constituted the main food items of *C. gariepinus*. In South Africa, *C. gariepinus* from Lake Sibaya were found to have preference for fish or crustaceans, while terrestrial and aquatic insects were the targets of juvenile and in some cases adult fish inhabiting the shallow waters (Bruton, 1979). From Zimbabwe, studies on *C. gariepinus* in Lake McIIwaine showed a transition in the feed composition as fish became larger. Chironomids dominate the diet of smaller fish and as the fish grew, zooplankton became more important and dominated in the diet of the larger fish (Munro, 1967). The dominance of zooplankton in the diet of large fish was believed to be as a result of efficient filter feeding due to the increased gape and number of gills rakers in larger fish. Studies by Omondi, Yasindi and Magana (2013) in Lake Baringo also suggest that *C. gariepinus* fed mainly on fish, detritus and zooplankton. However, higher plants materials were also found but in small proportions. The authors further explained that *C.*

gariepinus feeds by feeling and as such not affected so much by the turbidity of the water in which they are found. Another notable observation made about the species is that it is photophobic, and therefore prefers to feed in the dark. This attribute has been reported from observations both from natural habitats and culture experiments (Adewolu, Adeniji, & Adejobi, 2008; Clay, 1979a).

Similarly, *Heterobranchus longifilis* is reported to be very active usually at night and feeds on any available food. This includes mostly invertebrates for juveniles, then fish and other small vertebrates for adults. It is also known to feed on carcasses and waste from land (Skelton, 2001).

2.5 Sex Ratio

Reproductive success of a fish population partly depends on the sex ratio in an aquatic system. Sex ratio is a biological indicator which provides basic information on proportions of males and females in a population, and even highlighting on the dominating sex within the population. Also, sex ratio is used as an assessment tool in studying the reproductive potentials of a fish population (Morgan, 2008).

Temperature is reported to have an influence on sex ratios in fish populations especially among cichlids, as the sexes are said to be labile at the infant stages (Baroiller & D'Cotta, as cited in Arizi, Obodai, & Aggey-Fynn, 2014). On this basis, the authors explained that high water temperatures promote female-biased sex ratios while low temperatures tend to promote male-biased sex ratios. This is evidenced in the relatively high number of female *Sarotherodon melanotheron* observed during sunny periods in the Dominli lagoon in Ghana by

Arizi et al. (2014). Meanwhile, Onimisi and Adeyemi (2018) also suggested that dominance of one sex over the other in a population can occur when one of the sexes has some particular advantage over the other. For instance, under unfavourable environmental conditions, the better adapted sex will be advantageous over the other sex. This, the authors said could lead to the production of a greater number of the advantaged sex. Another explanation put forth was that, after spawning, the males migrate to feeding grounds where they get exposed to be caught, whiles the females move to areas with submerged vegetation or rocks to carry out incubation activities thereby hiding from fishing gears. Thus differences in sex ratio could result from differential sexual migration (Offem et al., 2008).

In the Anambra River Basin of Nigeria, Eyo and Mgbenka (1992) found no significant variation in the annual sex ratio of *C. gariepinus*. In the same country, a unity sex ratio was found for *C. gariepinus* in the Ogbese River (Idowu, Odeyemi, Adewunmi, & Oyedeji, 2017). It must however, be noted that the findings of Idowu et al. (2017) do not give a good representation of the entire population of the species in the Ogbese River as their sampling was done for only three months (July to September). This period forms part of the breeding season of the species hence could be the reason a unity sex ratio was obtained. This explanation is possible because of the fact that courtship of one male to one female precedes mating among the species, so the likelihood of encountering an equal number of males and females during a breeding season is high. In a culture experiment, Ayo-Olalusi (2014) also observed a unity sex ratio for *C. gariepinus* cultured in flow-through system tanks, and indicated that this ratio is highly desirable for broodstock development and hatchery operations for the species. Eyo and Mgbenka (1992) explained that the non-significant difference in sex ratio during most of the breeding season could be a reproductive strategy employed by *C. gariepinus* to ensure that all ripe fish find mates for successful breeding since courtship is a characteristic behaviour of the species prior to spawning. Other authors also added that a unity sex ratio implies that there is no difference in the longevity of the sexes, serving as an indicator that equal proportion of males and females are caught from the population, and therefore no disparity in the survival of both sexes in their habitat (Idowu et al., 2017). In another culture experiment however, Abanikannda, Jimoh, Giwa, and Awosanya (2019) found a significant deviation from the expected 1:1 sex ratio in favour of the males. The researchers explained that the preponderance of the males over the females may be as a result of higher survival rate for the male at the earlier stages of development.

Findings from studies on *H. longifilis* in river Okura in Nigeria, indicate no significant difference in the male to female ratio of the species (Onimisi & Adeyemi, 2018). However, in a study conducted from January 2004 to December 2005 on the Cross river (also in Nigeria), males of *H. longifilis* consistently out-numbered females in all the months save four months. The result was an overall male preponderance over female. The authors explained that females are less susceptible to catch during spawning hence the dominance of males in their catches (Offem et al., 2008).

2.6 Fecundity

Studies on fecundity and development of gonads are important components of the reproductive biology of fish (Ekanem, Eyo, Udoh, & Udo, 2013). Fish fecundity is the number of eggs ripening between current and next spawning period in female fish. So, fecundity is a measure of the number of eggs carried by a gravid female fish. It is an important feature considered when selecting species for aquaculture, and used as one of the indices for evaluating the performance of new aquaculture feed (Eyo et al., 2016)**.**

Fecundity has been found to vary among as well as within populations. Differences in fecundity between fish populations have been linked with habitat variations, which in turn are reflected in differences in body condition and growth between populations (Lowe-McConnell, 1982). It has been observed that a fish population in good body condition tend to be more fecund than the one in poor body condition. These differences in fish fecundity among populations have been demonstrated, considering the fact that fecundity is related to fish size (length and/or weight) and gonad weight (Lowe-McConnell, 1975). Offem et al. (2008) also suggested that the variations in fecundity among individual species and populations to be merely as a result of the diversity of the aquatic environment.

Bagenal and Braum (1978) noted in graphical representations that, if the slope of the graph is about three, then fecundity is related to fish length and if it is about one, then it is related to fish weight. Another observation is that, fecundity increases in proportion to between 2.81 to 3.96 the power of total body length among many tropical fish species (Lowe-McConnell, 1975). This means that absolute fecundity within the same population may differ among individuals as a function of body size.

In tropical inland waters, it is generally believed that fish can breed continuously throughout the year. However, several species have been found to show periods of intensive or peak breeding activity within a year. This cycle of peak/intensive breeding is observed to be annual in some species and biannual in others (Lowe-McConnell, 1975).

It has been reported that *C. gariepinus* matures sexually after a year. This observation holds both for those in their natural environments and under culture conditions (Abanikannda et al., 2018; Yalçin et al., 2001). This implies that broodstocks can only be expected to develop gonads after a year.

In the case of *Heterobranchus longifilis*, Motwani (as cited in Legendre, 1986) noted that the species takes two years to reach sexual maturity in the Niger basin, which is a natural environment. Meanwhile, Micha (as cited in Legendre, 1986) argued that *H. longifilis* takes three or four years to mature sexually in ponds after attaining several kilogramme of weight. However, results by Legendre (1986) showed that the fish attained first sexual maturity at one year at an average weight of 1.5 kg when reared in the Ebrie lagoon (Ivory Coast). Moreover, Nguenga, Breine, Teugels, and Ollevier (1996) also indicated that the species took 12 – 14 months to attain sexual maturity in a culture experiment. Offem et al. (2008) from their studies, also observed that males mature sexually at 14.8 cm total length earlier than females (15.7 cm). The authors, however, did not indicate the age at which the fish reach those sizes. Compared to *C. gariepinus*, *H. longifilis* takes a relatively longer time to mature sexually.

Average fecundity of *C. gariepinus* in Lake Sibaya (South Africa) was found to be approximately 45,000 eggs for a 2 kg fish (Bruton, 1979). In Lake Babogaya in Ethiopia, Admassu et al. (2015) reported a fecundity range of 11,000 to 580,571 eggs for females ranging from 40 to 102 cm in total length and 700 to 7,000 g in weight. Relative fecundity range of 398 to 1,165 eggs per gram of ovary was also reported. However, in the same country of Ethiopia, Dadebo (2009) reported the fecundity of *C. gariepinus* in Lake Chamo ranging from 5,000 to 1,240,000 for fish size between 32.5 to 102.4 cm. Eyo and Mgbenka (1992) also observed fecundity of 9,000 to 25,000 for *C. gariepinus* in the Anambra River Basin (Nigeria). From the Ogbese River also in Nigeria, Idowu et al. (2017) reported 32,000 to 59,081 fecundity range for fish measuring 40.0 to 51.0 cm standard length. Willoughby and Tweddle (1978) also reported on the relative fecundity of 600 eggs per gram in the Malawian *C. gariepinus* and the Central African *C. lazera*. A fecundity of 4,483 to 336,157 was also reported from the Asi river in Turkey (Yalçin et al., 2001). The researchers suggested that the variations in fecundity among the same population could be attributed to differences in the sizes of females that makes up the spawning stock and the time of spawning. Admassu et al. (2015) also explained that the variations could be resulting from differences in body conditions and growth between the populations. This explanation was also given by Bagenal and Braum (1978). Onimisi and Adeyemi (2018) are also of the view that variations in fecundity among the same species could simply be a result of the level of food abundance. Thus, nutritional resources play a very crucial part in fecundity variations.

Sydenham (as cited in Eyo & Mgbenka, 1992) explained that the high fecundity of the species could be a protective adaptation as the species shows no parental care after spawning. A similar explanation was given by Abayomi and Arawomo (as cited in Offem et al., 2008) that the fish lay more eggs to account for losses to predators and harsh environmental conditions.

From the Okura River in Nigeria, Onimisi and Adeyemi (2018) reported a fecundity range of 17,001 to 97,122 for *H. longifilis* within a size range of 38.6 cm to 71.5 cm standard length, with the accompanying weight range of 625 g to 5158 g. An absolute fecundity range of 5,515 to 36,800 (for a size range of 14.8 cm, 102.4 g to 69.9 cm, 1625.5 g; total length and body weight) was recorded for the species from the Cross river in Nigeria. The authors indicated that the values recorded in their study were low as compared with what is reported for this species from different habitats and other Clariid species. However, it was also noted that the eggs were relatively large in size compared to reports for other Clariid species. It was further noted that Cross river was oligotrophic and generally produce fish of lower fecundity (Offem et al., 2008). A fecundity range of 43,150 to 71,195 was observed for the species in a culture experiment (Opeh et al., 2018). In another research, an average fecundity of 68,000 was recorded for *H. longifilis* reared in the Ebrie lagoon after being treated with human chorionic gonadotropin (HCG) during the rainy season (June/July). The fecundity drastically reduced when the treatment was done in the dry season (December) to

26,000. Though the fecundity was low in the dry season, the author admitted it is a positive sign for continual breeding all year round in aquaculture (Legendre, 1986).

Significant relationships have been found to exist between fecundity and fish size (that's total length and body weight), and gonad weight. Admassu et al. (2015) found fecundity to be linearly related to body weight and gonad weight. But between fecundity and total length, the relationship was found to be curvilinear. Though this agrees with findings of Clay (1979b) who mentioned that fecundity has an exponential relationship with total length, other authors had different findings. Eyo and Mgbenka (1992) found linear relationships between fecundity and standard length, gonad weight and body weight. In their study on a population of *C. gariepinus* in River Asi in Turkey, Yalçin et al. (2001) also observed linear relationships between fecundity and total length, total weight and gonad weight.

Significant linear regression was found between the fecundity and size (body weight and total length) of *H. longifilis* in the Cross river (Nigeria). However, the researchers indicated that the relationship could also be a power function as high determination coefficients were recorded in both cases (Offem et al., 2008). From the Idodo river basin (also in Nigeria), Inyang and Anibeze (1997) also reported a linear relationship between fecundity and total length, standard length, body weight and ovary weight, fecundity – ovary weight relationship being much more predictive. Legendre (1986) also reported a significant linear relationship between the fecundity and body weight of *H.*

longifilis in his culture experiment with the species in the Ebrie lagoon, Ivory Coast.

Eke, Odo, Agwu and Anya (2017) suggested that environmental factors such as pollution, food availability and disease affect fecundity. The rate of disease for instance, is known to be age dependent in organisms including fish. Age in fish can be estimated by fish length and weight, hence Eke et al. (2017) are of the view that the association between length and fecundity could be linked to environmental conditions as well. The authors further argued that egg production is not only a function of size, but also a function of age. This means that a big sized fish at old age may produce less eggs than a relatively younger smaller sized fish.

2.7 Gonadosomatic Index (GSI)

Gonadosomatic index (GSI) is an important aspect of fish reproductive biology which gives information necessary for successful fisheries management and recruitment of fish populations in aquatic systems (Njiru, Ojuok, Okeyo-Owuor, Muchin, Ntiba, & Cowx, 2006). The number of eggs produced by fish at a time is a critical biological trait that attracts much attention when considering fish populations for aquaculture operation. Good understanding of GSI of fish populations enhances interpretation of their breeding patterns as well as determination of breeding seasons for fish species (Weng, Liu, Lee, & Tsai, 2005). Bruton (1979) described the breeding style of *C. gariepinus*. The observation made was that, the fish migrate upstream or to near-shores of still waters prior to breeding. This is followed by courtship, spawning and egg laying, all of which usually occur at night after rainfall. The eggs stick to submerged vegetation, whether aquatic or terrestrial and hatching occurs hours after spawning. But there is no parental care for the offspring. The absence of parental care could be a reason why the fish spawns only under favourable environmental conditions. Eyo and Mgbenka (1992) also explained that the species produces relatively large eggs which results in large hardy larvae that have greater potential for survival. This could be an adaptation of the species to make up for the lack of parental care.

Periodicity of breeding in fish has also been observed to be an adaptation to environmental fluctuation, such that offspring are produced during optimum conditions for maximum growth and survival (Admassu, 1996). Environmental factors, thus act as trigger signals and timing determinants of spawning activity. In the tropics, rainfall and associated factors such as rise in water level and seasonal flooding are very key in timing for intensive breeding among several species. De Graaf, Galemoni and Banzoussi (as cited in De Graaf & Janssen, 1996) indicated that *C. gariepinus* exhibits seasonal gonadal maturation that is often associated with the rainy season. The processes of maturation of the gonads are influenced mainly by changes in water temperature and photoperiodicity. But the final cue for spawning is caused by a rise in water level mostly due to rainfall. In Lake Victoria (Kenya) for instance, reproduction commences in March, right after the start of the heavy rains and completes in July with the gonadosomatic index remaining low until November, after which the oocytes gradually commence maturation and ripening again by March (De Graaf & Janssen, 1996).

Similar conclusions have been made by several other researchers on various populations of *C. gariepinus* in Africa (Admassu et al., 2015; Eyo & Mgbenka, 1992; Idowu et al., 2017; Willoughby and Tweddle, 1978). In Turkey, Yalçin, Solak, and Akyurt (2001)**,** found that the period from November to April was a sexually resting time for *C. gariepinus* in river Asi, as they did not encounter any ripe gonads within this period. However, Eyo and Mgbenka (1992) indicated that given suitable environmental conditions, the fish may be able to spawn more than once a year. Hogendoorn and Vismans (1980) also suggested that, *Clarias gariepinus* have been known to spawn more than once a year in captivity when favourable culture conditions are provided. Khoo (1979) further explains that where there is enough food and tolerable water temperature range, multiplication of oogonia and early development of oocytes take place continuously in sexually mature fish independent of pituitary influence. To this, Admassu et al. (2015) pointed out that other environmental factors aside rainfall influence spawning in tropical fishes. Additionally, the generally constant temperature and photoperiod in the tropics have been identified to influence spawning in *C. gariepinus* in the dry season. Holl (2015) also asserted that spawning can be delayed when conditions are unsuitable.

According to Eke et al. (2017)**,** improvement in the GSI of some fish species have been observed as the fish mature. Thus, increases in length and weight of fish brings about the development of gonads, hence an improvement in GSI. The authors also suggested that decline in GSI after certain length of fish may be due to decline in egg production at old age.

From Lake Babogaya in Ethiopia, GSI of *C. gariepinus* was found to significantly vary monthly in both sexes. The observation was made that the fish bred from February to September and that breeding was intense in April and in June-July. It was however, mentioned that some level of breeding activity (though very low) was observed in the other months (Admassu et al., 2015). In the Ogbese River of Nigeria, higher GSI was recorded in females (0.3 – 12.9) than in males (0.1 – 6.2) of *C. gariepinus* (Idowu et al., 2017). This is normal in most fishes as the egg mass is usually bigger and heavier than the gonad (semen) of the male which is usually small and lighter in weight. The authors also found linear relationships between GSI and body weight for both males and females and the combined sexes. Similarly, Yalçin et al. (2001) recorded the highest GSI for the species between May to July in the Asi river of Turkey, with indications that the species spawns from May to August.

Two peaks of GSI were recorded for *H. longifilis* in the months of October and February, from river Okura in Nigeria. The major peak being in October. It was indicated that the fish spawns intensely from July to October which coincides with the rainy season (Onimisi & Adeyemi, 2018). The authors suggested that the minor peak in GSI in February with the concomitant brief spawning within that period, could be due to residues of left-over ova after the major breeding season in October. In the same country (Nigeria), Offem et al. (2008) had different findings from the Cross river. The authors observed a single peak of GSI for *H. longifilis* in June/July, and a synchronic ovarian development. This implies a single but long annual spawning period (April to August) for the species, and this, the authors explained is a disadvantage to the adequate sustainability of the species in the habitat. The GSI of females (0.12 – 4.06) was also found to be higher than that of males (0.06 – 1.67), most probably due to heavier gonads of females, as suggested by the authors.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter describes the various methods and tools employed in carrying out this study. It also highlights the specific equipment used for each measurement. Various formulas used in analyses were also cited and explained in this chapter.

3.1 Study Area

Samples of catfishes were obtained from landings of fishermen operating on the Offin River at Sofokrom, Dunkwa – on – Offin (05º 96.358' N; 001º 77.301' W and 05º 96.333' N; 001º 77.268' W) in the Central Region of Ghana. Figure 1 shows the location of the study area on the map of Ghana. The fishermen use gill set nets and traps made from metal and branches of raphia for their fishing. Of all the species of fish landed at the shores, the catfishes dominated. The Offin River takes its source from the Ashanti uplands and flows southwards to join the River Pra which empties into the Gulf of Guinea (Amisah, Gyampoh, Sarfo-Mensah and Quagrainie, 2009). The river is heavily being polluted by illegal small-scale gold mining activities (popularly known as "Galamsey") within its catchment. This is evident at first sight by the colour of the water. There are also pollution issues from the riparian communities through rainfall runoff from the communities and direct dumping of refuse in and around the bank of the river. These are depicted in Figure 2. Dunkwa-on-Offin used to be a predominantly farming community. But that has been taken over by alluvial Gold mining.

About 30 specimens of each fish species were obtained between the 14th and 18th of each month from September 2017 to August 2018. Fish samples were preserved on ice and transported to the laboratory at the Department of Fisheries and Aquatic Sciences of the University of Cape Coast. At the laboratory, sorting and identification up to species level were carried out using identification manuals by Holden and Reed (1972) and Yisa and Olufeagba (2005).

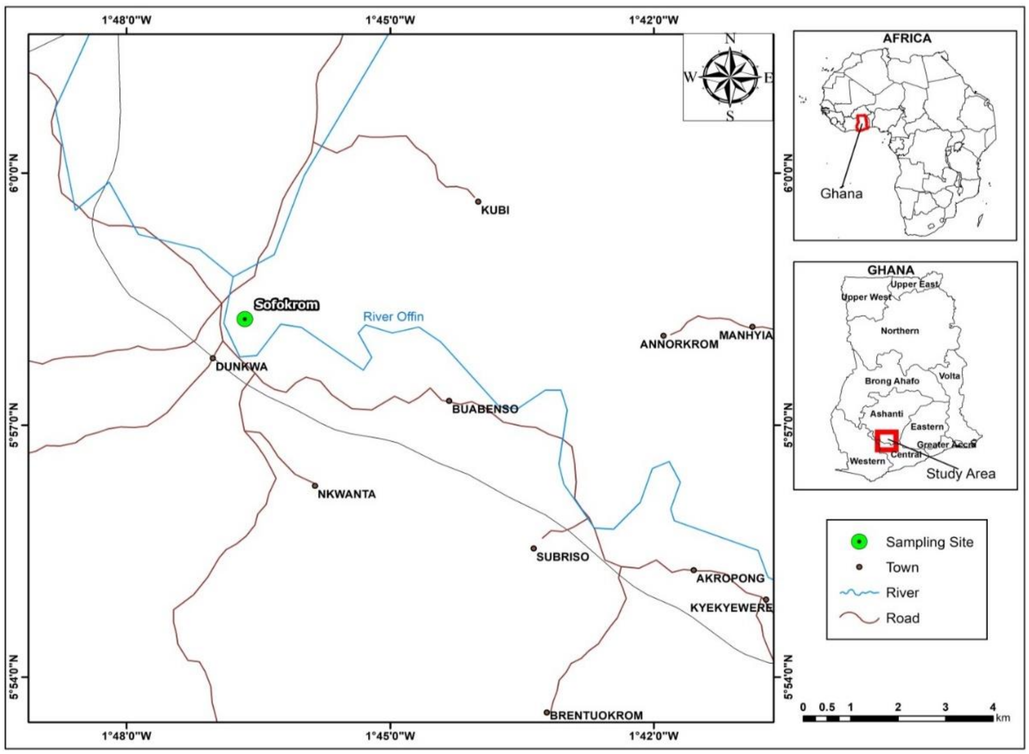

Figure 1: Map of Ghana showing river Offin and study area (Sofokrom).

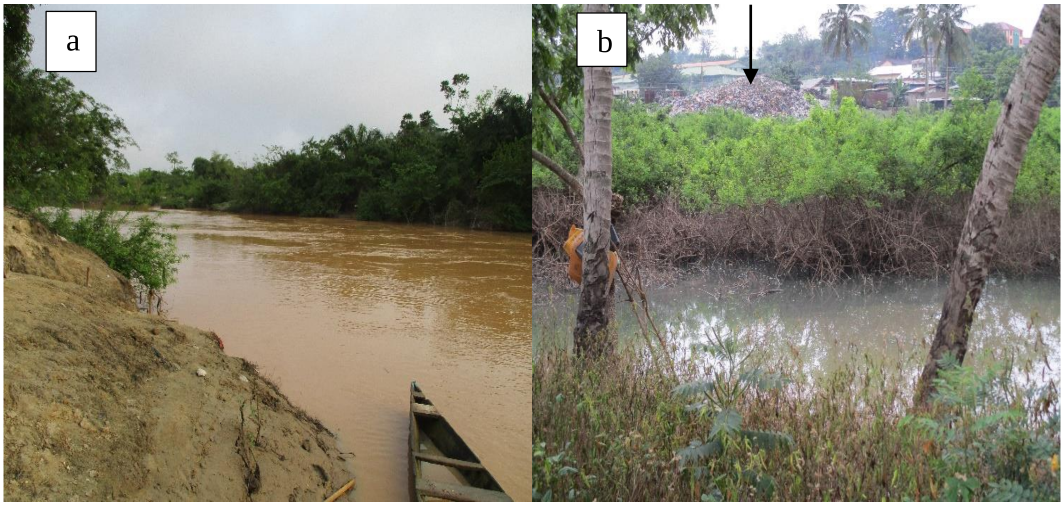

Figure 2: River Offin (a) dirty coloured water due to mining activities and (b) refuse dump (arrowed) within the catchment of the river.

3.2 Physico-chemical Parameters

Physico-chemical parameters were measured *in situ* except pH which was measured in the laboratory. The parameters measured included temperature, dissolved oxygen (DO), Hydrogen ion concentration (pH), and turbidity. Three replicates of measurements for each parameter were taken at three randomly selected stations. Temperature (ºC) and DO (mg/L) were measured with an YSI Environmental EcoSence DO200A. Turbidity (NTU) was measured using an OAKTON Turbidimeter T-100, and pH measured with an OAKTON pH 700 probe.

3.3 Measurement of Morphometric Characteristics

Fish were measured for total length (TL) and standard length (SL) to the nearest 0.1 cm using a Measuring Board. Body weight (BW) of fish was measured to the nearest 0.2 g, using an Ohaus Ranger 7000 R71MD15 electronic scale. The length-frequency distributions and the length-weight relationships were analysed for each species on bar charts and scatter plots respectively. Regression analyses were carried out using Microsoft Excel 2016 to determine the relationship between the length and weight of the fish in order to establish the form of body shape the fish exhibit as the fish grow.

3.4 Condition Factor

Fulton's condition factor for individual fish was computed using the formula according to Froese (2006):

$$K = \frac{W}{L^3} \times 100 \qquad \text{eqn 1)}$$

Where W = weight of fish (g), L = total length of fish (cm). Variations in the mean monthly condition factor were determined.

3.5 Examination of Stomach Content

Fish stomachs were removed after dissection and preserved in 10% formaldehyde. The stomach contents were later examined macroscopically and microscopically using a dissecting microscope. Individual prey items were counted and weighed to the nearest 0.01 g using an Ohaus Adventurer Pro AV412 electronic scale. The percentage frequency of occurrence (%FO) (Hyslop, 1980), percentage composition by weight (%Cw) and Index of Preponderance (Ip) (Needham, as cited in Alhassan & Ansu-Darko, 2011) were calculated for individual prey items as follows:

$$\%FO = \frac{number\ of\ stomachs\ containing\ a\ particular\ prey\ item}{total\ nuber\ of\ stomachs\ examined} \times 100 \qquad \text{eqn 2)}$$

$$\%Cw = \frac{weight\ of\ a\ particular\ prey\ item\ in\ all\ stomachs\ examined}{total\ weight\ of\ all\ prey\ items\ in\ all\ stomachs} \times 100 \qquad \text{eqn 3)}$$

$$Ip = \frac{(\%Cw \times \%FO)}{\sum(\%Cw \times \%FO)} \qquad \text{eqn 4)}$$

3.6 Sex Identification

In the Clariid catfishes, male and female are easily distinguished under field examination after they are about 10 cm long. Between the three fins at the caudal end of the fish on the underside of the body is a small roundish/domed shaped opening in the female. The male fish has in the same position a small long and conical tube called the genital papilla (Haylor, as cited in Yisa & Olufeagba, 2005).

Sex identification was carried out macroscopically by examination of the genital papilla and gonads of the fishes. Chi square test was used to compare the male to female ratio with the hypothesized sex ratio of 1:1.

3.7 Estimation of Fecundity and Gonadosomatic Index (GSI)

3.7.1 Fecundity

Gonads of fish were also removed after dissection, weighed to the nearest 0.01g on an Ohaus Adventurer Pro AV412 electronic scale. Absolute Fecundity was estimated using the gravimetric sub-sampling wet weight method as described by Lagler (as cited in Wijeyaratne and Costa, 1988). Ripe ovaries were preserved in Gilson's fluid (see Appendix B) for at least 24 hours to harden the eggs. The ova were teased out of ovarian tissues, washed and rinsed under running water. Water was then drained from the ova using filter paper. The total weight of the gonads was measured, after which three samples were taken, weighed and counted. The mean weight and number from the three samples were calculated and used to estimate the Absolute Fecundity for each fish. The Absolute Fecundity was plotted against total length, body weight and gonad weight of the fish using a scatter plot to establish the relationship between these parameters.

3.7.2 Gonadosomatic Index

Gonadosomatic index (GSI) was calculated for individuals with gonads using the formula according to Bagenal (as cited in Shinkafi & Ipinjolu, 2012):

$$GSI = \frac{Gonad\ weight}{Body\ weight} \times 100 \qquad \text{eqn 5)}$$

The mean monthly GSI was computed and presented graphically to ascertain the pattern of breeding in both species.

3.8 *In Vitro* Fertilization

Matured live fish (both male and female) weighing between 300g to 1000g were selected from collected samples. Fish were conditioned in concrete tanks for more than 24 hours. Final maturation and ovulation were induced in the females by injecting them with Human Chorionic Gonadotropin (HCG) hormone obtained from Add Pharma in Accra. The hormone was injected at 1.5 IU per kg of body weight for *H. longifilis* and 4.0 IU per kg of body weight for *C. gariepinus*. The hormone was injected intramuscular with a syringe in the dorsal muscle (just below the dorsal fin). Ovulation was checked after about 11 hours per the water temperature (Legendre, Teugels, Cauty, & Jalabert, 1992). The eggs were stripped from the females by gently applying slight pressure on the fish abdomen (De Leeuw, Goos & Eding as cited in Brzuska, 2002).

Testes were removed from the male fish and placed in a petri dish. They were quickly cut into small pieces with a pair of scissors and the milt pressed out. The milt together with pieces of testes materials were added to the stripped eggs and fertilization initiated by adding about the same volume of clean water. The water and egg mass were mixed by gently shaking of the container. Fertilization took place after 60 seconds and fertilized eggs were transferred into aquarium tanks. Hatching was found to take place within 20-36 hours. The unhatched eggs are siphoned out of the system to prevent fungal infection on the newly hatched fry (Ogunsina, 2010).

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter presents the findings obtained from the various measurements and observations made. It begins with an overview of the environment of the fish, then continues with the growth parameters and closes with the reproductive biology. The various findings are presented in tabular and graphical formats.

4.1 Physico-chemical Parameters

A summary of the physico-chemical parameters measured during the study period (September 2017 to August 2018) at the study area on the Offin River is presented in Figure 3. No measurements were taken in the months of September and October 2017 due to some challenges with equipment. All parameters were measured between the 14^{th} and 18^{th} of the month and between the hours of 0700 and 0900 GMT. Temperature declined from the start of the research (November 2017) from 28.89 ℃ to 27.84 ℃ in January 2018. Thereafter the temperature increased to a maximum of 29.46 ℃ in March 2018 and declined till July 2018 (26.60 ℃) as shown in Figure 3(a). Dissolved oxygen (DO) increased from 2.37 mg/L in November 2017 to a peak of 5.82 mg/L in January 2018. It then declined to a minimum of 1.01 mg/L in July 2018 (Figure 3b). The pH increased marginally from 7.68 in November 2017 till it peaked at 7.75 in March 2018. There was a continual decline to a minimum of 6.73 in July 2018 (Figure 3c). Turbidity increased at the start of the research from 822.10 NTU in

November 2017 to 828.27 NTU in December 2017. Thereafter it varied and reached a minimum of 524.33 NTU in July 2018 as indicated in Figure 3(d).

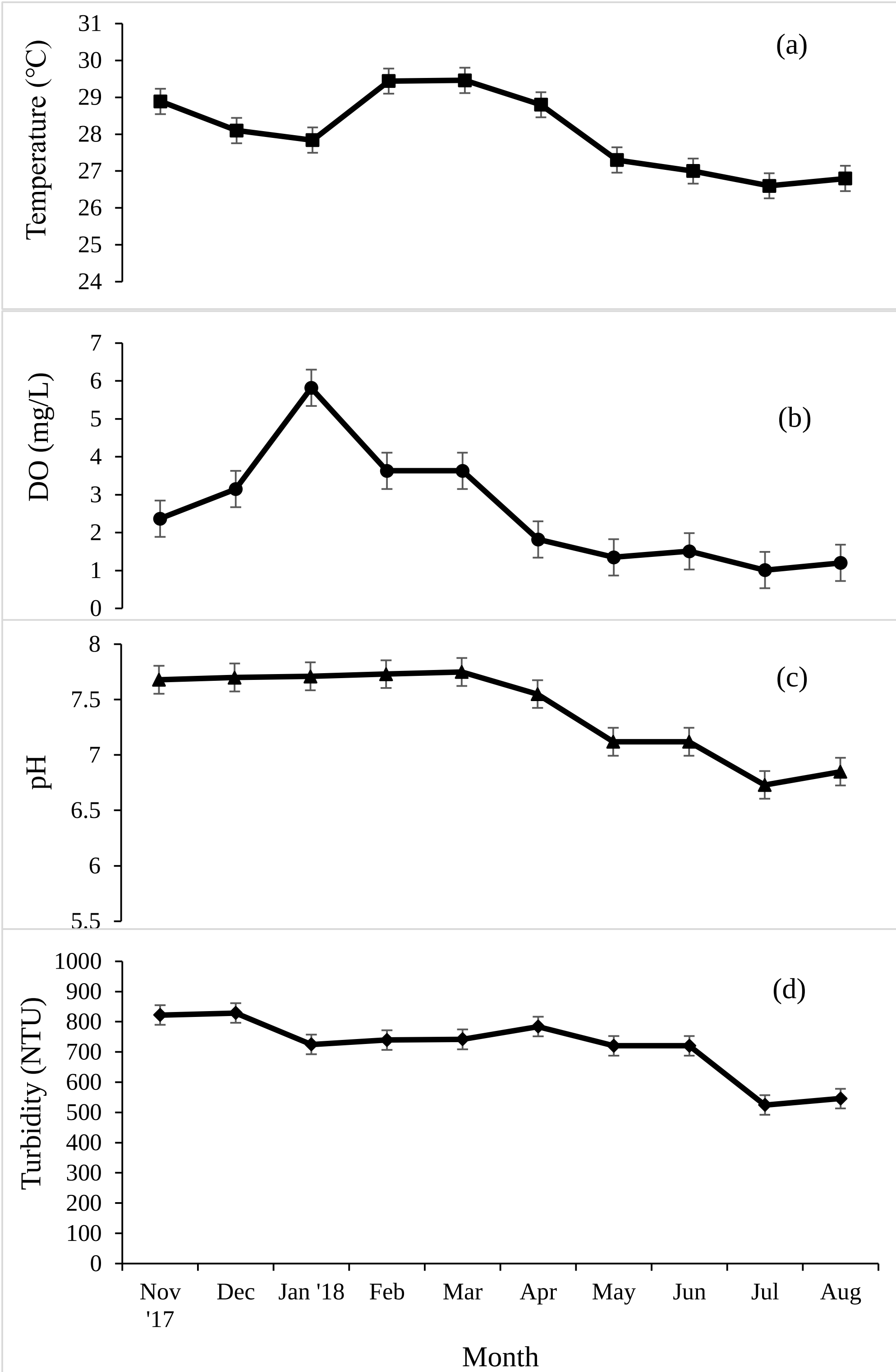

Figure 3: Physico-chemical parameters measured in River Offin: (a) Temperature, (b) DO, (c) pH, (d) Turbidity.

4.2 Length-frequency Distribution of Catfish

4.2.1 *Clarias gariepinus*

A total of 353 specimens were measured for length and weight and ranged in sizes from 13.0 to 74.1 cm total length (TL), with body weight (BW) from 37.2 to 2537.8 g. This comprised 164 males and 160 females whilst 29 were of indeterminate sex. Figure 4 shows the length-frequency distribution of *C. gariepinus*. The average fish size was 31.1 cm TL with a corresponding weight of 275.9 g. Males ranged in size from 18.0 to 74.1 cm TL and 37.2 to 2152.4 g in weight. The size range for females was from 19.2 to 72.3 cm TL and 43.0 to 2537.8 g in weight. Both males and females displayed a unimodal frequency distribution. Modal length class for males and females were 22.0 – 23.9 cm TL and 30.0 – 31.9 cm TL respectively.

4.2.2 *Heterobranchus longifilis*

A total of 188 specimens were examined. Males numbered 60, females 39 and 89 were of indeterminate sex. The fish measured 10.5 to 55.2 cm TL, and 11.4 to 1700.0 g BW. The males ranged in size from 19.8 to 49.5 cm TL and weighed 66.6 to 1398.2 g and females 18.4 – 55.2 cm TL and 55.2 – 1316.2 g in weight. Figure 5 shows the length-frequency distribution of the fish. Both males and females exhibited a unimodal frequency distribution. A modal class of 30.0 – 31.9 cm TL was observed for males and 26.0 – 27.9 cm TL for females.

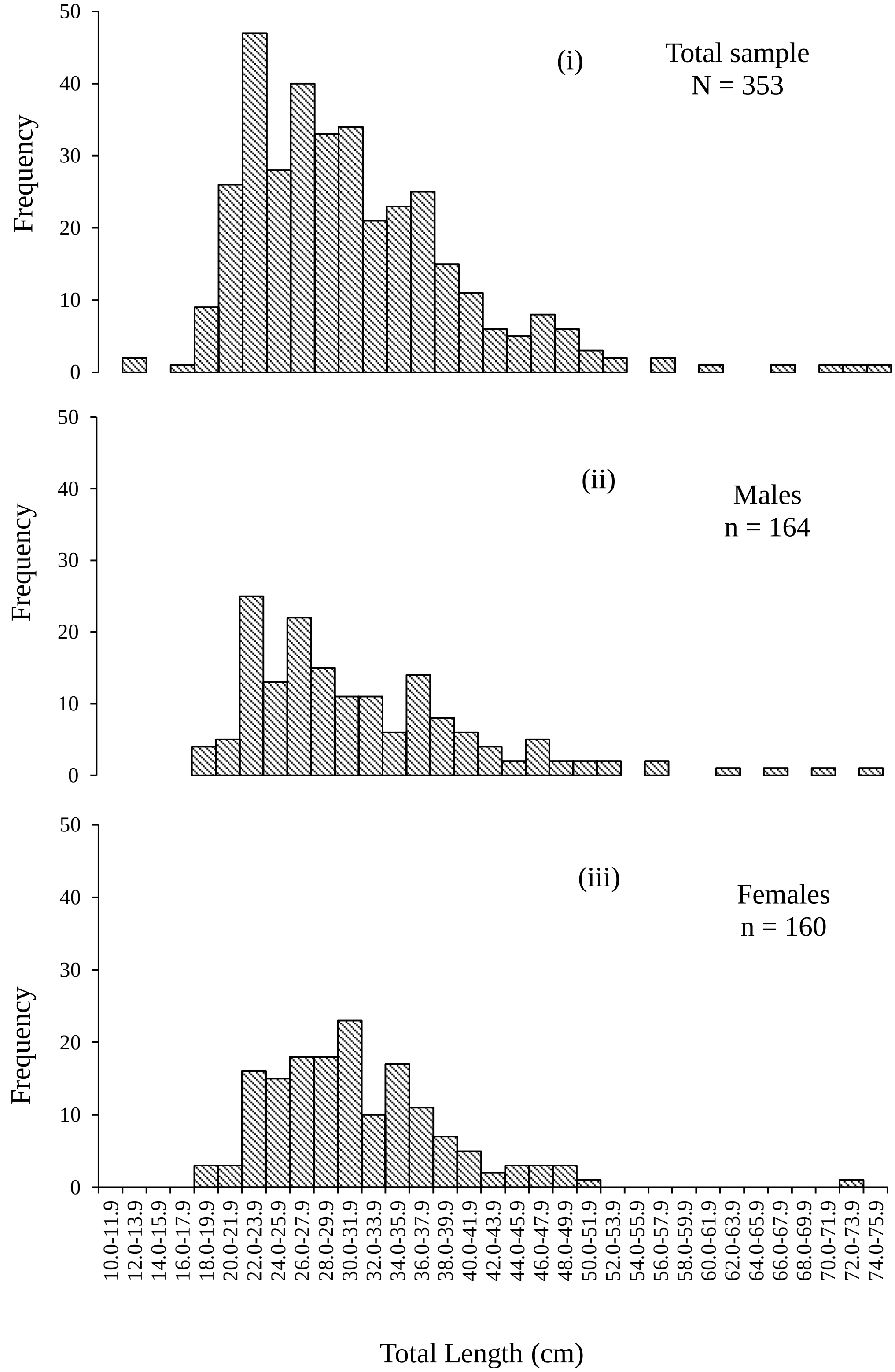

Figure 4: Length-frequency distribution of (i) total sample, (ii) males and (iii) females of *Clarias gariepinus* from River Offin.

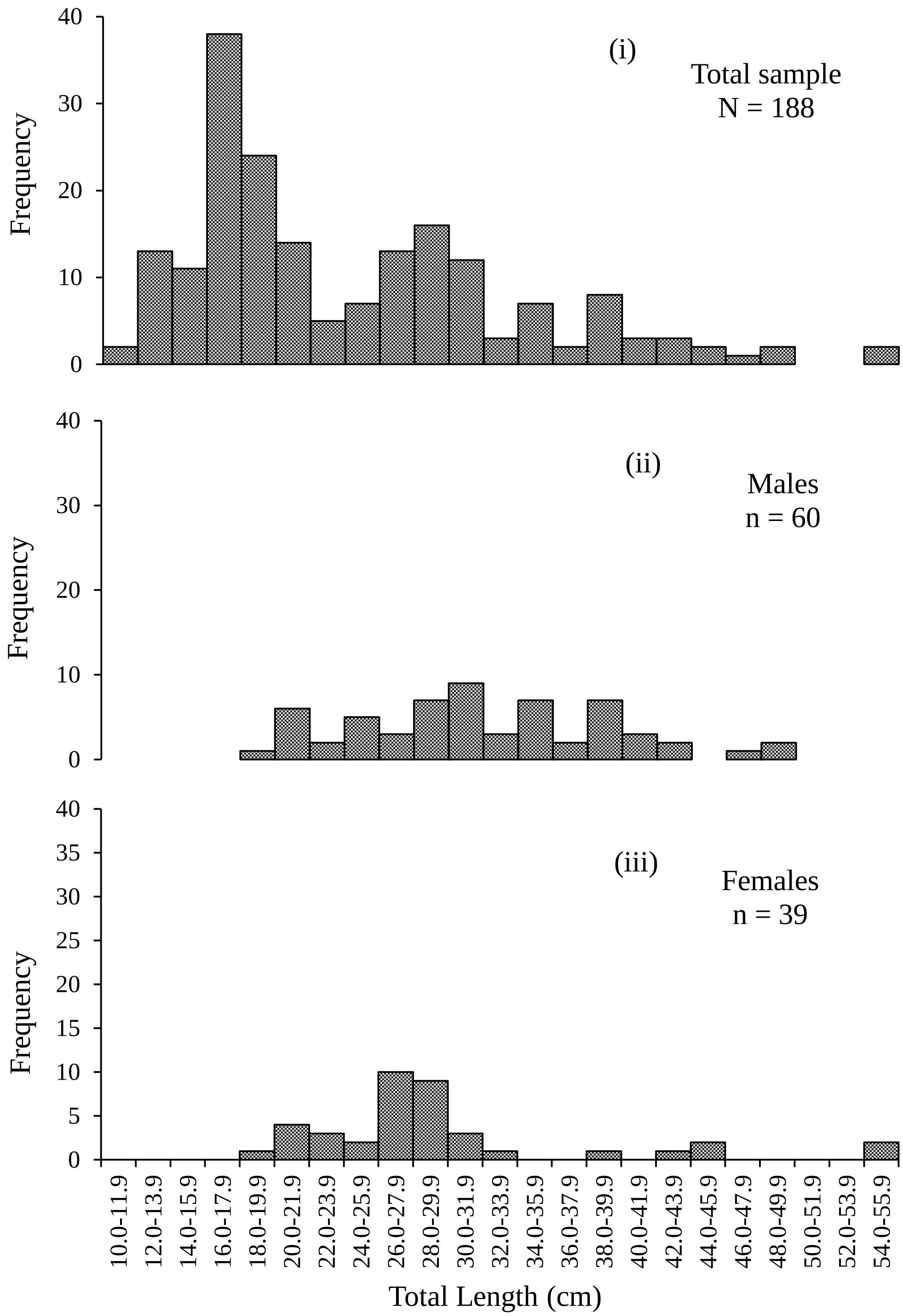

Figure 5: Length-frequency distribution of (i) total sample, (ii) males and (iii) females of *Heterobranchus longifilis* from River Offin.

4.3 Length-weight Relationship

4.3.1 *Clarias gariepinus*

Figure 6 shows the relationship between the total length and body weight of *C. gariepinus*. The equation $BW = 0.0198TL^{2.71}$ described a significant relationship between the two variables with a strong correlation of r = 0.97. The regression coefficient b = 2.71, differs statistically from the hypothetical value of 3.0.

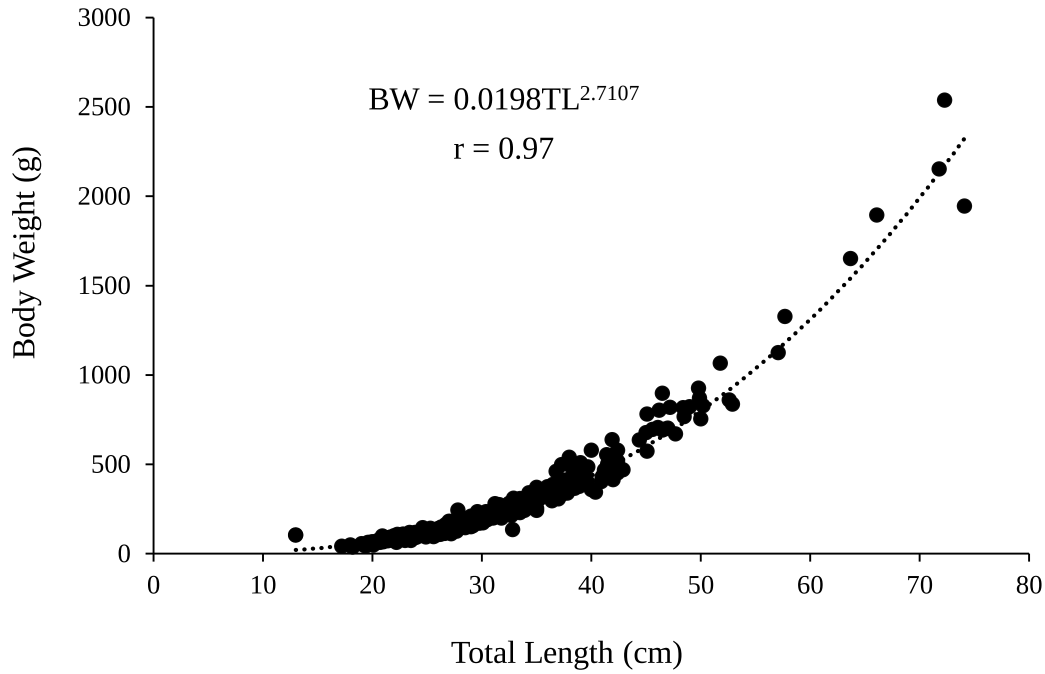

Figure 6: Length-weight relationship of *Clarias gariepinus* from River Offin. (BW is Body Weight and TL is Total Length).

4.3.2 *Heterobranchus longifilis*

The relationship between the total length (TL) and body weight (BW) of *H. longifilis* is displayed in Figure 7. A significant exponential relationship exists between the total length and body weight of the fish. This is described by the equation, $BW = 0.0142TL^{2.87}$ with a strong correlation, r = 0.98 between the variables. The regression coefficient b, which is 2.87, differs statistically from the hypothetical value of 3.0.

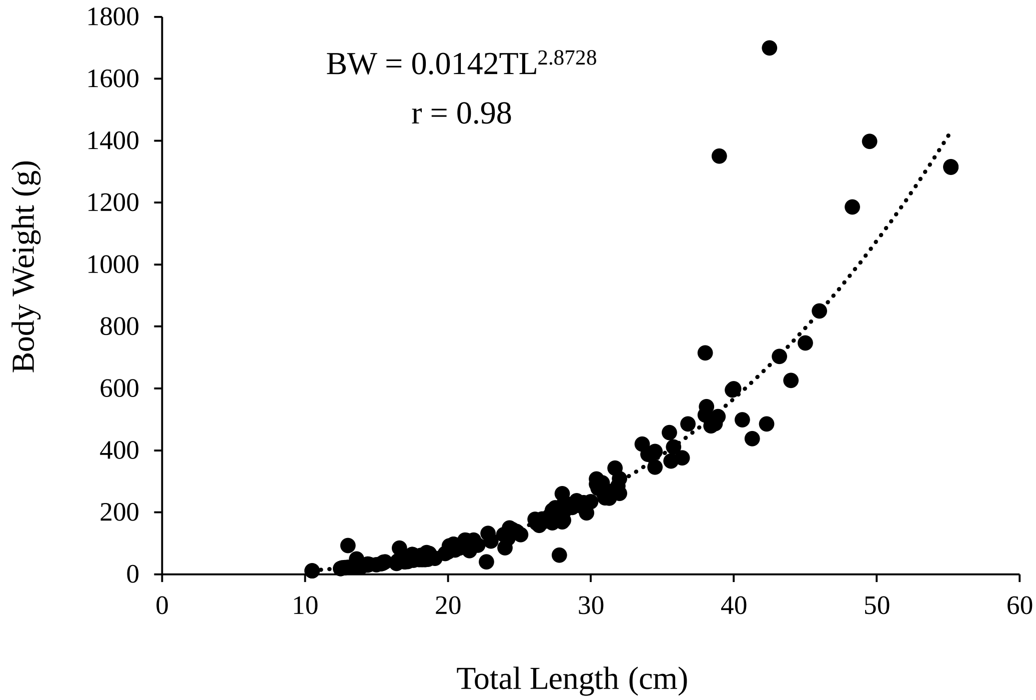

Figure 7: Length-weight relationship of *Heterobranchus longifilis* from River Offin. (BW is Body Weight and TL is Total Length).

4.4 Changes in Condition Factor

4.4.1 *Clarias gariepinus*

Changes in the mean monthly condition factor of *C. gariepinus* are illustrated in Figure 8. Generally, the mean condition factor of the combined sexes was around 0.75. For the males only, it was 0.76 and 0.75 for females. The monthly variations were marginal, except in December 2017 where a peak value (1.08) was recorded for males and in January 2018 where the lowest value (0.64) was recorded for females. For the males, the mean monthly condition factor varied between 0.67 in June 2018 and 1.08 in December 2017. For the females, it ranged between 0.64 in January 2018 and 0.86 in November 2017.

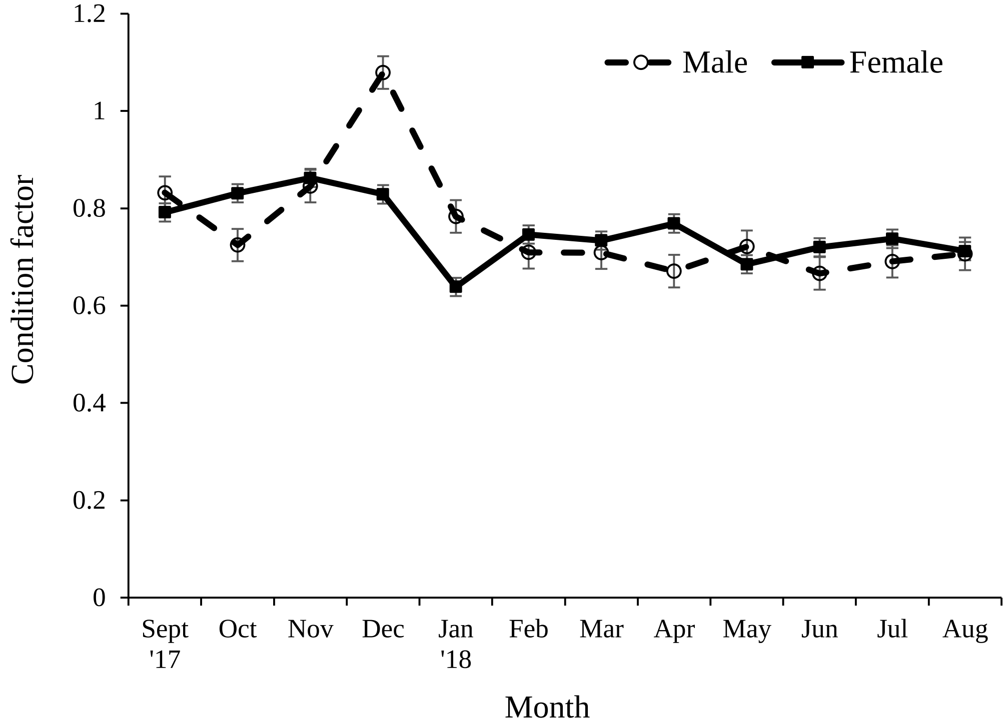

Figure 8: Mean monthly condition factor of *Clarias gariepinus* from River Offin.

4.4.2 *Heterobranchus longifilis*

The mean monthly variations in the condition factor of *Heterobranchus longifilis* are presented in Figure 9. Though the pattern of variation appeared to be similar for both sexes, the males had relatively higher values of 1.51 in September 2017 and 1.29 in February 2018. In August 2018, a higher condition index, 1.11 was observed for the females. The mean monthly condition factor for the males varied between 0.81 in July 2018 and 1.51 in September 2017. For the females, the value ranged between 0.68 in February 2018 and 1.11 in August 2018. The average value obtained was 0.98 for males, 0.86 for females and 0.96 for the combined sexes.

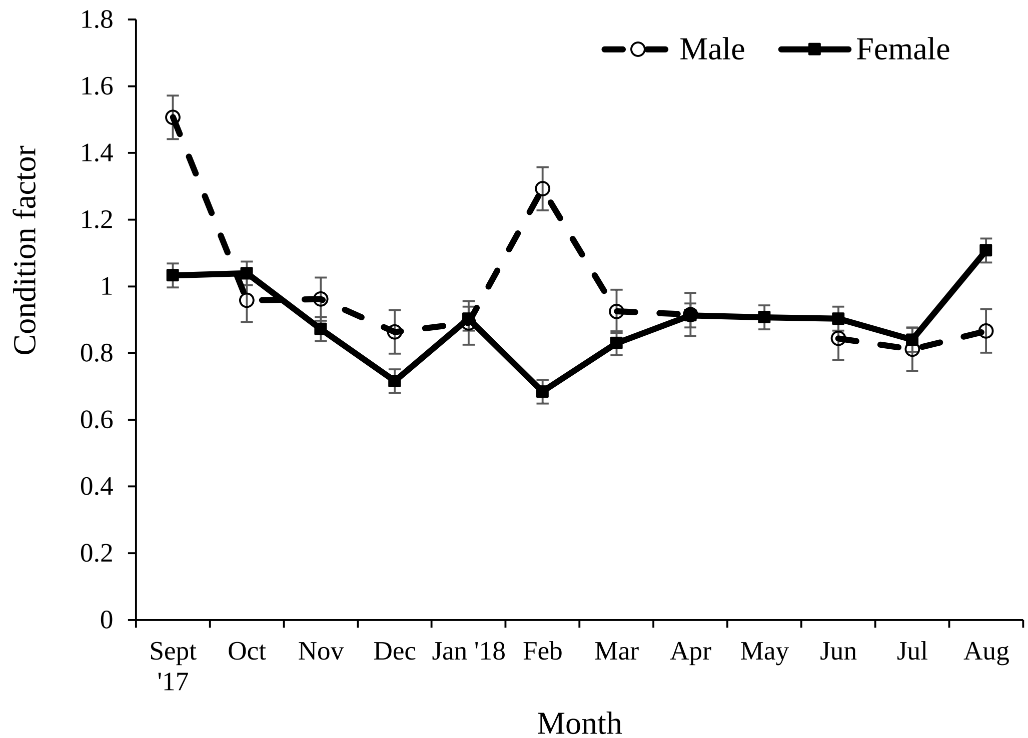

Figure 9: Mean monthly condition factor of *Heterobranchus longifilis* from River Offin.

4.5 Food and Feeding Habits

4.5.1 *Clarias gariepinus*

Food items explored by *C. gariepinus* from the Offin River are presented in Table 1. The diet of the fish comprised mainly of plant debris (0.760 Ip) which is made up of pieces of leaves and sticks. Detritus (0.066 Ip), followed by corn (0.055 Ip) made up the other major food items. Crab (4.0E-06 Ip), bean seed (4.2E-05 Ip) and animal meat (8.7E-05 Ip) constituted the least food items.

Table 1: *Stomach Content of Clarias gariepinus from River Offin*

Food category	Item	Weight (g)	Freq	%FO	%Cw	Ip
Fish	Fin fish	5.91	14	9.333	1.754	0.012
	Crab	0.03	1	0.667	0.009	4.3E-06
Aquatic invertebrates	Worms	10.87	13	8.667	3.226	0.020
	Snail	0.98	1	0.667	0.291	0.0001
	Insects	2.01	11	7.333	0.597	0.003
Plant Sources	Palm nut	2.08	4	2.667	0.617	0.001
	Corn	27.58	14	9.333	8.186	0.055
	Rice	32.93	2	1.333	9.774	0.009
	Cassava	17.37	4	2.667	5.155	0.010
	Bean seed	0.29	1	0.667	0.086	4.2E-05
	Debris	136.09	39	26.000	40.391	0.760
Domestic waste	Banku	30.56	6	4.000	9.070	0.026
	Charcoal	12.68	16	10.667	3.763	0.029
	Others	14.66	2	1.333	4.351	0.004
Terrestrial animals	Animal meat	0.61	1	0.667	0.181	8.7E-05
	Bird	19.32	1	0.667	5.734	0.003
Detritus	Detritus	22.96	20	13.333	6.814	0.066

Freq = Frequency; %FO = Percentage frequency of occurrence; %Cw = Percentage composition by weight; Ip = Index of preponderance.

4.5.2 *Heterobranchus longifilis*

Table 2 shows the food items fed on by *H. longifilis* in the Offin River. Palm fruits, corn and plant debris constituted the main food items with Index of preponderance (Ip) of 0.42, 0.17, and 0.10 respectively. Snails (1.0 E-05 Ip) constituted the least food items exploited by the fish.

Table 2: *Stomach Content of Heterobranchus longifilis from River Offin*

Food Category	Item	Weight (g)	Freq	%FO	%Cw	Ip
Fish	Fish	10.97	8	7.619	5.133	0.044
Aquatic invertebrates	Worms	11.12	7	6.667	5.203	0.039
	Snail	0.02	1	0.952	0.009	1.0E-05
	Insects	0.75	6	5.714	0.351	0.002
Plant Sources	Palm nut	76.01	11	10.476	35.565	0.420
	Corn	18.25	18	17.143	8.539	0.165
	Rice	0.08	1	0.952	0.037	4.0E-05
	Cassava	1.37	2	1.905	0.641	0.001
	Debris	11.07	18	17.143	5.180	0.100
Domestic waste	Banku	5.51	3	2.857	2.578	0.008
	Charcoal	15.6	9	8.571	7.299	0.071
	Onion	0.1	1	0.952	0.047	5.0E-05
Terrestrial animals	Animal meat	24.87	5	4.762	11.637	0.062
	Animal bone	18.83	2	1.905	8.811	0.019
Plastics	Gum	3.14	2	1.905	1.469	0.003
	Paint	0.97	1	0.952	0.454	0.0004
	Others	1.06	1	0.952	0.496	0.001
Detritus	Detritus	14	9	8.571	6.551	0.063

Freq = Frequency; %FO = Percentage frequency of occurrence; %Cw = Percentage composition by weight; Ip = Index of preponderance.

4.6 Sex Ratio

4.6.1 *Clarias gariepinus*

Out of the 353 individuals sexed, 164 were males, 160 were females and 29 were indeterminate (this group was used in all other analysis apart from reproductive biology). Generally, the males and females occurred equally in number, except for the month of May 2018, where females showed significant preponderance over males (1:2.09). The overall male to female ratio of 1.03:1 did not differ statistically from the hypothesised 1:1 ratio. The monthly sex ratios are presented in Table 3.

4.6.2 *Heterobranchus longifilis*

The monthly sex ratios of the species are presented in Table 4. A total of 188 individuals of *H. longifilis* were sexed, out of which 60 were males, 39 were females and the remaining 89 were indeterminate (the indeterminate group were used in all other analysis apart from reproductive biology). Although males were consistently higher numerically, no significant difference occurred in the sex ratios except in March 2018 where the preponderance of the males was statistically significant. The overall male to female ratio however, differed significantly from the hypothesised ratio of 1:1 in favour of the males (1.5:1).

Table 3: *Monthly Sex Ratio of Clarias gariepinus from River Offin*

Month	N	I	Males	Females	Sex Ratio M:F	$\chi2$	P $_{(0.05)}$
September '17	20	2	9	9	1:1	0.000	1.000
October	17	5	6	6	1:1	0.000	1.000
November	12	1	6	5	1.2:1	0.091	0.763
December	47	15	17	15	1.1:1	0.125	0.724
January '18*	3	0	2	1	2:1	-	-
February	24	2	14	8	1.8:1	1.636	0.201
March	54	1	31	22	1.4:1	1.528	0.216
April	24	1	12	11	1.1:1	0.043	0.835
May	34	0	11	23	1:2.1	4.236	0.040
June	64	0	36	28	1.3:1	1.286	0.317
July	39	1	13	25	1:1.9	3.789	0.052
August	15	1	7	7	1:1	0.000	1.000
Total	353	29	164	160	1.03:1	0.049	0.824

*Values were too small to calculate for Chi square.

N = Total number; I = Indeterminate; S = Significant; NS = Not Significant; χ^2 = Chi-square value; P $_{(0.05)}$ = Probability at 0.05 significant level

Table 4: *Monthly Sex Ratio of Heterobranchus longifilis from River Offin*

Month	N	I	Males	Females	Sex Ratio M:F	$\chi 2$	P $_{(0.05)}$
September '17*	10	4	5	1	5:1	-	-
October	17	5	7	5	1.4:1	0.333	0.564
November*	5	1	3	1	3:1	-	-
December*	65	59	4	2	2:1	-	-
January '18*	3	0	2	1	2:1	-	-
February	29	20	7	2	3.5:1	2.778	0.096
March	11	0	9	2	4.5:1	4.455	0.035
April*	7	0	3	4	1:1.3	-	-
May*	6	0	0	6	-	-	-
June	15	0	8	7	1.1:1	0.067	0.796
July	13	0	6	7	1:1.2	0.077	0.782
August*	7	0	6	1	6:1	-	-
Total	188	89	60	39	1.5:1	4.455	0.035

* Values were too small to calculate for Chi square.

N = Total number; I = Indeterminate; S = Significant; NS = Not Significant; χ^2 = Chi-square value; P $_{(0.05)}$ = Probability at 0.05 significant level

4.7 Variations in Gonadosomatic Index (GSI)

4.7.1 *Clarias gariepinus*

Variations in the mean monthly gonadosomatic index (GSI) of *C. gariepinus* are presented in Figure 10. Generally, both sexes exhibited a similar pattern of variation. The males recorded a range of 0.1 in August 2018, to 0.3 in May and June 2018. Females recorded the least GSI in February 2018 at 0.4 and the highest in April 2018 at 10.6. Females had a remarkably higher GSI than males. Both sexes had two major peaks; May and June 2018 for males, then April and June 2018 for females. There were minor peaks for both sexes between April and August 2018. Out of the 99 individuals used for this analysis, there were months where no gonads were encountered during sampling. These months were allocated with zero as GSI values.

4.7.2 *Heterobranchus longifilis*

Figure 11 shows the mean monthly variations in the gonadosomatic index (GSI) of *H. longifilis* for both sexes. The mean GSI of males ranged from 0.10 in June-August 2018 to 0.30 in November 2017. Females showed the least GSI in May 2018 at 1.15 and the highest in June 2018 at 10.2. The pattern of variation displayed by both sexes is dissimilar. Males had one major peak in November 2017 and three minor peaks from June-August 2018. For females, there was one major peak in June 2018, and two minor ones in February and April 2018. Months with GSI at zero accounts for the months in which no gonads were encountered during the study. Data for this analysis was scanty as only 16 individuals were used.

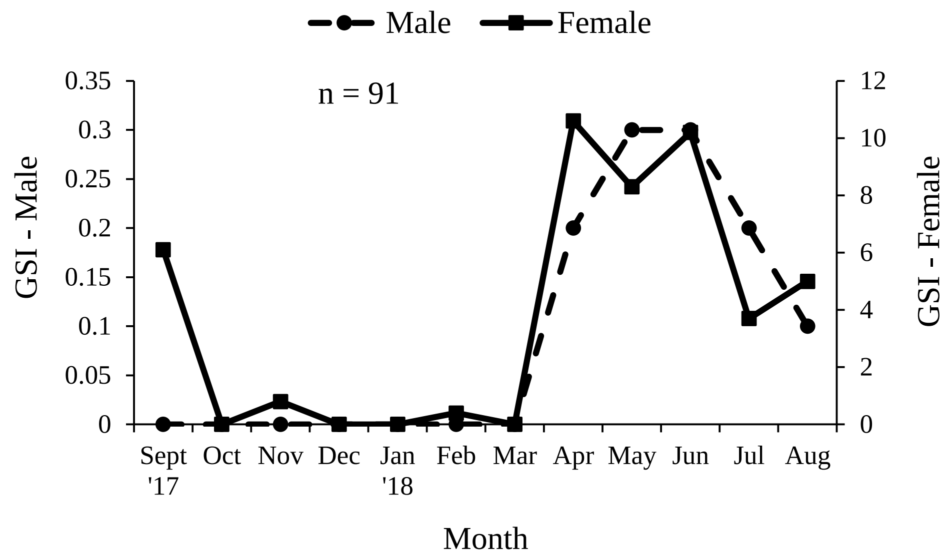

Figure 10: Mean monthly Gonadosomatic Indices (GSI) of male and female *Clarias gariepinus* from River Offin.

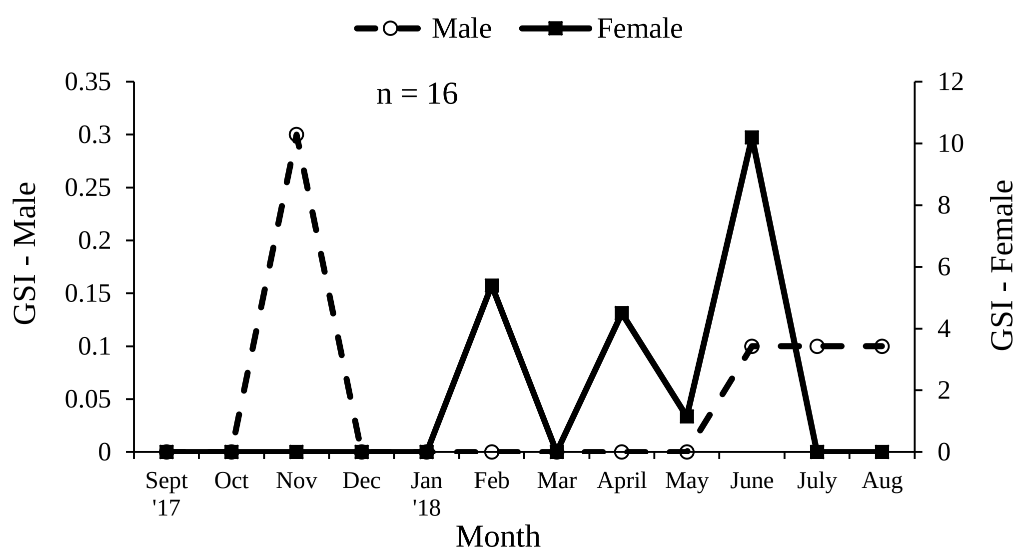

Figure 11: Mean monthly Gonadosomatic Indices (GSI) of male and female of *Heterobranchus longifilis* from River Offin.

4.8 Fecundity

4.8.1 *Clarias gariepinus*

Fecundity was found to be within the range of 1,750 to 88,930 eggs. This is observed for fish size of 28.8 cm TL and 163.8 g weight to 46.5 cm TL and 897.6 g. Figures 12-14, respectively illustrate the relationship between fecundity (F) and total length (TL), body weight (BW) and gonad weight (GW) of *C. gariepinus* from River Offin. All the relationships were found to be significantly positive linearly, and are described by the equations:

F = 1178.8TL – 18518 (r = 0.50)

F = 21.154BW + 15647 (r = 0.42)

F = 495.19GW + 7893.4 (r = 0.80).

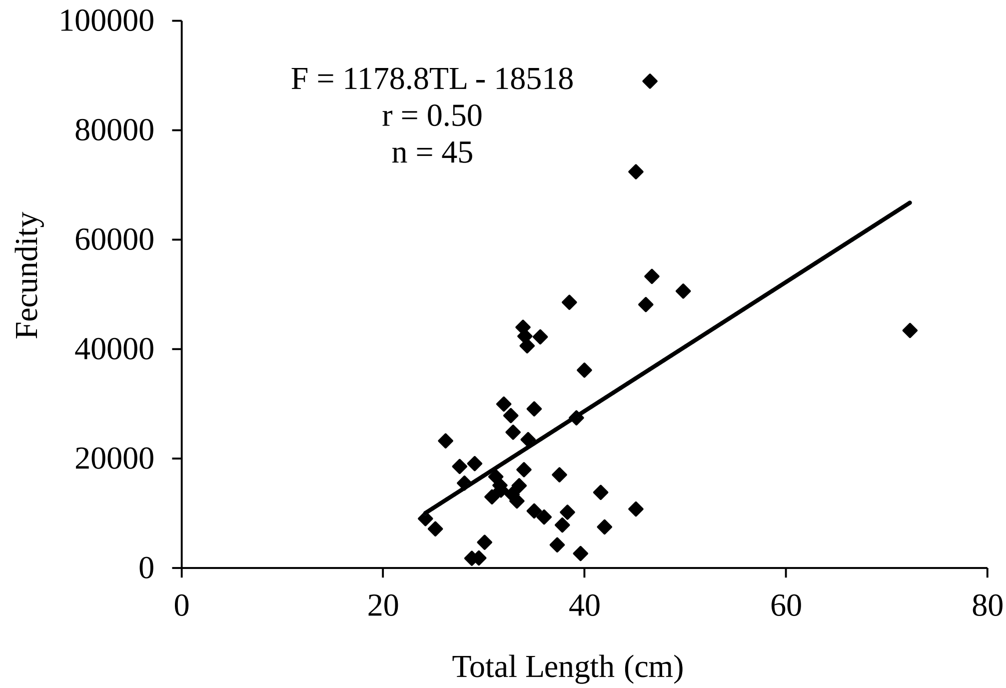

Figure 12: Relationship between Fecundity (F) and Total Length (TL) of *Clarias gariepinus* from River Offin.

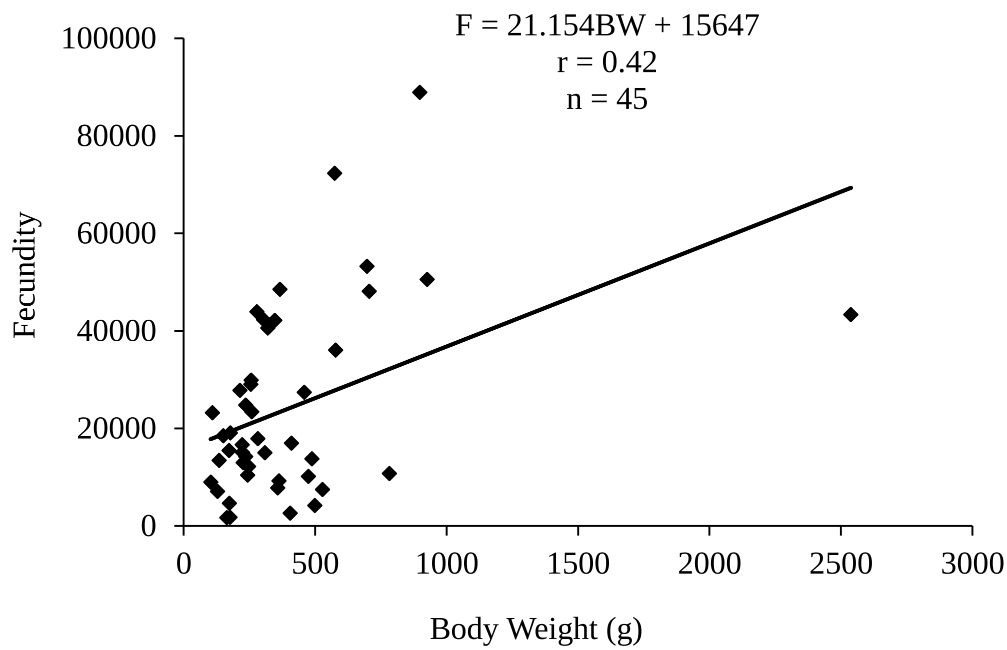

Figure 13: Relationship between Fecundity (F) and Body Weight (BW) of *Clarias gariepinus* from River Offin.

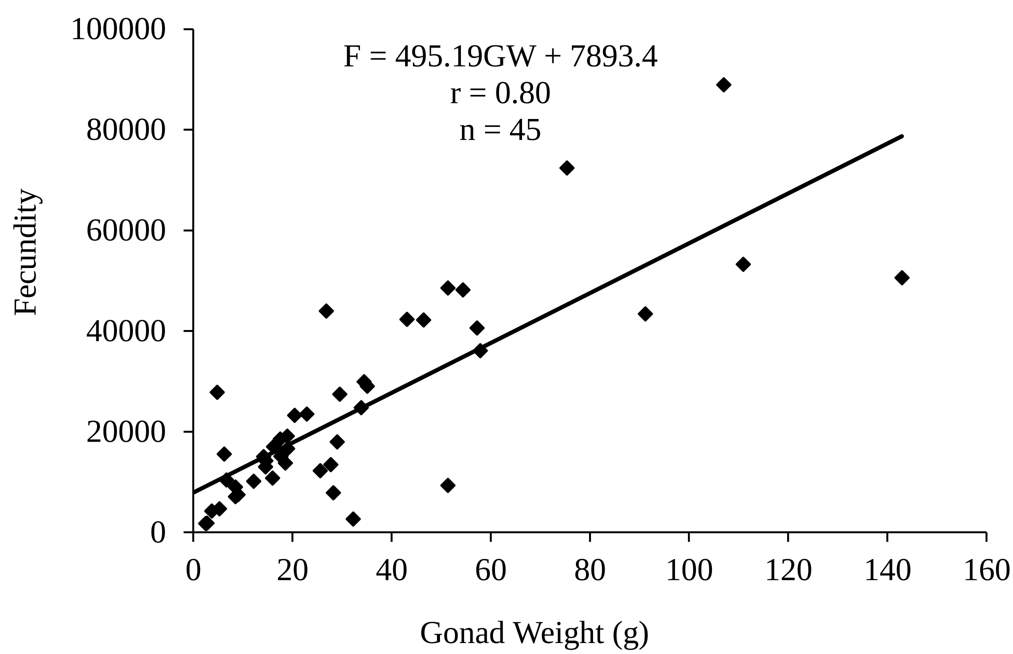

Figure 14: Relationship between Fecundity (F) and Gonad Weight (GW) of *Clarias gariepinus* from River Offin.

4.8.2 *Heterobranchus longifilis*

Fecundity ranged from 39,170 to 53,891 eggs for fish that measured in size between 44.0 cm TL, 626.2 g weight, and 55.2 cm TL, 1316.2 g weight. Due to the insufficient number of females (3) with ripe gonads, relationships between fecundity and total length, body weight and gonad weight could not be analysed.

4.9 *In vitro* Fertilization

This experiment was unsuccessful due to the unavailability of live female brood fish with ripe ova during the study period.

CHAPTER FIVE

DISCUSSION

5.0 Introduction

In this chapter, the results, as presented in the previous chapter, are interpreted, explained and compared with findings from other studies. The inter-relation between the various parameters are discussed as well. The presentation follows the order in which the results were presented in the previous chapter.

5.1 Physico-chemical Parameters

It was observed that the pattern of variations was similar for all the parameters. From November 2017 to March 2018 (which marked the dry season), all measured parameters were generally high. During the rainy season, April to August 2018, all measured parameters were generally low. The dry season is usually accompanied with high temperatures while the rainy season comes with low temperatures. Therefore, the pattern of variation observed for the water temperature was normal, since it is largely influenced by ambient temperature. Temperature affects the dissolution of oxygen in water. At high temperatures, dissolution of oxygen in water is low and vice versa. However, this was not the case in this study. Generally, dissolved oxygen (DO) was higher during the period of high temperatures (dry season) and low during the period of low temperature (rainy season). This phenomenon could be attributed to the high influx of silt and or allochthonous materials from rainfall runoff and the accompanying decomposition of these materials leads to reduction of DO. The pH of the water remained largely alkaline except in July and August 2018 where it fell slightly into the acidic range. The range of values recorded for the pH are within acceptable limits for most culture fish species. The turbidity of the water was generally high throughout the period of this study. This could probably be as a result of the Gold mining activities (especially Galamsey) within the catchment of the river. The dry season was marked with higher turbidity. The drop in the turbidity during the rainy season is possibly because of the influx of fresh rainwater, diluting the cloudiness in the water column. Clariid catfishes are known to be tolerable to poor environmental conditions (Offem et al., 2008; Eyo et al., 2016), hence their adaptation to this environment. This probably explains why these catfishes regularly dominated the catches of the fishermen operating in that area (from personal observation). Also, this characteristic is an advantage for these species in aquaculture, such that they can be cultured at high densities even under extensive or semi-intensive culture systems, and in the event of water quality decline, fish kill may be minimal before restoration interventions are made.

5.2 Growth

C. gariepinus and *H. longifilis* both exhibited negative allometric growth. That means the fish increases in length more than in weight.

Ayo-Olalusi (2014) reported a positive allometric growth for *C. gariepinus* cultured in flow-through system tanks. A negative allometric growth was observed for *H. longifilis* from the Idodo River in Nigeria (Anibeze, 2000). Bagenal and Tesch (1978) explained that variations in the growth pattern of fish of the same species could be accounted for by the differences in environmental conditions, season, sex and maturity stage.

The International Game Fish Association, IGFA (2001) reported a maximum length of 170.0 cm for *C. gariepinus*. In this study, the maximum size of *C. gariepinus* encountered was 74.1 cm total length with a corresponding weight of 2,537.8 g. For *H. longifilis,* the maximum observed size was 55.2 cm total length and 1,700 g body weight. Anibeze (2000) however, reported a bigger size of 64.0 cm for males and 93.6 cm TL for females from the Idodo River in Nigeria.

The average length of the total sample of *C. gariepinus* was 31.1 cm TL. That of males was 32.4 cm TL and females, 31.5 cm TL. For *H. longifilis*, average length observed was 24.1 cm TL for the total sample, 31.4 cm TL for males and 29.3 cm TL for females. So, for both species, males were generally but not significantly larger than females. Also, *C. gariepinus* was relatively larger than *H. longifilis* from the Offin River.

For aquaculture purposes, the insignificant difference between the size variations of males and females implies that both sexes can be cultured for optimum growth.

5.3 Condition Factor

The two sexes of *C, gariepinus* were in similar condition since their average condition factor did not differ significantly. The monthly variations in condition factor shows marginal variations except in December 2017. It is important to note however, that apart from December 2017 when a condition factor of 1.08 was observed for males, condition factor for all other months for both sexes were below 1.00. The results of this study is in line with findings of Ayo-Olalusi (2014), who reported a condition factor range of 0.50 to 1.42 with mean values of 0.80 for males and 0.79 for females in a culture system. However, in the Malilangwe reservoir in Zimbabwe, Dalu et al. (2013) found condition factor for *C. gariepinus* to range from 0.70 to 2.14 with a mean value of 1.27 for both species. According Dalu et al. (2013), mean values greater than 1.0 indicates that the fish is above average condition. Therefore, *C. gariepinus* is below average condition in the Offin River. Moreover, Bagenal and Tesch (1978) suggested 2.90 – 4.80 as recommended range of values for condition factor for mature freshwater fish. The generally low condition factors observed for the species could possibly be due to poor environmental conditions, of which mining activities could be a major contributing factor.

For *H. longifilis*, the males appeared to be in a better condition than the females just as was found in *C. gariepinus*. This result is contrary to findings by Anibeze (2000) on the same species from the Idodo river (Nigeria), where the females had higher condition factor than males. He also reported that, the values were generally higher for both sexes in the rainy season. But the observation in this study does not give any seasonal trend regarding the wellbeing of the fish. Considering the mean values for both sexes, it can be concluded that the wellbeing of *H. longifilis* was also below average in the Offin River based on the recommended values by Bagenal and Tesch (1978), Dalu et al. (2013). This can also be accounted for by the same issues of poor environmental conditions.

5.4 Food and Feeding Habits

Examination of the stomach contents of *C. gariepinus* showed that the fish fed on a wide array of food items from plants to animals and terrestrial waste. Even though fish were found in the diet, it was not as much as corn and domestic waste. From this study, *C. gariepinus* can be said to be opportunistic in feeding. Thus the fish feeds on whatever is available unselectively. The abundance of domestic waste and detritus in the diet also points to the fact that the fish scavenges and is a bottom feeder as well. The results of this study agree with earlier findings by researchers on the same species. Generally, *C. gariepinus* is accepted to be an omnivore (Adewolu et al., 2008; Dadebo, 2000; Omondi et al., 2013; Skelton, 2001; Yalçın et al., 2001). Classifying the species as a bottom feeder agrees with the work of Omondi et al. (2013).

Similar observations were made for *H. longifilis* upon examination of their stomach contents. Palm fruits, corn, plant debris, domestic waste (charcoal) and detritus make up the major food items. Insects, plastics and snails were the least explored items by the fish. It can therefore be seen that plants dominate the diet of *H. longifilis* from the Offin River. The presence of plastics tells the level of 'un-selectiveness' of the fish when feeding, leading to the ingestion of non-food items. This also points to some pollution issues from anthropogenic sources. The amount of detritus in the diet is an indication that the species is also a bottom feeder. *H. longifilis* is known to be very active at night and feeding on any available food, as well as scavenging on waste from land (Skelton, 2001). This observation agrees with the results of the current study. The prominent presence of domestic waste, plastics and other plants materials such as palm nut, grains of rice and corn, cassava could be the result of the closeness of riverside communities and a refuse dump site to the river. Moreover, the level of pollution in the river from the activities of Galamsey operators within the riparian vegetation could also explain the low abundance of other aquatic life. This makes the immobile foods from terrestrial sources more readily available to the fish. This probably could be the reason for the abundance of waste and plant materials in the diet of the two species. For culture purposes, domestic waste could serve as an alternative source for feeding these fish species.

5.5 Reproductive Biology

The male to female ratio for *C. gariepinus* did not deviate from the hypothesised 1:1 sex ratio. However, in the month of May 2018, the number of females was about twice the number of males. It is not clear the factor(s) responsible for this observation. The findings of this study falls in line with results by Eyo and Mgbenka (1992) who also reported a 1:1 sex ratio for *C. gariepinus* in the Anambra River Basin of Nigeria. Similar finding was also reported by Idowu et al. (2017) for the species in the Ogbese River, also in Nigeria. In two separate culture experiments, a 1:1 sex ratio was found in one of the experiments (Ayo-Olalusi, 2014) and a deviation in favour of the males was found in another (Abanikannda et al., 2019). It can therefore be established that *C. gariepinus* from the Offin River generally exhibits a 1:1 sex ratio. The equal male to female ratio favours optimum reproduction. This is important because courtship preceedes reproductive activities. However, considering the level of pollution going on in the river currently, there is a possibility of changes in this finding in the near future as an adaptive behaviour by the species.

For *H. longifilis*, the males showed dominance over the females for the overall sample. However, there were no deviations in the monthly samples from the expected 1:1 ratio, except for the month of March 2018 when the males dominated. No specific factor was identified to be responsible for the male dominance, though environmental conditions could be suspected and or behavioural differences between the sexes. This result agrees with findings of Offem et al. (2008). They also recorded a male dominance in the Cross River of Nigeria. However, Onimisi and Adeyemi (2018) found a unity sex ratio for the species in the Okura River, also in Nigeria. To the aquaculturist, it can be inferred for both species, that certain culture conditions or systems may favour one sex over the other.

The pattern of variations in GSI observed for *C. gariepinus* indicates that the species spawns between April and July, but could be prolonged into August. The higher value of GSI recorded in September, outside the main breeding period could be a mere coincidence or a delayed gonad development in some few female individuals, as the value for males was at zero. Two peaks of GSI were observed in April and June with a slight drop in May for females. Males exhibited a similar pattern with a rise in April and peaks in May and June. April to July marks the major rainny season in the year, thus the spawning period coincides with the rainy season. Rainfall have been mentioned (Admassu et al., 2015; De Graaf & Janssen, 1996; Eyo & Mgbenka, 1992; Idowu et al., 2017; Willoughby and Tweddle,

1978) as the major factor that triggers spawning in *C. gariepinus*. The outcome of this study agrees with findings from other studies (Admassu et al., 2015; Eyo & Mgbenka, 1992; Idowu et al., 2017; Willoughby &Tweddle, 1978). Eyo and Mgbenka (1992) suggested that when given suitable environmental conditions, the species can spawn more than once in a year. However, looking at the GSI pattern observed in this study, it is quite clear that the species have one spawning period in the Offin River. This could most probably be due to the environmental conditions which may not be very favourable for the species, as evidenced from the physico-chemical parameters measured in the river.

The pattern of variations in GSI observed for *H. longifilis* shows no similarity between males and females. While the males had a major peak in November and three minor ones in June to August, the females had no continuous peaks. The peaks rather fluctuated; a major one in June, then two minor ones in February and April. July and August form part of the rainy season hence were suspected to have peaks. Contrarily, GSI was at zero in these two months. From this study, it is not so clear the pattern of spawning exhibited by the species. Moreover, available samples for this analysis were small (16 individuals), making it more difficult to arrive at any concrete conclusion on the breeding pattern of *H. longifilis*. Nonetheless, it is suspected that the species has a similar spawning period as *C. gariepinus*.

Fecundity ranged from 1,750 to 88,930 eggs for *C. gariepinus.* This corresponded to fish size between 163.8 g and 897.6 g. The observed fecundity in this study is higher than what was reported for the same species in other places though the fish sizes observed in this study are relatively smaller. Bruton (1979) reported an average of 45,000 eggs for a 2 kg fish in Lake Sibaya, South Africa; Eyo and Mgbenka (1992) reported a range of 9,000 to 25,000 eggs in the Anambra River Basin, Nigeria; Idowu et al. (2017) reported a range of 32,000 to 59,081 eggs in the Ogbese River, also in Nigeria. This notwithstanding, other studies reported far higher fecundity for the species. From Lake Babogaya (Ethiopia), Admassu et al. (2015) reported fecundity ranging from 11,000 to 580,571 eggs; Dadebo (2009) reported of 5,000 to 1,240,000 eggs in Lake Chamo, also in Ethiopia. It is worthy to note that the fish sizes reported by these authors are also larger than those observed in this study. This could possibly explain why they had higher fecundities. Also, considering the fact that fish of size 102 cm (Admassu et al., 2015) and 104 cm (Dadebo, 2009) were found in such habitats, could be an indication of better and more favourable environmental conditions as compared to conditions in river Offin. Even though bigger sizes of fish were observed by other authors (Bruton, 1979; Eyo & Mgbenka, 1992; Idowu et al., 2017) that reported of fecundity less than the current findings, age can be considered as a factor responsible for the low fecundity they observed. This was also suggested by Eke et al. (2017) as they observed a decline in egg production at a certain age as the fish matures. This supports the suggestion that fecundity is not only a function of fish size, but also of age.

The linear positive relationships observed between fecundity and total length, body weight and gonad weight are indications that fecundity is a function of these three parameters. An increase in any of these three will produce a resultant increase in fecundity. Similar findings were made by Admassu et al. (2015) who found fecundity to linearly relate to body weight and gonad weight, but curvilinear with total length. Eyo and Mgbenka (1992) also reported linear relationships between fecundity and standard length, gonad weight and body weight. The same observation was made for the species from River Asi in Turkey (Yalçin et al., 2001).

Fecundity observed for *H. longifilis* was from 39,170 to 53,891 eggs, relatively lower than that of *C. gariepinus*. The size range of fish for the observed fecundity was 44 cm to 55.2 cm TL. Onimisi and Adeyemi (2018) found fecundity to range from 17,001 to 97,122 eggs for fish size of 38.6 cm to 71.5 cm standard length. The larger size of fish observed in their study probably resulted in the higher fecundity recorded. Their result appears to be similar to the results of the current study with reference to the size and fecundity values. Meanwhile, a relatively lower fecundity range of 5,515 to 36,800 was observed for the species in the Cross River in Nigeria. This fecundity range was accompanied with a size range of 14.8 cm to 102.4 cm (Offem et al., 2008).

In culture terms, the generally high fecundity exhibited by both species is a positive sign for hatchery breeding and stocking. The age factor as an influence on fecundity should inform hatchery operators on how long brood stocks can be used for breeding programmes for optimum production. Furthermore, it can be inferred that anything that enhances the length and weight of the fish under culture may proportionally enhance fecundity as well.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This chapter presents the conclusions drawn based on the data obtained from the study and suggests recommendations for other studies on certain aspects of the biology of the fish species under consideration and possible applications of this study.

6.1 Conclusions

Clarias gariepinus were more abundant and relatively larger in size in the samples obtained than *Heterobranchus longifilis*. However, the sizes obtained for both species on the average are marketable sizes. The two species were found to be growing allometrically as their regression coefficients differed statistically from the hypothetical value of 3.0. This means that the two species change their body shape as they grow (thus they increase in length more than in weight). *H. longifilis* appeared to be in better condition than *C. gariepinus.* However, both species were below reported average condition in wellbeing. For optimum production, an aquaculturist must therefore be mindful of the water quality parameters in a culture system for both species even though the species are considered to be hardy.

From the food items observed in the gut of the two species, it can be concluded that both species were omnivorous and exhibited similar food preferences and feeding habit. Therefore, available commercial feeds for *C. gariepinus* can be administered to *H. longifilis* under culture conditions with guarantee for optimum production. The abundance of plant and domestic waste in the diet of both species is an indication that the species could utilise food from primary production in culture systems. Also, food from these sources (plant and domestic waste) can be incorporated into the feeds of the two species especially for extensive, semi-intensive and integrated culture systems.

The overall sex ratio exhibited by *C. gariepinus* was unity. In the monthly analysis, the ratio remained 1:1 throughout the year, except the month of May 2018 when the number of females was twice the number of males. The reason for this observation is not certain. Equal proportions of male and female in a population is good for brood stock development in hatchery operations for aquaculture purposes. Males of *H. longifilis* showed preponderance over their female counterparts in the ratio of 1.5:1. The reason for the male dominance could not be ascertained from this study.

The males and females of *C. gariepinus* exhibited similar pattern of gonadosomatic index (GSI) throughout the year. The GSI values for females were higher than that of the males. This is not surprising considering the fact that the size and weight of gonads of females outweighed the gonads of males. From the GSI patterns, it could be inferred that the fish spawned mainly from the month of April to June but could extend to August. For extensive aquaculture where seeds are usually obtained from the wild, this knowledge should inform farmers on the spawning season and the subsequent timing for collection of seed. The data gathered on the GSI of *H. longifilis* in this study were insufficient to arrive at any meaningful conclusion on the pattern of spawning for the species though it is suspected to be similar to that of *C. gariepinus*.

There was positive linear relationship between fecundity and total length, body weight and gonad weight of *C. gariepinus*. This means that fecundity in *C. gariepinus* was a function of size and weight of the fish and gonads. So, bigger and heavier fish will produce more eggs. *C. gariepinus* was more fecund than *H. longifilis* in the Offin River. However, the fecundity of the two species is considerably high for aquaculture purposes.

6.2 Recommendations

- Further studies should be carried out on the GSI of *H. longifilis* in order to ascertain the pattern of spawning. This is necessary for hatchery operators and farmers that may be obtaining fingerlings from the wild.
- *H. longifilis* is recommended for aquaculture in addition to *C. gariepinus*. However, efforts should be made towards culture-based experiments especially on *H. longifilis*.
- Available culture technology for *C. gariepinus* can be applied to *H. longifilis* considering the similarities between the two species biologically.
- Experiments on artificial fertilization and cross breeding of *C. gariepinus* and *H. longifilis* will be very beneficial to produce hybrids of the two species for improved strains.

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APPENDICES

APPENDIX A – TAXONOMY OF THE CATFISHES INVESTIGATED

Appendix A1 – *Clarias gariepinus*

Kingdom: Animalia

Phylum: Chordata

Subphylum: Vertebrata

Class: Actinopterygii

Order: Siluriformes

Family: Clariidae

Genus: *Clarias*

Species: *gariepinus*

Appendix A2 – *Heterobranchus longifilis*

Kingdom: Animalia

Phylum: Chordata

Subphylum: Vertebrata

Class: Actinopterygii

Order: Siluriformes

Family: Clariidae

Genus: *Heterobranchus*

Species: *longifilis*

APPENDIX B – PREPARATION OF GILSON'S FLUID

Measure 800 ml of distilled water into a beaker. To a portion of the distilled water in a conical flask, add 20 g of Mercuric Chloride. Heat and stir until there is total dissolution. Add 15 ml of 80% Nitric acid. Add 18 ml of Acetic acid. Add 100 ml of 60% Ethanol. Add the remaining portion of the measured distilled water and stir.

APPENDIX C – SOME FISHING GEARS USED IN RIVER OFFIN BY FISHERS AT SOFOKROM

Appendix C1 – Trap made from metals, used by fishermen at Sofokrom in river Offin

Appendix C2 – Trap made from raphia branches, used by fishermen at Sofokrom in river Offin

Appendix C3 – Gill set net used by fishermen at Sofokrom in river Offin