UNIVERSITY OF CAPE COAST

ASPECTS OF THE BIOLOGY OF CICHLIDS IN THE BRIMSU RESERVOIR IN CAPE COAST, GHANA

BY

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THESIS SUBMITTED TO THE DEPARTMENT OF FISHERIES AND AQUATIC SCIENCES OF THE SCHOOL OF BIOLOGICAL SCIENCES, UNIVERSITY OF CAPE COAST, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN ZOOLOGY

FEBRUARY 2012

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2012

DECLARATION

Candidate's Declaration

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

…………………………… ……………………..

KWADWO KESSE MIREKU DATE

(CANDIDATE)

Supervisors' Declaration

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

…………………… …………………..

PROF. JOHN BLAY DATE

(PRINCIPAL SUPERVISOR)

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PROF. KOBINA YANKSON DATE

(CO-SUPERVISOR)

ABSTRACT

An investigation was conducted into the species composition, growth, reproductive biology and food spectrum of cichlids in the Brimsu Reservoir in Cape Coast, Ghana. Five species of cichlids: *Sarotherodon melanotheron, Tilapia zillii, Tilapia guineensis, Hemichromis fasciatus* and *Oreochromis niloticus* representing four genera were encountered. *S. melanotheron* was the most abundant with numerical composition of 44.80 %, while *T. zillii*, *T. guineensis* and *H. fasciatus* represented 26.57 %, 25.10 % and 2.65 % of the total sample respectively. *Oreochromis niloticus* was rare in the reservoir and represented by a single specimen of standard length of 12.0 cm. The fish sample ranged from 5.8 cm to 17.6 cm (SL). The modal size of *S. melanotheron* was 10.0 cm (SL), while *T. zillii* and *T. guineensis* had modal size of 9.0 cm and *H. fasciatus,* 8.0 cm. The blackchin tilapia, *S. melanotheron,* matured at a bigger size (11.26 cm and 11.34 cm for male and female respectively) than the other cichlids in the Brimsu reservoir. Male cichlids matured at a bigger size (11.26 cm) than females (11.34 cm). *S. melanotheron* and *T. guineensis* fed primarily on phytoplankton whereas *T. zillii* fed mainly on aquatic macrophytes. *H. fasciatus* is carnivorous and fed on other fish and invertebrates. The choice of food item was dependent on the abundance of that food item in the environment. There was seasonality in the condition index. However, all the cichlids exhibited isometric growth. The cichlids spawn in most part of the year, however, the wet

season was the major breeding season. Observations on the ovum diameter distribution indicate that the cichlids spawn in batches.

ACKNOWLEDGEMENTS

I acknowledge the immense support of my two supervisors of the Department of Fisheries and Aquatic Sciences; Professor John Blay and Professor KobinaYankson. I am very grateful for their advice, and the trouble they took to read through this thesis.

I am also grateful for the moral support of all the academic staff and non-academic staff of the department of Fisheries and Aquatic Sciences. I am really thankful for their words of encouragement. I wish to express my heartfelt gratitude to Prof. E. A. Obodai who has been an inspiration and a counselor to me.

I would further like to thank all my colleagues and friends who have been supportive of me throughout this period. I am grateful for the support of Nicholas Parden for his words of motivation. My gratitude also goes to Dr. Rofela Combey, Mrs. Dzigbordi Atebi, Mr. Lawrence Ahiah and Isaac Otchere for their words of encouragement.

My appreciation also goes to my loving and caring family. I am grateful for the prayers, financial and moral support of my Dad, Mr. Samuel A. Mireku, my Mom Mrs Comfort Larbi, my brother Kofi O. Mireku and my two sisters, Abena O. Mireku and Victoria Akosua Otubea Moamere.

Finally, I wish to acknowledge the support of Miss Angela Randolph who stood with me throughout the course of my postgraduate studies.

DEDICATION

To my parents, Mr. Samuel Asafo Mireku and Mrs. Comfort Larbi.

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CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

Background of study

Inland fisheries are of immense importance as they provide a means of livelihood and an important source of protein (Welcomme, 1979; Lowe-McConnell, 1991). Ghana has a system of rivers and lakes that form the basis of an inland fisheries industry. The freshwater systems consist of numerous inland water systems such as the Volta River (Black Volta and White Volta), Oti, Pru and Asukawkaw that flow through the Volta system into the Atlantic Ocean. Other rivers such as Pra, Offin, Birim, Tano, Bia, Ankobra, Densu empty into the Atlantic Ocean mostly as individual rivers.

Landings from lakes form an important part of the catch for the inland fisheries industry. Among the lakes in Ghana, the Volta, Weija and Bosomtwi are of immense importance. These water bodies provide potable drinking water, serve as irrigation facilities and also serve as a source of livelihood for riparian communities. The Volta Lake, the largest man-made lake (8,480 km^2), contributes up to 70 % of the total inland fisheries.

Man-made lakes or reservoirs are but one example of water resources which form part of the larger system, the watershed. Human activities in the watershed therefore influence the water in the reservoir and downstream. Deforestation and removal of the vegetal cover generally results in silting of the reservoir. Agricultural practices within the catchment area of reservoir contribute to the addition of nutrients which are generally brought about by run-offs through streams and other head waters.

Reservoirs are directly affected by human activities like fishing and recreation which greatly influences the water quality. In developing countries, such as Ghana, water resources are under great pressure from the array of human activities which are geared towards increasing agricultural production to match the ever-increasing human population. In the light of this, reservoirs are becoming increasingly important as providers of animal protein and employment opportunities, particularly to poor communities, which also often happen to be rural.

In the world, the total number of inland fisheries is relatively small, and has contributed about 7–8.5 % to fish supplies over the years (De Silva, 2001). In Africa, reservoir fisheries contribute about 10 % to the total inland fisheries (FAO, 1984). However, the biological and economic potential of these reservoirs have not been fully harnessed mainly because they have been created mainly for purposes other than fisheries. This has led to productivity of the fisheries in reservoirs being far below the identified biological potential. However, fisheries and their associated activities (fish processing and fish trading) have been recognized to play an important role in terms of food security and economic development in developing countries.

Reservoirs are important resources which have the potential to enhance the fisheries of many countries. However, one problem which confronts many fishery scientists is the different classification of reservoirs adopted by many countries. Srivastava *et al.* (1985) classified reservoirs as small (<1000 ha), medium (1000 to 5000 ha) and large (>5000 ha), whereas De Silva *et al.* (1991) based their classification on capacity; where small, medium and large reservoirs refer to capacities of less than 10×10^6 m^3, 10 –100 $\times 10^6$ m^3 and more than 100 $\times 10^6$ m^3, respectively. Reservoirs have also been classified as perennial or non-perennial.

Abban, Agyakwah and Falk (2004) noted that the composition of African inland fishes broadly consisted of two major groups: the non-cichlid fishes (about 3000 species) and the cichlid fishes (about 870 species which include the tilapias). They further noted that in Africa the three to five most commercially and thus socio-economically important inland fish taxa include the tilapias. According to Arawomo and Fawole (1997), cichlids are among the commercially exploited fishes for human consumption especially in African lakes.

In Ghana, the Volta River system and its tributaries drains more than two-thirds of the total land area (Dankwa, Abban & Teugels, 1999; Safo, 2007) of which cichlids including the Nile tilapia, *Oreochromis niloticus*, and the Mango tilapia, *Sarotherodon galilaeus*, constitute an important part of commercial fish stocks (Ofori-Danson, 2000). Dankwa *et al.* (1999) identified 157 freshwater species of fish belonging to 28 families and 73 genera of which nine (9) species are endemic to Ghana. Other studies on the reservoirs in the northern part of Ghana indicate that cichlids dominated the catches of artisanal gill net fishery of some of these reservoirs (Amevenku & Quarcoopome, 2006; Ofori-Danson & Kwarfo-Apegyah, 2008; Kwarfo-Apegyah & Ofori-Danson, 2010).

Most works which have been conducted on cichlids have concentrated more on coastal water bodies with a lot of emphasis on *S. melanotheron* probably due to their ability to improve the fisheries of these water bodies (Abban, Asante & Falk, 2000, Abban, Falk & Agyakwah, 2004). These include works done on aspects of parasitology (Pauly, 1974), reproductive biology (Eyeson, 1983, 1992), growth and mortality parameters (Blay & Asabere-Ameyaw, 1993; Blay, 1998; Ekau & Blay, 2000), genetics (Abban *et al.*, 2000) and feeding ecology (Ofori-Danson & Kumi, 2006). However, scanty literature exists on aspects of the biology of cichlids in the freshwater bodies of which the Brimsu reservoir is no exception.

Distribution

Cichlids are a group of bony fishes belonging to the family Cichlidae, in the order Perciformes and suborder Labroidei. They are the third largest family of bony fish after Cyprinidae and Gobiidae. This family is very diverse with 2500 species of which 1300 species belonging to 220 genera have been scientifically identified (Kullander, 1998; Froese & Pauly, 2007). However, new species are being reported on regular basis while many species remain undescribed. A new species of Tilapia (*Tilapia pra*) has been recently identified in the Pra River, Ghana (Dunz & Schliewen, 2010) while another cichlid, *Crenicichla ypo*, was identified in Argentina (Casciotta, Almiron, Piálek, Gómez & Rícan, 2010).

The Cichlidae is a species-rich monophyletic group of freshwater and brackishwater perciform fishes. This group of fish can be found throughout Africa, Madagascar, South and Central America, Arabia and India. However, a vast majority of cichlids (> 1000 species) hail from Africa with a significant number of them inhabiting the Great Lakes of East Africa: Lakes Malawi, Victoria and Tanganyika. Europe, Australia, Antarctica, and North America have no native cichlids. However, they have been introduced either intentionally or unintentionally in various countries.

Although cichlids have become widespread as a result of unintentional introduction, they show high levels of endemism. Lake Tanganyika is noted for its amazingly rich profusion of different cichlid species (approx. 250 species) many of which are endemic to the lake. This Lake is where the most specialized and diverse cichlid collections are found. Over 95 % of the described cichlids from Lake Tanganyika are endemic to the lake. Lake Victoria fish fauna included an endemic cichlid flock of more than 300 species until the Nile perch (*Lates* sp) was introduced.

Cichlids of the genera *Paratilapia*, *Ptychochromis*, *Ptychochromoides*, *Oxylapia* and *Paretroplus* are endemic to Madagascar whereas *Iranocichla hormuzensis* is found only in Southern Iran. Endemic cichlids are largely absent in Asia except for four species in the Jordan Valley in the Middle East, one in

Iran, and three in India and Sri Lanka. Four species of cichlid have also been found in Cuba and Hispaniola (Chakrabarty, 2004).

In Ghana, seventeen cichlid species belonging to nine genera have been identified (Dankwa *et al*., 1999) with more being identified from time to time. Of the cichlids identified, *S. melanotheron, S. galilaeus, Oreochromis niloticus, Tilapia zillii* and *T. guineensis* are of immense importance. *Hemichromis frempongi, Limbochromis robertsi* and *Chromidotilapia bosumtwensis* are endemic to Ghana.

Anatomy

Cichlids are characterized by having single continuous dorsal fin with spines and soft rays; single pair of nostrils; anal fin with three or more spines; two fused lower pharyngeal bone into a tooth-bearing structure (also with Labroidei) and an interrupted lateral line. They have no bone shelf below the orbit of the eye; however, a distinctly shaped otolith is present. The small intestines of cichlids exist on the left side of the stomach instead of its right side as in other Labroidei.

They span a wide range of body sizes, from species as small as 2.5 cm in length (e.g. female *Neolamprologus multifasciatus*) to much larger species approaching 1m in length (e.g. *Boulengerochromis* and *Cichla*).

Environmental tolerance

Although cichlids are mainly freshwater, some species survive and reproduce in brackish water systems. Several species from the genera *Sarotherodon*, *Tilapia* and *Oreochromis* are euryhaline. The abundance of *S. melanotheron* in coastal lagoons in West Africa has earned it the name "West African lagoon tilapia" (Eyeson, 1979). This fish can spawned at salinities of up to 35 ‰ and survived briefly to exposures of hypersaline waters of up to 100 ‰ under experimental conditions (Jennings & Williams, 1992). The Mozambique tilapia (*Oreochromis mossambicus*) has been reported to survive salinities up to 75 ‰. This species grows well and reproduces at salinities up to 50 ‰ (Balarin & Haller, 1982; Wohlfarth & Hulata, 1983).

Cichlids have a wide range of temperature and oxygen tension tolerance. The Mayan cichlid *Cichlasoma urophthalmus* is capable of surviving in extreme hypoxia, although it does well in water with dissolved oxygen content of at least 3.5 mg/L. This cichlid is an oxygen conformer, becoming much less active in hypoxic water, and even surviving virtual anoxia for up to two hours (Martinez-Palacios & Ross, 1986; Gamboa-Perez & Schmitter-Soto, 1999).

Tilapia guineensis is known to tolerate temperature between 14 – 33 °C and a low lethal oxygen level of 0.2 mg/L. This cichlid can tolerate acidic conditions up to pH of 3.4 (Wokoma as cited in FAO, 1987a). The blackchin tilapia, *S. melanotheron*, requires waters above 23 °C for successful rearing of their young (Schreitmuller as cited in Trewevas, 1983), however, a lower lethal temperature of 10.3 °C was noted by Shafland & Pestrak (1982) under experimental conditions.

The ability of some cichlids to withstand extremes of environmental conditions has made them the preferred fish for both aquaculture and aquaria.

Reproduction

Parental care exhibited by cichlids fall into four types: open brooding, cave brooding, ovophile mouthbrooding and larvophile mouthbrooding (Balon, 1975; Keenleyside, 1991). Some species including *Tilapia sp* are substrate spawners, laying their eggs on the ground or any hard surface; in which case parental care then consists of guarding the eggs, fanning them to provide oxygenated water; and then caring for the hatchlings which eventually become free swimming fry. It is common to observe both parents undertaking this form of parental care.

Another form of parental care provided by some cichlids is mouthbrooding. This care is particularly common among cichlids found in the Great Lakes of Africa. Although not specific to fishes of the family Cichlidae, it is very common among cichlids. Where mouthbrooding or oral brooding occurs, the eggs are incubated in the buccal cavity of either the female or male (Eyeson, 1992). Oral brooding is characteristic of tilapiine belonging to the genera *Oreochromis* and *Sarotherodon*.

Feeding habits

Cichlids exhibit astonishingly diverse feeding habits and may consume virtually every type of food source available in the freshwater habitat they are found. This is because cichlids exhibit numerous modifications of the lips, teeth, jaws and gill rakers. Many are primarily herbivores feeding on algae and plants whiles small animals, particularly invertebrates, form only a small part of their diet. *Tilapia* species, *O. niloticus* and *S. galilaeus* are identified as plankton feeders. Some cichlids are detritivores and eat all types of organic material; among these species are the tilapiines of the genera *Oreochromis*, *Sarotherodon* and *Tilapia*. Some cichlids such as *T. guineensis* have also been described as being iliophagous; subsisting on a high proportion of silt.

Juveniles of cichlids usually have a different feeding ecology from the adults. In tilapias, juveniles feed mainly on zooplankton whereas adults are herbivorous, mainly feeding on epiphytes, macrophytes and attached algae. Pauly (1976) noted that juveniles of *S. melanotheron* were much more carnivorous than adults and consumed small crustaceans and zooplankton. Amisah & Agbo (2008) also observed that the juveniles of *S. galilaeus multifasciatus* fed mainly on insects and insect larvae and relatively small quantities of diatoms but avoided macrophytes.

Other cichlids are predatory; subsisting on other food sources than plants. Piscivorous cichlids such as *Cyrtocara* sp feed on whole fish, the fry, larvae, or eggs of mouthbrooding species, and the scales or fins of various fishes. Adult *Hemichromis fasciatus* have been reported to feed on other fish species (Fagade & Olaniyan, 1973; Ugwumba, 1988)

Importance of cichlids

Tilapias have been intentionally dispersed worldwide for use as a food fish, biological control of aquatic weeds (Wheeler, 1985; Greenwood & Stiassny, 2002) and insects, as baitfish for certain capture fisheries and for aquaria. Globally, tilapia is the second most cultured freshwater fish after the carp (Popma & Masser, 1999) and the third most cultured fish. Two major cichlid species, *Oreochromis mossambicus* (Peters) and *Oreochromis niloticus* (L.) and their hybrids are the most common in culture. These fish have been exploited immensely for aquaculture primarily due to their ability to thrive in a wide range of culture environments as well as their fast growth rate.

Aquaculture and selective breeding

Cichlids have been widely introduced, either deliberately for aquaculture or accidentally through the aquarium trade (Lever, 1996). The group of cichlids known as the 'tilapia' have played an important part in the development of aquaculture of many countries. The common cichlids in aquaculture include *Oreochromis* spp, *Sarotherodon melanotherodon*, *Tilapia rendali* and *Tilapia zillii* (FAO, 1997). However, the Nile tilapia, *Oreochromis niloticus*, and its hybrids have been the mainstay. The positive attribute of tilapias are their tolerance to poor water quality and their ability to eat a wide range of natural food. Through a series of selective breeding programmes different stocks of tilapia have been produced. Of particular importance is the Genetic Improvement of Farmed Tilapia (GIFT) strain, which has demonstrated that simple selection for faster growing fish can yield significant increases in growth of tilapia.

Biological constraints to the development of commercial tilapia farming are their inability to reproduce below 18 °C and early sexual maturity which results in precocious spawning before the fish reaches market size. Probably, it is for this reason that most aquaculturist have ventured into monosex production of all-male or all-female tilapias. However, all-male tilapias have been the preferred choice since most male tilapia have superior growth rate than the females.

Aquaria and Angling

A vast majority of cichlid species are used in aquaria because of their beautiful coloration, fascinating and complex breeding behaviours. In addition to the aforementioned attributes, cichlids are fairly hardy, long-lived and easy-to-feed aquarium fish (Zurlo & Schleser, 2002 as cited in Froese & Pauly, 2007). The popular angelfish (*Pterophyllum scalare*), oscar (*Astronotus ocellatus*), discus (*Symphysodon* sp), convict cichlid (*Archocentrus nigrofasciatus*) and others such *Hemichromis* sp, *Cichlasoma* sp, are all popular in the aquaria business.

In addition to the above listed uses, many large cichlids also make good game fish. Cichlids preferred by anglers include the oscar (*Astronotus ocellatus*), Mayan cichlid (*Cichlasoma urophthalmus*), jaguar guapote (*Parachromis managuensis*) and the strong, hard-fighting peacock bass (*Cichla* species) of South America. In some states of USA, such as Florida, angling generates US$ 8 million per annum.

In spite of the above outlined benefits derived from this group of fish, they are sometimes considered a nuisance in places where their introduction has led to a change in the population of the native fishes (Zaret & Paine, 1973; Courtenay, 1997). They are trophic generalists (Dempster *et al*., 1993; Traxler & Murphy, 1995), and their reproductive biology is characterized by short generation time, multiple clutches and extended breeding seasons (Naylor *et al*., 2000, 2001; Coward & Little, 2001; Stickney, 2002).

Although this family of fish have a diverse mating pattern and brood care behaviour, they are endemic to small geographical locations and therefore can be threatened relatively easily. The introduction of the Nile perch and water hyacinth into the Lakes Victoria and Kyoga has made over 200 species of the cichlids endangered. Furthermore, The International Union for Conservation of Nature and Natural Resources (IUCN, 2007) red list classifies 156 cichlid species as "vulnerable", 40 as "endangered", and 69 as "critically endangered" while 6 are extinct in the wild.

Justification of the Study

In spite of the thriving fisheries in a total of about 1530 reservoirs in Ghana (National Dam Safety Unit as cited by Ofori-Danson & Kwarfo-Apegyah, 2008), very little is known about the state of the fish stocks. However, reservoirs have the potential to contribute to the enhancement of fisheries of the country (Abban, Ofori-Danson & Biney, 1994) but poor management practices and over-exploitation have caused a decline in the catch of some reservoirs (Obodai & Waltia, 2003). Other reasons which have accounted for the decline in catches have been attributed to over-exploitation of stocks, environmental degradation, low water levels (Abban *et al.*, 2000; Amevenku & Quarcoopome, 2006) and siltation (Adwubi *et al.*, 2009). The consequence has been a reduction in the number of persons employed by the sector (FAO, 1998).

Cichlids constitute a significant percentage of catch in reservoirs and lakes (FAO as cited in Ofori-Danson *et al.* 2002; Kwarfo-Apegya & Ofori-Danson, 2010; Quarcoopome & Amevenku, 2010) and most coastal waters in Ghana (Blay & Asabere-Ameyaw, 1993; Abban, Agyakwah & Falk, 2004), however, their habitats are threatened by pollution, siltation of lagoons, over-fishing, destructive fishing methods, habitat degradation and destruction (Abban *et al.*, 2000; Ofori-Danson, 2000). In some cases, there has been decline or disappearance of some species in reservoirs as result of the change from an originally lotic system to a lacustrine condition (Quarcoopome & Amevenku, 2010).

The Brimsu reservoir which is an important source of livelihood for fishers and people living within the catchment area has been reported to experience high levels of siltation (Akayuli *et al.*, 2007). In spite of the immense importance of this reservoir, there is inadequate information on its fauna and flora. However, given the current increase in human population which has its attendant repercussions on food security and livelihood of fishers, the need to study inland fisheries has gained relevance. Studies on the biology of fish in reservoirs to ascertain their potential for enhancing inland capture fisheries as well as culture based fisheries will provide information on the state of the fisheries in the reservoir and provide baseline data for management of the reservoir.

Objectives of the study

The research is set at providing information on aspects of the growth, diet and reproductive pattern of cichlids in the Brimsu reservoir.

The specific objectives are to investigate some physico-chemical parameters prevailing in the reservoir; determine the monthly species composition of cichlids; determine the feeding habits of the cichlids and also study the changes in the condition indices of the cichlids. In addition to the above, the research also investigated monthly changes in the gonadosomatic index of cichlids and determined the absolute fecundity of cichlids.

CHAPTER TWO

MATERIALS AND METHOD

Study Area

The reservoir is located at Brimsu, about 15 km northeast of Cape Coast in the Central Region of Ghana. The Brimsu reservoir which was formed by the construction of a dam across the Kakum River in 1928 is located on 5°11'N and 1°16'W (Fig 1). The reservoir was created primarily to supply domestic water to the surrounding communities. It also provides livelihood opportunities to fishermen in the nearby communities.

The reservoir is fed primarily by the Kakum River and has a catchment area of 867 km^2 and surface area of about 278 ha (GWSC as cited in Bosque-Hamilton, Nana-Amankwah & Karikari, 2004). At full capacity, the reservoir has a storage volume of 2.3×10^6 m^3 (Gordon, 2006) and maximum depth of approximately 7m. The Kakum River passes through the Abura-Asebu-Kwamankese District and Cape Coast Metropolitan area.

The hydrological cycles of the reservoir is characterized by a rise in the water level in the month of April, at the beginning of the rainy season. The reservoir fills quickly reaching maximum level by June or July. The water level begins to fall from October and reaches a low level in December –March (Bosque-Hamilton *et. al.*, 2004).

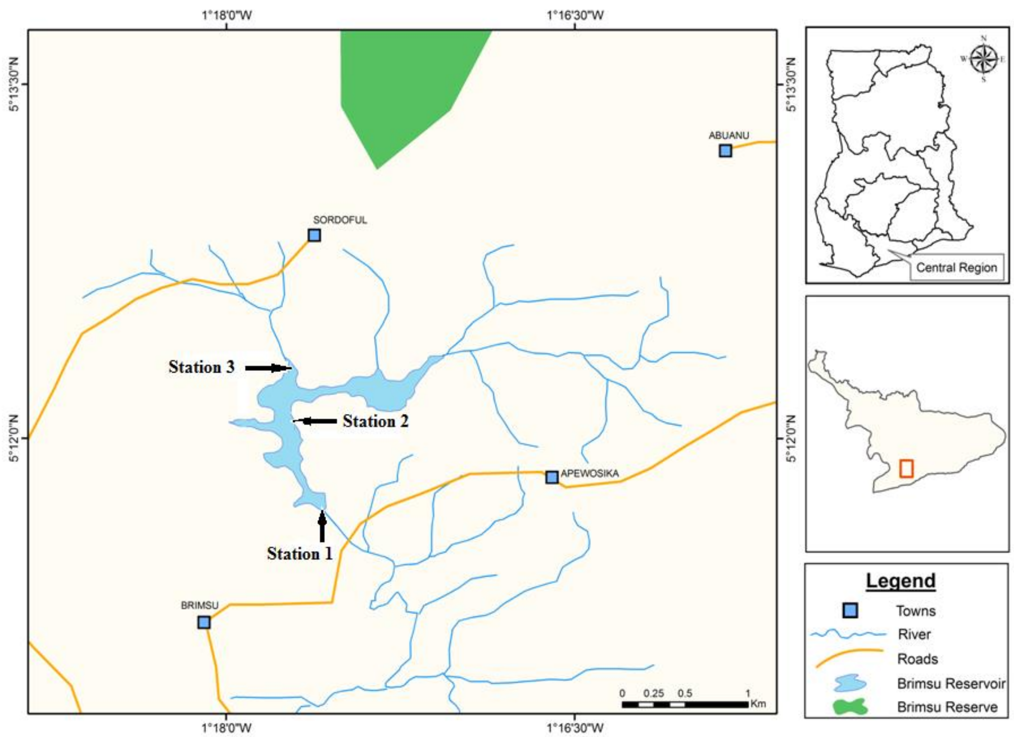

Figure 1: Map of Ghana showing the Brimsu reservoir and its catchment area.

Most of the suburbs of Cape Coast depend on the reservoir for the supply of potable water. Other small settlements such as Kukua, Akraabu and Aboatunpan also utilize untreated water from the reservoir. The Brimsu basin is also intensively used for the cultivation of both cash and food crops. Principal food crops cultivated within the basin are cassava, maize, yam, plantain, banana and cocoyam. Cash crops include cocoa, oil palm, papaya, pineapples, mangoes and citrus.

The Brimsu basin lies within two climatic zones, namely: the wet semi-equitorial northern zone and the dry equatorial coastal belt. The northern part of the basin receives a mean annual rainfall of 1250 to 2000 mm whiles the coastal belt has a mean annual precipitation of 740 – 890 mm (Dickson & Benneh, 1988).

Three sampling stations were chosen based on accessibility: sampling station 1 was closest to the dam; station 2 was at the confluence where water from Apewosika and the Abasa joined and station 3 at the Abasa landing site. Physico-chemical parameters were taken during the fourth week of each month from September 2009 to September 2010.

Determination of Physico-chemical parameters

Temperature

Temperature was measured by immersing the YSI Probe (Model 63) in the water to a depth of between 30 and 40 cm. Two readings were then taken from each sampling station after which the average was calculated.

Transparency

A Secchi disc was lowered into the reservoir to the limit where the disc just disappeared. The disc was then lowered further into water and brought up gently to the point where the disc just reappeared. The average of the two readings was taken from each of the three sampling points.

Conductivity

Conductivity was measured by immersing the YSI Probe (Model 63) in the water to a depth of between 30 and 50 cm. Two readings were then taken from each sampling station and the average value was determined.

pH

The pH was measured by immersing the YSI Probe (Model 63) in the water to a depth of between 30 and 40 cm. Two readings were taken from each sampling station.

Dissolved Oxygen

Water samples were collected at depths of 30 – 40 cm with 250 cm^3 sample bottles for determination of dissolved oxygen using the Winkler method (Skoog & West, 1976).

Collection of fish specimens

Fishes of the family Cichlidae were sampled monthly (from the reservoir using a gill net of mesh size 25 mm (knot to knot), length of 50 m and a depth of 1.5m for thirteen months (September 2009 – September 2010). Fish were kept under ice to minimize post mortem decomposition and later taken to the Department of Fisheries & Aquatic Sciences laboratory for further analysis. At the laboratory, each specimen was identified using the keys of Dankwa *et al.* (1999) and Paugy, Lévêque & Teugels (2003).

Morphometric measurements of fish

The total length (TL) of each fish was determined as the length measured from the tip of the snout to the end of the caudal fin while standard length (SL) was determined as the length measured from tip of the snout to the base of the caudal fin to the nearest 0.1 cm using a fish measuring board. The body weight

(BW) was ascertained by weighing each specimen to the nearest 0.01g using an electronic balance.

Gonadal staging

Each specimen was dissected and the gonads removed and weighed to the nearest 0.01g using an electronic balance. The ovaries were then staged using a modification of the classification described by Witte & Van Densen (1995).

The ovaries were staged as:

Stage I – Immature: ovaries translucent; small eggs can be seen with magnifying glass;

Stage II – Developing: Ovaries pinkish; eggs visible to eye;

Stage III – Developed: Ovaries with eggs clearly discernible; ovaries occupy about two-thirds of central cavity; Ovary becomes more enlarged occupying almost entire body cavity, with large number of big, turgid, spherical, translucent, swollen ova;

Stage IV – Gravid / Ripe or ready to spawn: Ovaries fill ventral cavity, eggs completely ovoid and released from ovary with slight pressure on abdomen;

Stage V - Spent: Shrunken gonads; ovaries are flaccid, sac-like and reduced in volume. Ovary contains ripe unspawned eggs and a large number of small ova.

The testes were staged I and II;

Stage I - immature testes: testis very tiny, transparent and may appear pale red;

Stage II - mature testes: testis less translucent, or opaque and becomes milky, milt may flow with when pressure is put on the abdomen.

Estimation of absolute fecundity

Ripe ovaries (Stage IV) from gravid females were stored in 10 % formalin for at least one week to ensure hardening of the ova. The ovaries were then washed and rinsed with water prior to counting the eggs after teasing out the ovarian tissues. The whole count method was employed for species with low fecundity while the sub-sampling technique was used for species with high fecundity (Bagenal & Braum, 1978).

Determination of gonadosomatic index (GSI)

The gonadosomatic index (GSI) of the fish was computed according to the equation of Marcus & Kusemiju (1984) as follows:

$$\text{GSI} = \frac{\text{GW}}{(\text{BW}-\text{GW})} \times 100$$

where GW is the gonad weight and BW the body weight in grams.

The monthly mean GSI of the individual sexes of the various species were determined to ascertain the breeding pattern of the species.

Measurement of ova diameter

Three gravid females from each species were selected for the determination of their ova diameter after their ovaries had been preserved in 10% formalin for at least a week to facilitate the separation of the eggs from the ovarian tissues. The ova were placed on a microscope glass slide and the diameter of each measured to the nearest 0.1 mm with a stage micrometer under a dissecting microscope. Data from the measurements were grouped into diameter classes of 0.2 mm intervals after which a frequency distribution was plotted for each species to ascertain the spawning pattern of the cichlids.

Visceral fat index

Visceral fat from each specimen was examined macroscopically and staged using a five point scale (adapted from Kwei, 1970):

1 point – least amount of fat

2 points – moderate amount of fat

3 points – considerable amount of fat

4 points – very high quantity of fat

5 points – extremely high quantity of fat

The mean visceral fat for each month was then determined as:

$$mean\ fat\ index = \frac{\sum p}{n}$$

where p is the point scored by a fish specimen and n is the total number of specimens within a sample.

Analysis of stomach contents

The stomachs of specimens were removed, and preserved in 10% formalin. Each stomach was then slit open, and the contents poured into a petri dish. Random samples of the stomach contents were taken and dropped on slides with the aid of a dropping pipette and observed under a light microscope. The stomach contents were identified to the genus level and analyzed using the frequency of occurrence method (Bagenal, 1978) as well as the "points methods" (Hynes, 1950; Lima- Junior & Goitein, 2001). Points were awarded as follows: 5points ($\frac{1}{4}$ full); 10points ($\frac{1}{2}$ full); 15points ($\frac{3}{4}$ full) and 20points (completely full).

The frequency of occurrence of a food item was determined using the equation:

$$F_i = \frac{100n_i}{n}$$

where: F_i is the frequency of occurrence of the *i* food item in the sample;

n_i: number of stomachs in which the *i* item is found;

n: total number of stomachs with food in the sample.

The composition of food item by the points method was determined as:

$$\%\text{ composition of food item } i = \frac{\text{Total points obtained by food item } (T_i)}{\text{Total points of stomachs examined } (T_n)} \times 100$$

Percentage of specimens with empty stomachs

The proportion of fish specimens with empty stomachs in every monthly sample was sorted and expressed as a percentage of the total number of specimen per sample. The result was input the MS Excel 2007 programme from which a line graph was produced.

Length - frequency distribution

The standard lengths (SL) of each species were converted into length frequencies at class intervals of 1cm and histograms were plotted. Furthermore, the overall length-frequency distribution of individual species was obtained by pooling all thirteen monthly frequencies.

Length – weight relationship

The length-weight relationships of the various species of cichlids were plotted as scatter diagrams and a regression analysis carried out to determine the relationship between the length and weight of the fish using the least square method.

Determination of condition factor (K)

The condition factor or somatic index (K) of the various species of cichlids was calculated by using the equation of Le Cren (1951):

$$\mathrm{K} = \frac{(\mathrm{BW} - \mathrm{GW})}{\mathrm{SL}^3} \times 100$$

where SL is the standard length in centimeters and BW and GW are the body weight and gonad weight, respectively in grams. The mean monthly condition factor for the species was determined to ascertain the fluctuation in the well-being of the fish. A student's t-test was used to ascertain whether seasonal changes in condition factor for the species were statistically significant.

Mean length at first sexual maturity, L_m

The mean length of the fish at sexual maturity, (L_m), defined as the length at which 50 % of individuals in the population are sexually mature (i.e. ovaries and testes in an advanced stage of development), was estimated for both females and males.

To determine the minimum size of fish at first maturity, developed and ripe female and male specimens were used. The length at which 50% of the individuals were mature was estimated by fitting frequency data of mature individuals by length class using a cumulative frequency method.

CHAPTER THREE

RESULTS

Physico-chemical factors of the reservoir

Temperature

The surface water temperature of the Brimsu reservoir fluctuated between 27.5 °C and 29.9 °C during the study period (Fig. 2). Temperature increased from 28.7 °C in September 2009 to 29.9 °C in February 2010. Thereafter there was a gradual decrease to a minimum of 27.5 °C in September 2010.

Transparency

Transparency increased from 78 cm in September 2009 to a maximum of 112 cm in January 2010 before declining steadily to 53 cm in September 2010 (Fig. 2).

Dissolved oxygen content

The monthly fluctuation of dissolved oxygen content in the Brimsu reservoir during the study period is shown in Figure 2. The dissolved oxygen content of the reservoir showed two major peaks, i.e. November 2009 (4.92 mg/L) and June 2010 (4.78 mg/L). The lowest value of 4.22 mg/L was recorded in the September 2010. There was a sharp decline in the dissolved oxygen content in December 2009 and remained generally low until March 2010 after which it began to rise again.

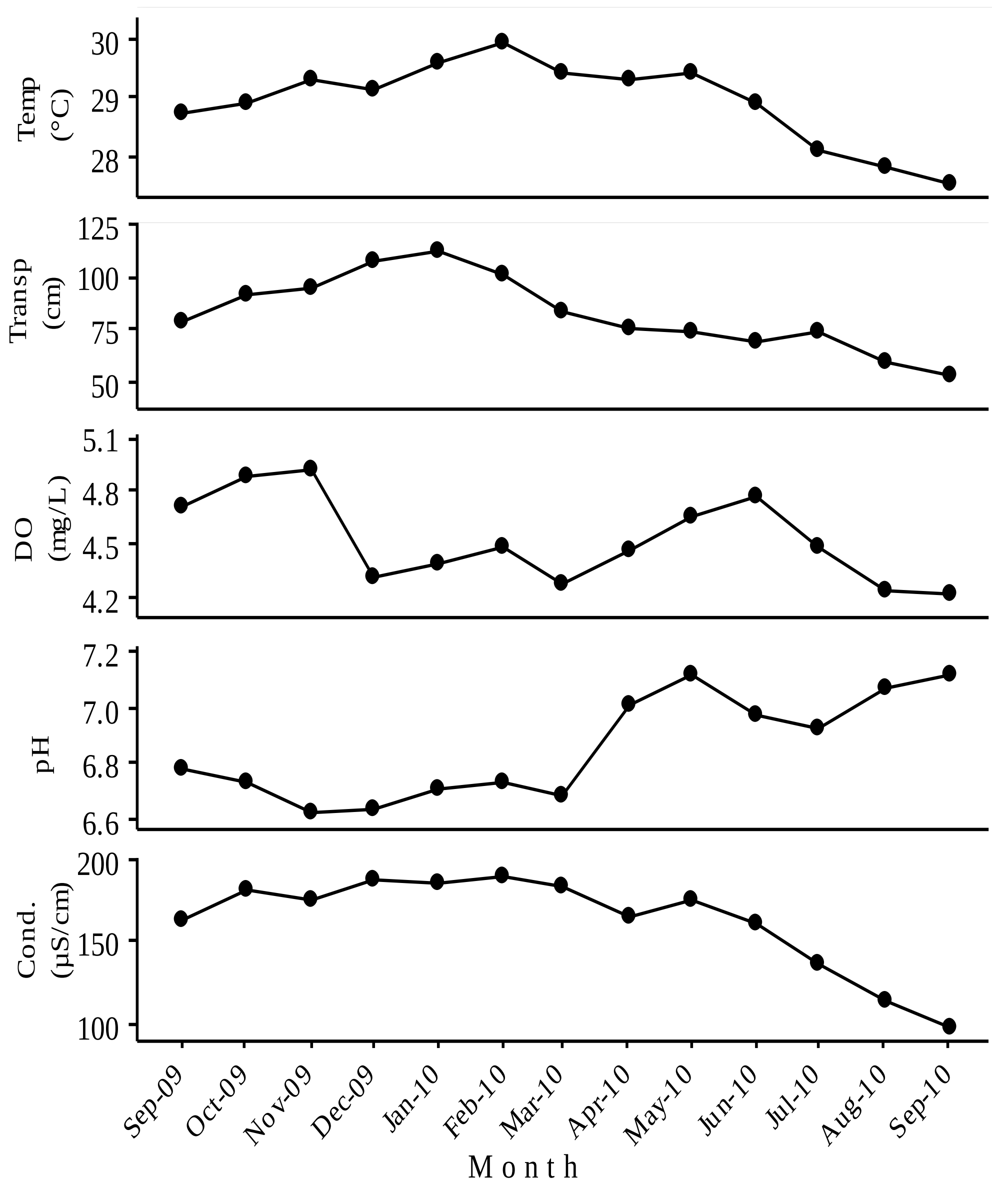

Figure 2: Changes in some physico-chemical factors in the Brimsu reservoir from September 2009 to September 2010.

Hydrogen ion concentration (pH)

The hydrogen ion concentration in surface waters varied from slightly acidic conditions (6.63) to near neutral conditions (7.12) during the study period (Fig. 2). There were two distinct pH regimes recorded from the Brimsu reservoir; acidic conditions were recorded from September 2009 to March 2010 while near neutral conditions occurred from April 2010 to the end of September 2010.

Conductivity

Two distinct regimes of changes in conductivity were recorded during the study period (Fig. 2). The conductivity remained fairly high from September 2009 to June 2010 varying between 162 µS/cm and 191 µS/cm, However it decreased from 162 µS/cm in June 2010 to the lowest value of 97 µS/cm in September 2010.

Species composition of the cichlids

A total of 1012 specimens consisting of five species of cichlids from four genera were caught in the reservoir. These were *Sarotherodon melanotherodon* (Rüpell, 1852), *Tilapia zillii* (Gervais, 1848), *Tilapia guineensis* (Bleeker, 1862), *Oreochromis niloticus* (L) and *Hemichromis fasciatus* (Peters, 1857). Numerically, the blackchin tilapia, *S. melanotheron* was the commonest species constituting 45.16 % of the catch (Fig. 3). This was followed by *T. zillii*, *T. guineensis*, *H. fasciatus* and *O. niloticus* which represented 26.78 %, 25.30 %, 2.67 % and 0.10 % respectively.

In terms of weight, *S. melanotheron* accounted for over 50% of the group while *T. zillii* and *T. guineensis* made up 22.97 % and 21.96 % of the cichlid biomass respectively. *H. fasciatus* and *O. niloticus* were lowly represented with both constituting less than 2% of the catch.

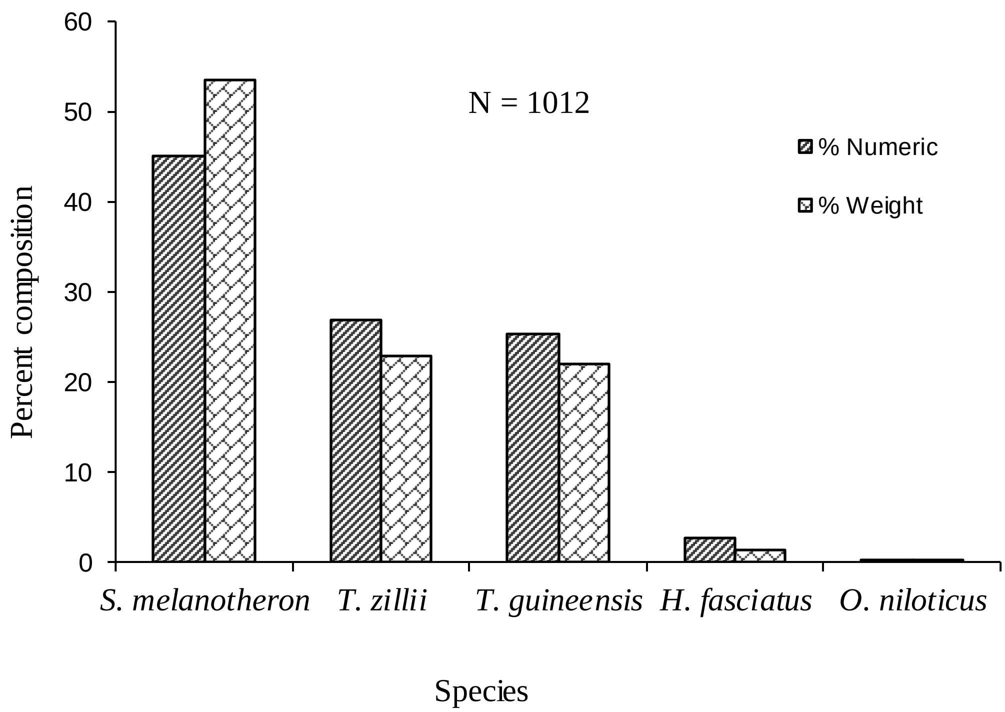

Figure 3: Composition of cichlids in the Brimsu reservoir from September 2009 to September 2010.

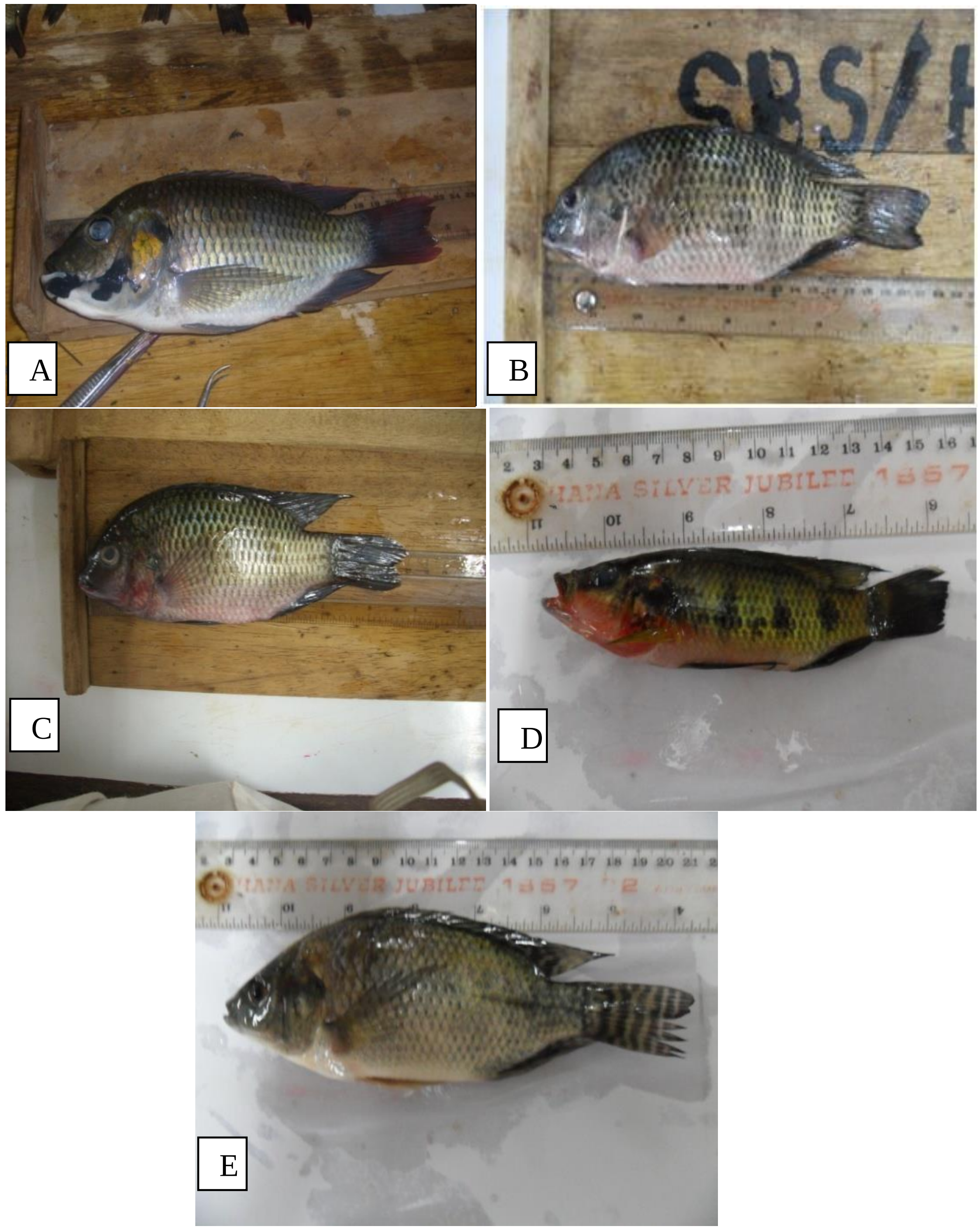

Plate 1: Cichlid species obtained from the Brimsu reservoir: (A) *Sarotherodon melanotheron*, (B) *Tilapia zillii* (C) *Tilapia guineensis* (D) *Hemichromis fasciatus* and (E) *Oreochromis niloticus*.

Monthly changes in numerical composition of cichlids

Three species, namely: *S. melanotheron*, *T. zillii* and *T. guineensis* occurred in all the monthly samples (Fig. 4), however, *H. fasciatus* was sparsely represented whereas the only specimen of *O. niloticus* was caught in October, 2009. The highest composition of *S. melanotheron* (93.93 %) was recorded in December 2009 and the lowest composition (19.69 %) was recorded in July 2010. The numerical composition of the blackchin tilapia was relatively high from September 2009 to April 2010 except in October 2009. The composition was however low from May to September 2010.

The composition of *T. zillii* in the catch increased from 20.9 % in September 2009 to 62.9 % in October 2009 after which it decreased to the lowest (3.4 %) in April 2010. The subsequent months were characterized by a gradual increase in composition from less than 4 % in April to 39.7 % in September 2010. *T. guineensis* was low (< 20 %) in composition from September 2009 to December 2009. This was followed by a marginal increase from 1.5 % in the latter month to 27.9 % in February 2010. From March 2010, there was a considerable increase in the composition of this species reaching 72.5 % in June and decreasing slightly in the subsequent months.

H. fasciatus was generally low in composition throughout the period of the study. The highest composition of this species was obtained in October 2009 (11.7 %). A few specimen were obtained from January to April 2010, however this reduced drastically in the subsequent months. *O. niloticus* was however, very rare in the reservoir with the only specimen obtained in October 2009 (see Appendix B).

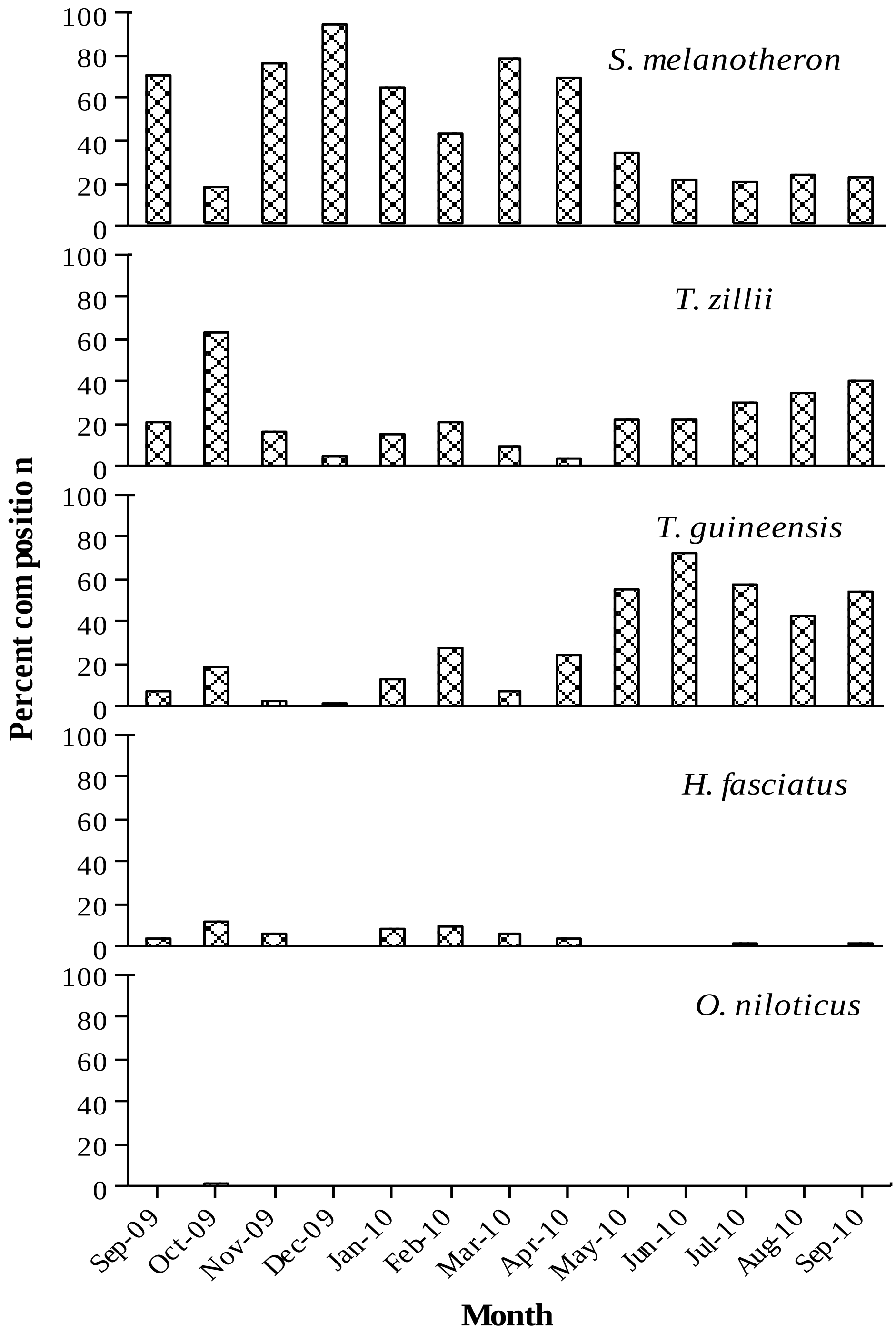

Figure 4: Monthly numerical composition of cichlids of the Brimsu reservoir.

Length-frequency distribution

Sarotherodon melanotheron

The length of *S. melanotheron* ranged from 7.5 - 17.6 cm (Fig. 5a) showing a unimodal distribution with the 10.0 – 10.9 cm size group as the modal class. The length-frequency distributions for males and females were also unimodal with modal class of 10.0 – 10.9 cm for both sexes (Fig 5b). The smallest fish obtained for both sexes fell within the 7.0 – 7.9 cm size group. Although both sexes had the biggest individual in the 17.0 – 17.9 cm size group, there were more males that were bigger in (> 14.0 cm) than females. A student's t-test performed on the two sexes indicated no significant difference in the size distribution ($p > 0.05$) (see Appendix C). The overall distribution of the species was also unimodal with modal class of 10.0 – 10.9 cm.

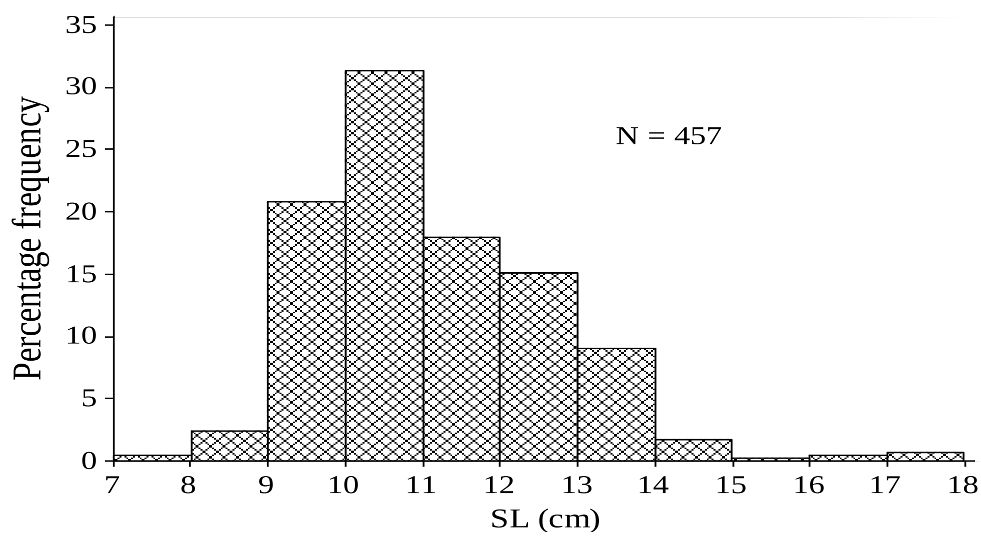

Figure 5a: Composite length frequency distribution of *S. melanotheron* (both sexes combined) from the Brimsu reservoir from September 2009 to September 2010.

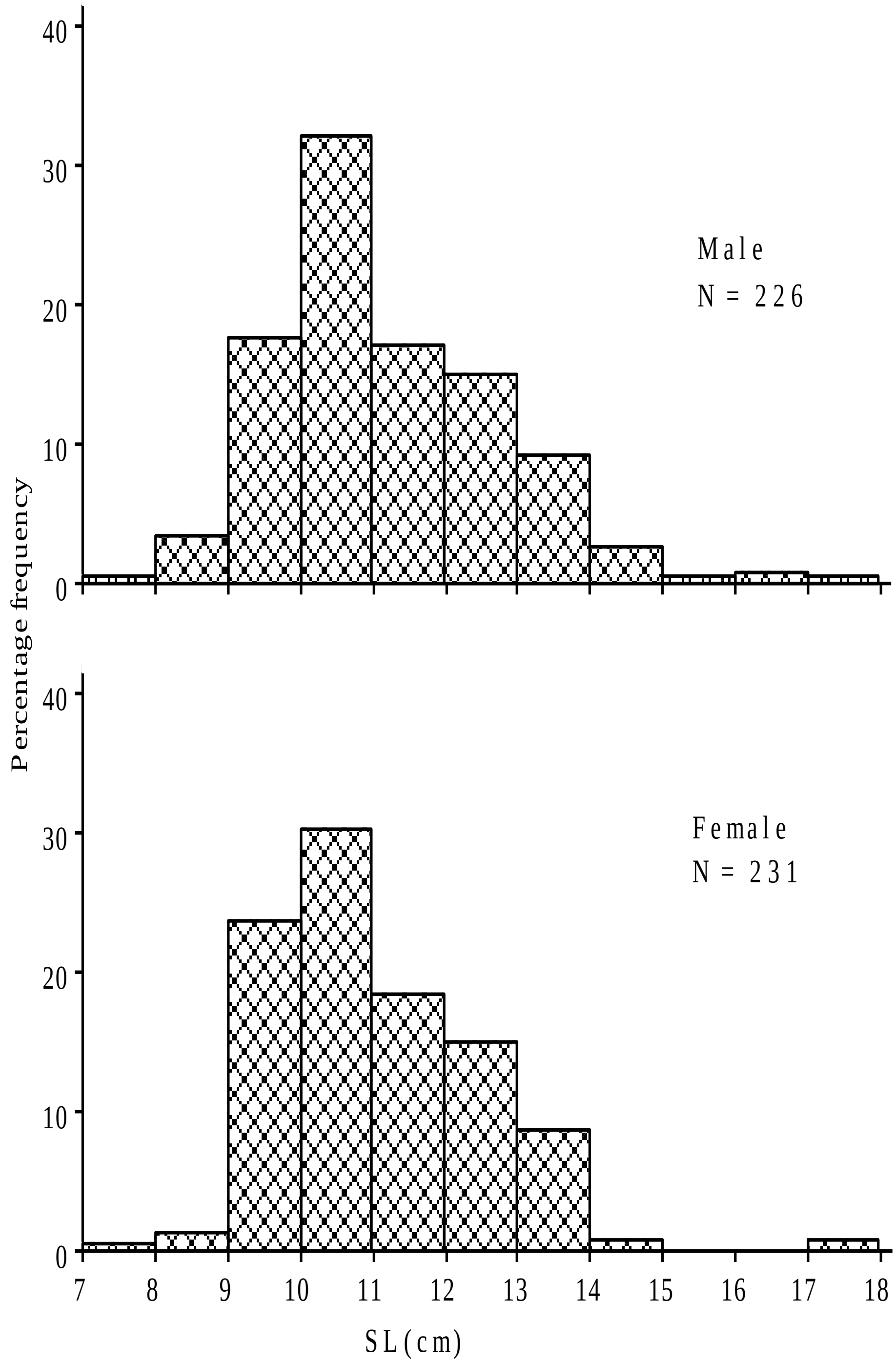

Figure 5b: Composite length frequency distribution of *S. melanotheron* (male and female) from the Brimsu reservoir from September 2009 to September 2010.

Tilapia zillii

The size distribution of *T. zillii* caught in the Brimsu reservoir is shown in Figure 6a. The distribution was unimodal and had a range of 7.0 and 13.9 cm, with a modal length class of 9.0 – 9.9 cm. Male and female specimens obtained in the reservoir had the same modal class of 9.0 – 9.9 cm (Fig 6b). The distribution was unimodal with the biggest specimen being a male in the 13.0 – 13.9 cm size group.

A student's t-test performed on the two sexes indicated no significant difference in the size distribution ($p > 0.05$) (see Appendix D). The distribution of the combined sexes was also unimodal with a mode of 9.0 – 9.9 cm.

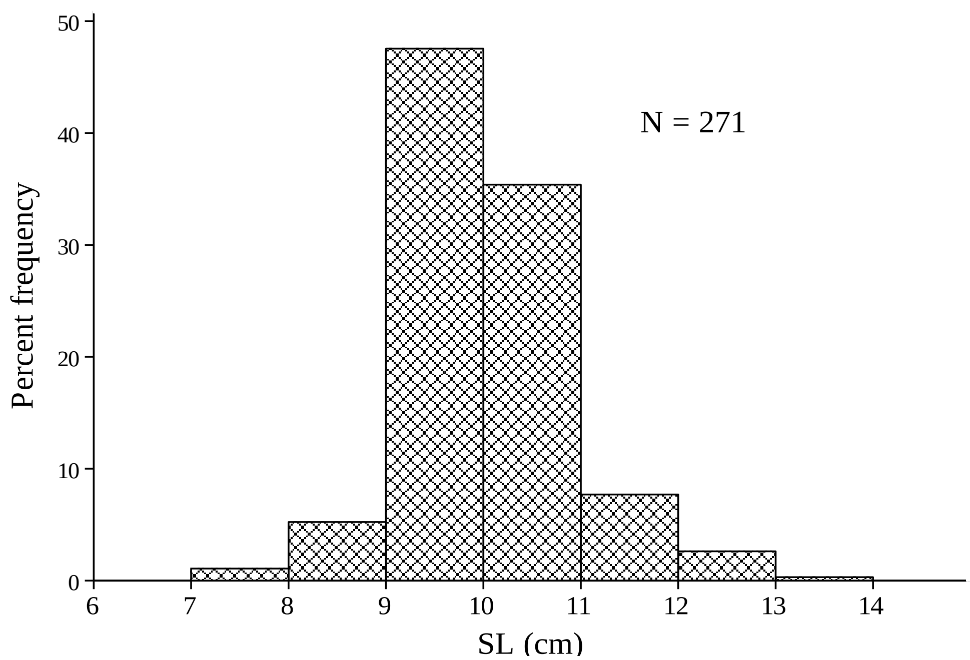

Figure 6a: Composite length-frequency distribution of *T. zillii* (both sexes combined) obtained from the Brimsu reservoir from September 2009 to September 2010.

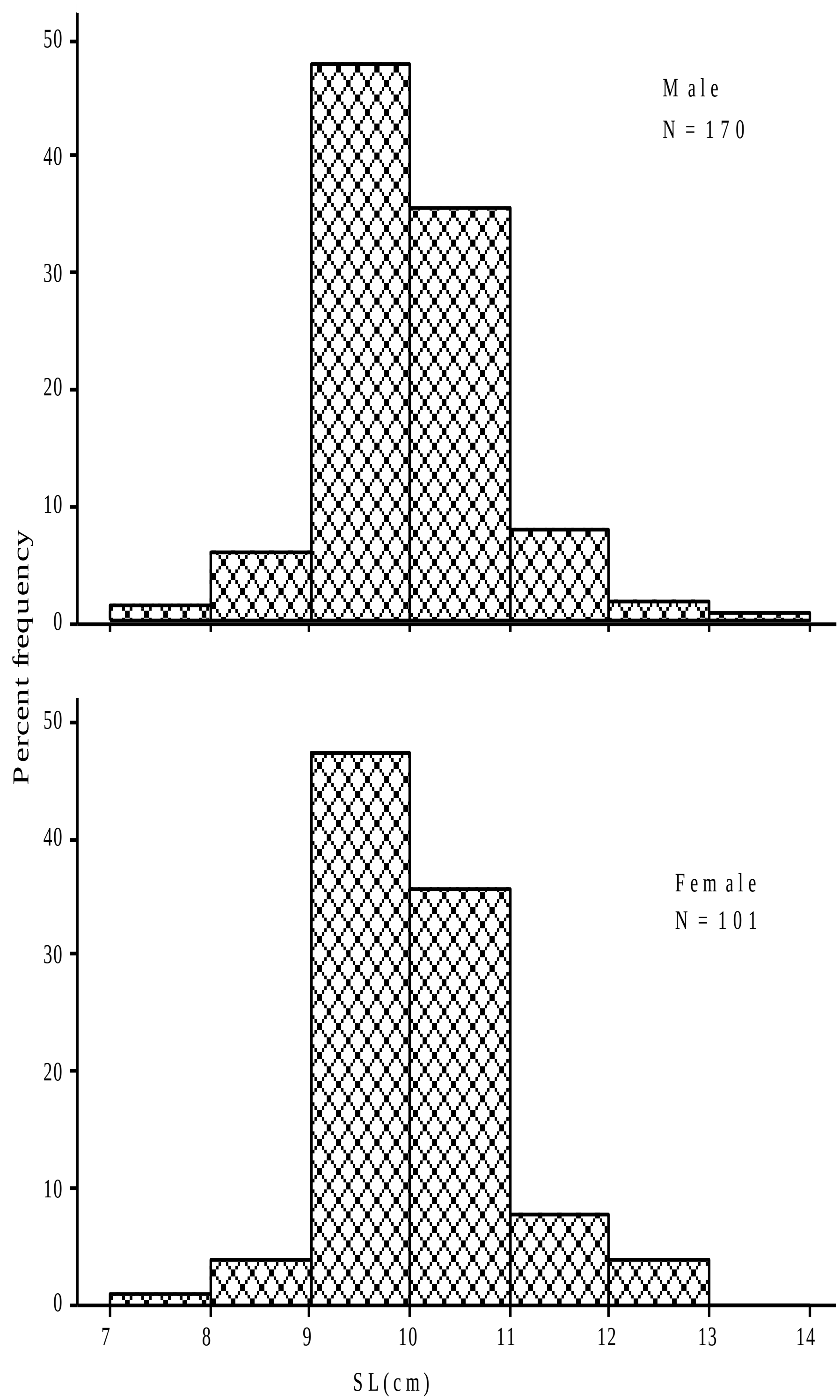

Figure 6b: Composite length-frequency distribution of *T. zillii* (male, female) obtained from the Brimsu reservoir from September 2009 to September 2010.

Tilapia guineensis

There was a wide range of 5.8 – 16.3 cm sizes in *T. guineensis* obtained from the reservoir (Fig. 7a & b). The least sized individual was a female measuring 5.8cm and the biggest individual was a male which measured 16.3cm. The distribution was unimodal with modal length class of 9.0 – 9.9 cm. The length-frequency distribution of both sexes of *T. guineensis* were similar with both showing a unimodal distribution with modal length of 9.0 – 9.9cm. A student's t-test performed on the two sexes indicated no significant difference in the size distribution ($p > 0.05$) (see Appendix E). The distribution for the combined sex was also unimodal and similar to the individual sexes.

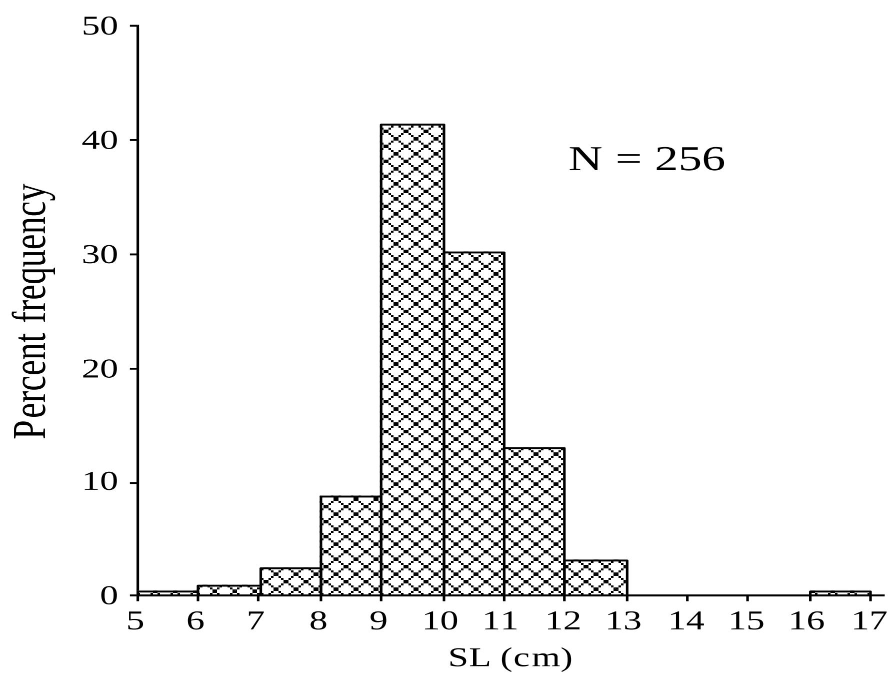

Figure 7a: Composite length-frequency distribution of *T. guineensis* (both sexes combined) from the Brimsu reservoir from September 2009 to September 2010.

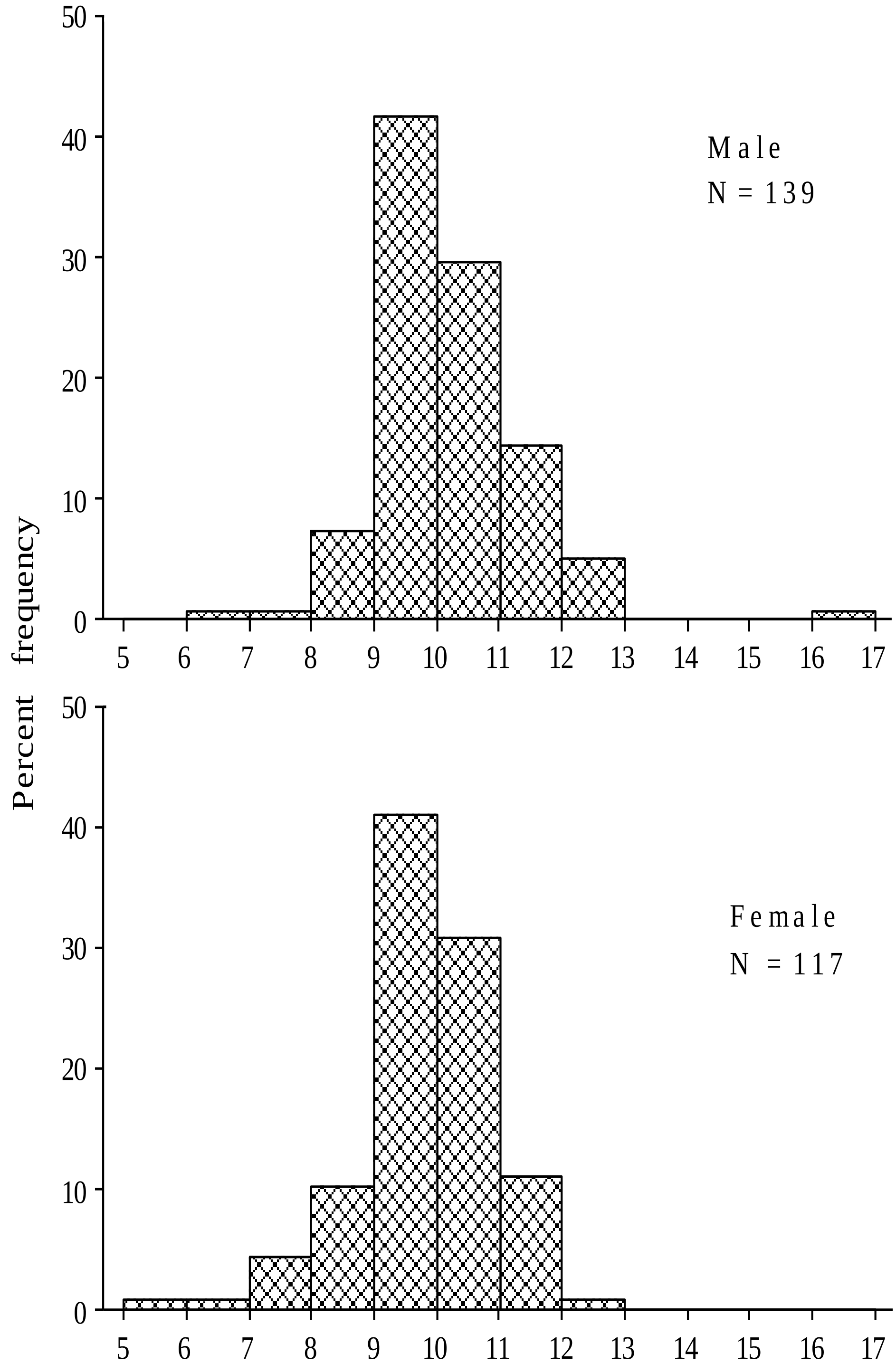

Figure 7b: Composite length-frequency distribution of *T. guineensis* (male, female) from the Brimsu reservoir from September 2009 to September 2010.

Hemichromis fasciatus

Twenty-seven (27) specimens were obtained from the reservoir. The length-frequency distribution of *Hemichromis fasciatus* was between 8.0 and 14.0 cm (Fig. 8). The distribution was bi-modal with modal length class of 8.0 – 8.9 cm and 11.0 -11.9 cm respectively.

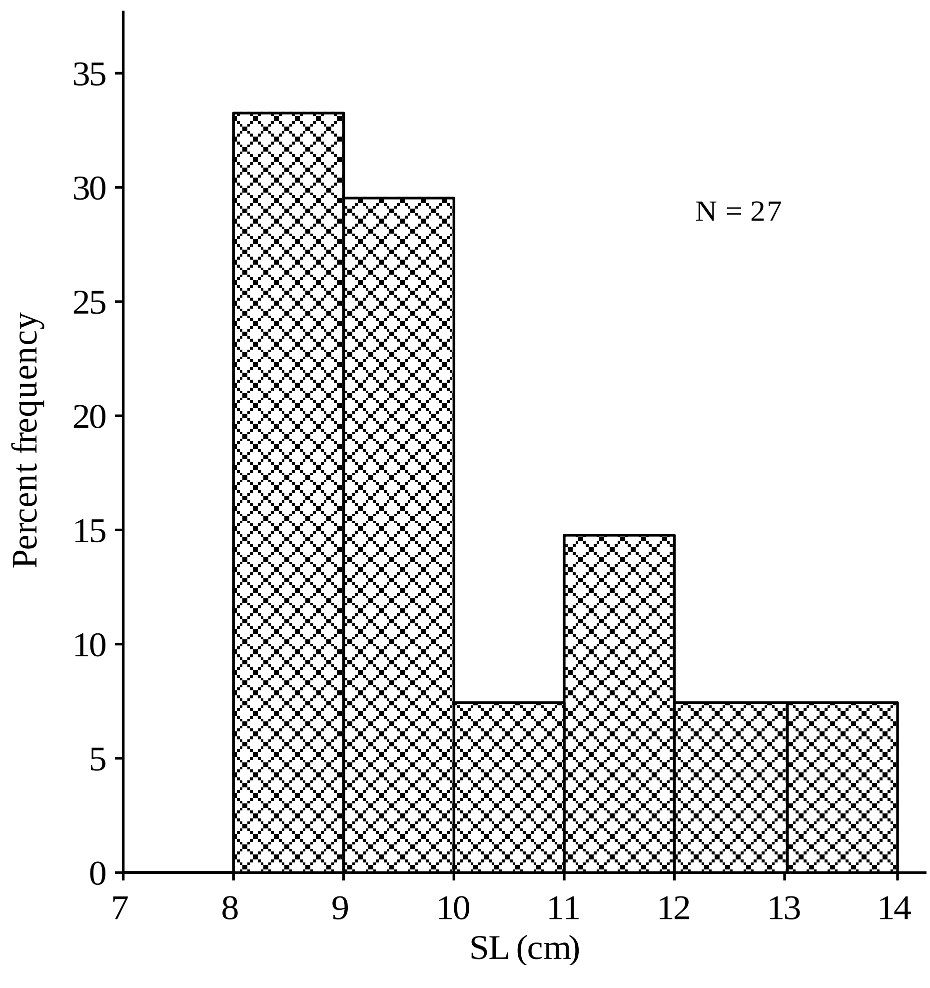

Figure 8: Composite length-frequency distribution of *H. fasciatus* obtained from the Brimsu reservoir.

Oreochromis niloticus

The only specimen of *O. niloticus* was a male of 12.0 cm (SL) weighing 70.74 g obtained in October 2009.

Monthly length-frequency distribution of the species

S. melanotheron

The monthly length- frequency distribution of *S. melanotheron* is shown in Figure 9. In September 2009, the modal length (SL) was 9.0 - 9.9 cm which increased to 10.0 – 10.9 cm in October and remained at this mode till December 2009. There was a progressive increase in the mode from January 2010 (10.0 - 11.9 cm) to March –April 2010 (13.0 – 14.0 cm); but this decreased to 10 - 10.9 cm in May 2010 and 9 – 9.9 cm in June 2010.

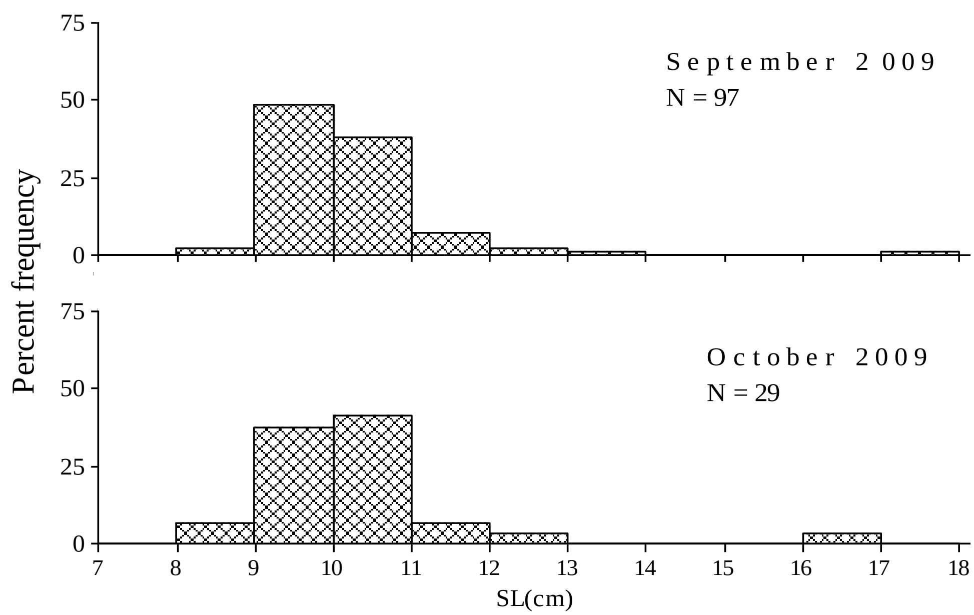

Figure 9: Monthly length-frequency distribution of *S.melanotheron* from the Brimsu reservoir from September 2009 to September 2010.

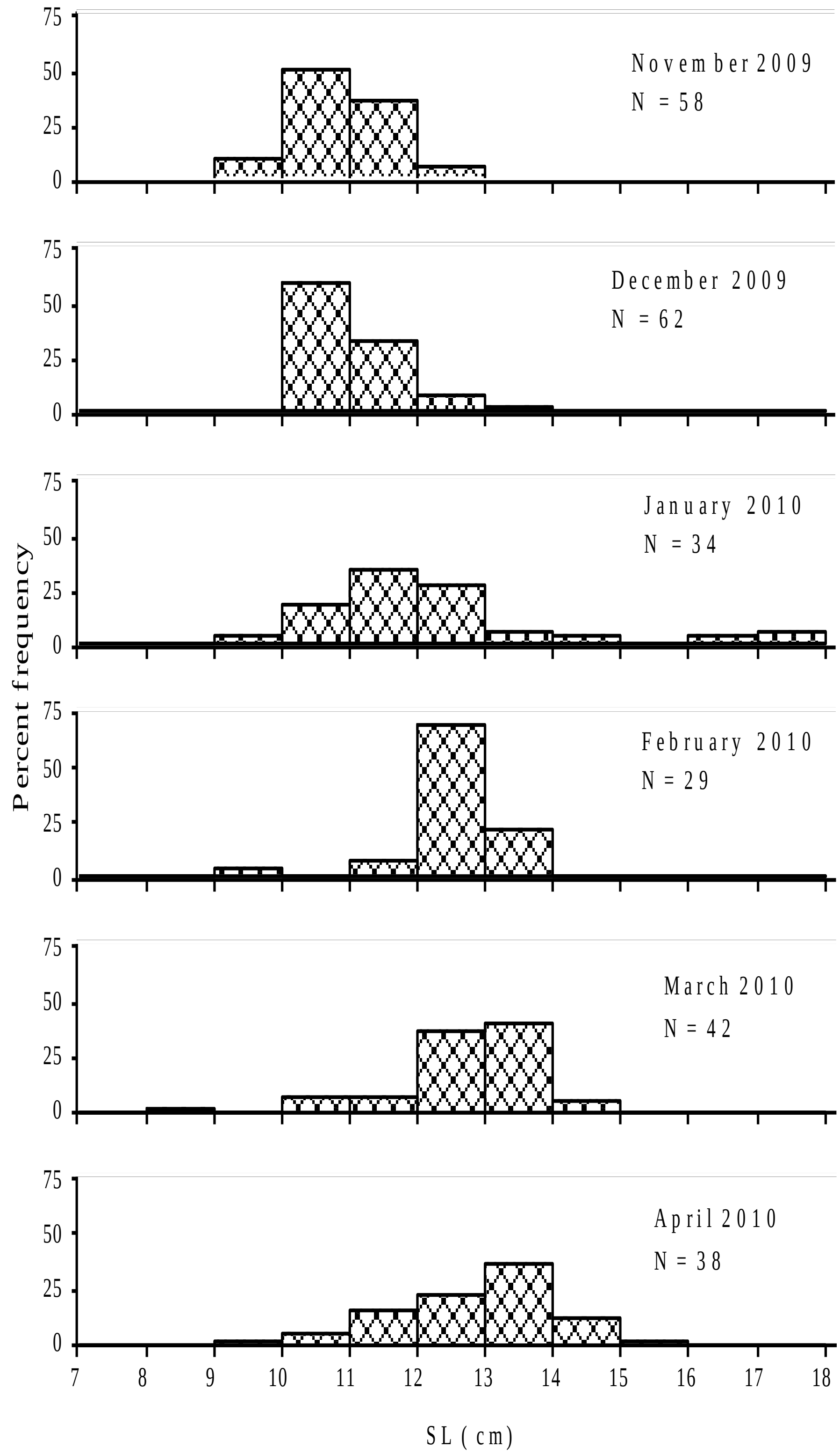

Figure 9: Monthly length-frequency distribution of *S.melanotheron* from the Brimsu reservoir from September 2009 to September 2010.

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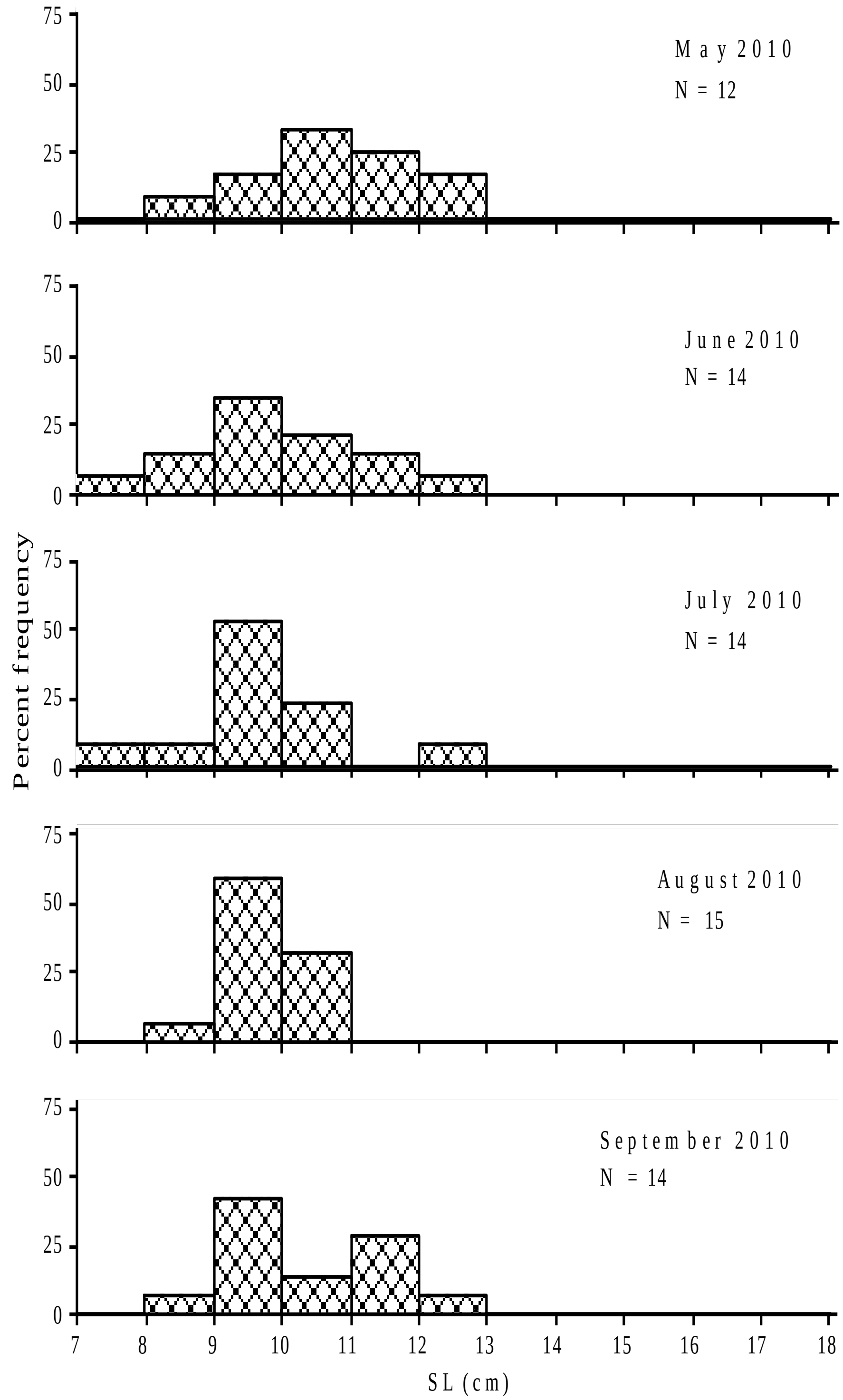

Figure 9 (cont'd): Monthly length-frequency distribution of *S. melanotheron* from the Brimsu reservoir from September 2009 to September 2010.

Tilapia zillii

In September 2009 the modal class was 9.0 – 9.9 cm and remained the same for the next month (Fig. 10). This was followed by an increase in the modal size to 10 cm in November 2009. This was maintained till June 2010 and decreased to 9.0 cm in July 2010 and remained unchanged to the end of September 2010.

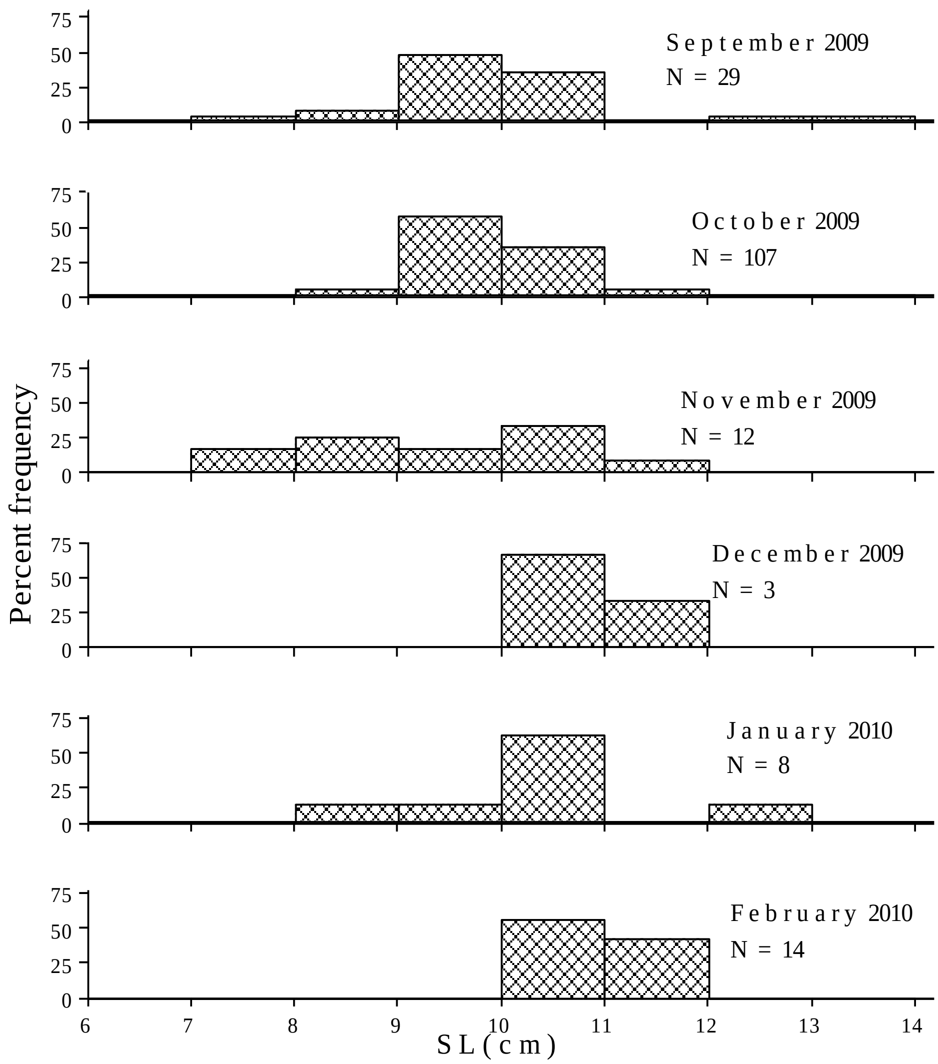

Figure 10: Monthly length-frequency distribution of *T. zillii* of the Brimsu reservoir from September 2009 to September 2010.

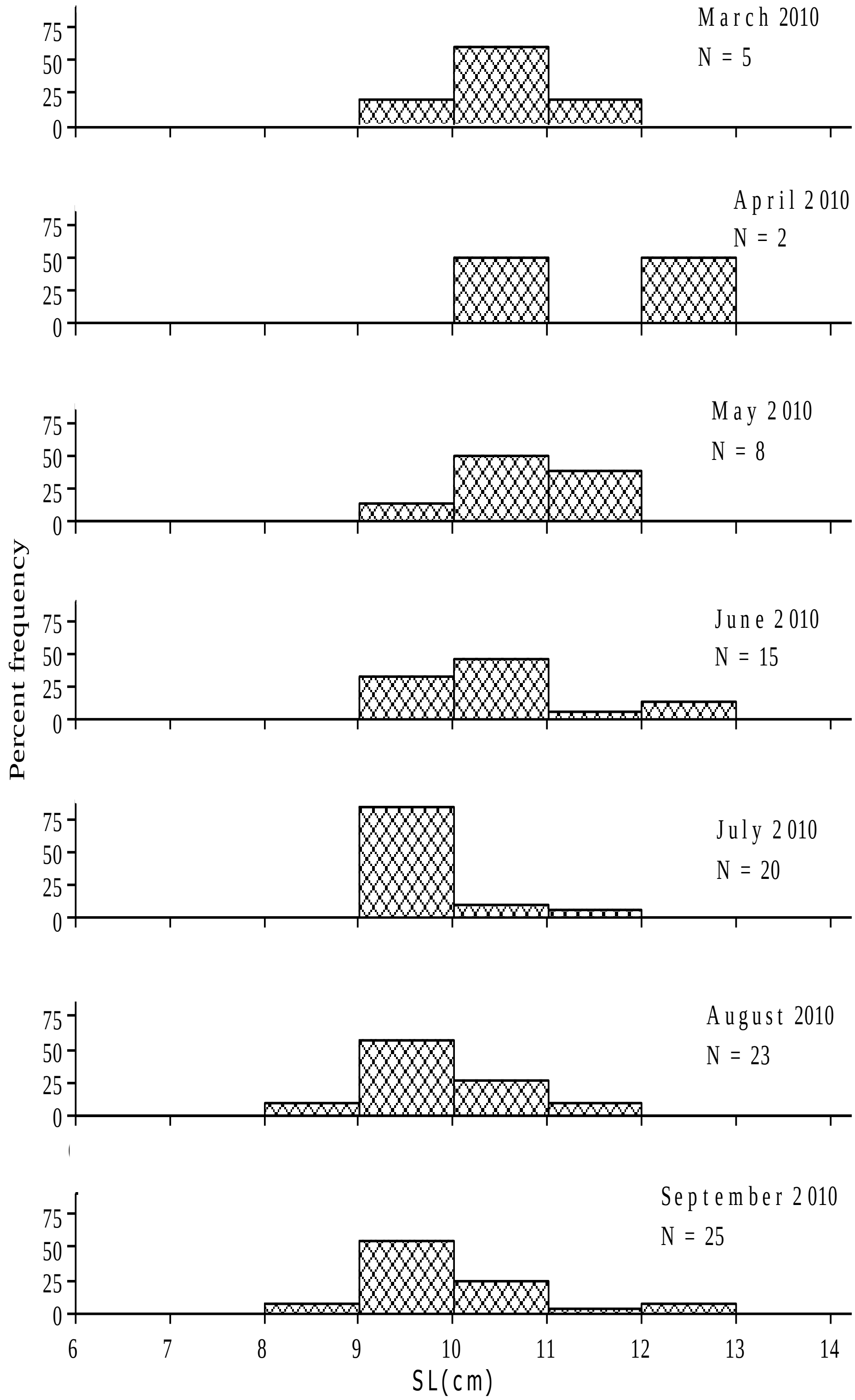

Figure 10 (cont'd): Monthly length-frequency distribution of *T. zillii* of the Brimsu reservoir.

T. guineensis

The modal size of the fish population in September 2009 was 9.0 cm and remained unchanged in October 2009 (Fig. 11). However, there was a gradual increase in the mode to 11.0 cm in December 2009 and remained the same till February 2010. This was followed by a marginal increase to 12.0 cm in March 2010. The modal size then began to decrease from 10.0 cm in May 2010 to 9.0 cm in July 2010 and remained at this mode till September 2010.

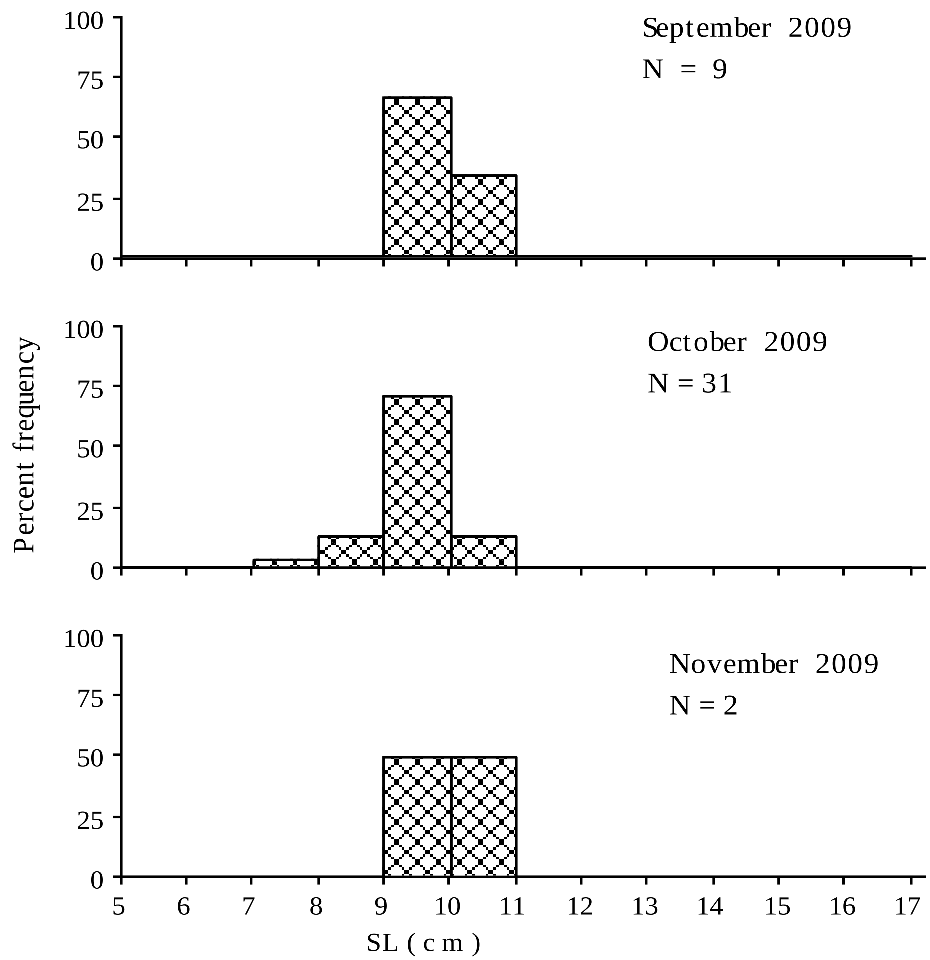

Figure 11: Monthly length-frequency distribution of *T. guineensis* of the Brimsu reservoir from September 2009 to September 2010.

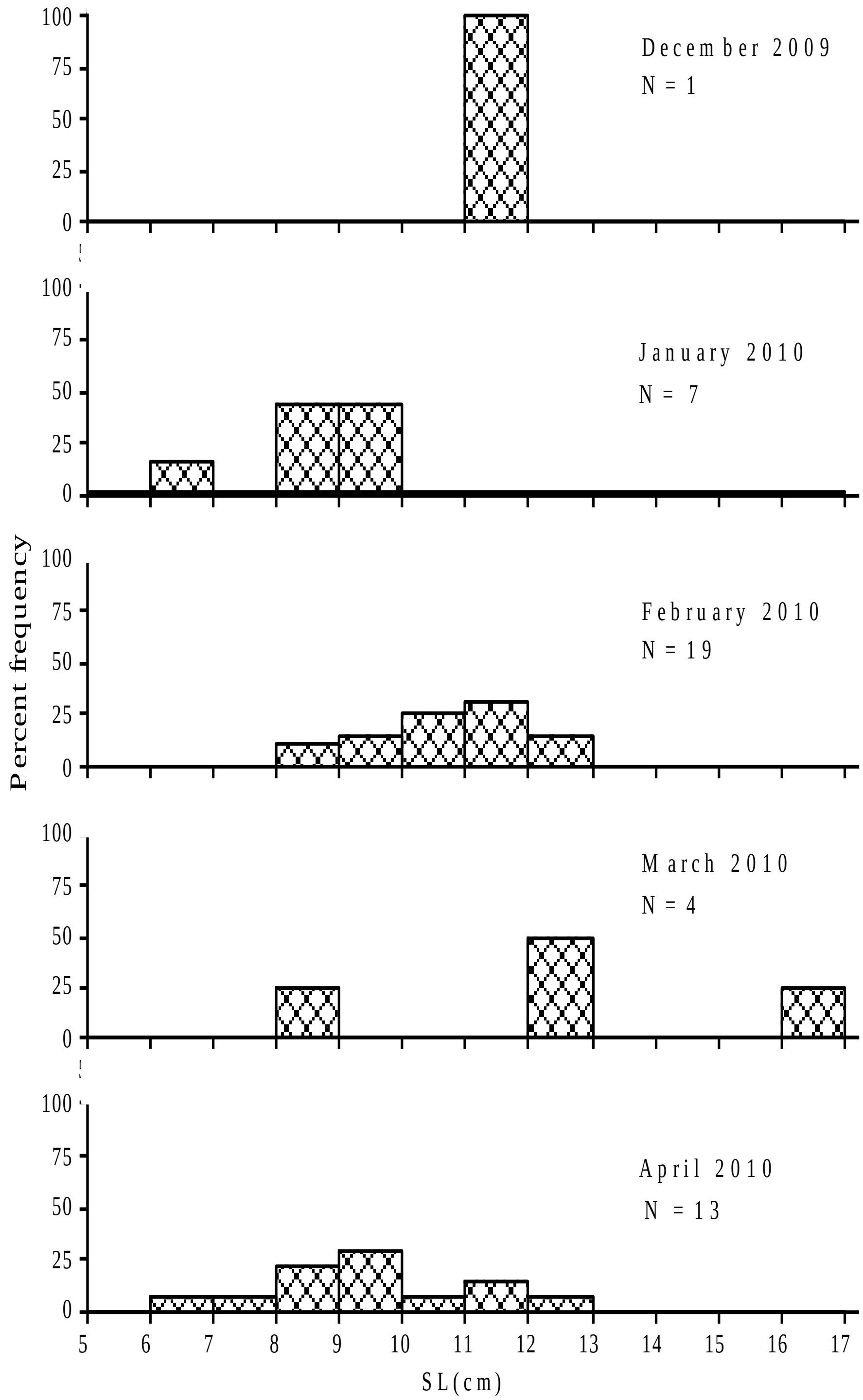

Figure 11 (cont'd): Monthly length-frequency distribution of *T. guineensis* of the Brimsu reservoir from September 2009 to September 2010.

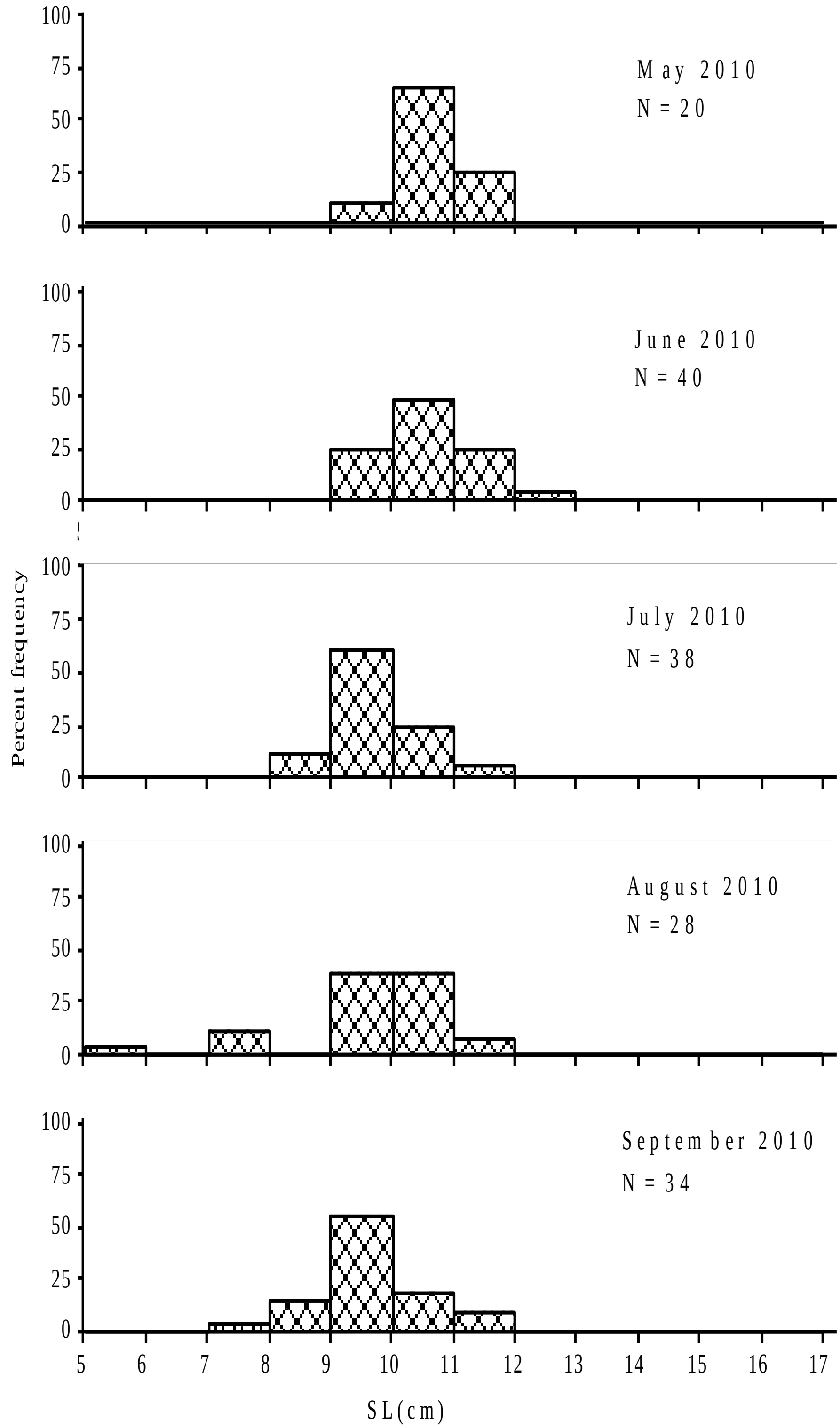

Figure 11 (cont'd): Monthly length-frequency distribution of *T. guineensis* of the Brimsu reservoir from September 2009 to September 2010.

Sex ratio of cichlids

S. melanotheron

A total of 457 specimens of *S. melanotheron* were caught of which 227 were males and 230 females. The Chi square test (χ^2) showed no significant changes in the sex ratio throughout the period of study (Table 1). In May 2010 a sex ratio of 1:2 was noted however, χ^2 test did not indicate any significant change in sex ratio due to the lower numbers of specimens in the sample.

Table 1: Summary of the sex ratio of *S. melanotheron*

Months	Number of specimens		Sex Ratio	χ^2	$P_{(0.05)}$
	Male	Female	M : F		
Sept, 2009	51	46	1 : 0.9	0.26	NS
October	17	12	1 : 0.7	0.86	NS
November	28	30	1 : 1.1	0.07	NS
December	36	26	1 : 0.7	1.61	NS
January, 2010	15	19	1 : 1.3	0.47	NS
February	14	15	1 : 1.0	0.03	NS
March	16	26	1 : 1.6	2.36	NS
April	20	18	1 : 0.9	0.11	NS
May	4	8	1 : 2.0	1.33	NS
June	5	9	1 : 1.8	1.14	NS
July	8	5	1 : 0.6	0.69	NS
August	6	9	1 : 1.5	0.60	NS
September	7	7	1 : 1.0	0.00	NS
Total	227	230	1 : 1.01	0.02	NS

NS = Not significant

T. zillii

The monthly sex ratio of *T. zillii* is shown in Table 2. In all, a total of 170 males and 102 females were recorded. No male specimen was obtained in April. With the exception of October 2009 where there was a significant difference in the sex ratio, the other months did not show any significant difference from the expected sex ratio of 1:1. However, the total sex ratio indicated that males were significantly more than females in the sample.

Table 2: Summary of the sex ratio of *T. zillii*

Months	Number of Specimen		Sex ratio	χ^2	$P_{(0.05)}$
	Male	Female	M : F		
September, 2009	19	10	1 : 0.5	2.79	NS
October	79	28	1 : 0.3	24.31	S
November	9	3	1 : 0.3	3.00	NS
December	1	2	1 : 2.0	0.33	NS
January, 2010	3	5	1 : 1.7	0.50	NS
February	8	6	1 : 0.8	0.29	NS
March	2	3	1 : 1.5	0.20	NS
April	0	2	-	-	-
May	2	6	1 : 3.0	2.00	NS
June	10	5	1 : 0.5	1.67	NS
July	12	8	1 : 0.7	0.80	NS
August	10	13	1 : 1.3	0.39	NS
September, 2010	15	10	1 : 0.7	1.00	NS
Total	170	101	1: 0.6	17.57	S

T. guineensis

The monthly sex ratio of *T. guineensis* is shown in Table 3. Apart from September and October 2009 which recorded significantly high numbers of males than females, the sex ratio for other months did not show any significant difference from the expected 1:1 ratio. The total sex ratio however, did not indicate any significant difference from the expected 1:1 ratio.

Table 3: Summary of the sex ratio of *T. guineensis*

	Number of specimen		Sex ratio	χ^2	$P_{(0.05)}$
Months	Male	Female	M : F		
September, 2009	9	2	1 : 0.2	4.45	S
October	21	10	1 : 0.5	3.90	S
November	2	0	-	-	-
December	1	0	-	-	-
January, 2010	2	4	1: 2.0	0.67	NS
February	12	7	1 : 0.6	1.32	NS
March	3	1	1 : 0.3	1.00	NS
April	7	6	1 : 0.9	0.08	NS
May	9	11	1 : 1.2	0.20	NS
June	26	24	1 : 0.9	0.08	NS
July	21	17	1 : 0.8	0.42	NS
August	10	18	1 : 1.8	2.29	NS
September 2010	18	16	1: 0.9	0.12	NS
Total	139	117	1 : 0.8	1.89	NS

S = Significant; NS = Not significant

H. fasciatus

Of the 27 specimens collected, there were 16 males and 11 females. The overall sex ratio was 1 : 0.69 and Chi square test (χ^2) did not indicate any significant difference from the expected ratio of 1:1. ($p < 0.05$).

Length-weight relationships of cichlids

The scatter plots of the body weight (BW) and standard length (SL) of the cichlids are shown in Figure 12. The BW/SL relationship for *S. melanotheron* was described by the equation: $BW = 0.06SL^{2.89}$, whereas those for *T. zillii*, *T. guineensis* and *H. fasciatus* were $BW = 0.07SL^{2.82}$, $BW = 0.07SL^{2.85}$ and $BW = 0.07SL^{2.69}$ respectively. A student's t-test on the closeness of the coefficient of regression 'b' to the hypothetical value of 3.0 indicated that all the four fish species exhibited isometric growth (Appendix 6). Furthermore, the high value of the correlation coefficient, ($r > 0.90$), indicates a strong correlation between body weight and standard length of the cichlids. A summary of the BW/SL relationship of four cichlids is given in Table 4.

Table 4: Summary of length – weight relationship of cichlids

Species	Length -Weight relationship		
	Log transformed	Exponential form	r
S. melanotheron	Log BW = -1.24 + 2.89 Log SL	$BW = 0.06SL^{2.89}$	0.98
T. zillii	Log BW = -1.15 + 2.82 Log SL	$BW = 0.07SL^{2.82}$	0.95
T. guineensis	Log BW = -1.17 + 2.85 Log SL	$BW = 0.07SL^{2.85}$	0.97
H. fasciatus	Log BW = -1.17 + 2.69 Log SL	$BW = 0.07SL^{2.69}$	0.96

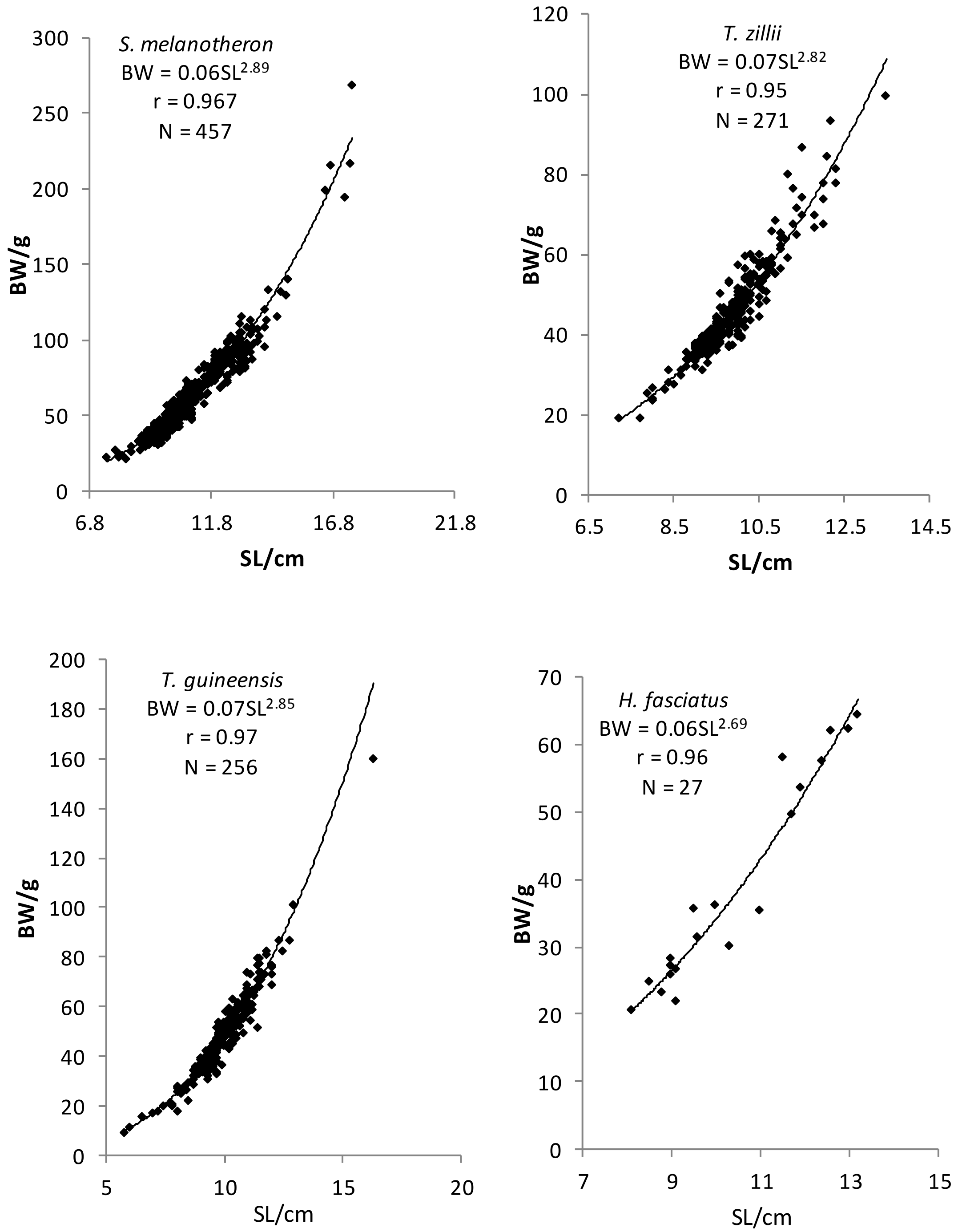

Figure 12: Length-weight plot for cichlids obtained from the Brimsu reservoir from September 2009 to September 2010.

Changes in condition factor of the cichlid populations

S. melanotheron

The condition factor (K) of *S. melanotheron* during the period of study is shown in Figures 13a & b. Condition factor of males fluctuated between 3.95 ±0.07 in September 2009 and 4.94 ±0.10 in January 2010 whiles that of the females fluctuated between 4.08 ±0.05 and 4.99 ±0.08 in September 2009 and December 2009 respectively. Condition of the two sexes reduced from 4.94 in January 2010 to a minimum of 4.03 in April 2010. Afterwards, the condition of the two sexes increased until May 2010 when that of the males began a decline to 4.49 ±0.15 in September 2010. However, there was improvement in the condition of the females after May 2010 with July and August 2010 recording a significant increase in the condition of females than males.

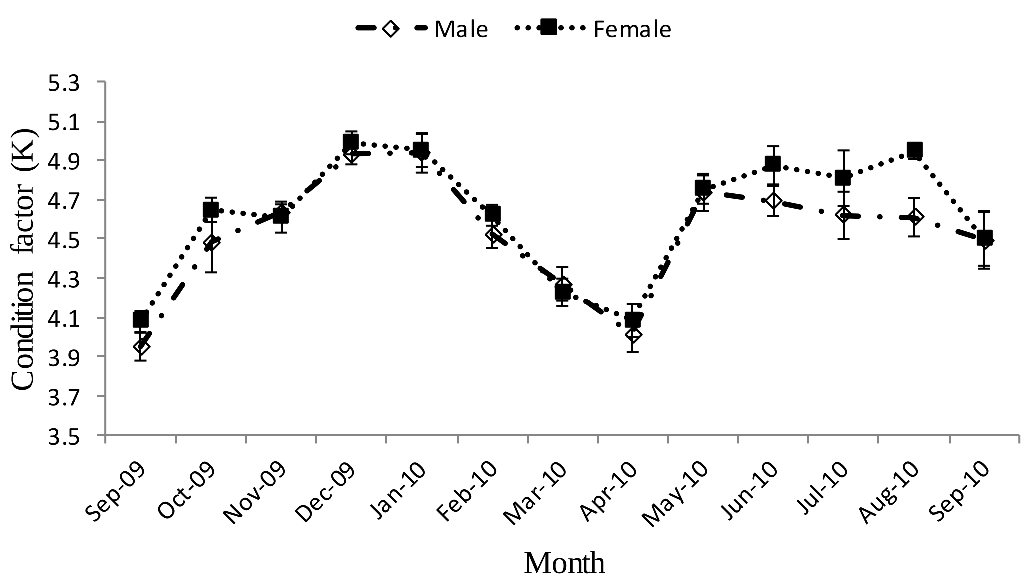

Figure 13a: Variation in the monthly condition factor of *S. melanotheron* (male and female) from the Brimsu reservoir from September 2009 to September 2010

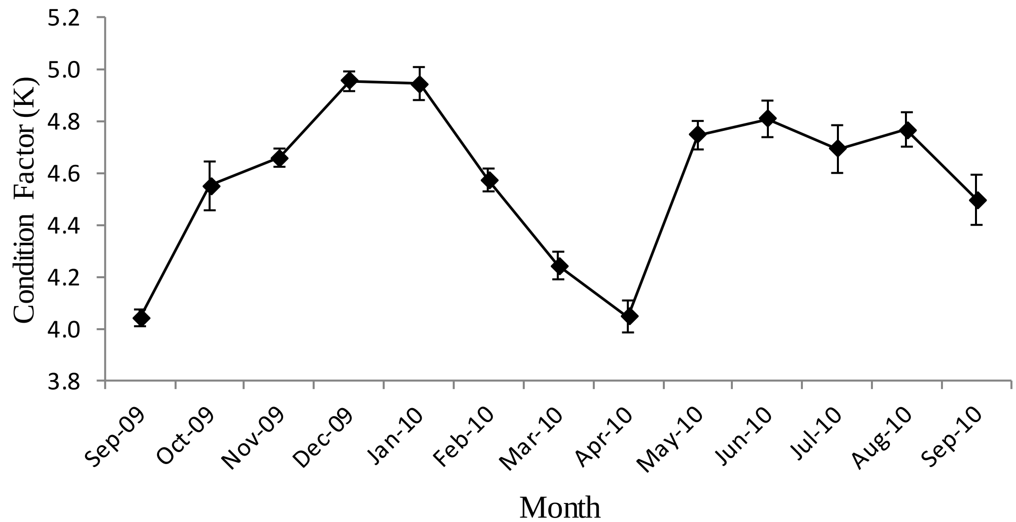

Figure 13b: Variation in the monthly condition factor of *S. melanotheron* (both sexes combined) from the Brimsu reservoir from September 2009 to September 2010.

T. zillii

The trend of fluctuation of the species (both sexes combined) was characterized by an improvement in the condition from 4.18 ± 0.05 in September 2009 to 4.85 ± 0.10 in November 2009 (Fig. 14). This was followed by a marginal decrease in December after which the condition improved to a maximum of 5.37 ± 0.09 in January 2010. There was a sharp decline in condition from January 2010 to a minimum in April 2010, after which the condition improved to 4.84 ±0.12 in June with a minimal decline recorded afterwards.

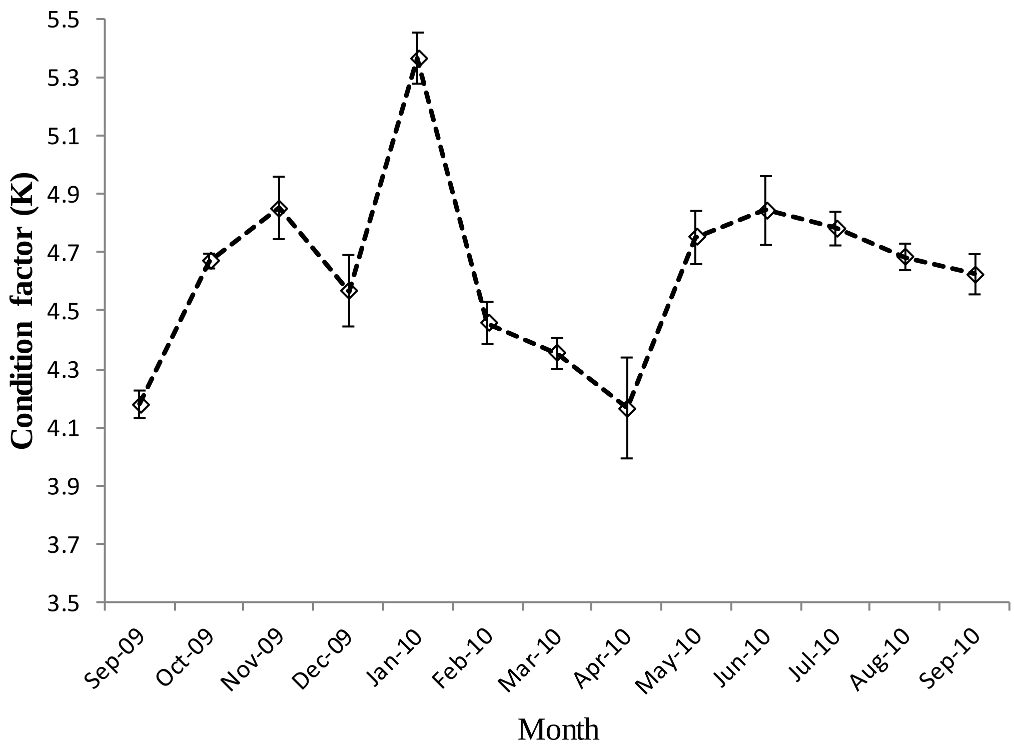

Figure 14: Variation in the monthly condition factor of *Tilapia zillii* obtained from the Brimsu reservoir from September 2009 to September 2010.

T. guineensis

The condition factor of *T. guineensis* increased from 4.27 ±0.11 in September 2009 to 4.72 ± 0.04 in October 2009 and reduced marginally to 4.57 in December 2009 (Fig. 15). This was followed by a significant improvement to 5.11 ± 0.14 in January 2010 after which the condition decreased to a minimum of 4.07 in March – April 2010. Subsequently, the condition of the species improved significantly after April to 4.73 ± 0.09 and remained virtually unchanged to September 2010.

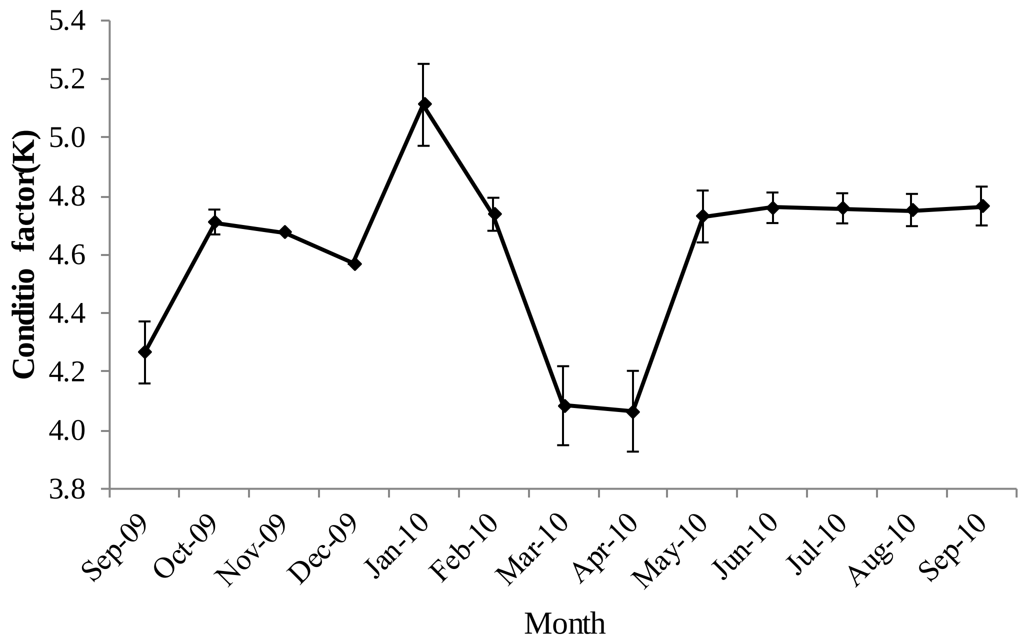

Figure 15: Variation in the monthly condition factor of *Tilapia guineensis* from the Brimsu reservoir from September 2009 to September 2010.

Visceral fat index of cichlids

S. melanotheron

There was reduction in the mean visceral fat index of the blackchin tilapia from 2.92 ± 0.07 in September 2009 to 2.21 ±0.14 in October 2009 (Fig. 16). This was followed by a gradual increase in the accumulation of fat in the species to a peak of 3.79 ± 0.05 in December 2010. Subsequently, there was a gradual reduction in the accumulation of fat to April – June 2010. Thereafter, there was a sharp increase in fat storage in July 2010 which declined in August 2010.

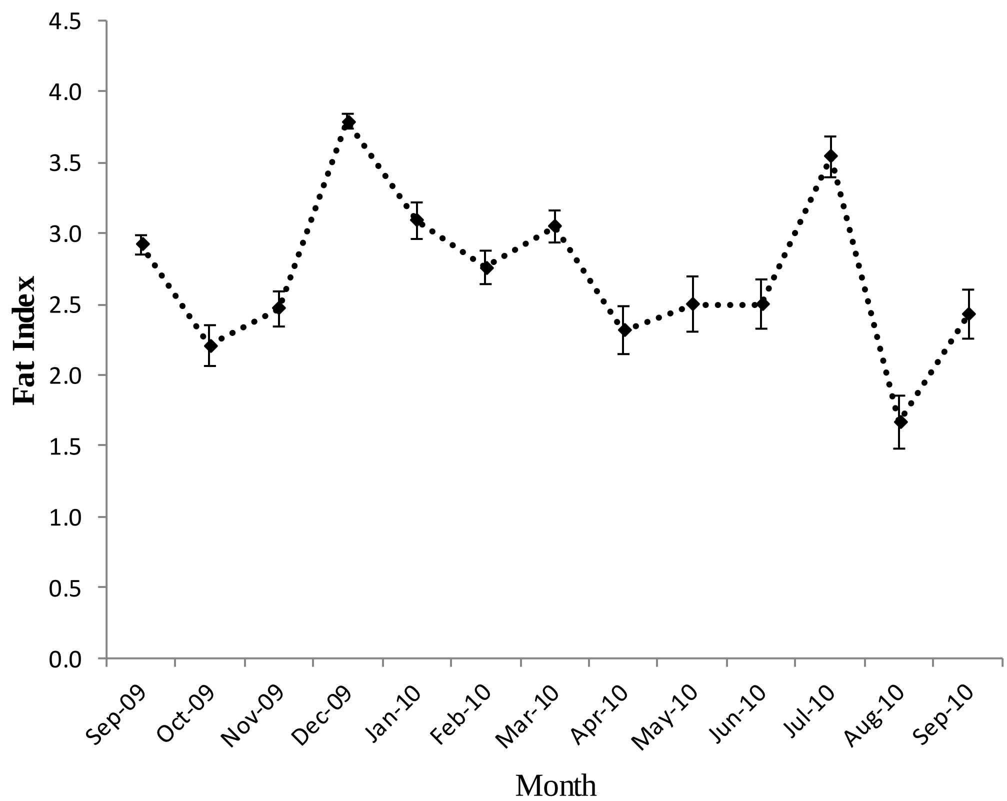

Figure 16: Changes in visceral fat index of *S. melanotheron* from the Brimsu reservoir from September 2009 to September 2010.

T. zillii

The mean visceral fat of *T. zillii* increased from 1.44 ±0.09 in September 2009 to 2.00 ±0.32 in March 2010 (Fig. 17). This was followed by an insignificant decrease in the fat index of the species in April 2010 after which the index increased significantly to 2.85 ± 0.22 in July 2010.

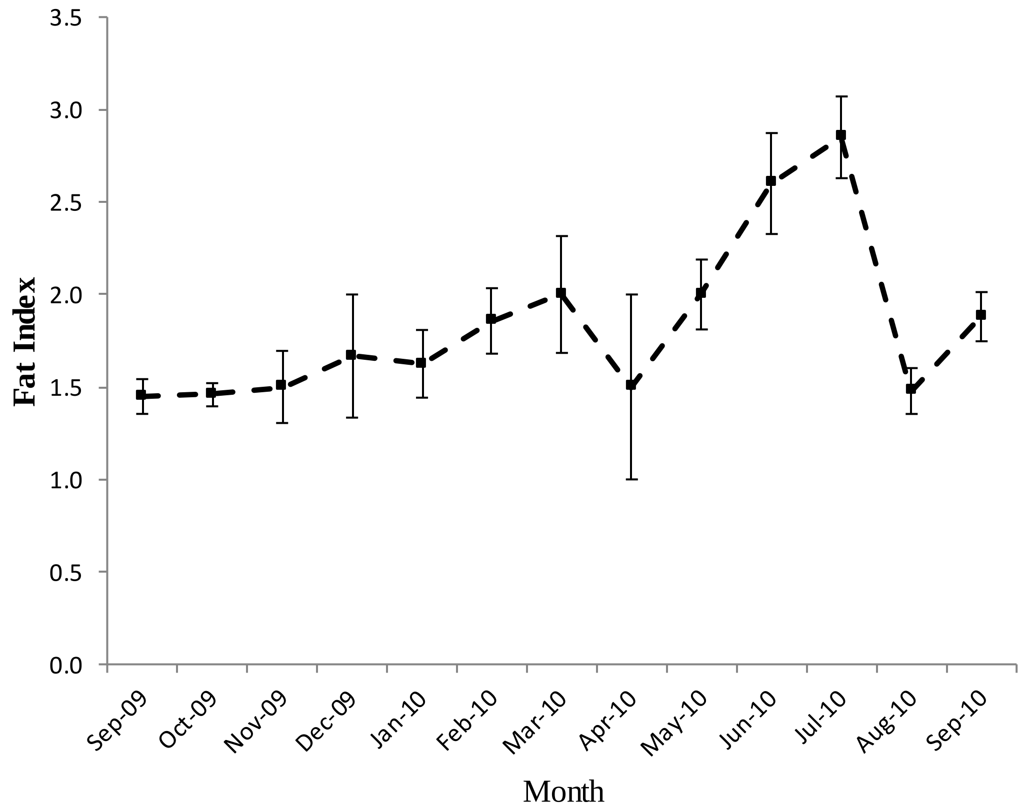

Figure 17: Changes in visceral fat index of *T. zillii* from the Brimsu reservoir from September 2009 to September 2010.

T. guineensis

The fluctuation in the mean visceral fat index of *T. guineensis* is shown in Figure 18. There was in increase in the storage of visceral fat from September 2009 (1.56 ± 0.18) to 2.0 in November and remained unchanged in December 2009. Thereafter, there was a considerable reduction in the mean visceral fat index to a minimum (1.0) in March 2010. This was followed by a gradual increase to a maximum of 2.47 ±0.16 in July 2010 and subsequently reducing to the end of the study period.

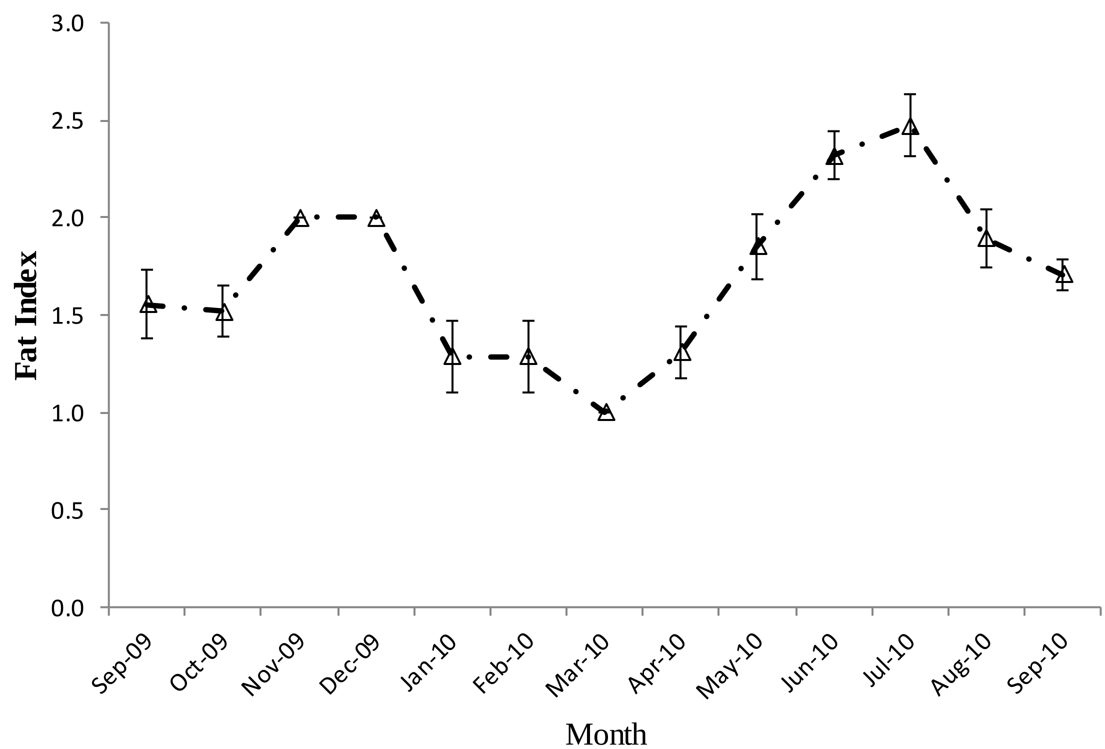

Figure 18: Changes in the visceral fat index of *T. guineensis* from the Brimsu reservoir from September 2009 to September 2010.

Stomach content analysis

S. melanotheron

Food items in the diet of the blackchin tilapia, *S. melanotheron* included blue-green, green algae, dinoflagellates, debris, insect larvae, fish parts, sand as well as some unidentified items (Fig. 19). The green algae were made up of diatoms such as *Melosira* sp, *Asterionella* sp, *Fragillaria* sp, *Tabellaria* sp, *Frustulia* sp, *Navicula* sp and *Eunotia* sp. Other green algae encountered were desmids and these included *Scenedesmus* sp, *Closterium* sp, *Gonatozygon* sp and *Pediastrum* sp. Blue-green algae in the stomach included *Anabaena* sp, *Ulothrix* sp, and *Oscillatoria* sp.

Although green algae were found in all the stomachs examined, they constituted less than 25 % of the composition of food items. However, dinoflagellates which occurred in less than 55 % of the stomachs constituted 37.5 % of the food. Sand occurred in over 90 % of the stomachs and represented 12 % of the food eaten, whereas rotifers and fish parts occurred in less than 10 % of the stomachs.

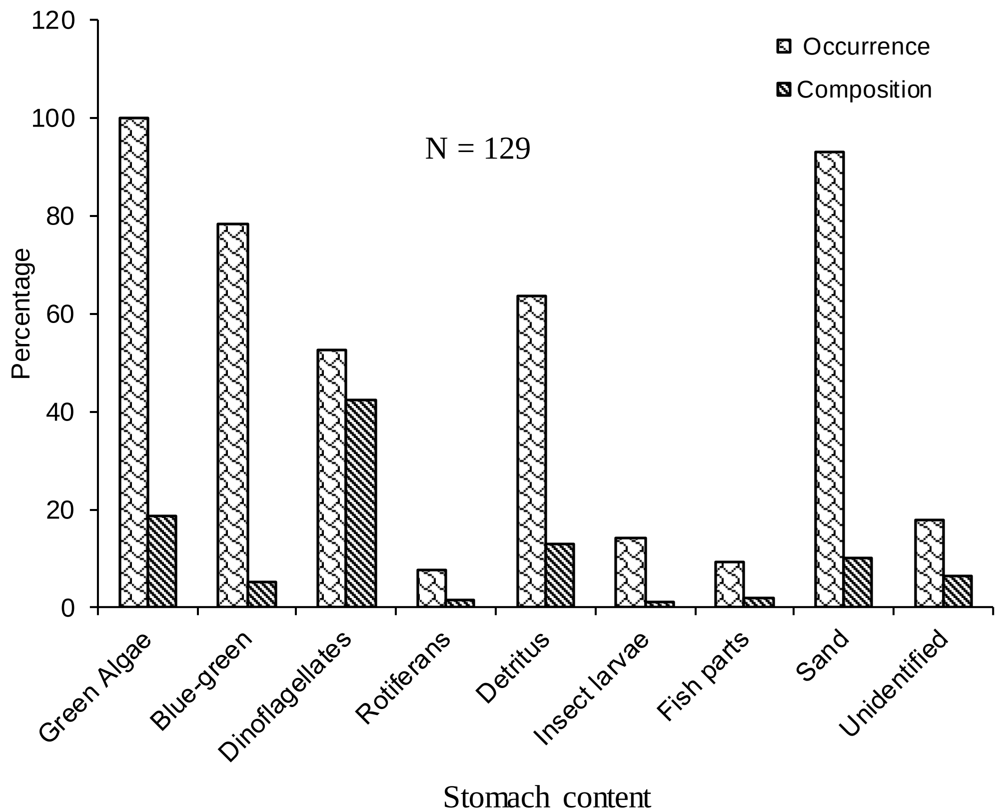

Figure 19: Percentage occurrence and composition of food item in the diet of *S. melanotheron* from the Brimsu reservoir.

T. zillii

The percentage occurrence and composition of food items in 68 examined stomachs of *T. zillii* is shown in Figure 20. The food items comprised of green algae, blue-green algae, rotifers, plant parts (macrophyte) and detritus. Other food items which occurred in lower proportion in the diet included: fish parts, sand and unidentified food. Green algae comprised species such as *Diatoma sp*, *Flagellaria sp*, *Frustulia sp*, *Navicula sp*, *Spirogyra sp*, *Euglena sp*, and *Phacus sp*. Although green algae were found in all the stomachs examined, they constituted 23.5 % of the diet of the species. Plant parts formed almost 50 % of the diet whereas detrital matter and the other food items formed less than 30 % of the diet of *T. zillii*.

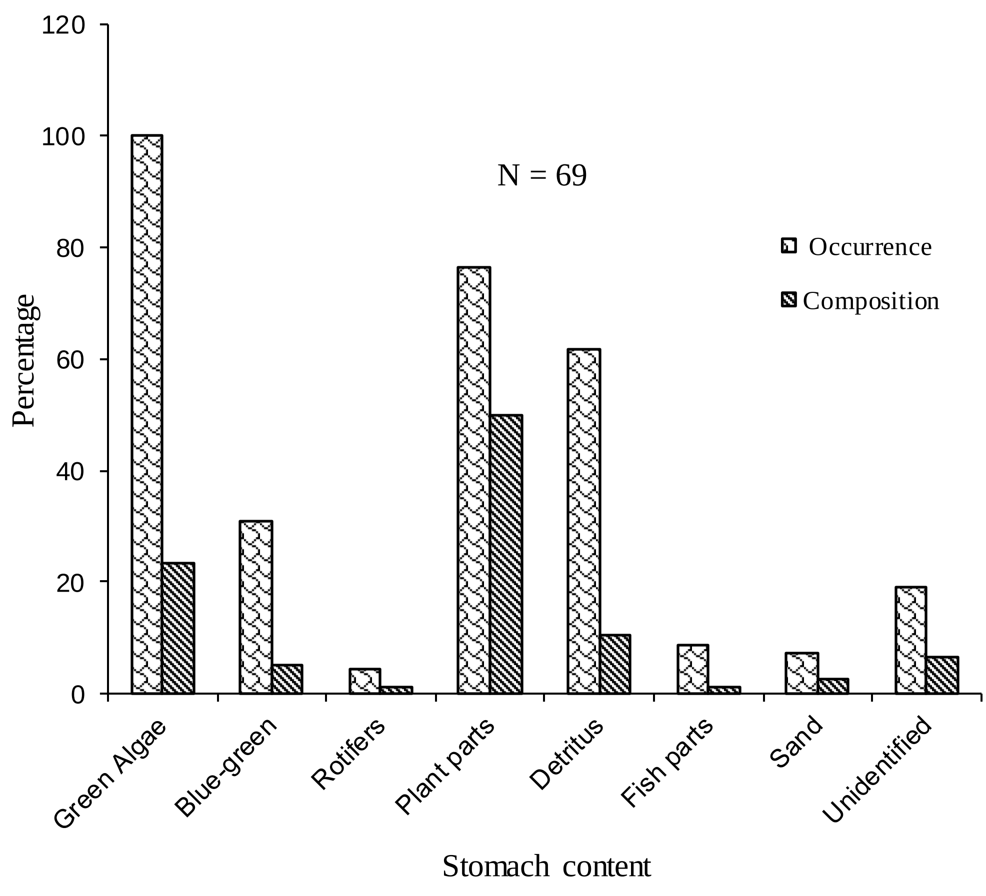

Figure 20: Percent occurrence and composition of food item in the diet of *T. zillii* from the Brimsu reservoir.

T. guineensis

The species fed on green algae, blue-green algae, detrital matter, silt and other minor food items (Fig. 21). Among the green algae identified were diatoms including: *Fragilaria* sp, *Eunotia* sp, *Asterionella* sp, *Hyalotheca* sp, *Diatoma* sp and *Cyclotella* sp. Other green algae identified were desmids such as *Closterim* sp, *Desmidim* sp, *Pediastrum* sp and *Cosmarium* sp. The blue-green algae consisted of *Calothrix* sp, *Oscillatoria* sp and *Anaebena* sp.

Green algae formed an important part of the diet of this fish constituting more than 50 % of the diet. Silt and blue-greens formed 20 % and 11 % of the diet of the species respectively whereas the other food items constituted less than 20 %.

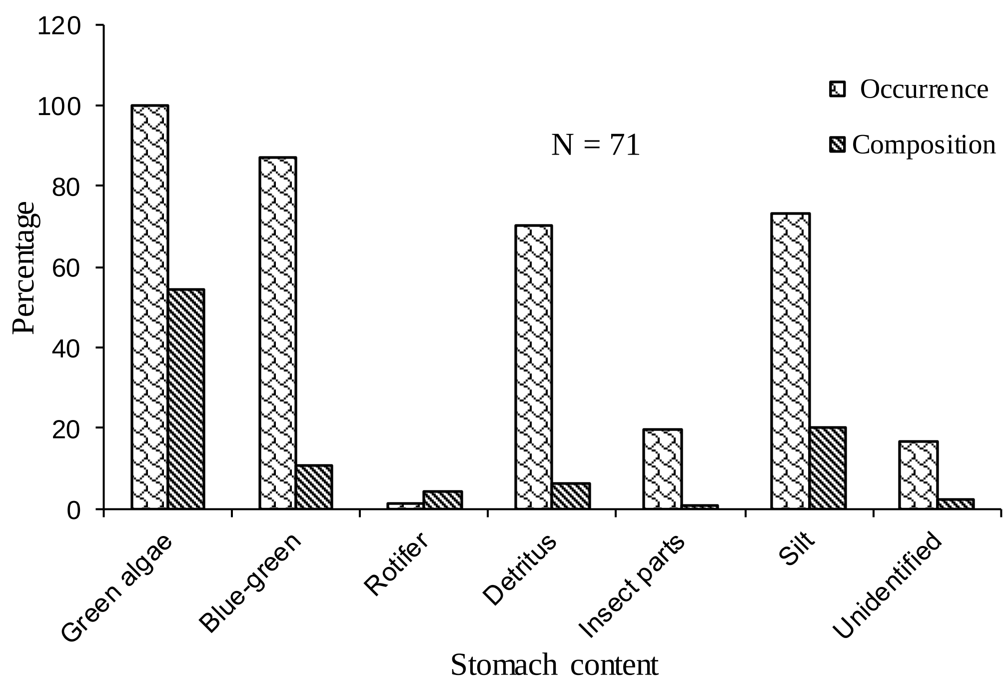

Figure 21: Percent occurrence and composition of food item in the diet of *T. guineensis* from the Brimsu

H. fasciatus

The stomach content contained a narrow range of food items including insect parts, fish, detritus and unidentified food items (Fig. 22). Insect parts were the most prevalent food item representing 60 %. This was followed by fish remains and detrital matter occurring in 30 % and 20 % of the stomachs respectively.

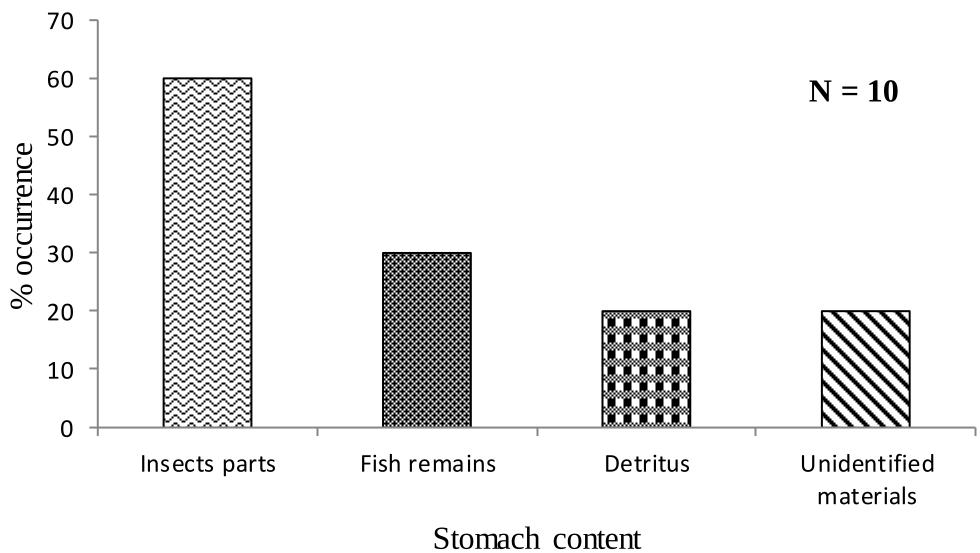

Figure 22: Percent occurrence of food item in the diet of *H. fasciatus* from the Brimsu reservoir.

Monthly changes in percentage of cichlids with empty stomachs

S. melanotheron

There was a decline in the number of *S. melanotheron* with empty stomach from 34.02 % in September 2009 to zero in December 2009 (Fig. 23). This however, changed drastically in the ensuing month with more than 40 %

of specimen having empty stomachs and increasing further to 60.53 % in April 2010. The subsequent months were characterized by minimal fluctuation varying between 40 % and 54 %.

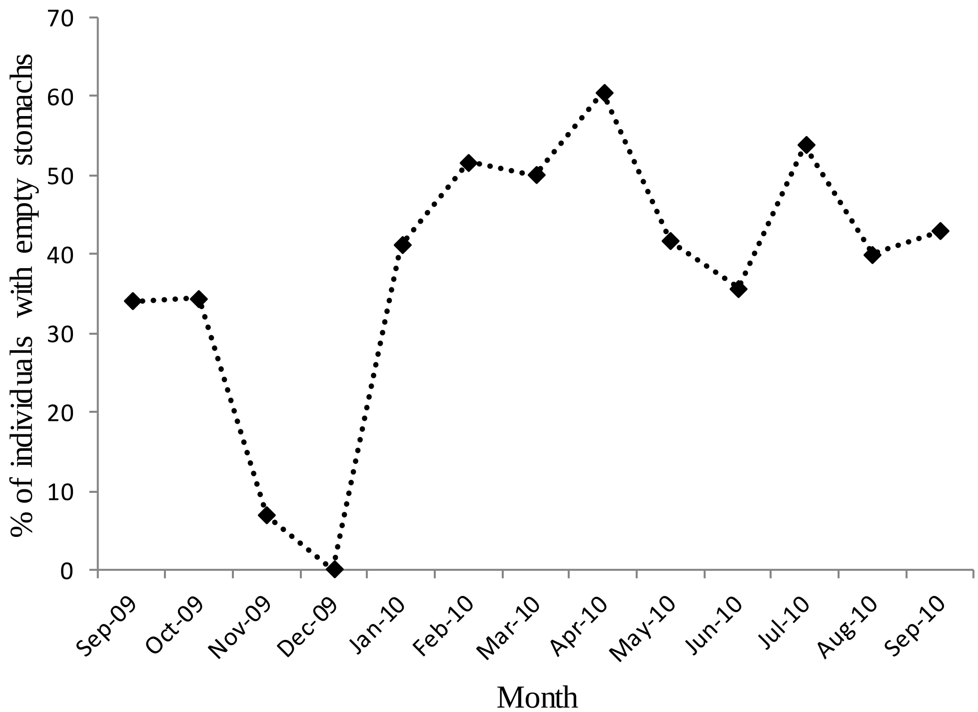

Figure 23: Variation in the proportion of *S. melanotheron* with empty stomachs from the Brimsu reservoir (September 2009 to September 2010).

T. zillii

The fluctuation in the percentage of individuals with empty stomachs of the species increased from more than 30 % in September 2009 to a maximum of 62.75 % in October 2010 (Fig. 24). This was followed by a sharp decline to

25 % in November 2009 and remained relatively stable till January 2010. The fluctuation then varied between 20 % and 50 % until April 2010. Afterwards, there was a gradual decline in the proportion of specimens with empty stomachs to a minimum of zero (0) in June 2010; thereafter, increasing to more than 60 % in August 2010.

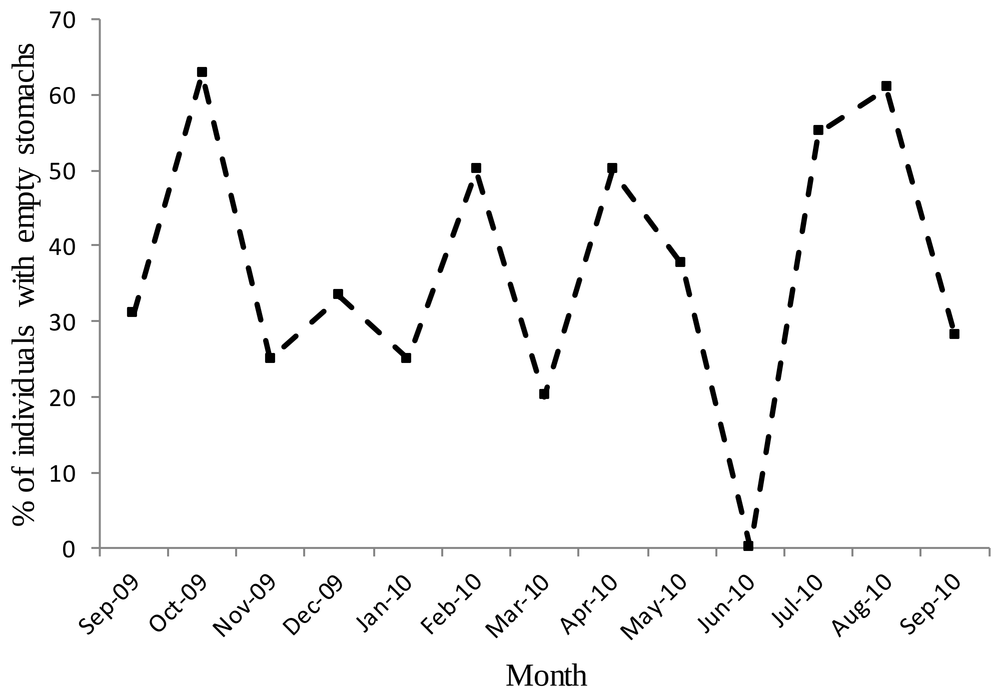

Figure 24: Variation in the proportion of *T. zillii* with empty stomachs from the Brimsu reservoir from September 2009 to September 2010.

T. guineensis

The monthly variations in the proportion of specimens of *T. guineensis* with empty stomach are shown in Figure 25. The marginal increase from September to October 2009 was followed by a drastic reduction in the proportion of specimens with empty stomach from 67.74 % in the latter month to 0.0 % in November 2009. This was then followed by an increase to over 70 % of specimens with empty stomachs which then reduced gradually to 25 % in March 2010. Afterwards there was a fluctuation in the proportion of specimens with empty stomach varying between 12 % and 57 %.

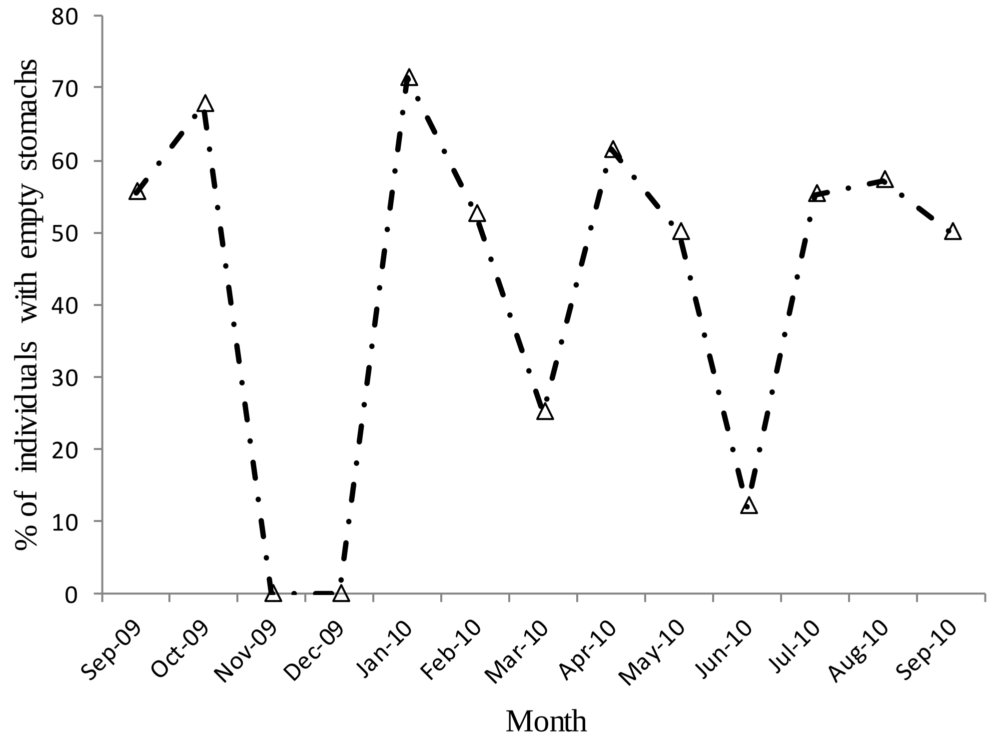

Figure 25: Variation in the proportion of *T. guineensis* with empty stomachs obtained from the Brimsu reservoir from September 2009 to September 2010.

Monthly fluctuation in the gonadosomatic index (GSI) of the cichlids

S. melanotheron

The GSI of the males had three peaks which occurred in October - November 2009, April 2010 and June 2010 (Fig. 26). The month of April 2010, recorded the highest GSI (0.17 ± 0.01), whiles the lowest GSI of 0.03 ± 0.001 was obtained in September 2009.

There was a steady increase in the GSI of female from 0.23 ± 0.12 in September 2009 to a maximum of 4.189 ± 0.53 in February 2010, followed by a gradual decline to 0.19 in August 2010 and a slight increase in September 2010 to 0.78 ± 0.15. Generally, the females had higher GSI values than the males.

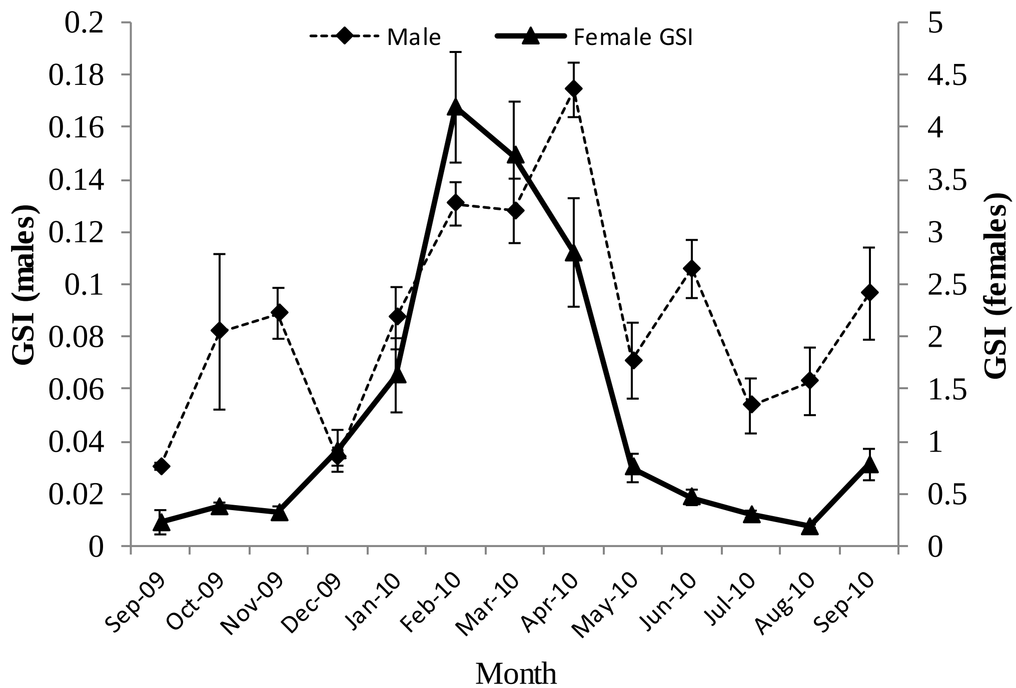

Figure 26: Monthly variation of GSI of male and female *S. melanotheron* from the Brimsu reservoir. Vertical bars represent 2s.e.

T. zillii

There was an increase in the GSI of males from 0.15 ± 0.01 in September 2009 to 0.21 ± 0.02 in October, 2009 and followed by a decrease in November 2009 (Fig. 27). GSI then increased again form 0.09 in November 2009 to a maximum of 0.47 ± 0.04 in February 2010. This was then followed by a gradual decline to the lowest point of 0.05 in July 2010.

The GSI of females was characterized by a marginal increase from 0.28 in September to 0.83 in October 2009 and followed by a sharp increase from November 2009 to December 2009. There was a sudden reduction in the GSI after the latter month to January 2010. GSI further increased to a steadily to a peak of 11.42 ±0.18 in March 2010 after which it declined steadily to 0.04 in July 2010.

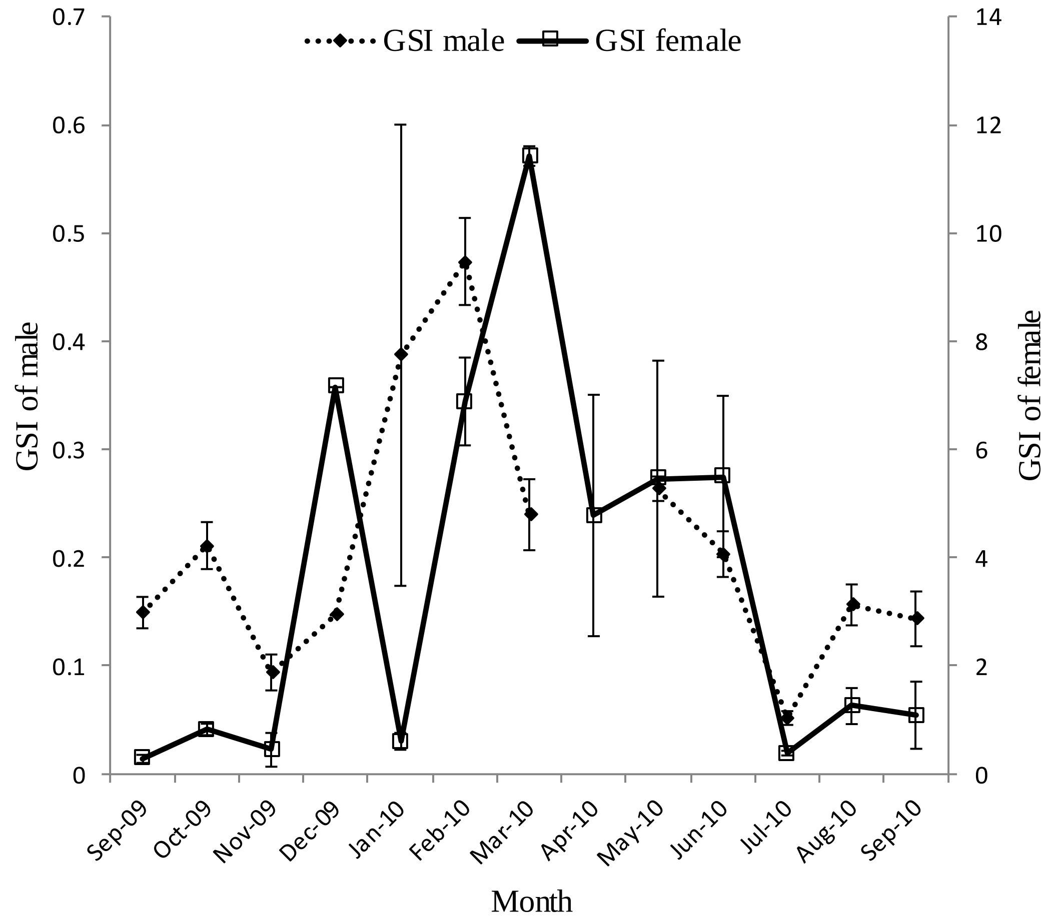

Figure 27: Monthly variations in GSI of *T. zillii* obtained from the Brimsu reservoir. Vertical bars represent 2s.e.

T. guineensis

The fluctuation in GSI both sexes was characterized by an irregular pattern (Fig. 28). Gonadosomatic index of males reduced from 0.33 in September 2009 to 0.15 in October 2009. Thereafter, there was a gradual increase in the accumulation of reproductive material from October 2009 to 0.48 ± 0.02 in March 2010. This was followed by a steady decrease in the GSI to the lowest point of 0.13 ± 0.01 in September 2010.

The GSI of the females decreased from 2.95 in September 2009 to 2.15 October 2009. In the two subsequent months, no females were obtained. However, between January 2010 and April 2010, the GSI fluctuated between 3.38 and 6.18 reaching a maximum of 6.77 in May 2010. Thereafter, GSI declined sharply to 0.47 in July 2010.

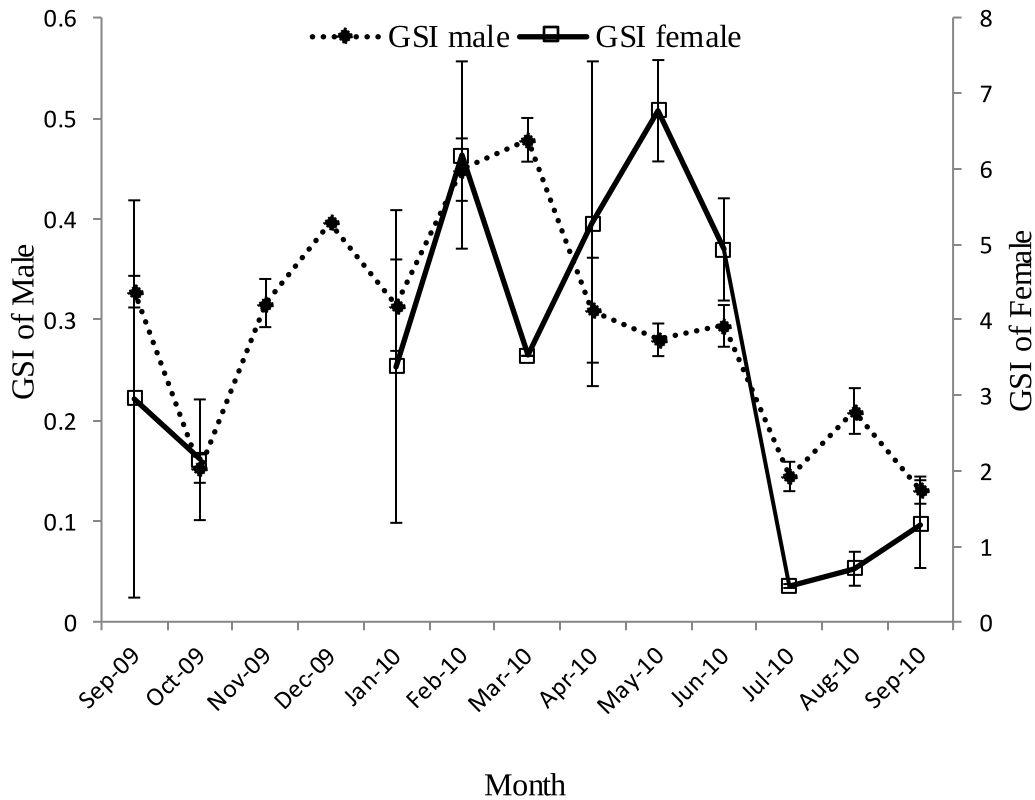

Figure 28: Monthly variations of GSI of *T. guineensis* obtained from the Brimsu reservoir. Vertical bars represent 2s.e.

Monthly variation in proportion of ripe gonads of the cichlids

S. melanotheron

The proportion of males with advanced stage of maturity reduced from 23.53 % in September 2009 to 0.00 % in November 2009 (Fig. 29). This was followed by a steady increase to 100% in April 2010 after which the proportion of ripe males reduced to till none in August 2010.

No ripe females were recorded for September and October 2009. The percentage of ripe females then began to rise gradually from October 2009 to a peak of 60 % in February 2010, followed by a decline to 0.00 % in May 2010. The subsequent months had no females with ripe ovaries.

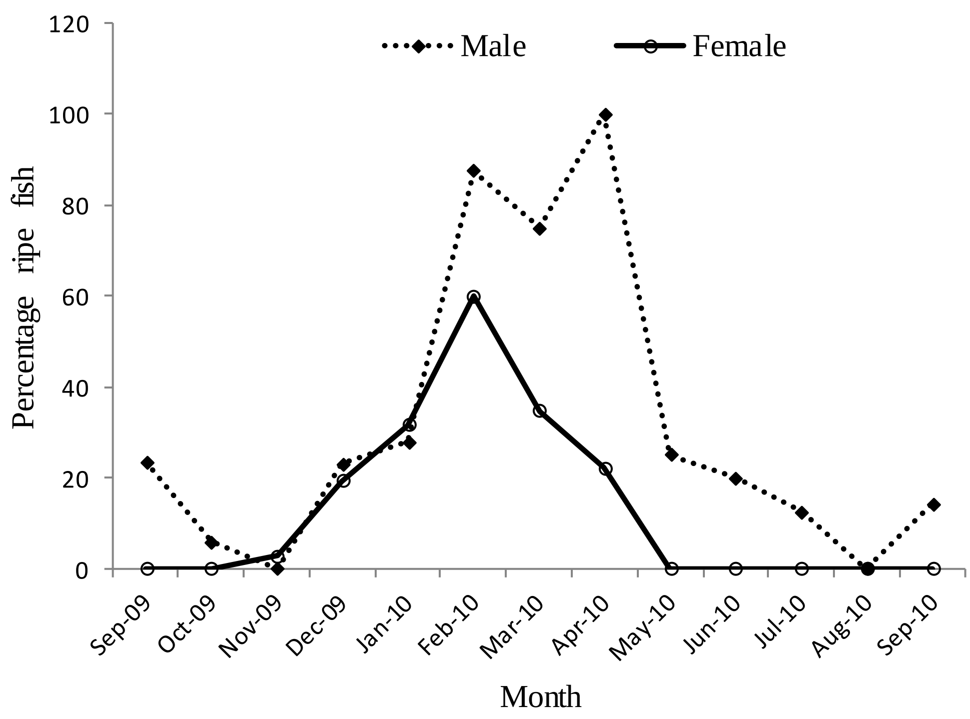

Figure 29: Percentage ripe gonads of *S. melanotheron* from the Brimsu reservoir from September 2009 to September 2010

T. zillii

The proportion of specimens with ripe gonads is shown in Figure 30. There were very few individuals with ripe ovaries and testes between September and November 2009. However, there was a sharp increase in the proportion of ripe individuals to 100 % in December 2009 (both male and female). The proportion of ripe individuals then decreased sharply again in January 2010. In April 2010, however, no male specimen of the species was obtained. Thereafter, the proportion of male specimens increased gradually to 100 % in May 2010 followed by a decline in the subsequent months

With the females however, there was a sharp increase in the proportion of fish with ripe ovaries from zero (0.0 %) in January 2010 to 100 % in March and April 2010. This was then followed by a gradual reduction 0.0 % in July 2010 with no change in the subsequent months.

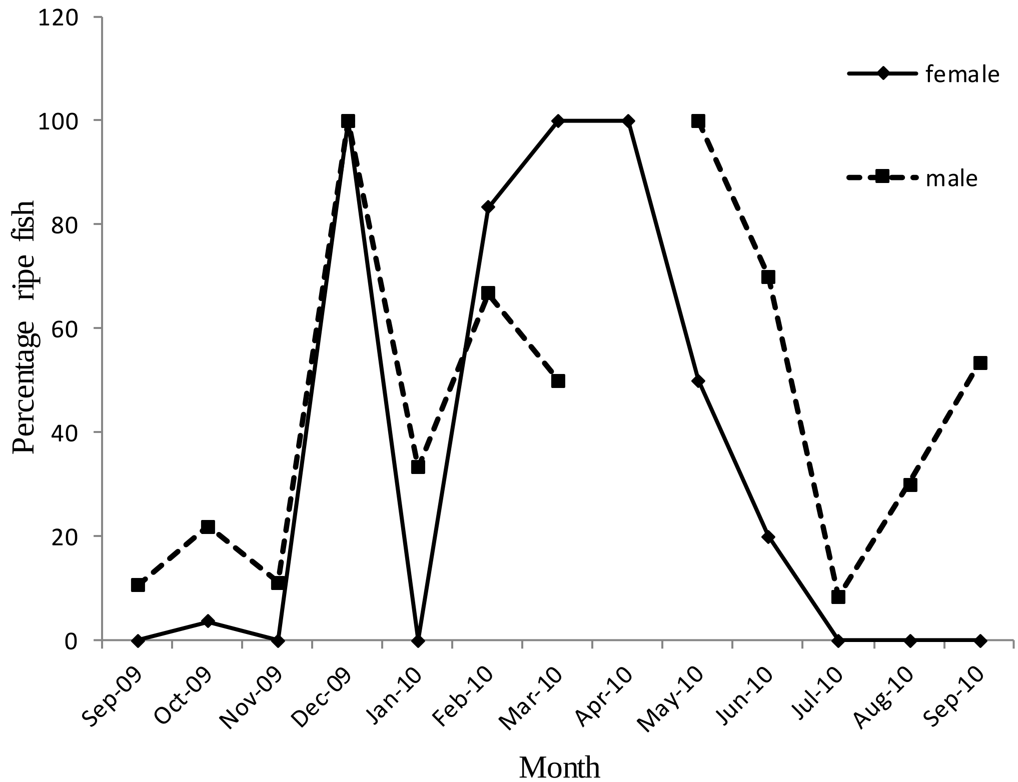

Figure 30: Percentage ripe gonads in *T. zillii* from the Brimsu reservoir.

T. guineensis

The proportion of ripe testes of the species reduced from less than 20 % in September 2009 to 0.0 % in November and December 2009 and increased thereafter to a maximum to 100% in March 2010 (Fig. 31). The subsequent month was characterized by a sharp decrease in proportion of specimens with ripe testes to less than 20 % and then increasing to less than 80 % in May 2010. Thereafter, the fluctuation varied between 69 % and 28%.

Percentage of fish with ripe ovaries fluctuated marginally from September to December 2009. It then increased from 0.0% in December 2009 to 71.43 % in February 2010 thereafter decreasing to 0.0 % in March 2010. Subsequently, there was a gradual increase in the proportion of ripe females to 100 % in May 2010 and thereafter declined to less than 20 % and fluctuated minimally to September 2010.

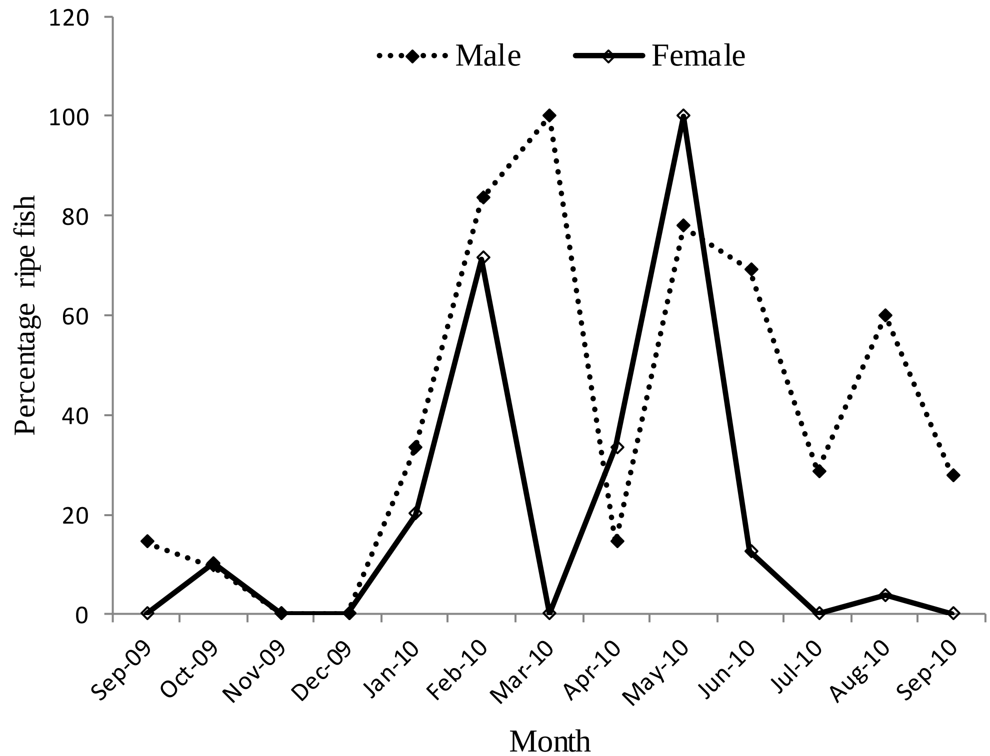

Figure 31: Percentage of ripe gonads in *T. guineensis* from the Brimsu reservoir

Absolute fecundity of cichlids

A summary of the absolute fecundities of *S. melanotheron*, *T. zillii*, *T. guineensis* and *H. fasciatus* is shown in Table 5. The blackchin tilapia, *S. melanotheron*, had the lowest absolute fecundity of 434.4 ± 24.5 while *T. zillii* had the highest fecundity of 3683 ± 210.

Table 5: Summary of absolute fecundity of the cichlids

Species	SL(cm)	BW(g)	Fecundity	
			Range	Mean ± s.e.
S. melanotheron	10.5 – 14.0	51.15 -111.53	187 - 732	434.4 ± 24.5
T. zillii	9.6 – 14.8	45.48 – 86.62	1483 - 4484	3683 ± 210
T. guineensis	8.0 -12.0	27.55 - 82.54	1968 – 4016	2945 ± 132
H. fasciatus	8.1 - 13.2	20.63 - 49.80	1212 - 2246	1614 ± 222

Relationship between fecundity and standard length of the cichlids

The relationships between the standard length (SL) and fecundity (Fec) of the cichlids were linear (Fig 32a,b,c). However, a stronger correlation for the relationship ($r = 0.77$) was characteristic of *S. melanotheron* while a weak correlation ($r < 0.35$) was noted in the *Tilapia* spp. The equation defining the relationship between the standard length and fecundity of the fishes were:

$Fec = 128.4SL - 1146$ ($r = 0.77$), *S. melanotheron*

$Fec = 433\ SL - 923.2$ ($r = 0.34$), *T. zillii*

$Fec = 198.9SL + 958.8$ ($r = 0.33$), *T. guineensis*

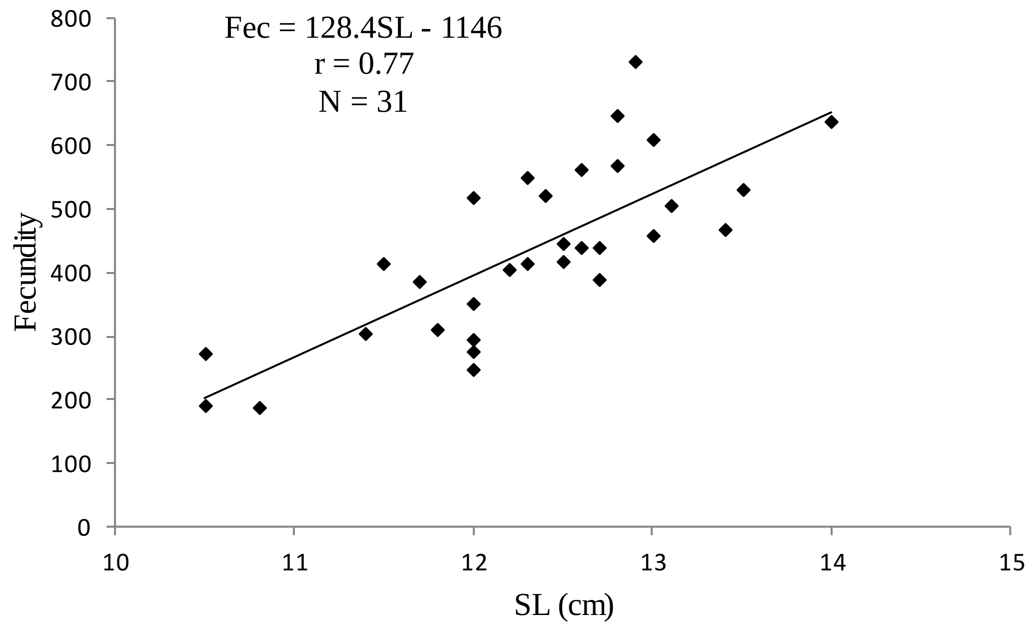

Figure 32a: Relationship between fecundity (Fec) and standard length (SL) of *S. melanotheron* from the Brimsu reservoir

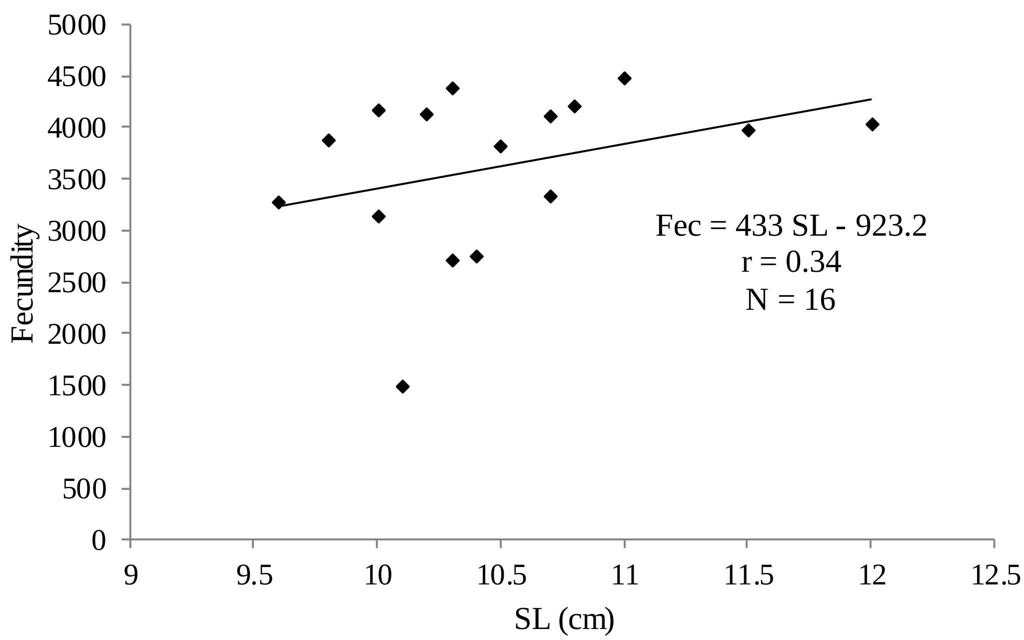

Figure 32b: Relationship between fecundity (Fec) and standard length (SL) of *T. zillii* from the Brimsu reservoir

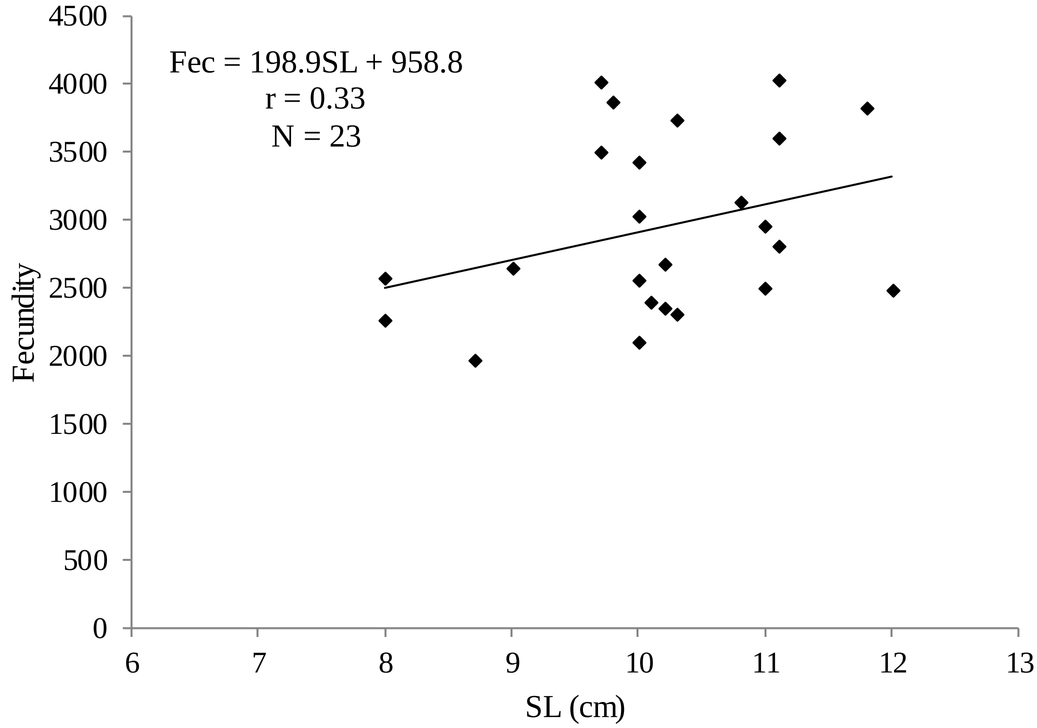

Figure 32c: Relationship between fecundity (Fec) and standard length (SL) of *T. guineensis* from the Brimsu reservoir.

Fecundity and body weight relationship of cichlids

Although the relationship between fecundity and body weight was linear (Fig. 33a, b, c) the correlation between the parameters was not very positive ($r < 0.60$). The relationships were given by:

Fec = 5.20BW - 23.06 (r = 0.58), *S. melanotheron*

Fec = 33.05BW + 1799 (r = 0.43), *T. zillii*

Fec = 14.34BW + 2202 (r = 0.32), *T. guineensis*

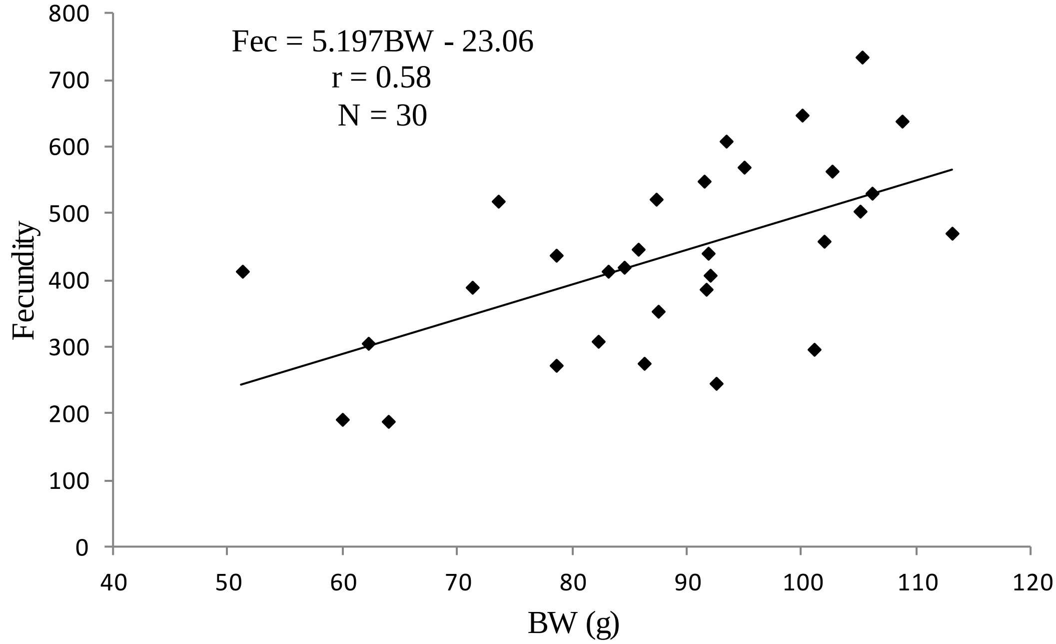

Figure 33a: Relationship between Fecundity (Fec) and body weight (BW) of *S. melanotheron* from the Brimsu reservoir

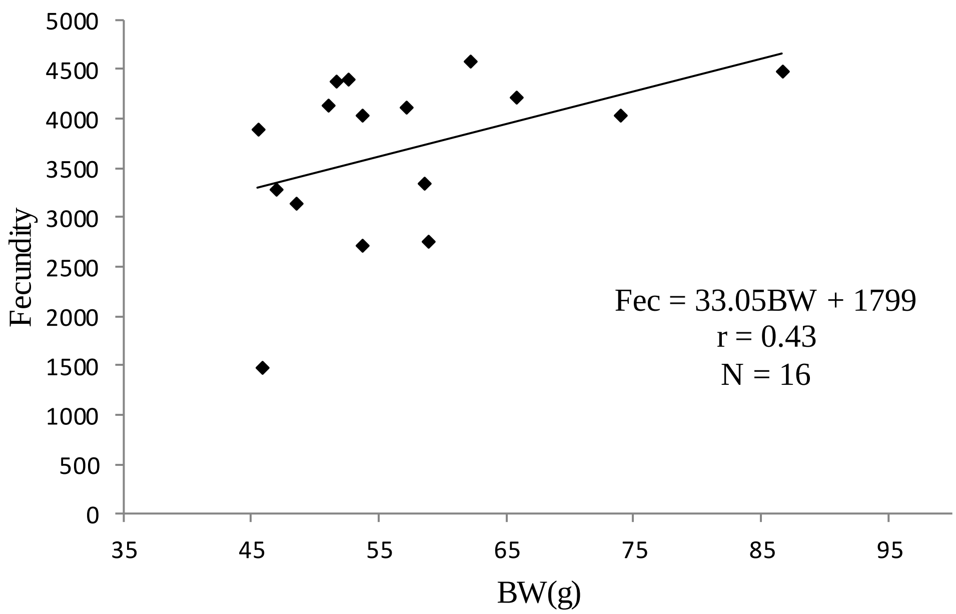

Figure 33b: Relationship between Fecundity (Fec) and body weight (BW) of *T. zillii* from the Brimsu reservoir

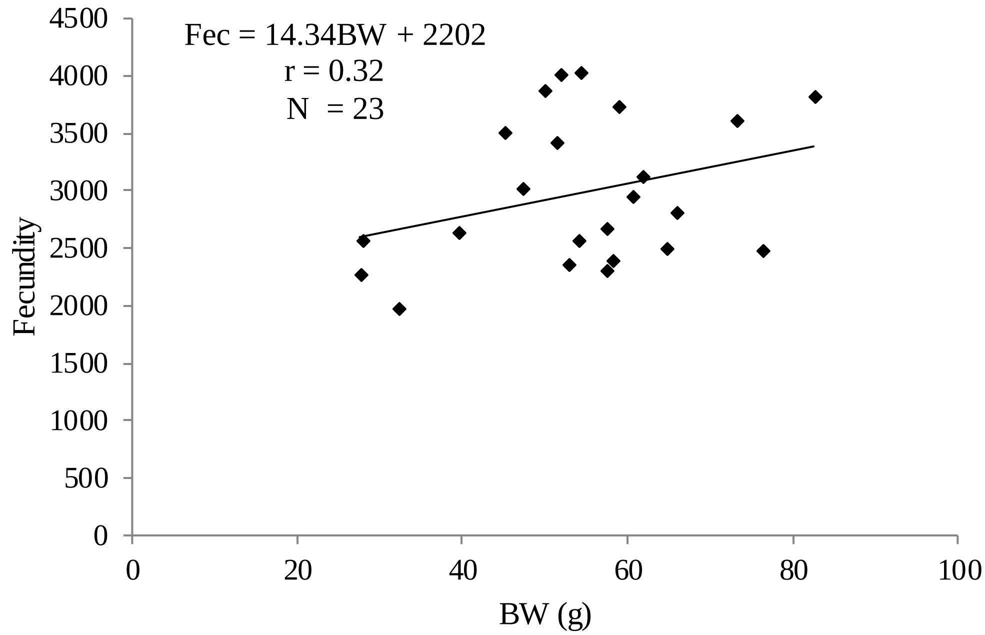

Figure 33c: Relationship between Fecundity (Fec) and Body weight (BW) of *T. guineensis* from the Brimsu reservoir

Fecundity and ovarian weight relationship of cichlids

All cichlids showed a strong correlation between the fecundity and the gonad weight ($r > 0.7$) (Fig. 34a,b,c). The relationship was very positive for *Tilapia zillii* ($r = 0.89$) whereas *S. melanotheron* had the least ($r = 0.72$).

The relationships for the cichlids were:

S. melanotheron: Fec = 58.24GW + 195.3 ; r = 0.72

T. zillii: Fec = 484.0 GW + 1545; r = 0.89

T. guineensis: Fec= 441.6 GW + 1405; r = 0.83

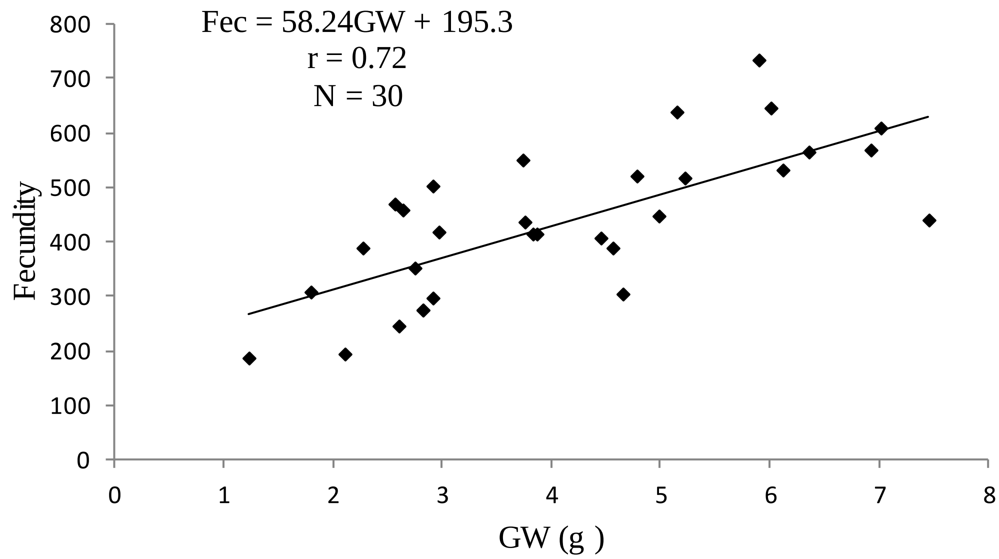

Figure 34a: Relationship between Fecundity (Fec) and gonad weight (GW/g) of *S. melanotheron* from the Brimsu resesrvoir

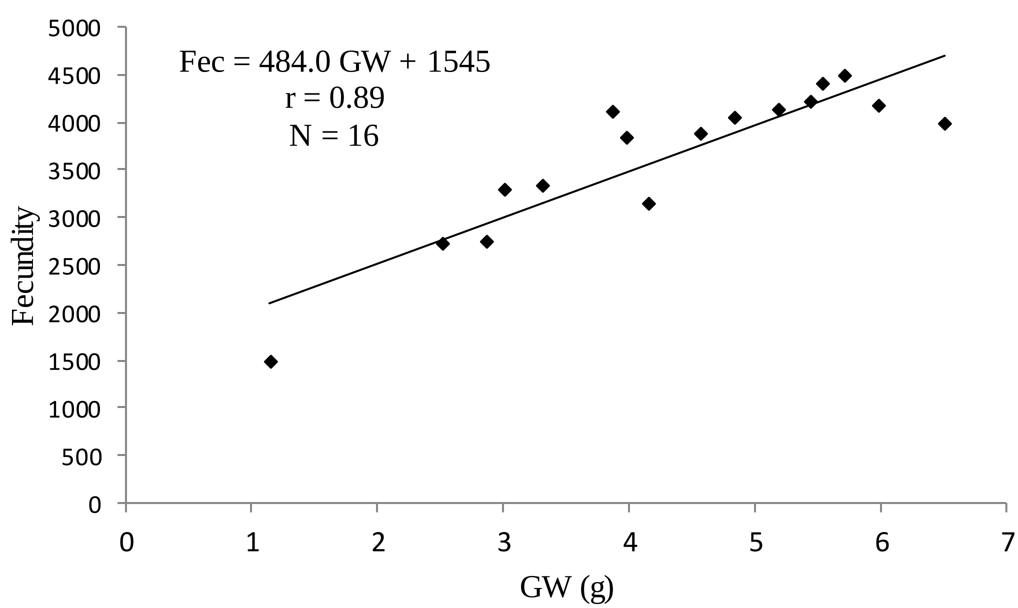

Figure 34b: Relationship between Fecundity (Fec) and gonad weight (GW) of *T. zillii* from the Brimsu reservoir

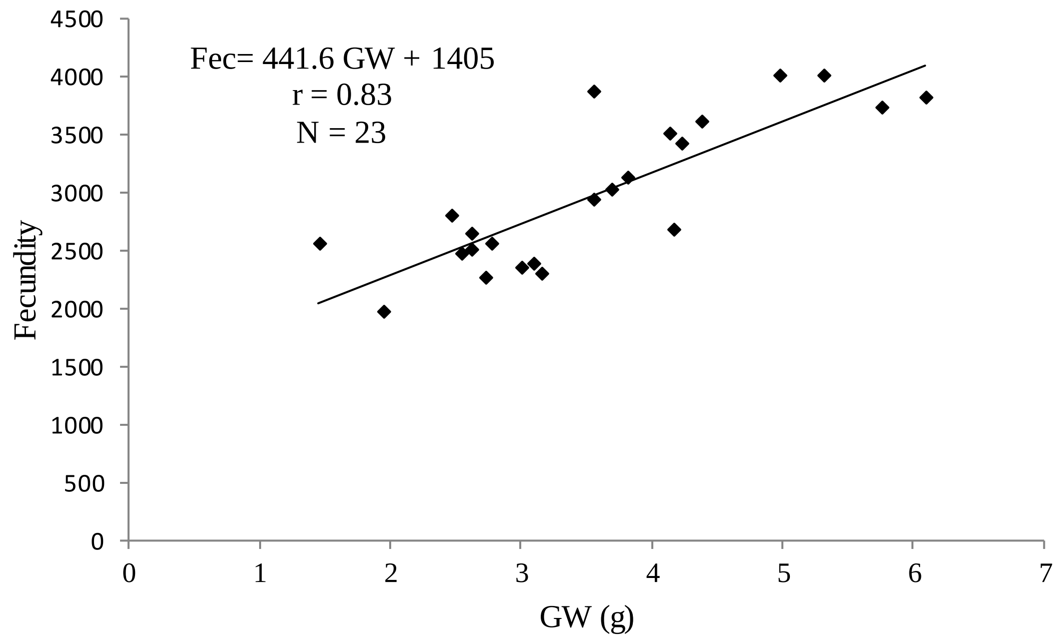

Figure 34c: Relationship between Fecundity (Fec) and gonad weight (GW) of *T. guineensis* from the Brimsu reservoir

H. fasciatus

Four ripe females were obtained from the reservoir. The fecundity varied from 1212 in fish of standard length 12.2 cm to 2246 in a specimen of 11.7cm standard length. The mean fecundity of the four specimens was 1614 ± 222.

Ova diameter of cichlids

S. melanotheron

The frequency distributions of ovum diameter of three ripe ovaries of S. *melanotheron* are shown in Figure 35. The ovum diameter ranged from 0.3 and 4.1 mm for fish measuring 12.8 and 14.8 cm SL. Two distinct peaks which were completely separated from each other were observed in each of the ovaries. The first peak at the 0.7 to 0.8 mm class and the other at the 2.7 – 2.8 mm class for fish measuring 13.2 cm.

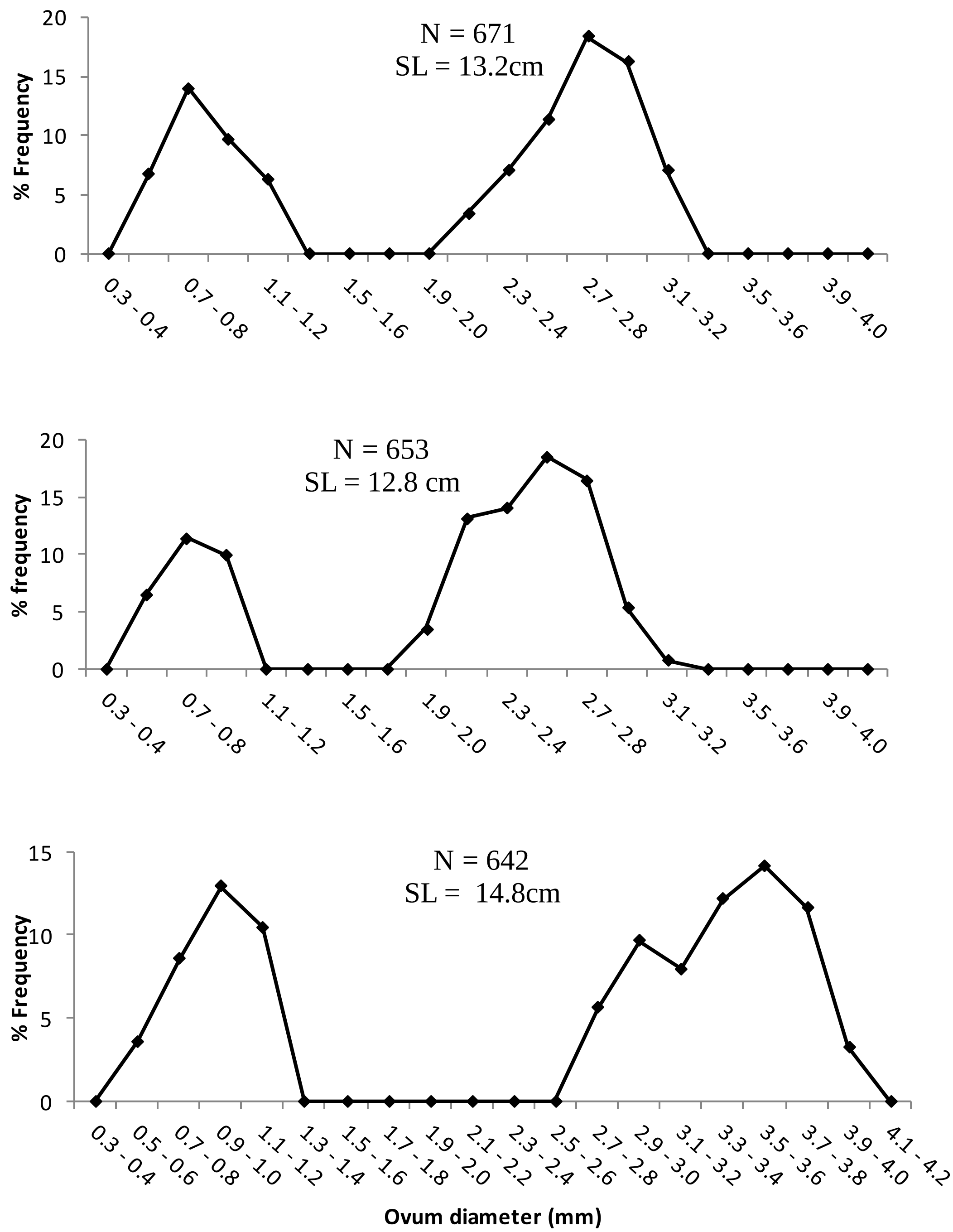

Figure 35: Frequency distribution of ovum diameter of three ripe ovaries of *S. melanotheron* obtained from the Brimsu reservoir.

T. zillii

The frequency distributions of ovum diameter of three ripe ovaries of *T. zillii* are shown in Figure 36. The ovum diameter ranged from 0.3 to 2.1 mm for fish measuring between 11.8 and 14.1 cm SL. The ovaries had two completely distinct peaks which were completely separated from each other with modes at 0.5mm and 1.7cm for fish measuring 11.8 cm and 12.2 cm SL and 0.5 mm and 1.8 mm for fish measuring 14.1cm SL.

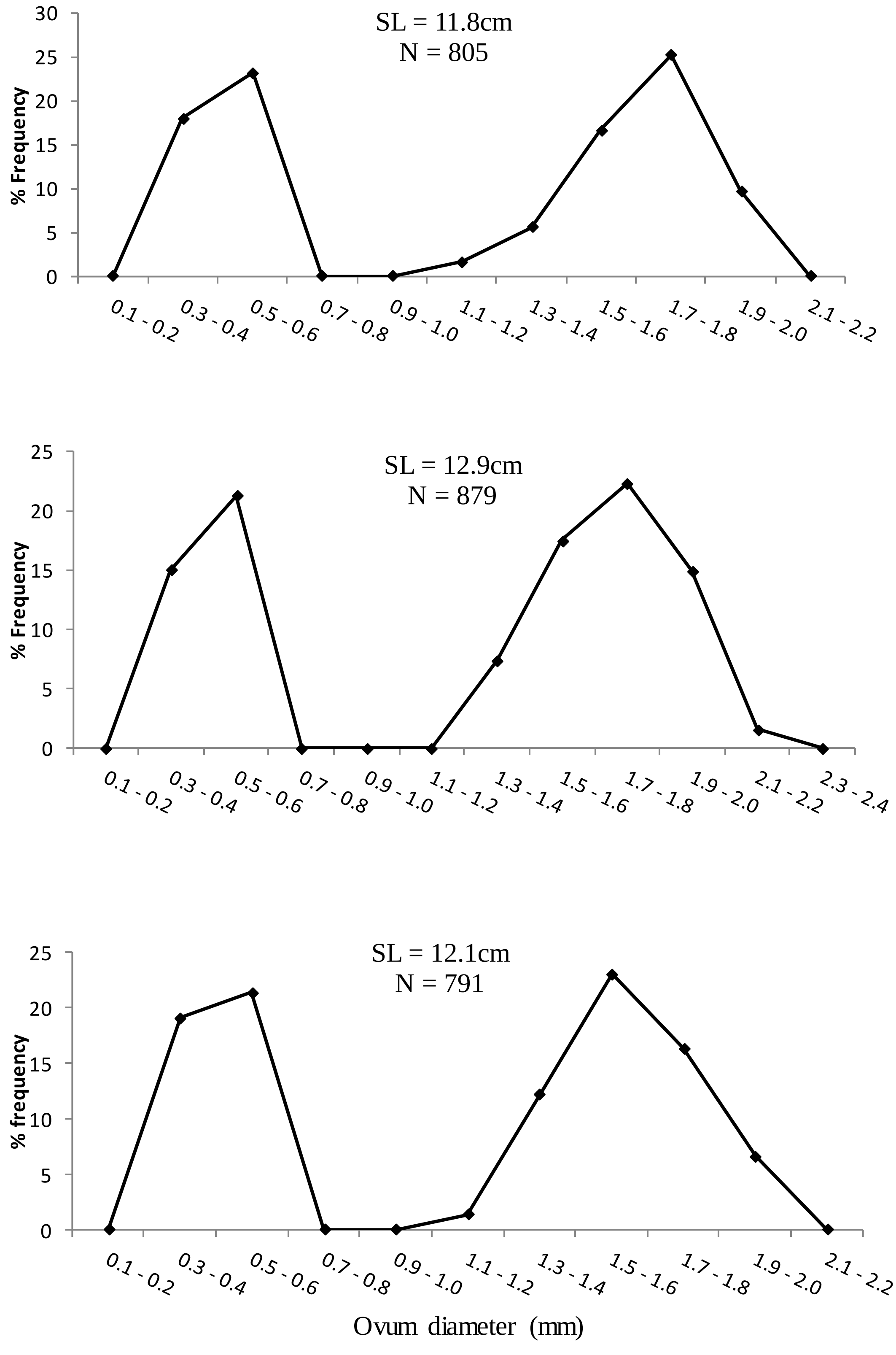

Figure 36: Frequency distribution of ovum diameter of three ripe ovaries of

T. zillii in the Brimsu reservoir (N = total number of ova).

T. guineensis

The frequency distributions of ovum diameter of three ripe ovaries of *T. gineensis* were characterized by two distinct peaks which were completely separated from each other (Fig. 37). The ovum diameter ranged from 0.3 to 2.2 mm for fish measuring between 10.9 and 12.8 cm SL. The modes were 0.5mm and 1.7 mm for fish measuring 10.9 cm and 12.8 cm SL and 0.5 mm and 1.8 mm for fish measuring 12.7cm SL.

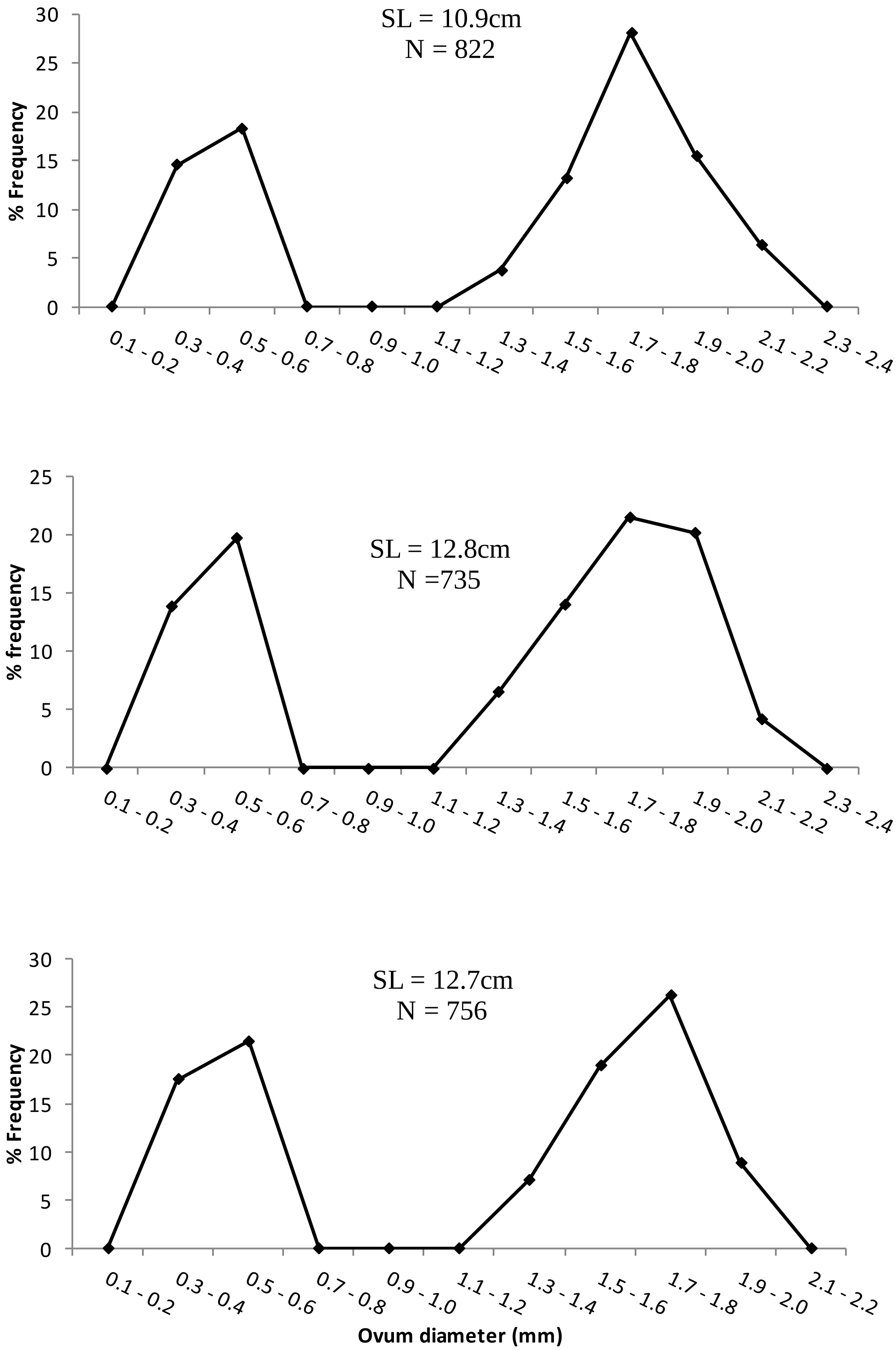

Figure 37: Frequency distribution of ovum diameter of three ripe ovaries of *T. guineensis* in the Brimsu reservoir (N = total number of ova).

Length at sexual maturity of cichlids

S. melanotheron

The length at sexual maturity of the blackchin tilapia, *S. melanotheron* was 11.26 cm and 11.34 cm for male and female respectively (Fig 38a & b). The least matured male and female in the population were 9.30 cm and 9.50 cm respectively.

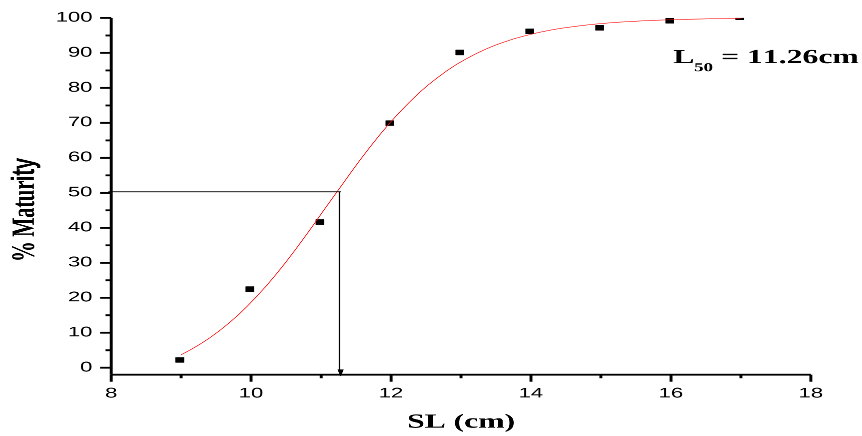

Figure 38a: Length at sexual maturity of male *S. melanotheron* in the Brimsu reservoir

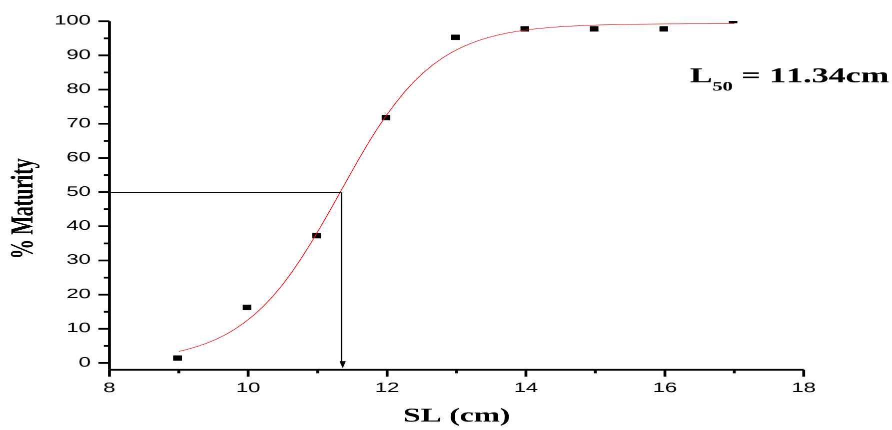

Figure 38b: Length at maturity of female *S. melanotheron* in the Brimsu reservoir

T. zillii

The sexual maturation of the species in relation to their growth is plotted in Fig 39a & b. The least matured male was 8.4cm whereas the smallest matured female was 9.3cm. However, males of this species matured at a smaller size (9.20 cm) than females (9.51 cm).

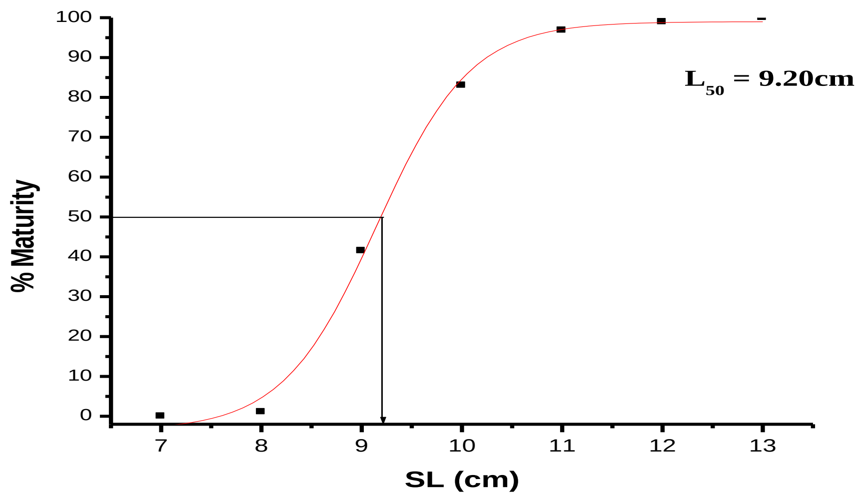

Figure 39a: Length at sexual maturity of male *T. zillii* in the Brimsu reservoir

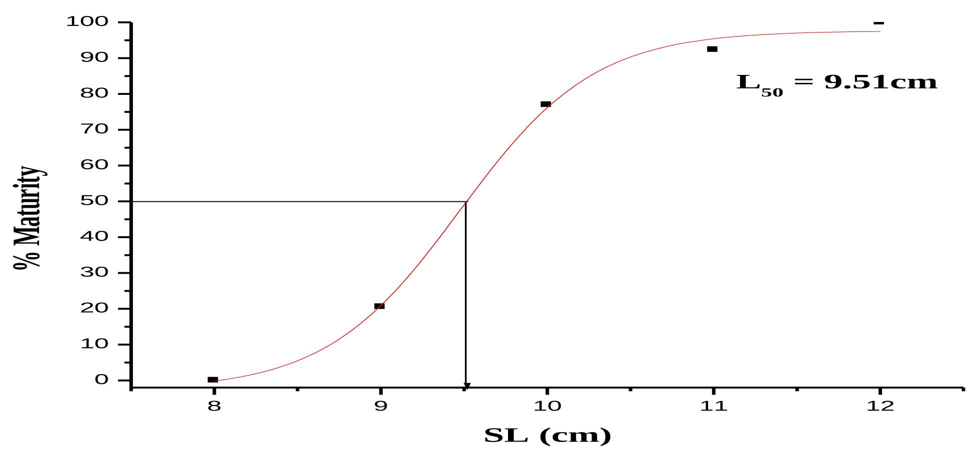

Figure 39b: Length at sexual maturity of female *T. zillii* in the Brimsu reservoir

T. guineesis

The red breast tilapia, *T. guineensis,* matured at 9.32 cm and 9.22 cm for males and females respectively (Fig 40a & b). However, for this species the smallest matured male and female fish were 8.3cm and 7.4 cm respectively.

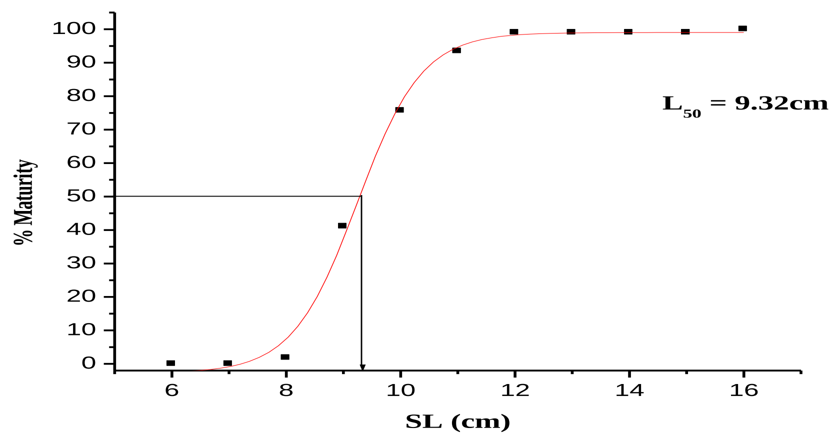

Figure 40a: Length at sexual maturity of male *T. guineensis* in the Brimsu reservoir

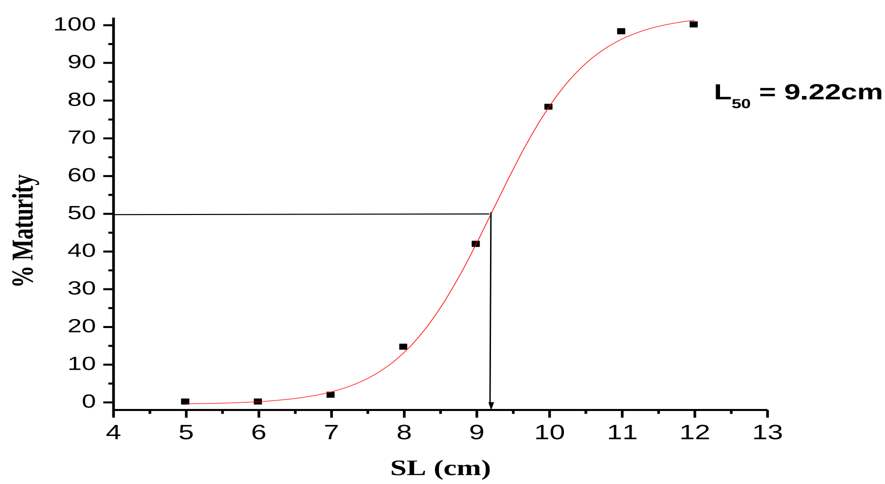

Figure 40b: Length at sexual maturity of female *T. guineensis* in the Brimsu reservoir

CHAPTER FOUR

DISCUSSION

The distribution of fish is determined by the physical, chemical and historical constraints of environmental conditions (Benson & Magnuson, 1992; Borcard *et al.*, 1992). Other factors such as availability of food, spawning rates, breeding grounds coupled with shelter, presence of current, vegetation, depth of water, breeding habits, migration and low predation have also been suggested as major limiting factors affecting the distribution and abundance of various fish (Ita, 1978). Fernando and Holćik, (1991) noted that the best adapted lacustrine fishes included several African fishes such as those from the Family Cichlidae. These fishes are characterized by their short food chains, high fecundities, pelagial adaptations and short lifespan.

Five species of cichlids: *Sarotherodon melanotheron, Tilapia zillii, Tilapia guineensis, Hemichromis fasciatus* and *Oreochromis niloticus* belonging to four genera were obtained from the Brimsu reservoir. All cichlids obtained from the reservoir were euryhaline species (Fryer & Iles, 1972; Trewavas, 1979, 1983). Quarcoopome and Amevenku (2010) in a study on the Weija reservoir found seven species of cichlids belonging to four genera. They observed that in terms of numerical composition cichlids formed more than 60 % of the catch in the reservoir.

Although the blackchin tilapia, *S. melanotheron*, is noted to be an important group of fish in the fisheries of brackish water (Eyeson, 1979; Ekau & Blay, 2000; Blay & Asabere-Ameyaw, 2003; Abban *et al.* 2004), it was also the most common cichlid (45.16 %) in the Brimsu reservoir, a freshwater system sampled for the present study. Tah *et al.*, (2009) reported that *S. melanotheron* comprised more than 40% of the commercial fisheries in the man-made Lake Ayamé (Côte d'Ivoire). The ability of this species to dominate systems it invades is gaining grounds (Dial & Wainright 1983; Orhihabor & Adisa-Bolanta, 2009; Kuton & Kusemiju, 2010).

The monthly composition of *S. melanotheron* in the reservoir revealed an increase in the proportion of the species during the major dry season. The period also coincided with an increase in the gonadosomatic index which suggests that there was a build up of reproductive materials during the dry season. Thereafter, there was a decline in the GSI from February to August which indicates that the species spawned within this period.

The proportion of *Tilapia zillii* and *T. guineensis* in the sample showed a high level of seasonality with lower proportions of the species in the sample during the dry season and a higher proportion during the wet season. Although these species have been described as a euryhaline tilapiine species (Philippart & Ruwet, 1982), *T. guineensis* is also a fish of the floodplains (Lesack, 1986; Ecoutin *et al.*, 2005; Louca *et al.*, 2010) as well as rivers (Holden & Reed, 1991).

During flooding, some fish migrate to flooded plains to spawn; therefore the use of gill nets in the reservoir was less efficient. The general reduction in the catch during the wet periods from the Brimsu reservoir could also have been due to expansion of the flooded areas allowing the fishes to disperse into larger flooded areas, leading to a subsequent reduction in density (Louca *et al.*, 2010). This period however, coincided with relatively higher proportion of *T. guineesis* and *T. zillii* in the catch than the other cichlids. The increase in the capture of *T. guineensis* confirms with works done by Welcomme (1979, 1985) who noted that abundance of floodplain fishes was strongly influenced by the seasonal flooding pattern. Hence the higher proportion of the latter species in the sample could be due to the differential movement of the species from the main reservoir into floodplains during the wet season.

The length of *S. melanotheron* ranged from 7.5 to 17.6 cm with a modal size of 10 cm. Blay and Asabere-Ameyaw (1993) reported a range of 1.5 to 16.5 cm (TL) for a stunted population of the species in the Fosu Lagoon, Cape Coast, Ghana. Blay (1998) further reported a range of 3.1 to 9.5 cm SL and a modal length of 5.0 cm in the Kakum River Estuary (i.e. lower reaches of the Brimsu reservoir). A maximum size of 27.0 cm has been reported for the Lagos Lagoon (Fagade, 1974 as cited in Blay & Asabere-Ameyaw, 1993).

The bigger modal size of the species in the current research might have been due to the mesh size of the gillnet used. This allowed smaller-sized individuals to pass through without being caught. Furthermore, the bigger size of the reservoir as well as the moderate physico-chemical conditions may have provided better conditions than the conditions in the estuary.

The monthly length frequency of *S. melanotheron* shows that the cohort increased by 4.0 cm from September to April 2010 with new cohorts added thereafter. This might suggest that this cichlid has one major breeding season which begins from March to August. Increase in flood zone might have provided food for the cichlids as well as minimizing the effect of predation on the juveniles of the cichlids that are produced during the spawning period. This is evidenced in smaller sized fish (less than 8.0 cm) caught during this period.

T. zillii was represented by a single cohort that grew from 9 cm in September 2009 to 13 cm in March 2009 whereas *T. guineensis* had multiple cohorts within the same period. However, the low numbers of the two species within the said period may also have accounted for the trend. For the three predominant cichlids - *S. melanotheron*, *T. zillii* and *T. guineensis* – May to July showed the recruitment of new cohorts and this was characterized by the presence of juveniles in the sample during this period. This period also marked periods of decrease in GSI as well as a decline in proportion of female specimens with ripe ovaries.

The length at maturity for the cichlids showed that generally males matured at a smaller size than females. Generally, *S. melanotheron* matured at a relatively bigger size (> 11.0 cm) than the other cichlids. However, this was similar to the mean size (11.04 cm) of the species but greater than the modal size (10.0 cm). The length at sexual maturity for females was smaller compared with 17.6 cm reported for the Ebrié lagoon, Ivory Coast (Legendre & Ecoutin, 1989).

The length at sexual maturity of the two *Tilapia* spp fell within the modal class of these species. This indicates that given this method of fishing, cichlids in the reservoir have a high chance of being established in the reservoir since most of the fish caught may have reproduced and added to the population before being captured.

Size at maturity of cichlids has been shown to bear a positive correlation with the surface area of the water body (Lowe-McConnell, 1958, 1982; De Silva, 1986; Legendre & Écoutin, 1989, 1996; Duponchelle & Panfili, 1998) as well as the environmental condition, fishing pressure and pollution. Eyeson (1983) reported that in a confined environment S. *melanotheron* can be sexually active at 4 to 6 months old and at a size as small as 4 to 4.5 cm (SL). In natural environments, however, Blay (1998) reported that the species matured at 3 months in the Kakum River estuary and 5 months in the Benya lagoon at 4.6 cm SL and 5.5 cm SL respectively.

The least size (SL) of mature male (8.3cm) and female *T. guineensis* (7.4 cm) were bigger than 4.3 cm and 5.8 cm (TL) for male and female respectively as reported by Louca *et al.* (2010) in the Gambian River flood plains. However, in both cases, the length at sexual maturity (L_{50}) of the population indicated that females matured at smaller sizes than males. The length at maturity 9.32 cm for males and 9.22 cm (SL) for females was higher than 8 cm (SL) for the same species in the Niger Delta (FAO, 1987); however, it was lower than 15.9 cm (FL) in the Ebrié lagoon, Cote D'Ivoire (Legendre & Ecoutin, 1989). This could be possible due to different environmental conditions as well as different fishing pressure.

Length-weight relationship of fish are important in fisheries biology because they allow the estimation of the average weight of a fish of a given length group by establishing a mathematical relationship between the two (Beyer, 1987). It further gives information on the condition and growth pattern of the fish (Bagenal & Tesch, 1978).

The relationship between the length and weight of *S. melanotheron*, *T. zillii*, *T. guineensis* and *H. fasciatus* were exponential and described by the equations $BW = 0.06SL^{2.89}$, $BW = 0.07SL^{2.82}$, $BW = 0.07SL^{2.85}$ and $BW = 0.06SL^{2.69}$ respectively. The values of the regression coefficient '*b*' for the relationship were not significantly different from 3.0 ($p > 0.05$). The values of '*b*' (growth exponent) for the four species examined were within the limits (2.0 and 4.0) reported by Tesch (1971). Hence the cichlids growth isometrically indicating that they did not increase in weight faster than the cube of their standard length.

Generally the sex ratios of the cichlids did not show a significant difference in the proportion of male and female for most part of the study period. However, significant differences in some of the cichlids occurred in October 2009 for *Tiliapia* spp. Subsequent months did not show any clear skewness in the sex ratio. This gives an indication that there may not be any differential movement in the different sexes to spawning grounds or feeding grounds in the reservoir. However, the overall high numbers of males of *Tilapia zillii* obtained in October 2009 might have accounted for the significant difference in the sex ratio of the overall pooled data which indicates a growing population (Komolafe as cited in Komolafe & Arawomo, 2008)

The stomach content analysis of the four predominant cichlids indicates different food preferences. *S. melanotheron* fed on a wide range of plankton as well as other accessory food items. The results confirm work done by other authors who also observed a similar food spectrum for the species (Ugwumba, 1988; Ofori-Danson & Kumi 2006; Ayoade & Ikulala, 2007). Although green algae occurred in all the stomachs that were analyzed, it formed a relatively small portion of the diet of the species. However, dinoflagellates formed an important part of the diet of the species. This could have been due to the abundance of this food item in the reservoir. The presence of fish remains and insect parts in some stomachs could have been ingested incidentally with other phytoplankton.

The presence of detritus and sand grains in the diet of both *S. melanotherodon* and *T. guineensis* indicate that the species are bottom grazers and inter-specific competition can be said to occur in the reservoir between the two species. However, the proportion of silt and detritus in the diet were relatively high in *T. guineensis* whiles green algae formed a more important part of the diet of *S. melanotherodon*. This might be a way of reducing the interspecific competition between the two species.

Ayoade and Ikulala (2007) and in a study of some cichlids in the Eleiyele Lake in South West Nigeria noted that sand grains occurred in more than 70% of the stomachs of *S. melanotheron* examined indicating the importance of this item in the diet. Oso *et al* (2006) also noted that sand occurred in the diet of *Sarotherodon galilaeus* from the Ero reservoir in Nigeria. The presence of sand grains in the diet of these cichlids reiterates the importance of this food item in the digestion of diatoms.

There was very little change in the diet of *T. zillii* probably because it fed predominantly on filamentous algae and macrophytes which are abundant in the reservoir throughout the study period. The species has been described as a macrophyte grazer (Buddington, 1979; Idodo-Umeh, 2003; Adesulu & Sydenham, 2007) and may also feed on other food matter. Although *T. guineensis* feed predominantly on phytoplankton (diatoms and desmids), the silt content in the diet increased considerably during the wet season probably due to the influx of freshwater from the riverine areas which contained silt and other allochtonous materials. The species was described by Louca *et al.* (2010) as being ilophagous, thus having a high portion of silt in its diet.

The period of increased feeding (April – June) corresponded with an increase in the storage of fat in the cichlids. This might have been the result of an increase in the littoral zone as a result of flooding which provided the cichlids with abundance of food resulting in the improvement of the condition factor which resulted in the accumulation of fat. Condition factor compares the wellbeing of a fish and is based on the hypothesis that heavier fish of a given length are in better condition (Bagenal & Tesch, 1978). This parameter has also been used as an index of growth and feeding intensity (Fagade, 1979). Hence the increase in condition factor of the cichlids from April to June could have been the result of increase in feeding intensity with a corresponding reduction in the proportion of fish with empty stomachs within the said period.

The increase in GSI of *S. melanotheron* from November 2009 to a peak in February 2010 also corresponded with an increase in the proportion of fish with ripe ovaries. The period was also characterized by an increase in fat storage and condition factor. This improvement in the condition and increased storage of fat might have probably aided in the production of reproductive materials for the spawning period which begun in February till August.

There was one major peak in the fluctuation in the GSI of *S. melanotheron*. The month of February was the period of highest production of reproductive material after which the GSI decreased gradually to August. However, the presence of ripe specimens for most part of the period suggests that although the cichlid spawns throughout the year, February to August is the major spawning period. This is confirmed by the presence of more than one cohort after April.

The reduction in the proportion of individuals with empty stomach from October and December indicates that feeding activity was high and this further resulted in fat accumulation during the period. The fat content increased prior to spawning and decreased during the spawning period. However, there was an increase in the feeding activity after spawning and this may have accounted for the increase in condition factor and the corresponding decrease in the number of *S. melanotheron* with empty stomachs from April to June.

The reproductive biology of *T. zillii* and *T. guineensis* was characterized by a continuous fluctuation of the GSI. The high value of the GSI in December might not reflect the true pattern of spawning in *T. zillii* since a single specimen was obtained during that month. However, whereas the decline GSI of *T. zillii* began after March 2010, that of *T. guineensis* showed a clear reduction after May 2010. This agrees with work done by other authors that most cichlids spawn during the major rainy season (Legendre & Ecoutin, 1989; Louca *et al.*, 2010). The assessment of the proportion of ripe females of the *Tilapia* spp also showed the presence of ripe females from December to July. This indicates that these species spawn during most part of the year - March begin the peak breeding season for *T. zillii* whereas *T. guineensis* has a maximum reproductive activity in May.

The gradual shifts in the modal size from September to March as well as the two distinct modes shown by the frequency distribution of ova diameter indicate that the two *Tilapia* spp spawn in batches. The ova diameter of *T. zillii* (1.2 – 2.1 mm) fell within the range (1.3 – 1.5 mm) that reported by Coward & Bromage (1999). The major period of spawning in cichlids from the Brimsu reservoir might begin in March and extend to July. Breeding or peak of sexual activity of cichlids in the reservoir seems to be linked with a rise in water level and a decrease in temperature.

Studies on reproduction tend to consider fecundity and egg size as separate indicators of reproductive performance (Coward & Bromage, 1999). It is generally accepted that there is an inverse relationship between fecundity and egg size: 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 also increases with body length (Hislop, 1988; Zivkov & Petrova 1993) although variation occurs among years in response to environmental conditions (Bagenal & Braum 1978). The cichlids in the Brimsu reservoir showed a variation in the fecundity with *T. zillii* having the highest fecundity (3683 ± 210) and *S. melanotheron* having the least fecundity (434.4 ± 24.5). This is primarily because *Tilapia* spp are substrate spawners whereas *S. melanotheron* undertakes oral brooding and thereby protects the eggs and fry from predation.

The fecundity was strongly correlated to the gonad weight of the cichlids ($r > 0.7$). In *S. melanotheron* there was a further strong relationship between fecundity and standard length and a rather weak relationship between fecundity and body weight. However, in the two *Tilapia* species, the relationships between fecundity and standard length and body weight were very weak ($r < 0.4$). It is not known what controls fecundity of tilapias, although Srisakultiew (1993) found that in *O. niloticus* spawning history may be an important factor. Peters (1983) claimed that in *O. niloticus* and *Sarotherodon*, egg size initially increased rapidly with increasing body weight and then stabilized. However, numerous authors have not found a clear cut relationship between the size of the egg and the fish size (Peters, 1983; Rana 1988). This might account for the poor correlation that was observed in the relationship between the number of eggs and the size of the cichlids.

The changes in the physico-chemical parameters may also have influenced various aspects of the biology of the cichlids. The decrease in temperature and conductivity of the reservoir from April to September 2010 coincided with an increase in the pH from a predominantly acidic condition to a more neutral condition. This might favour the growth of the offspring of the cichlids since most of them spawn within the said period.

The transparency of the reservoir was generally high from September 2009 to March 2010. This might have been the result of minimal mixing of the reservoir. The subsequent reduction in the transparency was also accompanied by a reduction in the conductivity of the reservoir as a result of inflow of freshwater from upstream into the reservoir. This caused an increase in silt, organic matter and nutrient in the reservoir hence increasing the productivity. The increase in nutrients may also have accounted for the increase in pH towards neutral.

The dissolved oxygen in the reservoir decreased from 4.7 mgL^{-1} in September 2009 to 4.2 mgL^{-1} in March 2010. This might have been the result of decrease in the photosynthetic activities of the reservoir. However, the increase in dissolved oxygen after March could have been the result of mixing of the water in the reservoir as a result of influx of freshwater from riverine areas. The increase in nutrients in the reservoir may have caused an increase in primary productivity leading to the depletion oxygen from June to September 2010.

Hence it can be deduced that the fluctuations in the physico-chemical parameter may be a key that trigger the reproduction of cichlids in the Brimsu reservoir.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The Brimsu reservoir is an important lentic system which supports different kinds of cichlids fisheries. Five cichlid species belonging to four genera occur in this reservoir. These species are *Sarotherodon melanotheron, Tilapia zillii, Tilapia guineensis, Hemichromis fasciatus* and *Oreochromis niloticus*. The catch composition of the cichlids revealed that *S. melanotheron* constituted 45.16 % whereas *T. zillii, T. guineesis, H. fasciatus* and *O. niloticus* represented 26.78 %, 25.30 %, 2.67 % and 0.10 % respectively and hence the dominant cichlid is *S. melanotheron*. The Nile tilapia, *O. niloticus*, was not an original inhabitant of the reservoir but has strayed into it from a nearby aquaculture facility and hence its lowest representation in the catch composition during the study.

The cichlids obtained from the reservoir were predominantly brackishwater cichlids. This indicates that these cichlids were able to establish their population in the reservoir after the damming of the Kakum River. Since *H. fasciatus* are relatively small fishes, they are likely to escape from the gill net with mesh sizes from 2.5 – 4.0 cm that were used in the sampling and hence their low composition in the catches. The number of cichlids might be a contribution from the various streams that feed into this reservoir.

The cichlids exhibited some amount of seasonality in their temporal distribution in the reservoir. The blackchin tilapia, *S. melanotheron* was most abundant during the dry season whiles *T. zillii* and *T. guineensis* dominated the catch during the wet season.

Ripe females of *S. melanotheron* were observed between November and April indicating that cichlid has an extended gonadal maturation and spawning period. This view was supported by the trend in GSI values which increased gradually from November to a peak in February after which it declined to July showing a peak spawning period from February to July. The breeding pattern for *T. zillii* and *T. guineensis* did not follow any regular pattern as they had different GSI peaks at various periods in the year and could be considered as multiple spawners. However, most of the cichlids start their spawning just before the onset of the wet season. This is perhaps an adaptation to ensure that the juveniles of this species have enough to feed on during the rainy season.

The following ranges were observed in fecundity values: *S. melanotheron* (187 - 732), *T. zillii* (1483 - 4484), *T. guineensis* (1968 - 4016) and *H. fasciatus* (1212 – 2246). This indicated that *T. zillii* was the most fecund whereas *S. melanotheron* was the least fecund. The difference in the fecundity could be due to differences in parental care of the cichlids. No clear relationship existed between fecundity and body weight (BW), however, fecundity correlated strongly with gonad weight.

The cichlids exhibited an array of feeding habits. *S. melanotheron* and *T. guineensis* were primarily planktonic feeders subsisting on microscopic green algae and detritus. *T. zillii* was macrophagous and fed mainly on plant parts and other filamentous algae whereas *H. fasciatus* was carnivorous. These were consistent with the food spectrum reported for other populations in Ghana.

In studying their natural environment, it was observed that the physico-chemical parameters studied, namely temperature, transparency, dissolved oxygen, pH and conductivity, were within the acceptable limits for the survival of these cichlids. The reservoir was generally acidic during the dry period and became slightly alkaline during the wet season. The wet season was also associated with lower transparency and conductivity values the dry season had higher transparency and conductivity values.

Recommendations

From the findings, of the biology of cichlids in the Brimsu Reservoir, the following recommendations have been made:

1. Restriction of fishing activities between February and July since that is the major spawning season for most of the cichlids.
2. The growth parameters of the cichlids in the reservoir should also be studied to provide management with baseline information required for the management of the cichlid fisheries in the reservoir.

3. This work could be done for a longer period than the current work in order to ascertain the periodicity of some biological cycles such as the reproduction, feeding ecology and recruitment patterns.

4. The presence of *Oreochromis niloticus* in the reservoir provides a cause for concern since it may outcompete the native species or otherwise. The species was not hitherto found in the reservoir, indicating the poor culture practices of aquaculture farms. It is recommended that education be given to fish farmers on how to manage their facility to reduce the escape of cultured species.

5. Levels at which the cichlids are being exploited should be studied to enable management put in necessary control measures so that they are not over-exploited.

6. Studies on the physicochemical factors should be conducted at a longer period to determine how they influence the biology of various organisms including the cichlids in the reservoir.

7. Selectivity of gears for the different cichlids to enable establishment of selectivity factor and length at first capture (L_{c50}).

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APPENDICES

Appendix A: Summary of the physico-chemical parameters in the Brimsu reservoir from September 2009 to September 2010.

Month	D.O. (mg/L)			Temp (°C)			pH			Conductivity (µs/cm)			Transparency(cm)		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
09-09	4.70	4.75	4.68	28.7	28.6	28.7	6.85	6.78	6.73	161	163	169	87.8	79.2	69.4
10-09	4.89	4.94	4.83	28.9	28.9	29.0	6.79	6.73	6.69	177	183	191	99.8	93.2	83.8
11-09	4.91	4.95	4.89	29.3	29.2	29.3	6.69	6.63	6.58	170	176	182	100.6	94.2	88.2
12-09	4.33	4.34	4.30	29.1	29.1	29.2	6.69	6.64	6.57	185	188	198	114.3	108.8	99.7
01-10	4.39	4.42	4.35	29.5	29.6	29.6	6.78	6.71	6.63	183	186	196	118.5	113.5	103.9
02-10	4.51	4.52	4.44	30.0	29.9	30.0	6.84	6.75	6.65	187	190	199	104.3	102.5	97.3
03-10	4.29	4.31	4.22	29.4	29.4	29.3	6.75	6.70	6.63	180	184	192	89.4	82.1	79.5
04-10	4.48	4.49	4.42	29.3	29.2	29.3	7.09	7.00	6.95	163	165	172	82.8	78.3	67.1
05-10	4.68	4.71	4.60	29.4	29.4	29.4	7.18	7.12	7.04	171	174	182	81.9	75.3	63.9
06-10	4.80	4.81	4.70	28.8	28.9	28.9	7.04	7.00	6.90	156	161	170	78.4	69.3	58.8
07-10	4.49	4.52	4.43	28.0	28.1	28.2	7.00	6.95	6.85	131	136	142	83.7	72.1	62.8
08-10	4.26	4.29	4.18	27.8	27.8	27.7	7.13	7.09	7.01	108	111	121	68.3	60.3	52.1
09-10	4.27	4.28	4.11	27.5	27.4	27.5	7.18	7.14	7.04	89	93	104	61.4	52.7	46.0

Appendix B: The number of individuals of different species of cichlids sampled from September 2009 to September 2010.

Month	*Sarotherodon melanotheron*	*Tilapia zillii*	*Tilapia guineensis*	*Hemichromis fasciatus*	*Oreochromis niloticus*
Sep-09	97	29	9	4	0
Oct-09	29	107	31	4	1
Nov-09	58	12	2	4	0
Dec-09	62	3	1	0	0
Jan-10	34	8	7	4	0
Feb-10	29	14	19	6	0
Mar-10	42	5	4	3	0
Apr-10	38	2	13	2	0
May-10	12	8	20	0	0
Jun-10	14	15	50	0	0
Jul-10	13	20	38	1	0
Aug-10	15	23	28	0	0
Sep-10	14	25	34	1	0

Appendix C: Results from Two-Sample T-Test and CI of standard length of *S. melanotheron*

	N	Mean	StDev	SE Mean
SL Male	226	11.12	1.58	0.11
SL Female	231	10.97	1.42	0.094

Difference = mu (SL Male) - mu (SL Female)
Estimate for difference: 0.151

95% CI for difference: (-0.125, 0.428)
T-Test of difference = 0 (vs not =): T-Value = 1.08 P-Value = 0.283 DF = 447

Appendix D: Results from Two-Sample T-Test and CI of standard length of *T. zillii*

	N	Mean	StDev	SE Mean
SL male	170	9.895	0.846	0.065
SL female	101	9.922	0.820	0.082

Difference = mu (SL male) - mu (SL female)
Estimate for difference: -0.026
95% CI for difference: (-0.232, 0.179)
T-Test of difference = 0 (vs not =): T-Value = -0.25 P-Value = 0.800 DF = 215

Appendix E: Results from Two-Sample T-Test and CI of standard length of *T. guineensis*

Two-sample T for SL Male vs SL female

	N	Mean	StDev	SE Mean
SL Male	139	10.06	1.20	0.10
SL female	117	9.72	1.02	0.095

Difference = mu (SL Male) - mu (SL female)
Estimate for difference: 0.341
95% CI for difference: (0.067, 0.616)
T-Test of difference = 0 (vs not =): T-Value = 2.45 P-Value = 0.015 DF = 253

APPENDIX F: Summary of the GSI of the different species of cichlids sampled from September 2009 to September 2010

Month	*S. melanotheron*		*T. zillii*		*T. guineensis*	
	Male	Female	Male	Female	Male	Female
09/09	0.0305	0.2270	0.1493	0.2835	0.3278	2.9500
10/09	0.0818	0.3764	0.2112	0.8270	0.1521	2.1450
11/09	0.0889	0.3233	0.0940	0.4510	0.3165	-
12/09	0.0336	0.9090	0.1471	7.1500	0.3963	-
01/10	0.0870	1.6300	0.3870	0.6080	0.3144	3.3800
02/10	0.1307	4.1890	0.4736	6.8860	0.4490	6.1800
03/10	0.1280	3.7240	0.2397	11.420	0.4786	3.5210
04/10	0.1742	2.8030	-	4.7800	0.3094	5.2700
05/10	0.0708	0.7450	0.2637	5.4600	0.2800	6.7660
06/10	0.1058	0.4646	0.2033	5.5000	0.2938	4.9300
07/10	0.0535	0.3040	0.0519	0.3900	0.1443	0.4735
08/10	0.0629	0.1903	0.1564	1.2590	0.2093	0.7020
09/10	0.0964	0.7780	0.1435	1.0900	0.1307	1.2930