University of Natural Resources and Life Sciences, Vienna

UNESCO-IHE Institute for Water Education

EGERTON UNIVERSITY

FEEDING HABIT, FECUNDITY AND OTHER BIOLOGICAL ASPECTS OF THE AFRICAN CATFISH *Clarias gariepinus* (CLARIIDAE) IN LAKE NAIVASHA, KENYA

Master of Science Thesis

by

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DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not been submitted or presented for examination in any institution.

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SM 19/23561/15

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RECOMMENDATION

This thesis has been submitted with our approval as supervisors for examination according to Egerton University regulations.

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ABSTRACT

The African catfish *Clarias gariepinus* is a non-native fish species to Lake Naivasha. The timing and method of its introduction into the Lake is not clearly known, but it is thought that it probably came through the inflowing rivers; Malewa, Gilgil and Karati. The biology and ecology of catfish in Lake Naivasha is poorly known. This lack of knowledge makes it difficult to estimate the trophic level, reproductive capacity and ecological role of the species in the Lake. Therefore, this study aimed to assess the feeding habit, fecundity and biology of *C. gariepinus.* The study was conducted between November 2015 and January 2016 in four stations. The feeding habit was assessed by analysing the stomach contents of 400 fish using the point method. The major food items consumed were zooplankton 24.6%, fish 23.1% and insects 21.4%. Ontogenic shift in the diet was evident where juvenile fish fed on high proportion of phytoplankton, insects and detritus while adults fed more on cray fish and zooplankton. Food selection using Strauss linear index revealed positive prey selectivity for Bacillariophyceae, Chlorophyceae and Cyanophyceae and negative selection for Desmidiaceae, Dinophyceae and Euglenophyceae. The sex ratio was significantly different from the hypothetical ratio of 1:1 (χ^2=77.28, df = 5, P < 0.05). Length-Weight relationship of males and females of *C. gariepinus* among all sampling stations was not significantly different (t=0.373, df = 6, P > 0.05) from the isometric exponent value of 3. Relative condition factor showed that *C. gariepinus* in Lake Naivasha are in a good condition with a value of 1 except at Crescent Island station with a value of 0.95. Length at first maturity (Lm_{50}) of females and males was 18.9 cm and 42 cm respectively. Fecundity ranged from 1,260 to 354,361 eggs. There was significant variation in fecundity between different size classes (one way ANOVA, F = 9.13, df = 2, P < 0.05). The relationship between fecundity with total length and total weight were curvilinear while the relationship of fecundity with ovary weight was linear. A significant correlation was observed between fish condition factor and pH (r = 0.83, P < 0.05) and dissolved oxygen with fish length-weight relationship (r = 0.87, P < 0.05). The relationships between temperature and conductivity with condition factor and length-weight relationship were not significant (P > 0.05). This study found out that *C. gariepinus* is a generalist and has an opportunistic feeding behaviour ingesting a variety of food organisms ranging from phytoplankton to fish. In addition, the biology of *C. gariepinus* is affected by key water quality parameters such as pH and dissolved oxygen in Lake Naivasha.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CPUE	Catch Per Unit Effort
CI	Confidence Interval
DO	Dissolved Oxygen
FAO	Food and Agricultural Organization
KMFRI	Kenya Marine and Fisheries Research Institute
Kn	Condition factor
Lm_{50}	The Length at which 50% of fish in a given size class reach maturity
LWR	Length-Weight Relationship
NFP	Netherland Fellowship Programme
OW	Ovary Weight
PASW (SPSS)	Predictive Analytic Software
TL	Total Length
TW	Total Weight

CHAPTER ONE

INTRODUCTION

1.1 Background information

The African Catfish *Clarias gariepinus* (Burchell, 1822) is distributed widely in Africa ranging from the Nile River Basin to West Africa and Algeria in the North (Solak and Akyurt, 2001). They inhabit freshwater lakes, rivers, swamps and lagoons as well as man-made habitats (Nyamweya *et al*., 2010). African Catfish is known for its hardiness and adaptability to various adverse environmental conditions. They are omnivorous and feed on a variety of organisms including fish and plant materials. Catfishes have a suprabranchial air breathing organ which function as a lung enabling them to breath and survive in low oxygen concentrations and survive long periods out of water (Abidjan and Ivoire, 2014). *Clarias gariepinus* is an important food fish and one of the most important commercial freshwater species (Dadebo, 2000; Nyamweya *et al*., 2010). Studies have shown that, the African Catfish is also generally considered to be one of the most successful fish species in tropical aquaculture (Nyamweya *et al*., 2010). Kwak *et al*., (2011) showed that the ecology of *C. gariepinus* is relatively well studied in some African Lakes including Lakes Victoria and Baringo in Kenya. However, nothing is known about the species in Lake Naivasha apart from recent studies on its length-weight relationships and condition factor in the lake (Keyombe *et al*., 2015).

Earlier studies indicate that apart from providing food, the fingerlings of *C. gariepinus* are used as baitfish for the Nile Perch fishery in lake Victoria due to their resistance to extreme conditions and can wriggle on the hook for over a week (Ponzoni and Nguyen, 2008). According to Lung'ayia, (1994), *C. gariepinus* is euryphagous in its feeding habit and breeds in rainy seasons during high water levels in the months of April-June and September-October.

Studies in Lake Baringo showed that the native population of *C. gariepinus* is economically exploited (Nyamweya *et al*., 2010; Omondi *et al*, 2013). The fishery production in the Lake Baringo ranged from 500 to 600t year^{-1} by the late 1960's, declining to <200 t year^{-1} by the late 1980s (Nyamweya *et al*., 2010). *Clarias gariepinus,* is an exotic fish species in Lake Naivasha and was observed for the first time by Kenya Marine Fisheries Research Institute (KMFRI) in 2012, during regular fish stock assessement (Keyombe *et al*., 2015). Despite its ecological and commercial importance, very little is known about *C. gariepinus* in Lake Naivasha. This study provides some data on the feeding ecology, fecundity and other biological aspects of *C. gariepinus* in the lake. Furthermore, management options for the fish stock with continuous utilization of the resource by communities dependent on the fish around the lake will be proposed.

1.2 Statement of the problem

Lake Naivasha supports a productive fishery that provides jobs and incomes as well as being an important source of protein for local communities. The Lake fishing activity is based on introduced fish species such as *Cyprinus carpio* (L.), *Micropterus salmoides* (LaCepède), *Tilapia zillii* (Gervais), *Oreochromis leucostictus* (Trewavas) and *Oreochromis niloticus. Clarias gariepinus* is one of the non-native fish species which was introduced recently and first sighted in the year 2012. The incidental introduction of catfish in the lake could probably have come through the rivers flowing into the lake. Since catfish is non-native to the lake, its ecological consequences on fish assemblage and other biota is not known. Fish biology based studies are therefore necessary for understanding the trophic relationship of the fish and for sustainable utilization of the fishery resources as well. Since very little research has been done previously, assessing aspects of the ecology and biology of *C. gariepinus* is crucial for Lake Naivasha. The data obtained during this study will be important in assessing the ecological role of catfish in lake. The absence of this vital information provides a challenge in coming up with proper management and sustainable utilization of stocks in the future in Lake.

1.3 Objectives

1.3.1 General objective

To investigate feeding habit, fecundity and other biological aspects of the African catfish *C. gariepinus* in Lake Naivasha, Kenya.

1.3.2 Specific objectives

i).To determine food and feeding habit of *C. gariepinus* in different parts of Lake Naivasha.

ii).To estimate fecundity in different size classes of *C. gariepinus* in Lake Naivasha.

iii).To determine some biological aspects (length at first maturity, length-weight relationship, condition factor and sex ratio) of male and female *C. gariepinus* in Lake Naivasha.

1.4 Hypotheses

i). There is no spatial significant difference in food and feeding habit of *C. gariepinus* in Lake Naivasha.

ii). Fecundity of *C. gariepinus* does not vary significantly between different size classes in Lake Naivasha.

iii). Length at first maturity, length-weight relationship, condition factor and sex ratio of *C. gariepinus* do not vary significantly between males and females in Lake Naivasha.

1.5 Justification

Clarias gariepinus is an ecologically and economically important fish species in Kenya. It is one of the favoured aquaculture fish species in the tropics due to its rapid growth and resistance to stress. Scientific knowledge about catfish ecology and biology is required for sustainable exploitation and management of the stocks. However, studies on aspects of ecology and biology of catfish in Lake Naivasha are poorly known and undocumented. Lack of such vital information provides a challenge to fishery managers in assessing the impacts of management actions and anthropogenic influence on the resource they manage. Moreover, since the fish is exotic to the lake, ecological effects especially as a predator are not studied, documented and quantified. Therefore, this study will provide baseline data on the feeding habit, fecundity, size at first maturity and sex ratio of *C. gariepinus* in Lake Naivasha. The results obtained will be important for management and conservation of fisheries resources and for sustainable utilization of catfish by communities around the lake.

CHAPTER TWO

LITERATURE REVIEW

2.1 Global status of Catfish research

Catfish science is a diverse and growing field in terms of advances and scope of the topics. Growth of catfish studies reveals increase of interest in the species by anglers as a popular sport fish, by consumers as a food fish, and by aquaculturist as appropriate candidate for species propagation. The overall trend of increasing interest in catfish science through time is considered by changes in time based variation in magnitude and direction (Kwak *et al*., 2011). Scientific studies and publications on catfish varied over the past century with strong peaks during 1975–1979 and 2005–2010, which may be due to joint scientific and societal encouragements. In 1990s, catfish biology was a most important publication topic when ecology and management publications come to be familiar (Michaletz and Travnichek 2011; Kwak *et al*., 2011). Catfish ecology was most published in proceedings of two international catfish symposia. "Catfish 2000: The First International *Ictalurids* Symposium" and "Catfish 2010: The Second International Symposium" (Irwin *et al*., 1999; Michaletz and Travnichek 2011) are among the most important modern literature on catfish science. While biology of catfish has been the prevalent topic of journal publication over the past century, that topic was poorly demonstrated in the two symposia (Kwak *et al*., 2011). In Africa, the biology and ecology of catfish in some Rift valley lakes have been studied by various researchers (Lung'ayia, 1994; Dadebo, 2000; Ponzoni and Nguyen, 2008; Nyamweya *et al.*, 2010; Omondi *et al.*, 2013; Keyombe *et al.*, 2015).

2.2 Biology and Ecology of *C. gariepinus*

The African catfish, *Clarias gariepinus* is a freshwater fish species in the family Clariidae and belongs to the order Siluriformes. Catfishes are a highly diverse and widely distributed group of fish including more than 3000 species around the world (Ferraris, 2007). They are air breathing fish characterized by scale-less, bony, elongated body, with long dorsal and anal fins and helmet like head (Figure 1). The colour varies from dark to light brown dorsally and pale cream to white colour in the underside. They can grow very large with a maximum catch weight of 293 kg of the Mekong giant catfish recorded in the year 2005 (Hogan, 2011). The dorsal fin has 61-80 soft rays and the anal fin has 45-65 soft rays. They have strong pectoral fins with spines that are serrated on the outer side. Catfish are economically and ecologically important fish species in Africa and in other tropical countries (Davies *et al.,* 2013). They also play a key role in sport fishing by anglers. They possess many qualities which make them adapt to various environmental conditions. These include fast growth, resistance to diseases and possession of an air breathing suprabranchial organ. This organ helps them to breathe and survive in low oxygen concentrations (Davies *et al*., 2013).

Spawning of catfish mostly takes place at night in shallow inundated areas of rivers and streams. Males show highly aggressive behaviour during courtship. Mating and courtship takes place in the shallow waters between isolated pairs of males and females. The male lies in U-Shaped curve with head of females held for several seconds. A batch of milt and egg is released followed by distribution of eggs by females over a wide area. There is no parental care to ensure survival of catfish offspring except for appropriate site selection. According to FAO (2012), egg and larva development is rapid and the larva is able to swim within 48-72 hours after fertilization.

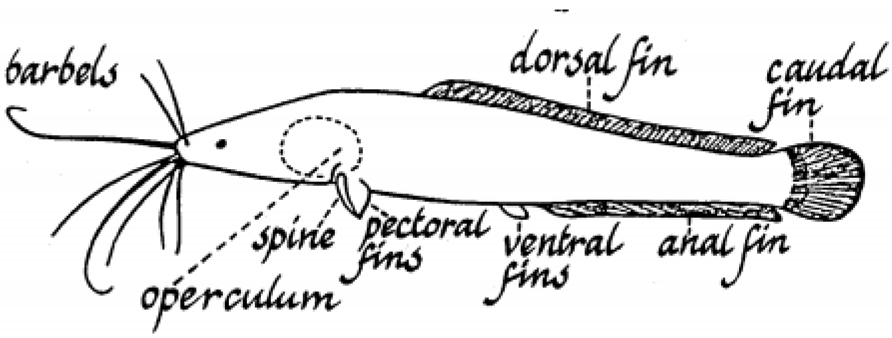


Figure 1: Morphological characteristics of *C. gariepinus* (FAO, 2012)

Catfishes are found in every continent in wide ranges of aquatic ecosystems and climatic conditions (Armbruster, 2011). Leonard *et al*., (2010), demonstrated that catfish populations are linked to numerous habitat variables at multiple scales. Latitudinal differences were found within Alabama small impoundments at relatively small scales and Mississippi streams showed variation in growth and maturation rates (Kwak *et al.*, 2011). Potts *et al*., (2008) stated that, feeding and growth of sharp tooth catfish *C. gariepinus* were related to trophic status in South Africa reservoirs. Another study showed that the environment and anthropogenic pressures affect species richness of catfish assemblages in Iowa, which were affected by gravel mining, heavy metals, impoundments and reduced annual flows (Sindt *et al*., 2011; Wildhaber, 2011). Catfish species were also shown to negatively affect other fish communities when they are introduced beyond their native range. Research conducted over the previous decade demonstrated that *in situ* investigations are well suited for examining diet and reproductive studies. These studies defined the ecological functions of catfish in aquatic ecosystems (Kwak *et al*., 2011).

2.3 Feeding habits and food selectivity

Determining the feeding behaviour and how diet affects the nutrition and growth of fish is crucial in considering the ecological role of the population in aquatic systems. Feeding methods of *Clarias* range from benthic omnivory, piscivory and also include specialists in seed and wood eating (Goulding, 1980; German, 2009). Catfish shows ontogenetic shift, as large individuals shift their diet towards other fish as they grow bigger. However, biotic and environmental factors can influence these shifts in feeding (Willoughby and Tweddle, 1978; Brewster, 2007; Omondi *et al*., 2013). Catfish feed on zooplankton during adult stage in Lake Baringo, which is an unusual feeding behaviour due to probably lack of alternative prey for large fish in the lake (Omondi *et al*., 2013).

Food selection in fish is related to the size and food availability, which is governed by the presence and abundance of certain prey types in the environment (Kahilainen and Lehtonen, 2003; Cantanhede *et al*., 2009). In early life stages, catfishes are invertebrativores depending on aquatic insects and crayfish as food, but as they mature they completely become carnivores, feeding mainly on live fish (Jackson, 1999; Pine, 2003; Brewster, 2007). Invertebrates are a significant part of the diet, but catfish starts to feed on fish at a smaller size when aquatic invertebrates are limited. Feeding selectivity of the fish is calculated by using frequency of prey items found in the stomach contents relative to the availability in the environment. This helps in determining the potential impact of introduced species in native fish assemblages (Pine *et al*., 2005). Turesson *et al*., (2002), reported that selective predation is the common phenomena to most predators mainly for piscivorous fishes. In a given system, information on the kind of food items preferred over the other is obtained using selectivity index.

2.4 Length-weight relationship and relative condition factor (Kn)

The length-weight relationship of fishes is important for fisheries biology and fish stock assessments in all water bodies. It provides important information on stock composition, and fish population structure (Hirpo, 2013). During sampling programs, it is easier to measure length only while the weight cannot be measured simply due to the wave actions. The length-weight relationship of particular species allows the interconversion of these parameters and for comparison of morphometric characters between species and populations (Keyombe *et al*., 2015). The length-weight relationship applications are significant when estimating the standing stock biomass and comparing the life history of particular fish species between regions (Moutopoulos and Stergiou, 2002). Length-weight relationship is therefore important in fishery biology because it allows the estimation of the average weight of fish of a given length group by establishing a mathematical relation between the two (Davies *et al*., 2013).

Relative condition factor (Kn) is an indication of the wellbeing or health status of the fish (Blackwell *et al*., 2000). It is therefore an index reflecting interactions between biotic and abiotic factors or the physiological condition of the fish. Condition factor (Kn) is vital for understanding the management of the fish stock and assessment of the potential of any fishery to support the fishing pressure. Fish of good condition factor are assumed to have greater reproductive potential, faster growth rate and high survival. In biological studies, the condition of the fish is important for understanding the life cycle of fish which contributes to the maintenance of equilibrium in the ecosystem (Moutopoulos and Stergiou, 2002). Therefore, measures of fish condition factor are of important value to fisheries managers in assessing the impacts of management actions and human influence on the resource. Several researchers have studied the condition factor of *C. gariepinus* in some African waters (Dadebo *et al.*, 2011; Davies *et al*., 2013; Konan *et al*., 2014) and results showed that condition factor of catfish were >1 during breeding and in wet season and lower in dry season.

2.5 Fecundity of catfish

Fecundity is defined as the number of ripening eggs found in the female just prior to spawning (Bagenal and Tesch, 1978). Kapoor and Khanna (2004), shown that fecundity is essential for studies of population dynamics and life history of fish. Potential annual fecundity is the total number of advanced yolked oocytes matured per year, while the batch fecundity is the number of eggs spawned per batch (Hunter *et al*., 1992). Fecundity calculations are of paramount importance in fishery management for estimating the number of offspring's produced in a season and reproductive capacity of species. Under suitable environmental conditions, a matured female of *C. gariepinus* can lay around 60, 000 eggs/ kg of body weight (FAO, 2012). There is a direct relationship between fecundity and total length, total weight and gonad weight of fish. Generally, fecundity increases with increasing brood fish size, but the egg size may vary from one spawning to another and the number of eggs contained in a specific volume may also be different (Carrillo *et al*., 2000). Several researchers have reported fecundity of catfish from some African waters (Lung'ayia, 1994;

Dadebo, 2000; Dadebo *et al*., 2011; Abdijan and Ivorie, 2014; Konan *et al*., 2014). However, there is no information on fecundity of catfish in Lake Naivasha.

2.6 Length at first maturity (Lm_{50})

Length at first maturity (Lm_{50}) is the length at which 50% of the fish are mature. Correct estimation of Lm_{50} gives vital information to fisheries managers in setting mesh sizes that will target mature fish which have contributed to the new generation and gives juvenile fish time to grow and mature (Clark, 1991; Reynolds *et al*., 2005; Karna *et al*., 2012). Due to the fact that fishing rates are usually set to keep a certain percentage of spawning females in a population, monitoring size and age at maturity is common and these are important parameters used in stock assessment (Matthews, 2012). Bruton, (1979) reported that the African catfish attain its first maturity at around 35 cm in length after a period of their second year of age.

2.7 Non-native catfish introduction and impacts

Catfish have been broadly introduced outside their natural range purposely and by accident as sport fishes, as food, as bait and through aquaculture activities. The timing and method of introduction of these species is not precisely known. Kwak *et al*., (2011) points out that elimination of exotic catfish populations becomes challenging once established. Fuller *et al*., (1999) also found out that introduced flathead catfish have been involved in the decline and loss of a number of sport fishes and amphibians in North America. Pine *et al*., (2007) reported a 50% decrease of biomass of native fish after the establishement of non-native flathead catfish in Cape Fear River of North Carolina.

Similarly, Cambray (2003) discovered that, the sharptooth catfish in Africa affects aquatic amphibian and other biota. Various researchers (Guier *et al*., 1984; Thomas, 1985; Pine *et al*., 2007; Keller, 2011; Kwak *et al*., 2011; Schloesser *et al*., 2011) demonstarted that a number of exotic catfish introductions affect native fish species and other biota in most parts of the world and in African waters. Ricciardi, (2001) found out that introduction of exotic fish species in the Laurentian Great Lakes negatively impacted the food webs, native fish, amphibians, aquatic invertebrates, zooplankton and algae. According to Kwak *et al*., (2011), ecological effects of introduced catfish population vary widely in their function and degree. Lake Naivasha has a long history of species introductions since 1920s, with examples of alien fishes, mammals, plants and invertebrates (Harper and Mavuti, 2004). Hickley *et al*., (2008) discovered that the introduction of piscivorous bass *Micropterus salmoides* (LaCepède) destroyed the unique single species *A. antinorri* "Naivasha" in the lake. Similarly, the exotic crayfish *Procambarus clarkii* (Girard) caused modification of aquatic food webs and disappearance of floating water lilies that caused increase of turbidity in the lake (Harper, 1992). Since *C. gariepinus* is an exotic fish species in Lake Naivasha, its ecological impact on other fish species in the lake is not known.

2.8 The fish assemblage, introductions and fisheries in Lake Naivasha

The lake Naivasha fishery is based on introduced fish species (Hickely *et al*., 2015). The single native fish species, *A. antinorii* (Vinciguerra), was last recorded in 1962 (Hickley *et al*., 1994). The introduced fish communities currently existing in the lake include; *C. carpio* (L.), *O. leucostictus* (Trewavas), *M. salmoides* (Lacepéde), *T. zillii* (Gervais), *P. reticulata* Peters, *O. mykiss* (Walbaum) and *B. paludinosus* (Peters). Recently the African Sharp-tooth catfish *C. gariepinus* was caught by researchers at Oserian Bay and Crescent Island and its length-weight relationship and condition factor was studied (Keyombe *et al*., 2015). It first appeared in catches in October 2012 (Table 1). The commercial fishery depends mainly on *C. carpio* in terms of biomass followed by *O. leucostictus* (Trewavas) and *O. niloticus* (Hickely *et al*., 2015). The fishery was also remarkably supported by riverine cyprinid, the Longfin barb *B. paludinosus* (Peters) and crayfish, *P. clarkii* (Girard) until 1980s (Njiru *et al*., 2015). By the year 2013, the fishery was dominated by *C. carpio* which contributed over 95% of the total fish landings, while the remaining species contributed 5% of the total relative abundance computed from CPUE of the commercial catches (Aloo *et al*., 2013).

Table 1: The biomass (kg) of fish species landed by the commercial fishery during 2011, 2012 and 2013 with 50 boats operating.

Year	*M. salmoides*	*T. zillii*	*O. leucostictus*	*O. niloticus*	*C. carpio*	*C. gariepinus*
2011	159	4	17	0	287 897	0
2012	178	189	138	145	142 533	139
2013	562	1	2381	5905	220 373	11

Source: Hickely *et al*., 2015

Gill-net fishery is the basis for *Common carp*, *Tilapia* and *Barbus* species. Bass are taken mainly by rod and line for sport. *Barbus* is also occasionally caught by dip net (Hickley *et al*., 1994).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

Lake Naivasha is a shallow freshwater lake in a closed basin in the Great Rift Valley of Kenya. Its freshness is attributed to surface water inflow, biogeochemical sedimentation and underground seepage (Gaudet and Melack, 1981). The lake has a surface area that ranges between 120 and 150 km^2 subject to the dry and wet seasons respectively, with a mean depth of 4-6 m (Njiru *et al.*, 2015). The lake is located at an altitude of 1885 m a.s.l between latitudes 00^{o}45' S – 00^{o}53' S and longitudes 36^{o}15' E –36^{o}30' E. In the year 1995, Lake Naivasha was declared a Ramsar wetland giving it international importance due to its freshness and diverse ecology. The mean temperature of the Lake is approximately 25^{o}C, with a maximum temperature of 30 ^{o}C (Ndungu *et al.*, 2013). Its mean annual rainfall ranges from about 60 mm at the Naivasha township to some 170 mm along the slopes of the Nyandarua mountains, with open water evaporation estimated at approximately 172 cm/year^{-1} (Awange *et al*., 2013).

3.2 Study design

3.2.1 Sampling sites

The study was conducted in four different stations in Lake Naivasha (Figure 2). The stations were: 1. Oserian Bay (00°45′40.4″ S, 036°21′20″ E), 2. Crescent Island (00°48′ 47″ S, 036° 17′52.8″ E), 3. Malewa River mouth (00°43′11.3″S, 036°20′1.14″ E) and Central Beach (00^o 43′ 42.1″ S, 036^o 24′ 53.0″E). Crescent Island is a station in Crater Lake located in the eastern side which occasionally separate from the main lake during low water levels (Ndungu *et al.*, 2013). Crescent Island and Oserian Bay are in the open waters and characterized by occasional invasion by floating mats of water hyacinth (*Eichhornia crassipes)* and papyrus (*Cyperus papyrus)* vegetation. In addition, Oserian Bay is a protected breeding area of the fish. Malewa River is located in the northern side and contributes 80% of discharge into the lake (Ndungu *et al*., 2013). Central Beach is located close to wetlands in the north of the lake and Naivasha town, which is the shallow part and characterized by sandy silt, muddy substrate with decayed plant materials. The average depths of the sites were 4.5, 12.2, 2.6 and 1.4 m respectively. The selection criteria of the above study stations were based on a pilot survey conducted for assessing the presence and possibility of catching catfish.

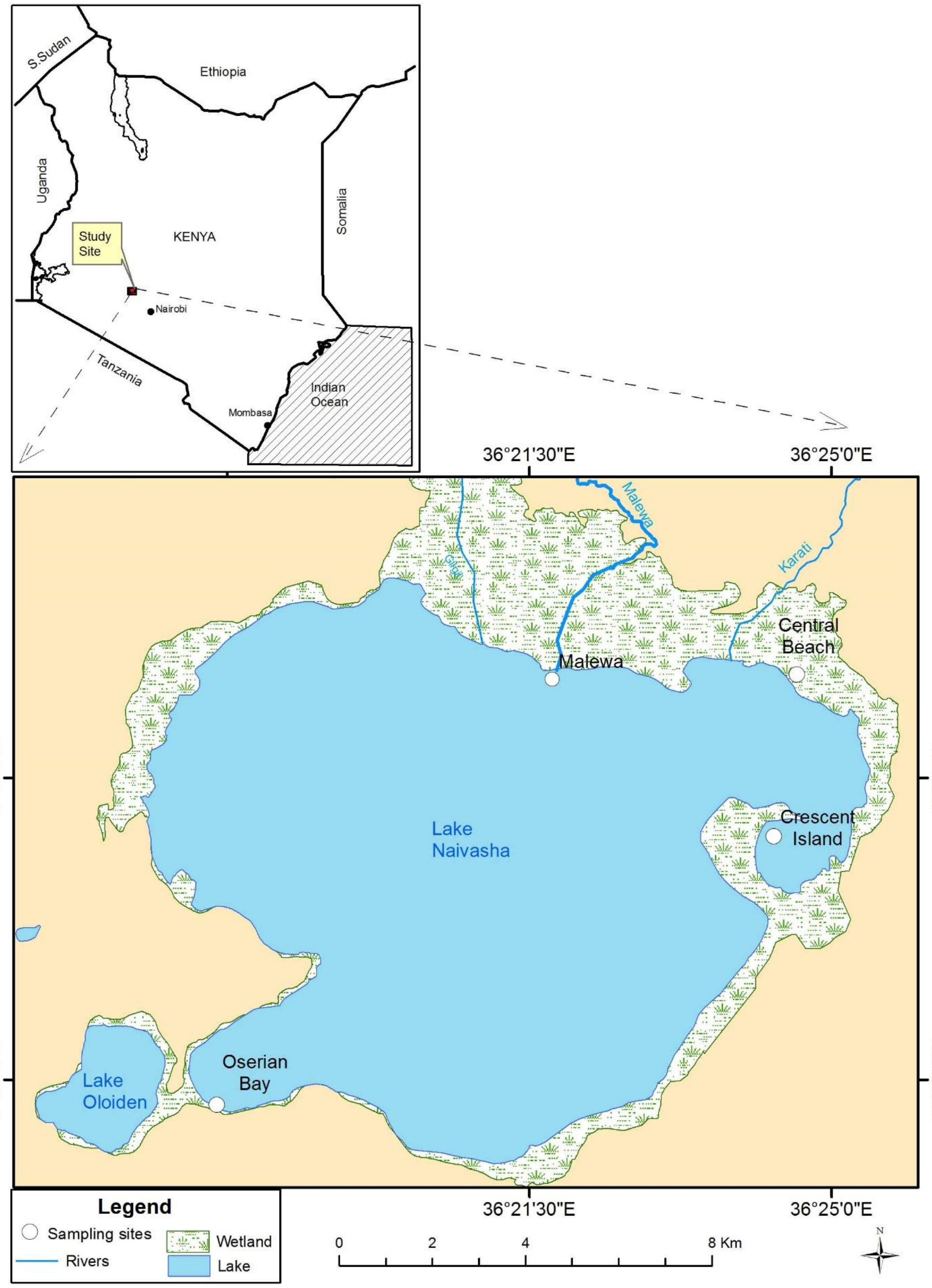


Figure 2: A map of Lake Naivasha showing the sampling stations (Source: Topographic Map of Kenya, scale 1:50,000).

3.2.2 Physico-chemical parameters

The physico-chemical parameters were measured at each sampling station before the start of fish sampling. Parameters such as temperature (^{o}C), dissolved oxygen (mg/L), pH and conductivity (µS/cm) were measured *in situ* using a Multi probe HQ40D meter (specification: HACH LDO; PHC301 and CDC41). Secchi disk of size 20 cm in diameter was used to determine the transparency of the lake at each sampling site. The disk was lowered vertically into the water until it just disappeared and then raised. The average depth of disappearance of the disk and the depth at which it was appeared as it is raised was used to determine the Secchi depth transparency.

3.2.3 Fish sampling

Samples of *C. gariepinus* were collected three times a month from November 2015 to January 2016, by setting gill nets of mesh size 50-200 mm at the four sampling stations. Gillnets were usually set in each sampling station and retrieved after five hours of fishing. In addition, mosquito nets were also used to get small fishes from the shallow littoral area. The seining was carried out using mosquito nets of length 195 cm x 250 m and mesh size of 3.4 mm. After removal, each fish was weighed to the nearest grams (g) using an electronic balance (Sartorius ED4202S) and total length was measured to the nearest cm by using a measuring board. The fish was taken to the laboratory, dissected and sex of individual fish was determined based on the method stated by Murua *et al*., (2003) and Muchlisin, (2014) as in Table 2.

Table 2: A generalized classification of gonad developmental stages in *Clarias gariepinus* (*Source*: Murua *et al*., 2003 and Muchlisin, 2014).

Maturity stages	Ovaries	Testes
Immature (I)	Colourless, small transparent ovaries without visible oocytes	Small flat, translucent to whitish, poorly developed with reduced fringes
Develop (II)	Large orange pale oocytes light yellow in colour, may be visible through the ovary tunic.	Testes more enlarged, whitish with voluminous fringes
Mature (III)	Very large ovaries, filling part of body cavity with blood capillaries, yellow/orange coloured	Very large, firm, white in colour
Ripe (IV)	Occupying the entire abdominal cavity, ovulated oocytes can be fully expelled from the oviduct with gentle pressure	Fully developed, turgid fringes, milky whitish in colour. Milt run out of the fish.
Spent (V)	Ovary wall thick and blood capillaries are big. Few remaining large oocytes observed and smaller size oocytes will be seen.	Bloody and flaccid fringes.

3.2.4 Phytoplankton and zooplankton samples

Integrated vertical samples of phytoplankton and zooplankton were collected using 25 µm and 50 µm mesh size nets respectively. The nets were dragged vertically from the bottom to the surface of the water. The samples were concentrated and transferred into 250 mL labelled vials. Lugol's solution (1 mL per litre) and 4% formalin were used for preservation for phytoplankton and for zooplankton respectively. In the laboratory, phytoplankton samples were stored in the dark for 24 hrs to allow settling. From the settled samples of phytoplankton, excess water was removed using a pipette and the rest of the sample was shaken for uniform distribution. A subsample of 1 mL was diluted in 19 mL of distilled water. Zooplankton samples were mixed immediately and a sub sample of 1 mL was diluted with 19 mL of distilled water. Identification of phytoplankton and crustacean zooplankton was done using keys in (Lizeth, 2001) and (Witty, 2004) respectively, while rotifers and protozoans were identified according to keys by (Kutikova, 2002) and (Fernando, 2002) respectively. For enumeration, 5 mL of the diluted subsample was used for both phytoplankton and zooplankton, respectively. The 5 mL subsample was placed on a Sedgwick Rafter and observed under the Motic BA210 inverted compound microscope (magnification at: x400 & x200) for identification and counting for phytoplankton and zooplankton, respectively. For every Sedgwick Rafter field with the diluted subsample, five fields were counted in triplicate and an average obtained (the location of the five fields was aided with Whipple Square). The number of organisms in the 5 mL undiluted subsample was computed by, multiplying the average organisms obtained in the five fields multiplied by the dilution factor (1:20mL). Then it was further multiplied by the volume of the undiluted subsample (5 mL). Both the volume of subsample and the volume of the sample used for analysis were taken into account. The number of phytoplankton and zooplankton per litre of lake water (D) was calculated using equation by Goswami, (2004):

$$D = \frac{N}{V} \tag{1}$$

Where,

N = Number of organisms in sample which was obtained by;

$$N = \frac{\text{No. in sub sample} \times \text{Vol. of sample}}{\text{sub sample volume}} \tag{2}$$

V= Volume of lake water filtered which was obtained by;

$$V = \pi \mathrm{r}^2 \mathrm{d} \tag{3}$$

Where,

r = radius of mouth of net

d = depth of haul

3.2.5 Stomach content analysis

Stomach contents were identified using the point method (Hynes, 1950). In this method, each food item in the stomach was allotted a certain number of points based on its volume. The fullness of the stomach was taken into account in the allotment of points. Full stomach was given 16 points (Table 3.) Thus points awarded from 0 to 16 were as follows: 0= empty stomach; 1= < quarter stomach; 2=quarter full stomach; 4=half full stomach; 8=three quarter full stomach; 16=full stomach. In the laboratory, the contents of stomach were transferred into a petridish and food items were identified and sorted into different categories. Large food items such as fish were identified visually. Smaller food items were sorted and counted by using the inverted compound microscope (magnification: x400). Stomach contents were assessed separately into each 10 cm length group to compare the contribution of the food item in each size class (ontogenic shift). The percentage contribution of each food item to stomach fullness in each size class was calculated on the basis of the awarded points using the equation by Zacharia, (1974);

$$\% \, contribution = \frac{A}{B} \times 100 \qquad (4)$$

Where,

A= point given for each food item

B= total point given for all foods in each stomach

Table 3: The point method for stomach content analysis of *C. gariepinus*

Fullness of the stomach	Points
Full	16
Three-quarter full	8
Half full	4
Quarter full	2
Less than quarter	1
Empty	0

(*Source*: Hynes, 1950).

3.2.6 Food selection

Most fishes have a range of preference for the organisms in the environment, so that some food items are consumed in large numbers, others moderately and some not at all. The index of such difference is called selection ratio. Phytoplankton in both the stomach and in the water samples were identified using “phytoplankton identification catalogue” (Lizeth, 2001). While, zooplankton were identified using the “practical guide to identifying fresh water crustacean zooplankton” (Witty, 2004). Strauss Linear index was used to calculate food selection from the formula of Strauss, (1979);

$$E = \frac{[ri - pi]}{[ri + pi]} \qquad (5)$$

Where, *ri* is the portion of plankton group in the stomach of the fish and *pi* is the portion of the same group in the Lake. The index has a possible range of values between 1 and -1. Prey items with Strauss positive index value indicate the food item is positively selected by the fish and was considered preferred. Prey items with negative values indicate the food item was not preferred by the fish and was considered avoided and 0 indicate random selection (Zacharia, 1974). The guts contents of individuals of *C. gariepinus* were investigated to measure selective predation of different prey items. Each stomach was emptied into a petridish and diluted to 40 mL of distilled water. A sub-sample of 5 mL was collected using a pipette and placed under inverted compound microscope (Motic BA 210) at x40 and x20 magnification for identification and counting for phytoplankton and zooplankton respectively. The mean proportion of individual prey items in the gut (*ri*) of *C. gariepinus* and the mean proportion of prey items in the lake (*pi*) was calculated and used to estimate Strauss E- values.

3.2.7 Fecundity

Ovarian developmental stage IV was used for counting of oocytes. Fish maturity stages I-III were considered immature and stage V had already started releasing eggs and remained with a few oocytes. The ovaries were kept in well labelled polythtene bags and preserved in Gilson's fluid which helps to break the ovarian tissue and to harden the eggs. Each ovary was weighed after washing off the preservative (using running water) and removal of excess water using filter paper. Sartorius ED4202S balance was used for weighing of ovaries (Max. 4200g, d= 0.01g). In this method, 20 mg sample of ovary was taken separately from anterior, middle and posterior portions of each ovarian lobe, weighed and eggs were counted. The average number of eggs in 20 mg sample was determined and used to calculate the total number of eggs in each ovary using the formula by Hunter *et al*., (1985);

$$F = \frac{n \times G}{g} \qquad (6)$$

Where, F= Fecundity, G= Total weight of the ovaries

n = number of eggs in subsample, g = weight of the three samples

The relationship between fecundity and some morphometric measurements (TL, TW and OW) were determined using regression analysis (Pearson Product Moment Correlation). A total of thirty six matured females of *C. gariepinus* were used for measuring egg sizes. From each ovary, individual eggs were randomly picked and the diameter was measured using a calibrated eyepiece graticule inserted in the eyepiece of the inverted microscope (1 division= 24.4 mm) at x20 magnification. From this, the diameter of matured eggs for individual ovary was estimated.

3.2.8 Length at first maturity (Lm_{50}) and sex ratio

Length at first maturity (Lm_{50}) was determined from the relationship between percentage of male and female fish with mature gonads plotted against different length classes using the logistic curve. Fish maturity stages I, II & III were considered immature, while stages IV and V were considered mature and used for Lm_{50} calculation.

The sex ratio (male: female) was analysed for each 10 cm size class and the null hypothesis was tested with deviation from 1:1 using Chi square test.

3.2.9 Length –weight relationship and relative condition factor (Kn)

The length-weight relationship of fish in each sex category was calculated using the formula by Wooton, (1990);

$$W = aL^{b} \tag{7}$$

Where *W* is body weight of fish in grams, *L* the total length in cm, *a*, the intercept and *b* the slope of the regression line.

Le Cren's (1951), modified formula was used for calculation of the relative condition factor;

$$Kn = \frac{W}{aL^{b}} \tag{8}$$

Where *Kn* is the condition factor *W* is the body weight of the fish in grams, *L* length in centimetres, *a*, is the intercept and *b* is the slope of the regression line.

3.3 Data management and analysis

Data collected was stored in Microsoft excel 2013 and statistically analysed using PASW version 21. All testes were carried out at 95% CI and the data subjected to a normality and homogeneity of variance tests. Normality distribution of data was checked using Shapiro-Wilk test while homogeneity of variance by Levene′s test. The data for fecundity within different size classes was normally distributed while the data for fecundity with morphometric measurements were not normally distributed. Log transformation was used to conduct parametric tests. Pearson Product Moment Correlation was used to test relationship of fecundity with total length, total weight and gonad weight. The variation of fecundity within different size classes and comparison of physico-chemical parameters among stations was tested using one way ANOVA. Correlation of physico-chemical parameters with fish condition factor and length weight relationship was tested using Pearson Product Moment Correlation. T=test was used to investigate the difference in slopes of regression line from the isometric exponent value of (b=3) between sexes. The relative condition factor values between sexes was tested using Mann Whitney test. Length at first maturity was investigated by fitting frequency data of mature fishes against length classes using logistic curve. The sex ratio was analysed in 10 cm size classes. Chi- square test was used to check the deviations of sex ratio from 1:1 and to identify spatial feeding pattern among stations.

CHAPTER FOUR

RESULTS

4.1 Fish morphometrics and physico-chemical parameters

Dissolved oxygen, pH, temperature and conductivity showed significant variations among stations (one way ANOVA, df=3, $P < 0.05$). The highest value (mean ± SD) of dissolved oxygen was recorded at Malewa River Mouth (7.5±1.2 mg/L) while the lowest value was recorded at Central Beach (5.4±0.5 mg/L). The values of dissolved oxygen (mean ± SD) at Oserian Bay and Crescent Island were 6.2±1.9 and 6.1±1.2 mg/L, respectively. The highest pH value was recorded at Central Beach (11.1) and lowest at Malewa River Mouth (8.4). The pH values at Oserian Bay and Crescent Island were 10.1and 8.8 respectively. The highest value (mean ± SD) of temperature was recorded at Malewa River Mouth and Oserain Bay stations (24.4±0.8°C) and the lowest was at Crescent Island (21.8±0.9°C). The highest value (mean ± SD) of conductivity was recorded at Crescent Island (283.0±4.6 µS/cm) and lowest at Malewa River Mouth (268.4±2.2 µS/cm). The values of conductivity (mean ± SD) at Oserian Bay and Central Beach were 281.4±4.4 and 273.4±5.8 µS/cm, respectively. A significant positive correlation was observed between fish condition factor and pH ($r = 0.83$; $P < 0.05$; Figure 3a). On the other hand, dissolved oxygen showed significant positive correlation with fish length-weight relationship ($r = 0.87$; $P < 0.05$; Figure 3b). The relationships between temperature, dissolved oxygen and conductivity with condition factor and length weight-relationship were not significant ($P > 0.05$).

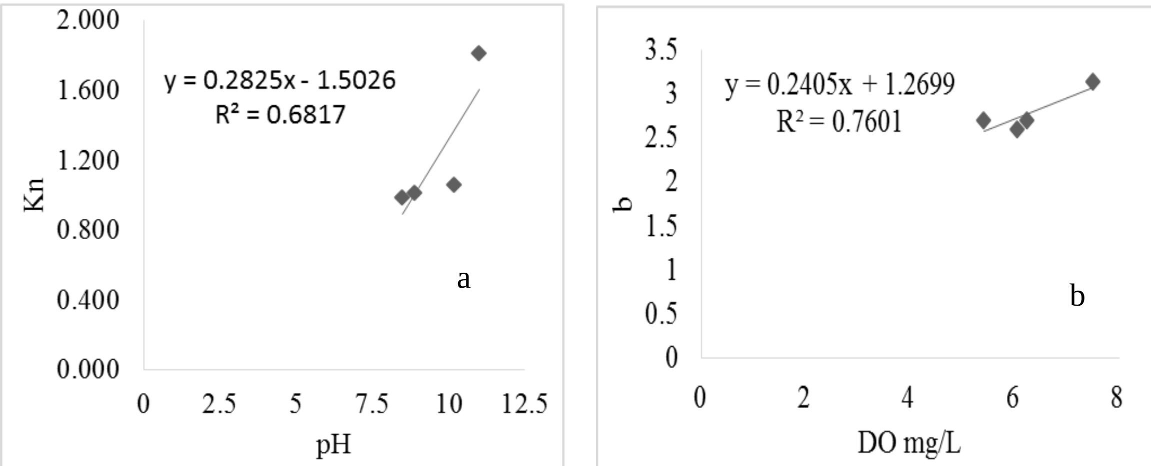


Figure 3: The correlation of pH with fish, (a) condition factor and (b) dissolved oxygen with length-weight relationship of *C. gariepinus*.

4.2 Phytoplankton and zooplankton abundance

4.2.1 Phytoplankton

Bacillariophyceae, dominated in all sampling stations. Oserian Bay and Central Beach showed a high number of species with dominant algae being *Aulacoseira* sp., *Pseodoastrum* sp., *Synedra* sp., and *Melosira* sp. Few specimens of *Cymbella* sp., *Ankyra* sp., and *Merismopedia* sp., were recorded at Crescent Island and Malewa stations. *Microcysits* belonging to Cyanophyceae was dominantly found at Malewa station, while relatively few numbers were recorded at Oserian Bay, Crescent Island and Central Beach stations (Table 4). *Cymbella* sp., and *Ankyra* sp., were absent from Malewa and Crescent Island stations, whereas *Navicula* sp., were absent from Crescent Island and Central Beach stations. In the other hand, *Peridinium* sp., *Coelastrum* sp., *Staurodesmus* sp., and *Merismopedia* sp., were absent from Central Beach station. From the Dinophyceae family, *Peridinium* sp., were absent from Oserian Bay and Malewa stations.

4.2.2 Zooplankton

Zooplankton belonging to Rotifera, namely *Keratella cochlearis* were the dominant species in all sampling stations followed by *Tricocerca* sp., and *polyarthra* sp. From Brachionidae family, *B. calyciflorus* and *B. falcatus* were absent from Crescent Island station while few specimens were recorded at Malewa and Central Beach stations. Among Synchaetidae family, Malewa station recorded high number of *Polyarthra* sp., while few specimens were recorded at Crescent Island, Oserian Bay and Central Beach stations respectively. In the Cyclopoidae family of Copepoda, *Thermocyclops* sp., were the dominant species at Oserian Bay and Crescent Island stations while few specimens were recorded at Malewa and Central Beach stations. Among the Daphniidae family of Cladocera, a relatively higher number of *Ceriodaphnia* sp., were recorded at Oserian Bay, Crescent Island and Central Beach stations while few specimens were recorded at Malewa station (Table 5).

List of species and abundance of phytoplankton and zooplankton species identified from four sampling stations in Lake Naivasha are presented in Tables 4 and 5;

Table 4: List of species and abundance (individuals per litre) of phytoplankton at four sampling stations in Lake Naivasha.

Family	Species	Oserian Bay	Crescent Island	Malewa River Mouth	Central Beach
Bacillariophyceae	*Melosira* sp.	62.6	61.1	63.8	68.4
	Aulacoseira sp.	28.5	38.1	46.9	45.3
	Synedra sp.	2.8	0.3	1.4	15.7
	Cymbella sp.	1.7	0	0	4.7
	Navicula sp.	0.5	0	3.5	0
Chlorophyceae	*Ankyra* sp.	2.8	0	0	1.7
	Pediastrum sp.	6.9	14.2	11.4	15.7
	Coelastrum sp.	3.3	3.5	3.3	0
Desmidiaceae	*Staurastrum* sp.	24.5	37.3	27.7	14.8
	Staurodesmus sp.	45.9	38.5	32.3	0
	Pseudostaurastum sp.	81.3	49.1	73.6	14.8
Dinophyceae	*Ceratium* sp.	20	25.1	9.2	29.5
	Peridinium sp.	0	1.6	0	0
Euglenophyceae	*Phacus* sp.	8.2	5.1	8.4	60
Cyanophyceae	*Microcystis* sp.	8.2	10.3	30.6	14.8
	Merismopedia sp.	0.5	3.2	0	0
Botryococcaceae	*Botryococcus* sp.	2.8	8.9	4.3	10.1
No. of species		16	14	13	12

Table 5: List of species and abundance (individuals per litre) of zooplankton at four sampling stations in Lake Naivasha.

Family	Species	Oserian Bay	Crescent Island	Malewa River Mouth	Central Beach
Cyclopoidae	*Thermocyclops* sp.	34.3	31.8	16.8	16.9
	Mesocyclops sp.	9.8	24.7	9.9	10.7
Daphniidae	*Ceriodaphnia* sp.	26.2	27.7	15.4	23.5
	Daphnia pulex	21.5	34.1	15.2	33.1
Sididae	*Diaphanosoma* sp.	13.2	6.1	11.5	14.6
Moinidae	*Moina micrura*	10.6	5.6	9.6	14.6
Chydoridae	*Chydorus* sp.	9.3	3.7	8.5	14.6
Brachionidae	*B. calyciflorus*	1.9	0	1.4	4.6
	B. angularis	10.3	7.8	5.8	8.5
	B.caudatus	6.7	5.6	9.5	3.9
	B.falcatus	6.9	0	5.1	1.5
	Keratella cochlearis	76.3	62.6	46.3	36
	Keratella tropica	15.4	27.5	10.7	9.1
Filiniidae	*Filinia* sp.	9.7	7.2	9.5	2.2
Synchaetidae	*Polyarthra* sp.	19.8	22.2	42.2	13
Trichocercidae	*Tricocerca* sp.	28.3	33.2	60.6	65.7
Vorticellidae	*Ciliated protozoans*	1.7	4.4	2.5	3.8
No. of species		17	15	17	17

4.3 Food and feeding

4.3.1 Feeding habit

Of the four hundred *C. gariepinus* examined, 100 (25%) were completely empty. From the rest, 53 (13.5%) were fingerlings and juveniles (4.5-11.5 cm length) which were collected using mosquito nets. All fingerlings collected had full stomachs. The major food items ingested by *C. gariepinus* were zooplankton (24.6%), fish (23.1%) and insects (21.4%) (Figure 4).

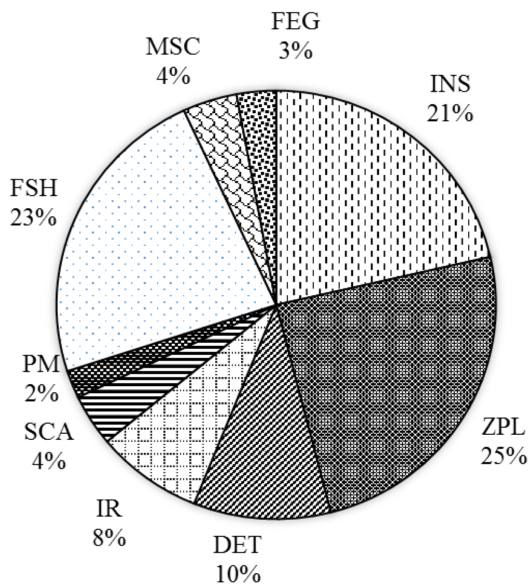


Figure 4: The percentage contribution of food items consumed by *C. gariepinus* in Lake Naivasha (INS-Insects, ZPL-Zooplankton, DET-Detritus, IR-Insect remains, SCA-scales, PM-Plant material, FSH-Fish, MSC-mollusc, FEG-Fish eggs).

Distribution of major food items ingested by *C. gariepinus* are presented in Table 6. The commonest ingested zooplankton was *Chydorus* sp. followed by *Ceriodaphnia* sp. and *Filinia Pejleri*. The most eaten insects were the Notonectidae *Micronecta scutellaris*, followed by chironomid larvae (Table 6). Detritus contributed 10.1% of total volume of food. Insect remains and fish scales accounted for 7.9 and 3.9 % of total volume, respectively. Mollusc and fish eggs contributed 4% and 2.9% of the food items. The contribution of plant material was low and accounted for 2.1% of the total volume (Table 6).

Table 6: The percentage occurrence of different food items identified from the stomachs of 400 individuals of *C. gariepinus* in Lake Naivasha.

Food items		Point method (%)		
Insects			Rotifers	
	Notonectidea	10.3	*Filinia Pejleri*	2.7
	Naucoridae	1.7	*Tricocerca*	2
	Chironomid larvae	6.7	*Keratella*	1.4
	Chironomid pupae	2.7	*Polyarthra*	1.3
		21.4		**7.4**
Cladoceras			Others	
	Ceriodaphnia	3.4	Detritus	10.1
	Diaphanosoma	2.2	Insect remains	7.9
	Daphnia pulex	5.6	Fish scales	3.9
	Moina micrura	1.8	Plant material	2.1
	Chydorus sp.	4.2	Fish	23.1
		17.2	Mollusc	4
			Fish eggs	2.9

4.3.2 Ontogenic shift

Ontogenic shift was observed in the diet of *C. gariepinus.* Small fishes tended to feed on high proportion of phytoplankton, insects and detritus while adults fed more on zooplankton, fish (*O. niloticus*) and cray fish (Figure 5).

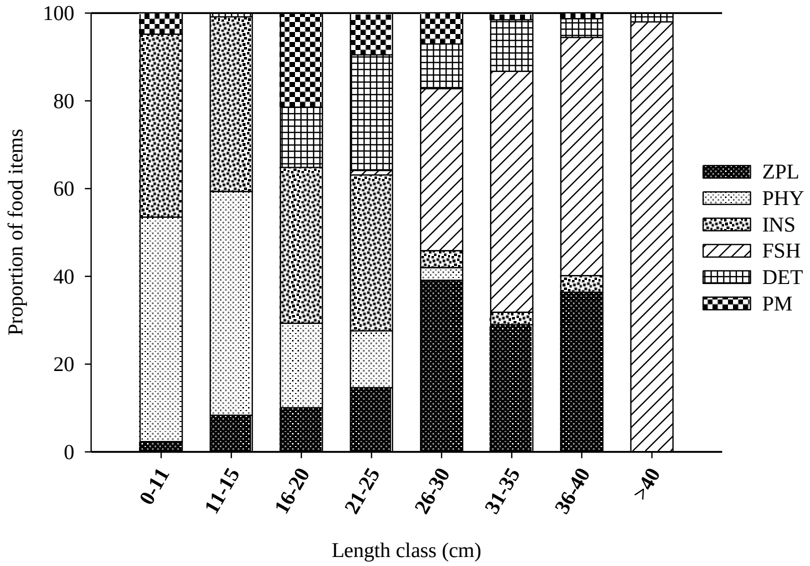


Figure 5: The percentage contribution of different food items consumed by *C. gariepinus* in different length classes (ZPL-zooplankton, PHY-phytoplankton, INS-insects, FSH-fish, DET-detritus, PM-plant material).

4.3.3 Spatial distribution

The analysis of stomach contents was used to investigate changes in spatial feeding pattern. Fish samples from Oserian Bay and Crescent Island stations fed on high proportion of fish (*O. niloticus*), crayfish and detritus (Figure 6). There were significant differences (χ^2 *test*; df = 7, P < 0.05) in consumed food items such as insects, detritus, scales plant material, fish and fish eggs between Malewa and Oserian Bay stations (χ^2 =15.9; P < 0.05, χ^2 =6.5; P < 0.05, χ^2 = 12.6; P < 0.05, χ^2 =20.6; P < 0.05, χ^2 =45.4; P < 0.05, χ^2 =8.3; P < 0.05). Fish from Malewa station fed on relatively high proportion of seeds, insect remains and insects (Figure 7). The proportion of insects consumed by *C. gariepinus* at Central Beach was higher followed by plant material and crayfish (Figure 7). There were significant differences (χ^2 *test*; df = 6, P = < 0.05) in consumed food items such as insects, zooplankton, scales, plant material and fish between Crescent Island and Central Beach stations (χ^2 =30; P < 0.05, χ^2 =24.7; P < 0.05, χ^2 = 11.6; P < 0.05), respectively.

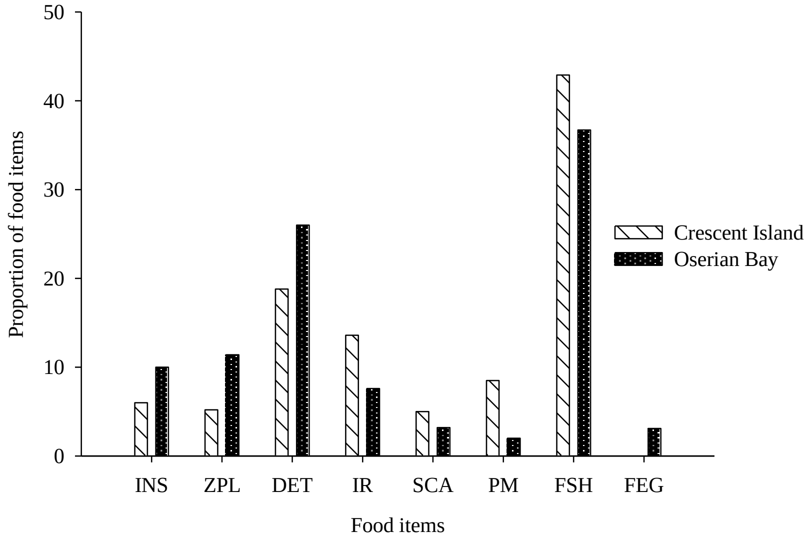


Figure 6: The percentage contribution of food items consumed by *C. gariepinus* at Crescent Island and Oserian Bay stations (INS-insects, ZPL- zooplankton, DET-detritus, IR-insect remains, SCA-scales, PM- plant material, FSH-fish, FEG- fish eggs).

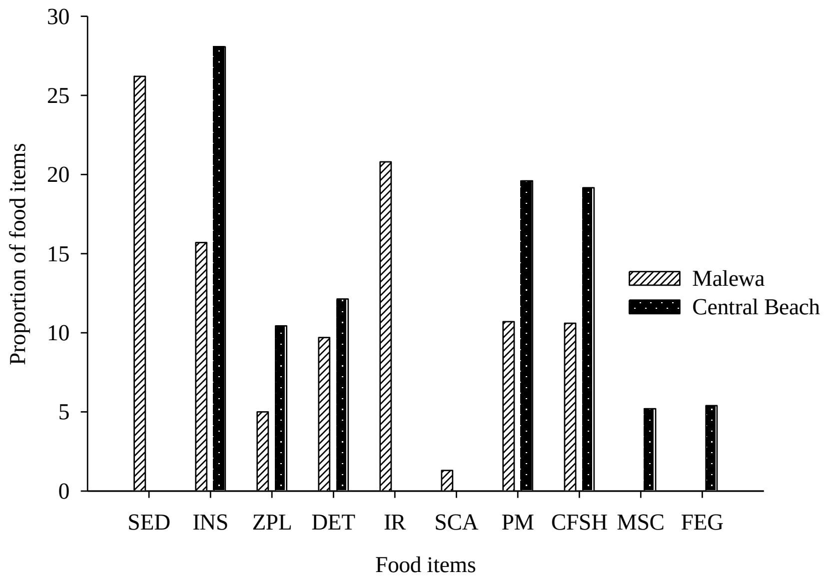


Figure 7: The percentage contribution of food items consumed by *C. gariepinus* at Malewa and Central Beach stations (SED- seeds, INS-insects, ZPL- zooplankton, DET-detritus, IR-insect remains, SCA-scales, PM- plant material, CFSH-cray fish, MSC- mollusc, FEG- fish eggs).

4.3.4 Food selection

Food selection analysis was done for 84 fishes in the size class that ranged from 4.5 - 40 cm. *Aulacoseira* sp. and *Melosira* sp. were consistently the most consumed prey items in the diet of *C. gariepinus*. Other intensively consumed food items were the phytoplankton, *Phacus* sp., *Microcystis* sp., and ciliated protozoa. Strauss selective (E) values showed positive selectivity for members of the Bacillariophyceae, Chlorophyceae, Cyanophyceae, Vorticellidae and Brachionidae and negative selectivity for the members of Desmidiaceae, Dinophyceae Euglenophyceae and Daphniidae families (Figure 8).

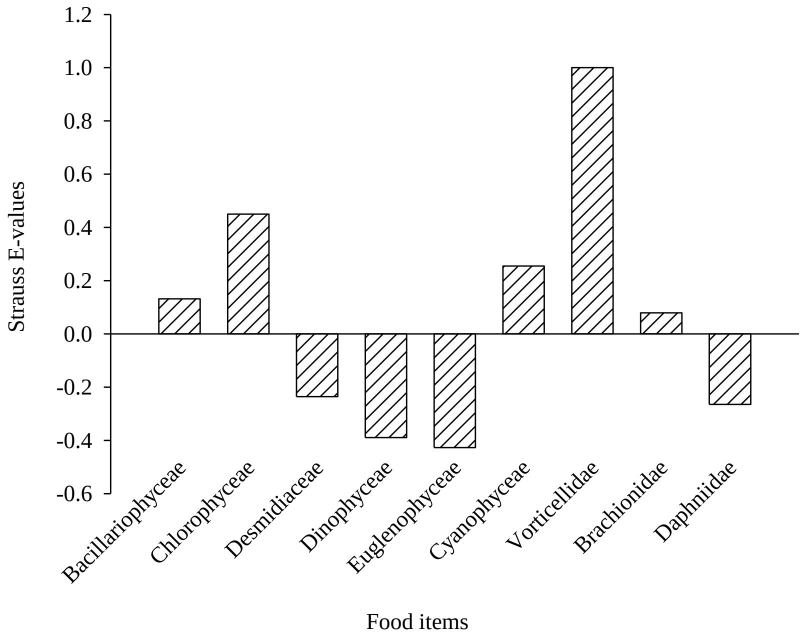


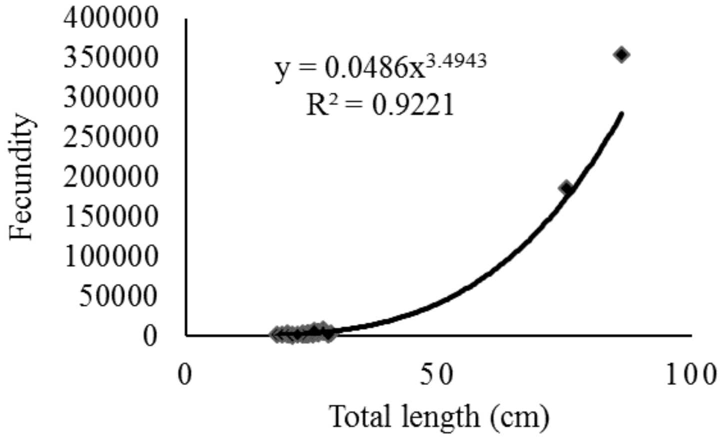
Figure 8: The feeding selectivity of *C. gariepinus* from Lake Naivasha, Kenya.

4.4 Fecundity

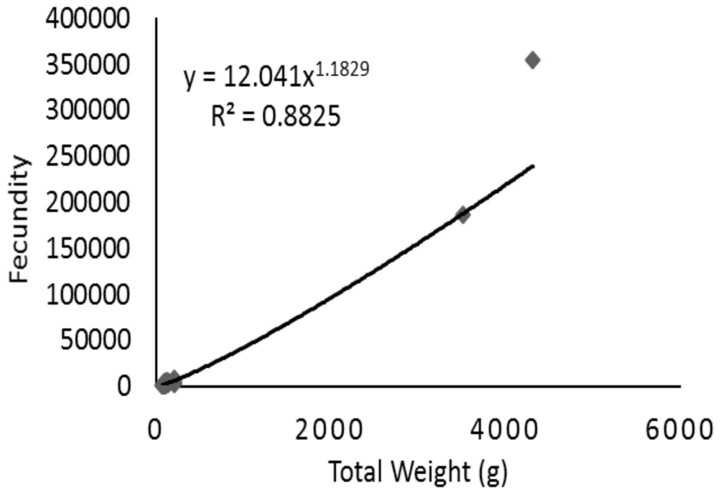
Fish samples used had lengths that ranged from 18 - 86 cm with a mean (mean ± SD) value of 27.2±13.5 cm and weight of 60 to 4300 g with a mean value of 326.3±885.1 g respectively. The weight of the ovaries used ranged from 2.3 g to 652.5 g with mean of 36.3±114.2 g. Fecundity from the samples ranged between 1,260 to 354,361 with a mean of 18,209±65,174 eggs. The diameter of eggs measured ranged from 1.5 mm to 2.4 mm with a mean of 1.9±0.2 mm. There were significant variations in fecundity between different size classes (One Way ANOVA, F= 9.12, df =2, P = < 0.05).

The relationships between fecundity and total length (cm) and total weight (g) were curvilinear while that of fecundity with ovary weight (g) was linear (Figure 9).

a)



b)



c)

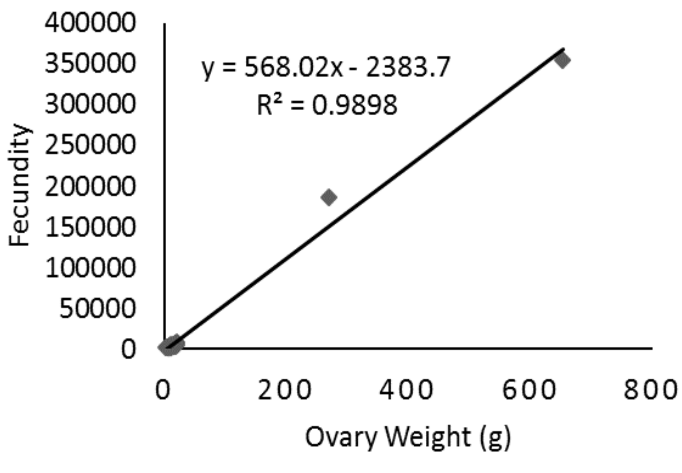


Figure 9: The relationships between fecundity and morphometric parameters, a) total length b) total weight, and c) ovary weight of *C. gariepinus* in Lake Naivasha.

The relationship of fecundity with morphometric parameters was described using the following equations;

$F=0.486TL^{3.494}$ (r^2= 0.922, P< 0.05)

$F=12.041TW^{1.182}$ (r^2= 0.882, P< 0.05)

F= 568.02OW 2383.7 (r^2= 0.989, P<0.05)

The curvilinear relationship between fecundity against total length and total weight showed positive correlation and directly proportional to the length and weight of the fish. On the other hand, the fecundity increased progressively with the ovary weight of the fish. There were significant relationships between fecundity with total length, total weight and ovary weight (P < 0.05).

4.5 Length at first maturity (Lm_{50})

The smallest mature female sampled was 18 cm and weighed 90 g while the smallest mature male sampled was 24 cm and weighed 100 g. The percentages of male and female fish having gonad developmental stages IV and V were plotted against length for each sex (Figure 10) to determine length at first maturity. The length at first maturity of both males and females were 18.9 cm and 42 cm, respectively.

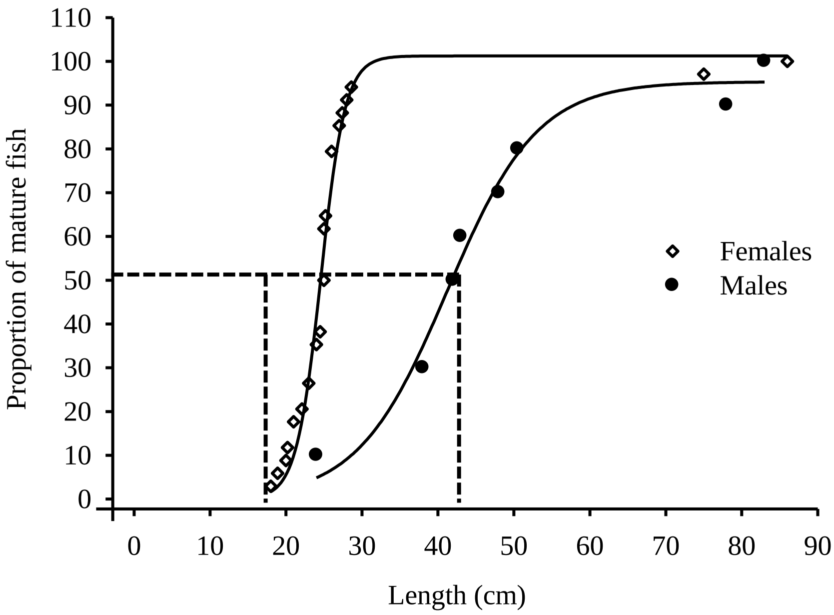


Figure 10: The length at first maturity of male and female *C. gariepinus* in Lake Naivasha.

4.6 Length - weight relationship

Length–weight equations were calculated separately for males, females and both sexes combined. A total of 324 males, 76 females and 400 combined sexes of individuals of *C. gariepinus* were used for length-weight calculation. Both male and female fish from Malewa station showed positive allometric growth with *b* values of 3.14 and 3.24 ($b > 3$) as shown in figures 11a and 11b. Female fishes from Crescent Island showed isometric growth pattern (b=3) whereas male fish showed negative allometric growth (Figures, 12a and 12b). Both male and female fish from Oserian Bay station showed negative allometric growth with *b* values of 2.79 and 2.71 ($b < 3$) as shown in figures 13a and 13b. Similarly both male and female fish from Central Beach stations showed negative allometric growth pattern with *b* values of 2.69 and 2.73 ($b < 3$) (Figures, 14a and 14b). The length-weight values for male, female and combined sexes among all sampling stations were 2.82, 2.88 and 2.84 respectively. However, the relationship was not significantly different (t=0.373, df=6, $P > 0.05$) from the isometric exponent value of 3 between sexes. The LWR equations for all sampling stations are summarized in Table 7 below;

Table 7: Length-weight relationship equations for *C. gariepinus* in Lake Naivasha

Station	LWR equation
Malewa River Mouth	$Log_{10}W=-2.4974+3.2469Log_{10}TL$
Oserian Bay	$Log_{10}W=-1.6926+2.7383Log_{10}TL$
Crescent Island	$Log_{10}W=-1.7449+2.7073Log_{10}TL$
Central Beach	$Log_{10}W=-1.7877+2.702Log_{10}TL$
All sampling stations	$Log_{10}W=-1.8968+2.8375Log_{10}TL$

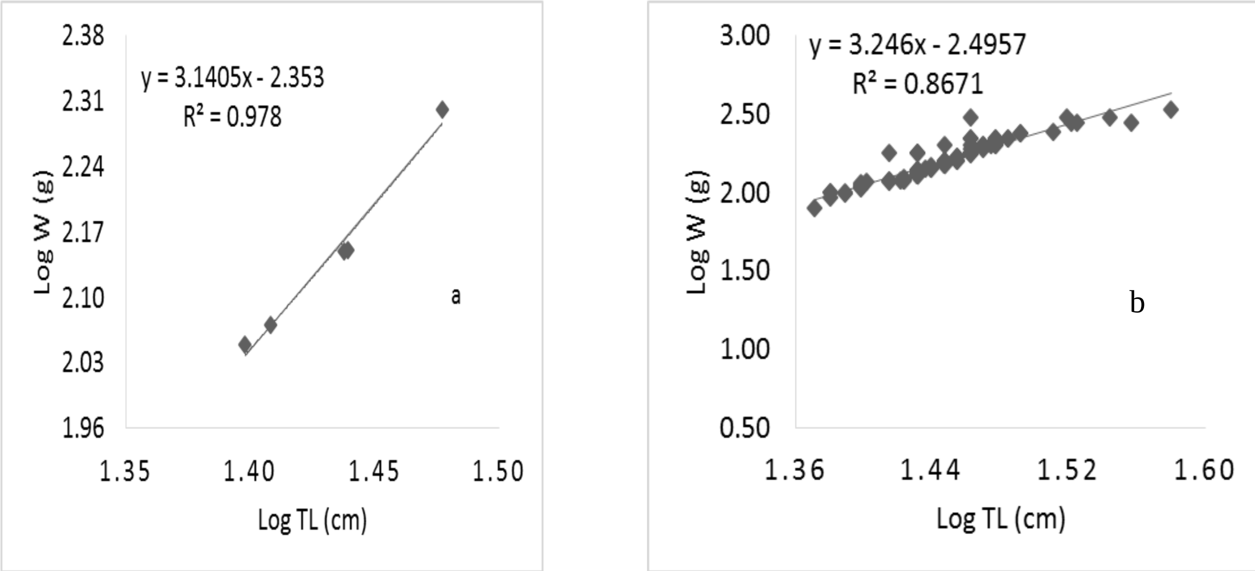


Figure 11: The length -weight relationship (Log TL, Log W) of a) female, and b) male *C. gariepinus* at Malewa.

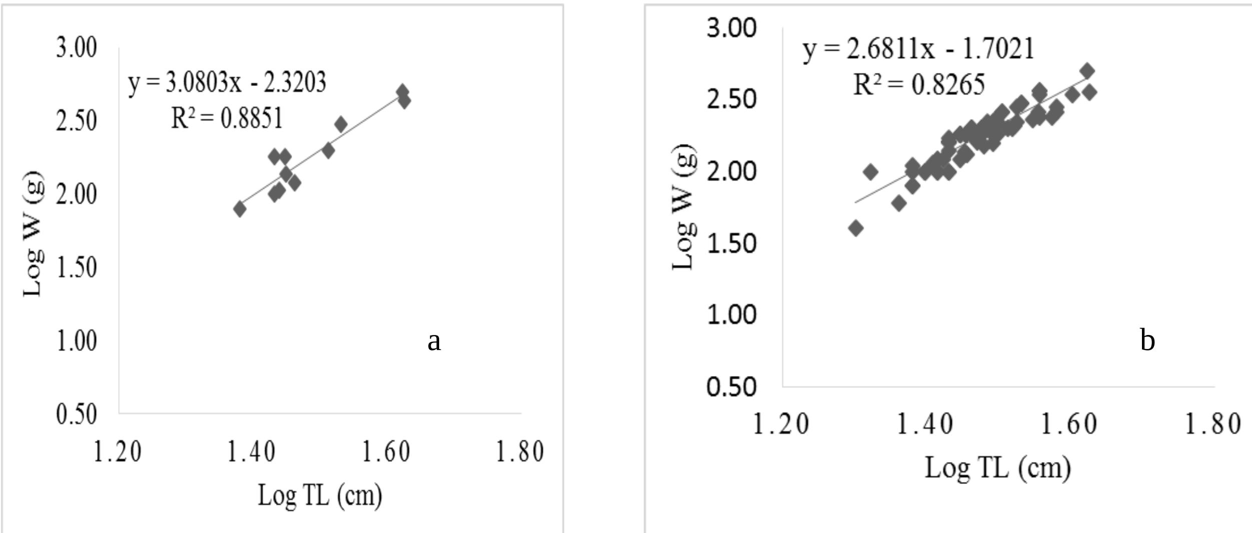


Figure 12: The length- weight relationship (Log TL, Log W) of a) female and b) male *C. gariepinus* at Crescent Island.

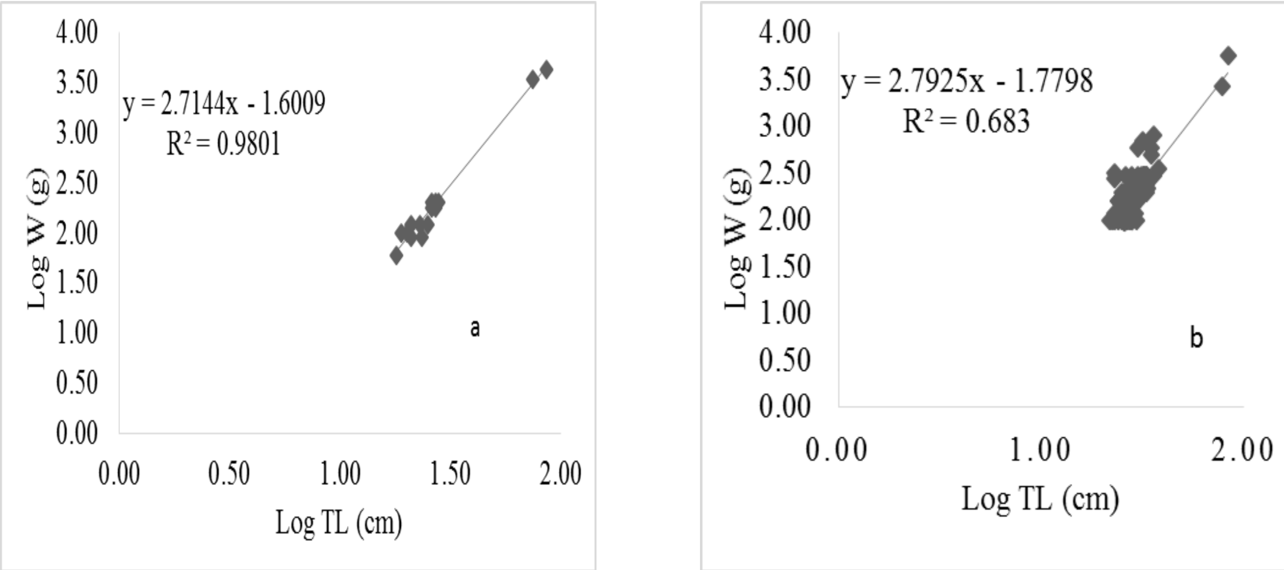


Figure 13: The length-weight relationship (Log TL, Log W) of a) female and b) male *C. gariepinus* at Oserian Bay.

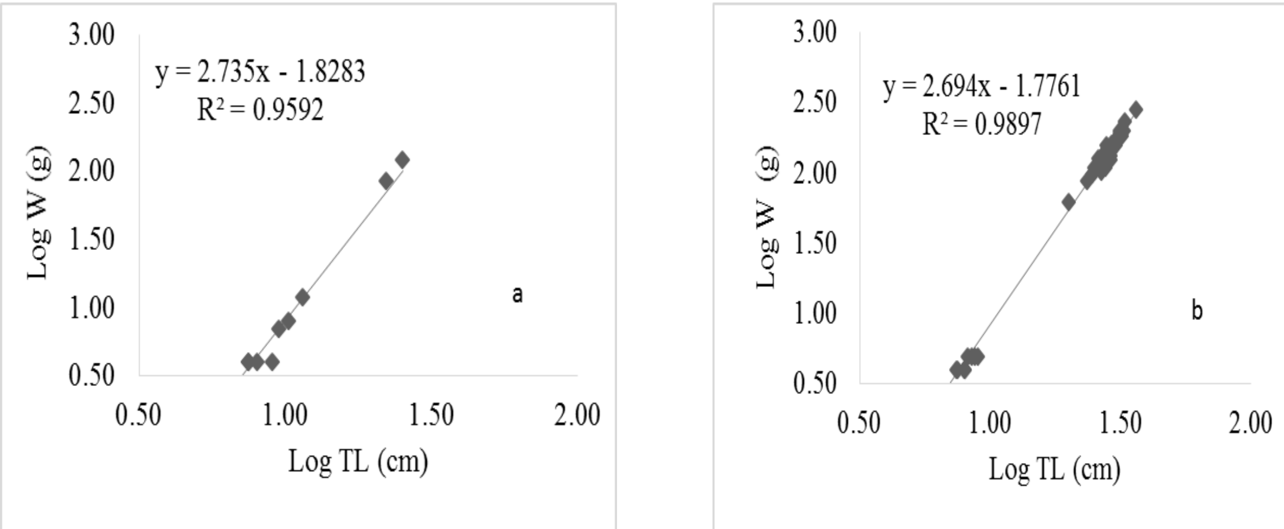


Figure 14: The length-weight relationship (Log TL, Log W) of a) female and b) male *C. gariepinus* at Central Beach.

4.7 Relative condition factor (Kn)

Relative condition factor of male *C. gariepinus* at Crescent Island station ranged from 0.668 to 1.462 while that of females ranged from 0.732 to 1.333. The relative condition factor of the male *C. gariepinus* at Oserian Bay station ranged from 0.465 to 2.943 while that of the females ranged from 0.777 to 1.575. The relative condition factor of the male *C. gariepinus* at Malewa station ranged from 0.002 to 1.674 while that of the females ranged from 0.938 to 1.015. The relative condition factor of the male *C. gariepinus* at Central Beach station ranged from 0.592 to 2.108 while that of the females ranged from 0.780 to 2.108, respectively. The mean condition values for all males, females and combined sexes in all sampling stations were 1.028, 1.409 and 1.030 respectively. The highest value (1.142) was recorded for female *C. gariepinus* at Oserian Bay station while the lowest value (0.957) was recorded for male fish at Crescent Island station (Figure 15). Relative condition factor values between sexes did not vary significantly (Mann-Whitney test=10892.500, n_1=76, n_2=324, $P > 0.05$). However, this values showed significant variation between sexes at Oserian Bay station (Mann-Whitney test=1216.00, n_1 =15, n_2 =109, $P < 0.05$).

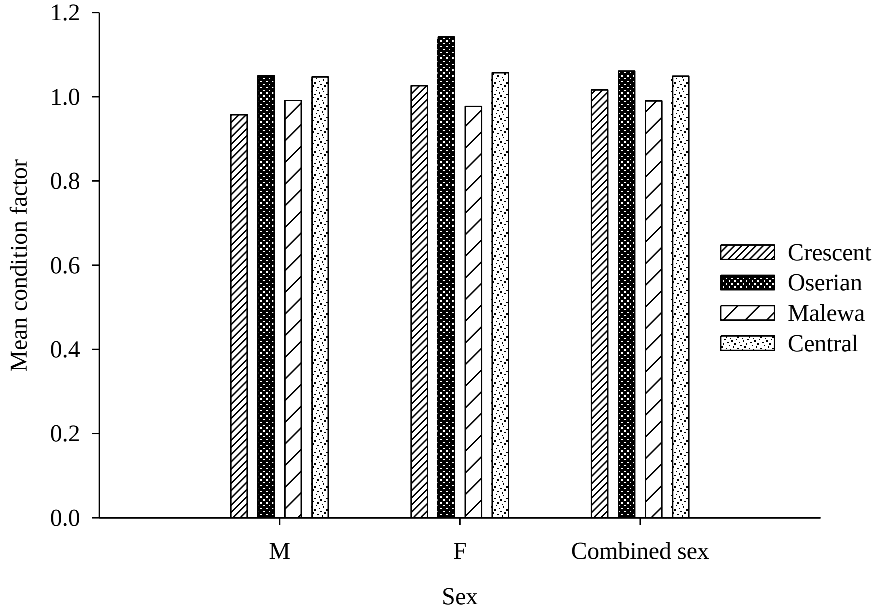


Figure 15: The relative condition factors of *C. gariepinus* in four sampling station in Lake Naivasha.

4.8 Sex ratio

From a total of 400 individuals of *C. gariepinus*, 324 (81.0%) were males while the remaining 76 (19.0%) were females. The males dominated the fish population in all sampling stations. The overall ratio of males to females was 4.26 (Table 8). This ratio was significantly different from the hypothetical ratio of 1:1 (χ^2=77.28; df = 5; P < 0.05). Fish of size class 20-29.9 cm recorded the highest value (5.6) while size class of 10-19.9 cm and ≥ 50 cm recorded the lowest ratio of 0.67 (Table, 8). The ratio of males to females was significantly different at size classes 0-9.9 cm (χ^2 =5.61; P < 0.05), 20-29.9 cm (χ^2 =56.44; P < 0.05), and 30-39.9 cm (χ^2 = 20.52; P < 0.05) (Table 8).

Table 8: The number of male and female *C. gariepinus* of different size classes and their corresponding sex ratios from Lake Naivasha (figures with * indicate significant at P=0.05).

Length class (cm)	Males	Females	Sex ratio	Chi-square
0-9.9	36	14	2.58	5.61*
10-19.9	2	3	0.67	0.40
20-29.9	196	35	5.6	56.44*
30-39.9	83	19	4.4	20.52*
40-49.9	5	2	2.5	4.29
≥50	2	3	0.67	0.40
Total	324	76	4.26	77.28*

CHAPTER FIVE

DISCUSSION

5.1 Fish morphometrics and physico-chemical parameters

Fish ecology and biology are known to be influenced by biotic and abiotic factors. Changes in physico-chemical parameters such as dissolved oxygen, temperature, pH and salinity are among the abiotic factors which influence the physiology of fish that indirectly affect metabolism, feeding rate and spawning seasons (Timmons *et al*., 2001). *Clarias gariepinus* tolerates a wide range of water quality parameters and survive in low oxygen concentrations (Skelton, 2001). However, healthy growth and reproduction are greater, within the optimum range of temperature; 26 to 32°c, dissolved oxygen; 3 to 5 mg/L and pH of 6.5 to 9 respectively (FAO, 2006). The various physico-chemical parameters recorded from four stations were within the acceptable limits for growth and health for *C. gariepinus*. The significant correlations observed between dissolved oxygen and pH with fish condition factor and slope of regression line *b* indicate the major roles played by dissolved oxygen in metabolism, food supply and growth of fish (Timmons *et al*., 2001; Taylor and Miller, 2001; Saloom and Duncan, 2005; Buentello *et al*., 2010). Studies by Kane *et al*., (2001), Boyd and Gross, (2000), and Bhatnagar and Devi, (2013) showed that temperature, pH and dissolved oxygen are among the most important factors that affect the body functions of fishes. In addition pH affects physiology and internal fluid balance of fish that interfere with metabolism and growth (Tassaduqe *et al*., 2003). Any variation beyond optimum range could be fatal to many aquatic organisms (Furhan *et al*., 2004). The insignificant correlation observed between temperature and conductivity with fish condition factor and length-weight relationship could be due to the fact that *C. gariepinus* has morphological characteristics that enable the species to adapt to various adverse environmental conditions. For example, possession of specialised suprabranchial organ for breathing. This organ is a large paired chamber with branches above the gill arches specifically adapted for air breathing that helps to survive for considerable periods without water (Van der Waal, 1998; Skelton, 2001). The species can live in very poorly oxygenated waters and is one of the last species to live in such uninhabitable places. They are also able to secret mucus to prevent drying and are able to burrow in the muddy substrate in drying water bodies (Van der Waal, 1998).

5.2 Phytoplankton and zooplankton analysis

The numerical dominance of Bacillariophyceae, algal group in all sampling stations is in line with the findings and observations made by Hubble and Harper, (2002) in Lake Naivasha. According to Hubble and Harper (2002), most diatoms are indicators of moderate to high nutrient conditions. These results also agree with other studies (Hubble and Harper, 2002; Ballot *et al*., 2009; Harper *et al*., 2011) which also reported the dominance of only two groups of phytoplankton (diatoms and cyanobacteria) in Lake Naivasha. Similarly Harper *et al*., (2011) reported the dominance of phytoplankton belonging to *Aulacoseira* sp., both numerically and in terms of contribution to overall primary production followed by toxin-forming *Microcystis* sp. This could be an indication of changes in physico-chemical parameters caused by horticultural runoff, pollution by livestock watering and cloth washing by local residents using phosphorus-based detergents around the lake. Degradation coupled with the effects of species introductions resulted in change in eutrophic state of the lake and in phytoplankton composition (Kitaka *et al*., 2002; Ballot *et al*., 2009; Harper *et al*., 2011). Degradation could also explain the dominance of only one family of zooplankton namely Brachionidae in all of four sampling stations followed by Trichocercidae and Cyclopoidae. This however disagrees with results of Uku and Mavuti, (1994), who recorded the dominance of Daphniidae in Lake Naivasha. This could be attributed to progressive changes and increase in nutrient concentrations in the lake leading to the dominance by species better adapted to the new conditions (Hubble and Harper, 2002; Mergeay *et al*., 2004). According to Mironga *et al*., (2014) high infestation and formation of dense mats by water hyacinth caused reduction in dissolved oxygen content and this affects abundance and diversity of zooplankton in Lake Naivasha. Thus, changes in physico-chemical parameters play a crucial role in determination of phytoplankton and zooplankton species richness and abundance (Uku and Mavuti, 1994).

5.3 Food and feeding habit

From the results, *C. gariepinus* fed on a variety of food items including all types of phytoplankton (e.g., *Microcystis)*, ciliated protozoa, zooplankton, insects, and other bottom fauna. This could be due to its morphological adaptations (big mouth, marginal and pharyngeal teeth, tough and muscular stomach and short intestine) and omnivorous predation habit, where *C. gariepinus* can switch from one type of food item to the other depending on availability (Dadebo, 2009; Wakil *et al*., 2014). Ontogenic shift observed during study could be due to changing capabilities of fish. Generally, fish grow in a pattern of level from eggs to adults and their feeding habit changes markedly throughout the life time thus, they become more effective at manipulating larger prey as they grow big that are more beneficial (Hildrew *et al*., 2007;Takefumi, 2015).

Spatial changes in feeding pattern of *C. gariepinus* were also observed in this study. Individuals from Malewa river mouth tended to feed on high proportion of seeds, insects and insect remains probably due to high abundance of these food items brought in by inflowing rivers. These results agree with those of Khan *et al*., (2013) who worked on freshwater catfish *Eutrophiichthys vacha* in Pakhtunghwa Rivers, Pakistan and Shinkafi *et al*., (2010) who worked on *Synodontis nigrita* in River Rima, Nigeria, and found that the fish fed predominantly on aquatic insects. High consumption of insects (*Hemiptera)* and plant materials were recorded in the guts of fish from Central Beach sampling station. This may be due to the dense vegetation and shallow nature of the area which was used as a habitat for free living insects. Fish collected from Oserian and Crescent stations had high proportions of fish followed by detritus in the diet. This could be attributed to easy accessibility of fish to open water and to the highly nutritional benefits of detritus to *C. gariepinus* (Dadebo, 2009).

The wide range of food exhibited by *C. gariepinus* revealed its feeding flexibility, and morphological adaptation that enables it to change from one food category to the other in response to the abundance of prey items in the environment. In a study of the feeding habits of five fish species (*O. leucostictus, T. zillii, M. salmoides, B. amphigramma and P. reticulata*) in Lake Naivasha, Hickley *et al*., (2002) concluded that zooplankton, phytoplankton and benthos especially chironomids were underutilized. This study has therefore revealed that, those food items that were previously underutilized are intensively consumed by *C. gariepinus* there-by filling some gap in the basic food web in the Lake. The feeding habits of *C. gariepinus* have been studied widely (Willoughby and Tweddle, 1978; Clay, 1979; Dadebo, 2000; Solak and Akyurt, 2001; Brewster, 2007; Dadebo, 2009; Dadebo *et al*., 2011; Omondi *et al*., 2013; Abera *et al*., 2014; Admassu *et al*., 2015). Their findings showed its euryphagous feeding habits including feeding on terrestrial and aquatic insects, snails, zooplankton, benthic organisms and fish which are similar to results obtained during this study.

5.4 Food selection

High consumption of phytoplankton especially diatoms by *C. gariepinus* reported in this study agrees with the study done by Khan *et al.,* (2013), in Pakhtunghwa Rivers, Pakistan. From the gut analysis of juvenile fishes, large amounts of *Microcystis* were also consumed by *C. gariepinus*. This indicated that the species is an omnivore that fed on all types of phytoplankton (Shinkafi *et al*., 2010). Pine *et al*., (2005) reported that catfish randomly and nonselectively fed on available food organisms when the density of preferred prey items is low. Another study by Yilmaz *et al*., (2006) also found positive prey selection by *C. gariepinus* for rotifers compared to other zooplankton species under laboratory conditions. This agrees with results recorded during this study. Positive selectivity for *Microcystis,* diatoms and rotifers in the diet of *C. gariepinus* could also be due to their high abundance in the lake. This indicated that *C. gariepinus* opportunistically fed on most common food items available in the system. Lowe-McConnell, (1995) found out that most fishes show considerable plasticity in their diet. Thus, most predator and omnivore fish fed on whatever food items are available seasonally or by active selection of preferred foods according to individual choice.

5.5 Fecundity

In this study, fecundity increased in proportion to 3.5 power of total length and 1.2 power of total weight. These results agree with the results of Bagenal and Braum (1978) who reported that the slope of the fitted line is 3 when fecundity is related with total length and 1 when it is related to total weight. The fecundity of *C. gariepinus* which ranged from 1,260 to 354,361eggs during this study is lower than 5,000 to 1,240,000 eggs reported by Dadebo *et al.,* (2011) for *C. gariepnus* in Lake Chamo. This is probably due to the fact that some fish species are known to exhibit wide variations in fecundity even within individuals of the same species (Wotton, 1990). Food availability can also influence the condition of the female producing eggs, altering strategies or change the best approach to egg size, depending on foods available to larvae in the environment (Offem *et al*., 2008; Matthews, 2012). Although LoweMcConnell, (1959) found that fish in poor conditions have lower fecundity than those in better condition. These results, show that fecundity increases with increasing fish size. However, the egg size decreased with increase in the number of eggs during the study, which is in line with findings by Bone *et al*., (1996).

The range of egg diameter observed in this study was larger compared to that found in eggs of other catfishes (Shinkafi and Ipinjolu, 2012; Offem *et al*., 2008). This could be due to the fact that larger eggs have more yolk, production of larger eggs could be attributed to extended protection strategy, thus when the eggs hatch the larva have more yolk to feed on. Moreover, the larva become independent of the mother and have greater chance of survival when environmental conditions are not satisfactory. Yalcin *et al*., (2001) found a size range of 1-1.54 mm diameter for *C. gariepinus* eggs in River Asi, Turkey. Shinkafi and Ipinjolu, (2012) found 0.70-1.85 mm diameter for giraffe nosed catfish (*Auchenoglanis occidentalis)* in River Rima, North-Western Nigeria. Dadebo *et al*., (2011) found egg size range of 0.47 to 1.36 mm diameter for *C. gariepinus* in Lake Chamo, Ethiopia. However, Offem *et al*., (2008) reported size range of 1.7-4.7 mm diameter for *C. nigrodigitatus* in Cross River, Nigeria, which is much larger than the present study. Wotton (1990) found out that egg-size variations in fishes are attributed to energy reserves over spawning season. Thus, a switch in the stored energy from reproduction to growth results in smaller and bigger eggs, respectively. Moreover, changes in environmental factors affecting the spawning adults may probably cause egg-size variations. Several researchers have reported fecundity of catfish from some African waters (Lung'ayia, 1994; Dadebo, 2000; Dadebo *et al*., 2011; Abdijan and Ivorie, 2014; Konan *et al*., 2014). Results showed that, fecundity is related to body weight, length and gonad weight of fish and regulated by availability of nutritional resources which is in line with the current study.

5.6 Length at first maturity (Lm_{50})

The length at first maturity is of special interest in fisheries management and is widely used as an indicator for minimum permissible capture size (Lucifora *et al*., 1999). Some fish species mature as early as in the first year. The time to maturity indicates a great deal about the productivity of a population and its ability to recover from environmental disturbances (Matthews, 2012). The mean size at first maturity was 18.9 cm for females and 42 cm for males. The maturity results for females in this study was much smaller than results reported by Dadebo *et al*., (2011) which was 58 cm for females and 52 cm for males in Lake Chamo, Ethiopia. These variations may be due to environmental factors, such as food availability. Thorpe *et al*., (1998) found out that the process of maturation is significantly influenced by the environment. Owiti and Dadzie, (1989), reported that catfish attain its first maturity in a range of 41-45 cm in low altitude environments. According to Blazek *et al*., (2013), dry and hot climate selected for short life span, while stable, predator-free and cold condition resulted in delayed sexual maturity and limited reproductive output in fishes. The results from this study differ from those recorded by Lung'ayia, (1994) who reported size at massive maturity of 21.0 cm for both sexes in the Kenyan part of Lake Victoria which is smaller than in the present study. The early maturity of females of *C. gariepinus* could be due to the fact that the species is new to Lake Naivasha thus, rapid production of early offsprings helps in establishment of the population. Matthews, (2012) found out that early maturity in fishes was often attributed to maximizing the reproductive success of the species in particular physical habitats. However, fishes are known to mature early when there is stress due to overfishing and use of inappropriate mesh size gear (Hossain *et al*., 2012).

5.7 Length-weight relationship

Fish can attain either isometric, positive allometric or negative allometric growth. Isometric growth is associated with no change of body shape as the fish grows. Negative allometric growth implies the fish becomes more slender as it increases in weight while positive allometric growth implies stoutness of the body as the fish increases in length (Riedel *et al*., 2007). In this study, both male and female fish from Malewa sampling station showed positive allometric growth with *b* values of 3.24 and 3.14, respectively. Similar results of 3.16 and 3.23 for males and females *C. gariepinus* were recorded by Dadebo *et al*., (2011) in Lake Chamo, Ethiopia. Willoughby and Tweddle, (1978) and Bruton, (1979) also reported similar length-weight regression coefficients. However, the researchers reported regression coefficients for both sexes combined. The positive allometric growth values also indicate homogeneity of fish groups in their populations. The length-weight values for combined sexes for all sampling stations obtained during the study showed negative allometric growth pattern with *b* value of 2.84. A similar study by Anyanwu *et al*., (2007), on *C. gariepinus*, found length-weight value of 1.87 for combined sexes, which is much smaller than the present study. Negative allometric growth indicates the fish becomes more slender as it increase in weight. However, similar study by Keyombe *et al*., (2015) working on *C. gariepinus* in Lake Naivasha, and Britton and Harper, (2006) in Lake Baringo obtained *b* value of 3.24 for combined sexes, indicating positive allometric growth, which disagrees with results of this study. This could be due to difference in sample size and spatial variation in food availability among stations. Moreover, the differences in *b* values are often related to allocation of energy for the production of gametes, degree of stomach fullness, sex and preservation techniques (Hossain, 2010). The amount of energy allocation will also depend on intrinsic (genetic) and environmentally driven factors such as temperature and feeding.

5.8 Relative condition factor (Kn)

Relative condition factor is an index reflecting the effect of interactions between biotic and abiotic factors on the physiological condition of fishes (Blackwell *et al*., 2000). It shows the wellbeing of fish. The mean condition factor obtained in this study was greater than one (1) except at Crescent Island station which showed a value of less than one. These results indicate the health status and better ecological adaptation of *C. gariepinus* in Lake Naivasha. The good condition factor values could also be due to water quality parameters which were within optimum range for *C. gariepinus* during this study. The values in this study were higher than 0.58 and 0.53 for male and female *C. gariepinus* reported by Keyombe *et al*., (2015) in Lake Naivasha. This could be due to differences in sample sizes and sampling stations. Thus, the previous work was based on 139 individuals of *C. gariepinus* collected from Oserian Bay and Crescent Island, whereas this study is based on 400 individuals collected from four sampling stations. Studies by Offem *et al*., (2008) and Dadebo *et al*., (2011) reported, 0.35 - 0.34 and 0.72 - 0.99 for female and male *C. gariepinus* which are smaller than the present study. This could be due to the fact fish condition factor (K) is influenced by a number of factors such as stress, sex, season, maturity stage, availability of food and water quality parameters (Khallaf *et al*., 2003; Davies *et al*., 2013). The relative condition factor values of the male and female fish were not significantly different in the present study. This might be attributed to either the small number of mature females among sampling sites or selectivity of the fishing gear. However, the value shows significant variations between sexes at Oserian Bay station. The reason could be due to the difference in availability and abundance of food items between sampling stations. Similar results were recorded by Anyanwu *et al*., (2007) and Hossain, (2010). A study by Hossain, *et al.*, (2012), concluded that condition of the fishes is generally affected by season and highly related with gonad development. However, short time data were used in the present study thus, it is therefore difficult to compare the condition of fishes throughout the year.

5.9 Sex ratio

The overall sex ratio of *C. gariepinus* in this study was significantly different from the expected 1:1 as the sample was dominated by males. This could be due to the difference in growth rates of both sexes. Offem *et al.,* (2008) working in the Cross River, Nigeria and Dadebo *et al*., (2011) working in Lake Chamo, Ethiopia reported faster growth of males than females. This leads in capture of higher percentage of males than females. The faster growth of males might be as a result of use of all the food for growth only. The slower growth of females could be due to more energy allocation for reproduction than growth (Willoughby and Tweddle, 1978). Bruton, (1979) pointed out that in African water bodies, it is common that the males dominate fish population due to their faster growth.

CHAPTER SIX
CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study found out that *C. gariepinus* is a generalist and has an opportunistic feeding behaviour ingesting a variety of food organisms ranging from phytoplankton to fish. This indicates that the species can easily establish in the lake. Spatial variation in feeding habit of *C. gariepinus* was observed. Fecundity studies showed wide variations in the number of eggs among different size classes of the fish. Smaller size at first maturity was exhibited by female *C. gariepinus*. Both male and female fish showed isometric growth pattern. Generally, catfish in Lake Naivasha are in good condition and its population is dominated by males. Insignificant correlations between some limnological parameters with fish morphometrics obtained during this study revealed tolerant nature of *C. gariepinus* which survive in extremely poorer conditions than any other fish species. This is the first study that provides baseline information on the feeding pattern, sex ratio, length at first maturity and fecundity of *C. garepinus,* and the first record of variability in spatial feeding regime among four sampling stations in Lake Naivasha.

6.2 Recommendations

The feeding habit analysed during this study was based on data obtained for short period of time. Due to the fact that catfishes are generalist feeders, the diet changes with seasonal changes in food availability. So this study recommends studies on feeding pattern to be carried out to investigate temporal variability and diel feeding rhythm. Also from the studies, all the fish samples caught were collected during night. Therefore it would be important to carry out more studies to investigate the diel feeding rhythm. Use of histological procedures would also be important for better estimation of fecundity. Awareness creation among local fishermen is necessary to avoid destructive fishing thus, helping juvenile fishes to grow and mature.

REFERENCES

Abera, L., Getahun, A., & Lemma, B. 2014. Composition of Commercially important Fish Species and some perspectives into the Biology of African catfish *Clarias gariepinus (*Burchell), Lake Zeway, Ethiopia. *International Journal of Advanced Research*, **2**(1), 864-871.

Abidjan, B. P., & Ivoire, C. 2014. Reproductive Strategies of the Catfish *Clarias buettikofer*i (Pisces, Clariidae) in the Tanoe-Ehy Swamp Forest (South-Eastern Côted’ Ivoire). *World Journal of Fish and Marine Sciences,* **6**(1) 16–23.

Admassu, D., Abera, L., & Tadesse, Z. 2015. The food and feeding habits of the African catfish, *Clarias gariepinus* (Burchell), in Lake Babogaya, Ethiopia. *Global Journal of Fisheries and Aquaculture,* **3**(4), 211–220.

Aloo, P.A., Oyugi, D.O., Morara, G. N., & Owuor, M. A. 2013. Recent changes in fish communities of the equatorial Lake Naivasha, Kenya. *International Journal of Fisheries and Aquaculture*, **5**(4), 45–54.

Armbruster, J. W. 2011. Global catfish biodiversity. In P. H. Michaletz and V. H. Travnichek, (eds). Conservation, ecology, and management of catfish: the second American Fisheries Society, Symposium 77, Bethesda, Maryland, pp 15-37.

Awange, J. L., Forootan, E., Kusche, J., Kiema, J. B. K., Omondi, P. A., Heck, B., & Gonçalves, R. M. 2013. Understanding the decline of water storage across the Ramser-Lake Naivasha using satellite-based methods. *Advances in Water Resources*, **60,** 7–23.

Anyanwu, P.E., Okoro, B.C., Anyanwu, A.O., Matanmi, M.A., & Ebonwu, B.I. 2007. Length-Weight Relationship, Condition factor and Sex Ratio of African Mud catfish (Clarias gariepinus) Reared in Indoor Water Circulation System Tanks. *Research Journal of Biological Sciences,* **2**(7*),* 780-783.

Ballot, A., Kotut, K., Novelo, E., & Krienitz. 2009. Changes of phytoplankton communities in Lakes Naivasha and Oloidien, examples of degradation and salinization of lakes in the Kenyan Rift Valley. *Hydrobiologia,* **632**,359–363.

Bagenal, T.B., & Tesch, F.W. 1978. Age and growth. In: Methods for assessment of fish production in fresh waters. In Bagenal, T (ed.). IBP Handbook No. 3. Blackwell Scientific Publications, London, pp 101-136.

Bagenal, T.B. & Braum, E. 1978. Eggs and early life history. In: Methods for assessment of fish production in fresh waters. In Bagenal, T (ed.). IBP Handbook No.3. Blackwell Scientific Publications, London, pp 165-201.

Bhatnagar, A., & Devi, P. 2013. Water quality guidelines for the management of pond fish culture. *International Journal of Environmental Sciences,* ISSN **3**(6), 0976 – 4402.

Blackwell, B. G., Brown, M. L., & Willis, D.W. 2000. Relative Weight (Wr): Status and current use in fisheries assessment and management. *Reviews in Fisheries Science,* **8**(1), 1-44.

Blažek, R., Polačik, M. & Reichard, M. 2013. Rapid growth, early maturation and short generation time in African annual fishes. *Evolutionary Developmental Journal*, **1**, 4 -24.

Bone, Q., Marshall, N.B. & Blaxter, J.H.S. 1996. Biology of fishes (second edition). Chapman and Hall, London, pp 332.

Boyd, C.E & Gross, A. 2000. Water use and conservation for inland aquaculture ponds. Fisheries Management and Ecology, pp 55-63.

Brewster, J. R. 2007. Trophic Relations of Introduced Flathead Catfish in a North Carolina Piedmont River. Retrieved October 19, 2015. http://repositor.edu/ir/bit stream/1840.16/70/1/etd pdf, pp 1-73.

Britton, J.R., & Harper, D.M. 2006, Length–weight relationships of fish species in the freshwater rift valley lakes of Kenya. *Journal of Applied Ichthyology,* **22**, 334-336.

Bruton, M.N. 1979. The breeding biology and early development of the catfish (C*larias gariepinus*) in Lake Sibaya, South Africa with a review of breeding in species of the sub genius Clarias (Pisces: Claridae). *Journal of Transdisciplinary Environmental Studies*. **35,** 1-45.

Buentello, J.A., Gatlin III, D.M., Neill, & W.H. 2000. Effects of water temperature and dissolved oxygen on daily feed consumption, feed utilization and growth of channel catfish *(Ictalurus punctatus*). *Aquaculture,* **182,** 339–352.

Cambray J. A. 2003. The need for research and monitoring on the impacts of translocated sharp tooth catfish, *Clarias gariepinus*, in South Africa. *African Journal of Aquatic Sciences*, **28(**2**),** 191–195.

Canthanhede, G. S., Fugi, R. & Hahn, N. S. 2009. Variation in prey selection of a piscivorous fish after the impoundment of a Neotropical reservoir: prey size and type. *Journal of Fish Biology,* **75**, 75–86.

Carrillo, M., Zanuy, S., Oyen, F., Cerda, J., Navas, J.M. & Ramos, J. 2000. Some criteria of the quality of the progeny as indicators of physiological brood stock fitness. Cahiers Options Mediterraneennes: Recent advances in Mediterranean Aquaculture. Finfish Diversification, **47**, 61-73.

Clark, W. G. 1991. Groundfish exploitation rates based on life history parameters. *Canadian Journal of Fishery and Aquatic Sciences*, **48,** 734-750.

Clay, D. 1979. Population biology, growth and feeding of African catfish (*Clarias gariepinus*) with special reference to juveniles and their importance in fish culture. *Archiv fur Hydrobiologie*, **87**, 453-482.

Dadebo, E. 2000. Reproductive biology and feeding habits of the catfish *Clarias gariepinus* (Burchell) (Pisces: Clariidae) in Lake Awassa, Ethiopia. *SINET: Ethiopian Journal of Science*, **23**(2), 231-246.

Dadebo, E. 2009. Filter-Feeding Habit of the African Catfish *Clarias gariepinus* Burchell, 1822 (Pisces: Clariidae) in Lake Chamo, Ethiopia. *Ethiopian Journal of Biological Sciences,* **8**(1), 15–30.

Dadebo, E., Gebre-mariam, Z., & Mengistou, S. 2011. Breeding season, maturation, fecundity and condition factor of the african catfish, *clarias gariepinus* burchell 1822 (pisces: clariidae) in Lake Chamo, Ethiopia . *SINET: Ethiopian Journal of Biological Sciences,* **10**(1), 1-17.

Davies, O. A., Tawari, C. C., & Kwen, K. 2013. Length – Weight Relationship, Condition Factor and Sex Ratio of *Clarias gariepinus* Juveniles Reared in Concrete Tanks, Nigeria. *International Journal of Scientific Research in Environmental Sciences*, (**1**)11, 324–329.

FAO, 2006. Aquaculture Production in Tanzania, *FAO Fishery Statistics, on Aquaculture production 2006.*

FAO, 2012. Cultured Aquatic Species Information Programme. *Clarias gariepinus*. Cultured Aquatic Species Information Programme. Text by Rakocy, J. E. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 18 February 2005. [Cited 11 September 2012]

Ferraris, C. J. 2007. Checklist of catfishes, recent and fossil (Osteichthys: Siluriformes), and catalogue of siluriform primary types. *Zootaxa*, **1418**, 1–628.

Fernando, C.H. (ed). 2002. A guide to Tropical Freshwater Zooplankton. Identification, Ecology and Impact on Fisheries. Miscellaneous Groups. Chap. **6**: 235-251.

Fuller, P. L., Nico, L. G., & Williams, J. D. 1999. Non-indigenous fishes introduced into inland waters of the United States. American Fisheries Society, Special Publication 27, Bethesda, Maryland.

Furhan, I., Ali, M., Salam, A., Khan, B.A., Ahmad, S., Qamar, M., & Kashif, U.2004. Seasonal Variations of Physico Chemical Characteristics of River Soan Water at Dhoak Pathan Bridge (Chakwal), Pakistan. *International Journal Agriculture & Biology*, **1**, 89-92.

Gaudet, J.J., & Melack, J. M. 1981. Major ion chemistry in a tropical African lake basin. *Freshwater Biology,* **11(**4)**,** 309-333.

German, D. P. 2009. Inside the guts of the wood-eating catfishes: can they digest wood? *Journal of Comparative Physiology*, **179**, 1011–1023.

Goswami, C.S. 2004. Zooplankton Methodology, Collection and Identification: A field manual. National Institute of Oceanography, Dona Paula, Goa, pp 26.

Goulding, M. J. 1980. The fishes and the forest: explorations in Amazonian natural history. University of California Press, Berkeley and Los Angeles, pp 1-367.

Guier, R. C., Nichols, L. E. & Rachels, R. T. 1984. Biological investigation of flathead catfish in the Cape Fear River. Proceedings of the Annual Conference South eastern Association of Fish and Wildlife Agencies, **35**, 607–621.

Harper, D.M. 1992. The ecological relationships of aquatic plants at Lake Naivasha, Kenya. *Hydrobiologia*, **232(**1), 65-71.

Harper, D. & Mavuti, K. 2004. Lake Naivasha, Kenya: ecohydrology to guide the management of a tropical protected area. *Ecohydrology and Hydrobiology,* **4**, 287–305.

Harper, D.M., Morrison, E.H.J., Macharia, M.M., Mavuti, K.M. & Upton, C. 2011. Lake Naivasha, Kenya: ecology, society and future. *Freshwater Reviews*, **4**, 89-114.

Hickley, P., North, R., Muchiri, S., & Harper, D. 1994. The diet of largemouth bass, *Micropterus salmoides*, in Lake Naivasha, Kenya. *Journal of Fish Biology,* **44,** 607-619.

Hickley, P., Bailey, R., Harper, D.M., Kundu, R., Muchiri, M., North, R., & Taylor, A. 2002. The status and future of the Lake Naivasha fishery, Kenya. 2002. Hydrobiologia, **488**, 181-190.

Hickley, P., Muchiri, M., Britton, R., & Boar, R. 2008. Economic Gain versus Ecological Damage from the Introduction of Non-native Freshwater Fish : Case Studies from Kenya. *The Open Fish Science Journal,* **1**, 36–46.

Hickley, P., Britton. R., Macharia, S., Muchiri, M., & Boar, R. 2015. The introduced species fishery of Lake Naivasha, Kenya: ecological impact vs socio-economic benefits. *Fisheries Management and Ecology*, **22,** 326–336.

Hildrew, A.G., Raffaelli, D.R., & Edmonds, B.R. 2007. Body size: the structure and function of aquatic ecosystems. Cambridge University Press, Cambridge, pp 343.

Hirpo, L. A. 2013. Reproductive biology of *Oreochromis niloticus* in Lake Beseka, Ethiopia. *Journal of Cell and Animal Biology*, **7**(9), 116-120.

Hynes, H. B. N. 1950. The Food of Fresh-Water Sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), With a Review of Methods Used in Studies of the Food of Fishes. *Journal of Animal Ecology*, **19** (1), 36-38.

Hogan, Z. S. 2011. Ecology and conservation of large-bodied freshwater catfish: A global perspective. American Fisheries Society Symposium, **77,** 39–53.

Hossain, M. Y. 2010. Length–weight, length–length relationships and condition factor of three Schibid catfishes from the Padma River, North western Bangladesh. *Asian Fisheries Science*, **23**, 329–339.

Hossain, M. Y., Jewel, M. A. S., Nahar, L., Mosaddequr, R., Naif, A., & Ohtomi, J. 2012. Gonadosomatic index-based size at first sexual maturity of the catfish *Eutropiichthys vacha* (Hamilton, 1822) in the Ganges River (NW Bangladesh). *Journal of Applied Ichthyology,* **28**, 601-605.

Hubble, D.S., & Harper, D.M. 2002. Phytoplankton community structure and succession in the water column of Lake Naivasha, Kenya: a shallow trophical lake. *Hydrobiologia,* **488**, 89-98.

Hunter, J.R., Lo, N.C.H & Leong, R.J.H. 1985. Batch fecundity in multiple spawning fishes. *In*: An egg production methods in estimating spawning biomass of pelagic fish: Application to the Northern anchovy, *Englauris mordax.* R. Lasker (ed.). *United States Department of Communication*. NOAA *Technical Representative,* **36**, 79-93

Hunter, J.R., Maciewicz, B.J., Lo, N.C.H. & Kimbrell, C.A. 1992. Fecundity, spawning, and maturity of female Dover sole, *Microstomus pacificus*, with an evaluation of assumptions and precision. Fisheries Bulletin U.S., **90**, 101-128.

Irwin, E. R., Hubert, W. A., Rabeni, C. F., Schramm, H. L., & T. CoonJr., (eds). 1999. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Jackson, D. C. 1999. Flathead catfish: biology, fisheries, and management. in E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., & T. Coon(eds). Catfish 2000: proceedings of the international ictlurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland, pp 23-36.

Kahilainen, K. & Lehtonen, H. 2003. Piscivory and prey selection of four predator species in a white fish dominated subarctic lake. *Journal of Fish Biology,* **63**,659–672.

Kane, S., Qarri, F., Lazo, P., & Bekteshi, L. 2001. The effect of physico-chemical parameters and nutrients on fish growth in Narta Lagoon, Albania. *Journal of Hygienic Engineering and Design*, UDC 639.32(496.5).

Kapoor, B.G. & Khanna, B. 2004. Ichthyology handbook. Springer-Verlag, Berlin, pp 57-108.

Karna, S.K., Sahoo, D., Panda, S., Vihar,V., Bhaban, M., & Nagar, S. 2012. Length Weight Relationship (LWR), Growth estimation and Length at maturity of *Etroplus suratensis*in in Chilika Lagoon, Orissa, India. *International Journal of Environmental Sciences,* **2**(3)**,** 1257–1267.

Keller, D. H. 2011. Population characteristics of white catfish and channel catfish in the Delaware River estuary in P. H. Michaletz & V. H. Travnichek (eds). Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland, pp 423–436.

Keyombe, J. L., Waithaka, E., & Obegi, B. 2015. Length – weight relationship and condition factor of *Clarias gariepinus* in Lake Naivasha, Kenya. *International Journal of Fisheries and Aquatic Studies,* **2**(6*),* 382–385.

Khan, U., Hasan, Z., Inayatullah, M., & Jan, A. 2013. Analysis of stomach contents of fresh water catfish, *Eutrophiichthys vacha* (Hamilton 1822) from Khyber Pakhtunkhwa Rivers, Pakistan. *Pakistan Journal of Zoology,* **45**, 1153-1156.

Khallaf, E., Galal, M., & Athuman, M. 2003. The biology of *Oreochromis niloticus* in a polluted canal. *Ecotoxicology*, **12**, 405-416.

Kitaka, N., Harper, D.M., & Mavuti, K.M. 2002. Phosphorus inputs to Lake Naivasha, Kenya, from its catchment and the trophic state of the lake. *Hydrobiologia,* **488**, 73-80.

Konan,Y.A., Kone, T., Mamba, M., & Kone, I. 2014. Reproductive Strategies of the Catfish *Clarias buettikoferi* (Pisces, Clariidae) in the Tanoe-Ehy Swamp Forest (South-Eastern Côte d'Ivoire). *World Journal of Fisheries and Marine Sciences,* **6**(1),16-23.

Kutikova, L. A. 2002. A guide to Tropical Freshwater Zooplankton. Identification, Ecology and Impact on fisheries. C.H. Fernando (ed) Backhuys publishers. Rotifera. Chap. **2**:23-67.

Kwak, T. J, Porath, M. T, Michaletz, P. H, & Travnichek, V. H. 2011. Catfish Science : Status and Trends in the 21st Century. Conservation, Ecology, and Management of Catfish*:* The Second International Symposium. American Fishery Society, **77,**755–780.

LeCren, E.D. 1951. The length-weight relationship and season cycle in gonad weight and condition in Perch *Perca fluviatilis. Journal of Animal Ecology,* **20**, 179-219.

Leonard, D. M., DeVries, D. R., & Wright, R. A. 2010. Investigating interactions between channel catfish and other sport fishes in small impoundments. *North American Journal of Fisheries Management,* **30**, 732–741.

Lizeth, B. 2001. Phytoplankton Identification catalogue. *Globsllast Monograph series* **7,** 1- 88.

Lowe-McConnell, R. H. 1959. Breeding behaviour patterns and ecological differences between Tilapia species and their significance for evolution within Tilapia (Pisces: Cichlidae). *Proceedings of the Zoological Society of London,* **32**, 1-30.

Lowe-McConnell, R.H. 1995. Ecological Studies in Tropical Fish Communities. Cambridge University Press, pp 241-278.

Lucifora, L. O., Valero, J. L., & Garcia, V. B. 1999. Length at maturity of the green-eye spurdog shark, *Squalus mitsukuii* (Elasmobranchii: Squalidae) from the SW Atlantic, with comparisons with other regions. *Marine and fresh water Research,* **50**,629–632.

Lung'ayia, H. B. O. 1994. Some Observations on the African Catfish *Clarias gariepinus (*Burchell) in the Sondu-Miriu River of Lake Victoria, Kenya. ICIPE SCIENCE, pp 105–114.

Matthews, W.J. 2012. Patterns in Freshwater Fish Ecology. Springer Science & Business Media, The university of Oklahoma, pp 423-475.

Mergeay, J., Verschuren, D., Kerckhoven, L.V., & Meester, L.D. 2004. Two hundred years of a diverse Daphnia community in Lake Naivasha (Kenya): effects of natural and human-induced environmental changes. *Freshwater Biology,* **49**, 998-1013.

Michaletz, P. H., & Travnichek, V.H. 2011. Assessing channel catfish stocking rates with simple growth increment indices. American Fisheries Society, Symposium 77, Bethesda, Maryland, pp 589–598.

Mironga, J.M., Mathooko, J.M., & Onywere, S.M. 2014. Effects of spreading patterns of water hyacinth (Eichhornia crassipes) on zooplankton population in Lake Naivasha, Kenya. *International Journal of Development and Sustainability,* **3**(10*)*, 1971-1987.

Moutopoulos, D.K., & Stergiou, K.I. 2002. Length- weight and Length-Length relationship of fish species from Aegean Sea (Greece). *Journal of Applied Ichthyology,* **18(**3**),** 200-203.

Muchlisin, Z.A., 2014. A General Overview on Some Aspects of Fish Reproduction. Syiah Kuala University, Banda Aceh, Indonesia. *Aceh International Journal of Science and Technology,* **3**(1), 43-52.

Murua, H., Kraus, G., Saborido-Rey, F., Wittames, P. R., Thorsen, A., & Junquera, S. 2003. Procedures to Estimate Fecundity of Wild Collected Marine Fish in Relation to Fish Reproductive Strategy. *Journal of Northwest Atlantic Fishery Science*, **33**, 33–54.

Ndungu, J., Augustijn, D. C. M., Hulscher, S. J. M. H., Kitaka, N., & Mathooko, J. 2013. Spatio-temporal variations in the trophic status of Lake Naivasha, Kenya. *Lakes and Reseviours: Research and Management*, **18**, 317-328.

Njiru, J., Morara, G., Waithaka, E., & Mugo, J. 2015. Fish kills in Lake Naivasha, Kenya : What was the probable cause ? *International Journal of Fisheries and Aquatic Studies,* **3**(1), 179–184.

Nyamweya, C. S., Mlewa, C. M., Ngugi, C. C., & Kaunda-Arara, B. 2010. Validation of daily growth of African catfish *Clarias gariepinus* (Burchell 1822) young-of-the-year from Lake Baringo, Kenya. *Lakes and Reservoirs: Research and Management*, **15**, 341–345.

Offem, B.O., Ayotunde, E.O., & Ikpi, G.U. 2008. Dynamics in the Reproductive Biology of H*eterobranchus longifilis Val*, (Pisces: 1840) in the Inland Wetlands of Cross River, Nigeria. *Journal of Fisheries and Hydrobiology,* **56**(4), 1785-1799.

Omondi, R., Yasindi, A.W., & Magana, A.M. 2013. Food and feeding habits of three main fish species in Lake Baringo, Kenya. *Journal of Ecology and The Natural Environment,* **5**(9), 24–230.

Owiti, D.O. & Dadzie, S. 1989. Maturity, fecundity and the effect of reduced rainfall on the spawning rhythm of a siluroid catfish, *Clarias mossambicu*s (Peters). *Aquaculture and Fishery Management,* **20(**4**)**, 355-368.

Pine, W. E. 2003. Population ecology of introduced flathead catfish. Doctoral Dissertation. North Carolina State University, Raleigh.

Pine, W. E., Kwak, T. J., Waters, D. S & Rice, J. A. 2005. Diet selectivity of introduced flathead catfish in coastal rivers. Transactions of the American Fisheries Society, **134**, 901-909.

Pine, W. E., Kwak, T. J. & Rice, J. A. 2007. Modelling management scenarios and the effects of an introduced apex predator on a coastal riverine fish community. Transactions of the American Fisheries Society, **136**, 105–120.

Ponzoni, R.W. & Nguyen, N.H. (eds). 2008. Proceedings of a Workshop on the Development of a Genetic Improvement Program for African catfish *Clarias gariepinus*. WorldFish Center Conference Proceedings Number 1889. The World Fish Center, Penang, Malaysia, pp,130 .

Potts, W. M., Hecht, T. & Andrew, T. G. 2008. Does reservoir trophic status influence feeding and growth of the sharp tooth catfish, *Clarias gariepinus* Teleostei: Clariidae)? *African Journal of Aquatic Science,* **33**, 149–156.

Reynolds, J. D., Dulvy, N. K., Goodwin, N. B., & Hutchings, J. A. 2005. Biology of extinction risk in marine fishes. *Proceedings of Royal society of London*, **272**, 2337-2344.

Riedel, R., Caskey, L.M., Hurlbert, S.H. 2007. Length weight relations and growth rates of dominant fishes of the Salton Sea: implications for predation by fish -eating birds. *Lake and Reservoir Management*, **23**, 528-535.

Ricciardi, A. 2001. Facilitative interactions among aquatic invaders: is an “invasional meltdown” occurring in the Great Lakes? *Canadian Journal of Fisheries and Aquatic Sciences,* **12**, 2513-2525.

Saloom, M.E. & Duncan, R.S. 2005. Low dissolved oxygen levels reduce antipredator behaviours of the fresh water Clam *Corbicula fluminea*. *Freshwater Biology*, **50**(7), 1233-1238.

Schloesser, R. W., Fabrizio, M. C., Latour, R. J., Garman, G. C., Greenlee, B., Groves, M., & Gartland, J. 2011. Ecological role of blue catfish in Chesapeake Bay communities and implications for management in P. H. Michaletz & V. H. Travnichek, (eds). Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland, pp 369–382.

Shinkafi B.A., Argungu, L.A., & Akanbi, H.S. 2010. Food and Feeding Habits of Catfish (*Synodontis nigrita* Cuvier and Valenciennes) In River Rima, Sokoto, Nigeria. *Nigerian Journal of Basic and Applied Science,* **18**(2), 304-307.

Shinkafi, B.A. & Ipinjolu, J.K. 2012. Gonadosomatic Index, Fecundity and Egg Size of *Auchenoglanis occidentalis* (Cuvier and Valenciennes) in River Rima, North-Western Nigeria. *Nigerian Journal of Basic and Applied Science*, **20**(3), 217-224.

Sindt, A. R., Fischer, J. R., Quist, M. C., & Pierce, C. L. 2011 in P.H. Michaletz and V. H. Travnichek (eds). Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland, pp 335–347.

Skelton, P. 2001. A complete guide to the freshwater fishes of Southern Africa. Struik Publishers, Cape Town.

Solak, K., & Akyurt, U. 2001. Stomach contents of the catfish (*Clarias gariepinus* Burchell, 1822) in the River Asi, Turkey. *Turk Journal of Zoology*, **25**, 461–468.

Strauss, R.E. 1979. Reliability estimates for Ivlev's Electricity Index, the forage ratio, and a proposed linear index of food selection. *Transactions of the American Fisheries Society*, **108**, 344-352.

Tassaduqe, K., Ali, M., Salam, A., Latif, M. & Zahra, T., 2003. Study of the Seasonal Variations in the Physico Chemical and Biological Aspects of Indus River, Pakistan. *Pakistan Journal of Biological Sciences*, **6**(21), 1795-1803.

Takefumi, N. 2015. Ontogenic niche shifts matter in community ecology: a review and future perspectives. *The Society of Population Ecology*, **57**(2), 347-354.

Taylor, J.C & Miller, J.M. 2001. Physiological performance of juvenile southern flounder, *Paralichthys lethostigma* (Jordan and Gilbert, 1884), in chronic and episodic hypoxia. *Journal of Experimental Marine Biology and Ecology*, **258**, 195-214.

Thomas, M. E. 1985. Monitoring the effects of introduced flathead catfish on sport fish populations in the Altamaha River, Georgia. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies, **47**, 531–538.

Thorpe, J.E., Mangel, M., Metcalfe, N.B, & Huntingford, F.A. 1998. Modelling the proximate basis of salmonid life-history variation, with application to Atlantic salmon, *Salmo salar L*. *Evolutionary Ecology*, **12**, 581-599.

Timmons, M.B., James, M.E., Fred, W.W., Sreven, T.S. & Brian J. V. 2001. *Recirculating Aquaculture Systems*. NRAC publication No.01-002.

Turesson, H., Persson, A., & Bronmark, C. 2002. Prey size selection in piscivorous pikeperch (*Stizostedion lucioperca*) includes active prey choice. Ecology of Freshwater Fish, **11**, 223–233.

Tweddle, D., & Turner, J.L. 1977. Age, growth and natural mortality rates of some cichlid fishes of Lake Malawi. *Journal of Fish Biology*, **10**(4), 385-398.

Uku, J.N., & Mavuti, K.M. 1994. Comparative limnology, species diversity and biomass relationship of zooplankton and phytoplanktpn in five fresh water lakes in Kenya. *Hydrobiologia*, **272**(1-3), 251-258.

Van der Waal, B.C.W. 1998. Survival strategies of sharptooth catfish *Clarias gariepinus* in desiccating pans in the northern Kruger National Park. *Koedoe - African Protected Area Conservation and Science*, **41**, 131-138.

Wakil, U.B., Haruna, A. B., Mohammed, G. A., Ndirmbita, W.L., Bukar-Kolo, M.Y., & Kumai, M. U. 2014. Examinations of the stomach contents of two fish species (*Clarias gariepinus* and *Oreochromis niloticus*) in Lake Alau, North – Eastern Nigeria. *Agriculture, Forestry and Fisheries*, **3**(5), 405-40.

Wildhaber, M. L. 2011. The Neosho madtom and the multifaceted nature of population limiting factors in P. H. Michaletz &V. H. Travnichek (eds). Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland, pp 281–294.

Willoughby, N.G. & Tweddle, D. 1978. The ecology of the catfish *Clarias gariepinus* and *Clarias ngamensis in* the Shire Valley, Malawi. *Journal of Zoology*, **184**, 507-534.

Witty, L. 2004. Practical guide to identifying freshwater crustacean zooplankton. Retrieved October 28, 2015, from http://41.215.122.106/dspace/handle/0/5674, pp 1-48.

Wooton, J. R. 1990. Ecology of Teleost Fishes. *Chapman and Hall, New York*, pp 404.

Yalcin, S., Solak, K., & Akyrut, I. 2001. Certain Reproductive Characteristics of the Catfish (*Clarias gariepinus* Burchell, 1822) Living in the River Asi, Turkey. *Turk Journal of Zoology*, **25**, 453-460.

Yilmaz, E., Bozkurt, A., & Gökçek, K. 2006. Prey Selection by African Catfish *Clarias gariepinus* (Burchell, 1822) Larvae Fed Different Feeding Regimes. *Turk Journal of Zoology,* **30**, 59-66

Zacharia, P.U. 1974. Trophodynamics and Review of methods for Stomach Content Analysis of Fishes. Retrieved October 16, 2015, from http://purl.org/utwente/doi/10.3990/1.97890365370011–12, pp 9.