

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF BIOLOGY



**Some aspects of the biology of *Garra dembecha* [Pisces: Cyprinidae] and
Clarias gariepinus [Pisces: Clariidae] in Lake Hayq, Ethiopia**

A thesis submitted to the School of Graduate Studies, Addis
Ababa University in partial fulfillment of the requirements for the
degree of Master of Science in Biology (Fisheries and Aquatic
sciences)

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DECLARATION

I, the undersigned, hereby declare that this thesis is my original work and that all sources of material used for the thesis have been duly acknowledged.

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ABSTRACT

Sex-ratio, length-weight relationship, condition factor, food and feeding habits of *Garra dembecha* (n=580) and *Clarias gariepinus* (n=121) in Lake Hayq were studied from monthly samples collected by gillnets of various stretched mesh sizes (3, 5, 8, 10 and 12 cm) and long lines between January 2009 and June 2009. Length of *G. dembecha* ranged from 8 to 13.3 cm for females and from 8 to 14 cm for males. Length of *C. gariepinus* ranged from 25 to 77 cm for females and from 20.5 to 50 cm for males. Male to female ratio was in favor of males in the total sample of *G. dembecha* (1.33:1). Sex-ratio was significantly different from 1:1 in three of the six sampling months and also in the total sample. Female preponderance over males in the total sample of *C. gariepinus* (1.02:1) was observed. Sex-ratio was not significantly different from 1:1 in the total sample of *C. gariepinus*. The relationship between total length (range: 8-14 cm) and total weight (range: 6-45 gm) of *G. dembecha* was found to be curvilinear and statistically significant ($p < 0.05$). The slope b was 3.14 for males and 3.11 for females, which was in both cases not significantly different from the expected value of 3 (t-test, $p > 0.05$). Thus, growth of the fish was isometric. The corresponding equations were represented by: Males: $TW = 0.0038x TL^{3.144}$ and Females: $TW = 0.012x TL^{3.109}$. The relationship between total length (range: 20.5-77 cm) and total weight (range: 75-3500 gm) of *C. gariepinus* was found to be curvilinear and statistically significant ($p < 0.05$) and suggesting isometric growth. The slope b was 3.04 for males and 3.27 for females, which was not significantly different from the expected value of 3 (t-test, $p > 0.05$). The corresponding equations were

represented by: Males: $TW = 0.005x TL^{3.038}$ and Females: $TW = 0.002x TL^{3.274}$. Monthly FCF of *G. dembecha* in this study ranged from 0.8 to 1.73 for females, and from 0.82 to 1.84 for males. Mean $FCF \pm SE$ was found to be 1.25 ± 0.02 and 1.33 ± 0.01 for females and males, respectively, with an overall value of 1.30 ± 0.01 . Generally, males had larger FCF values than females. Monthly FCF of *C. gariepinus* in this study ranged from 0.50 to 1.15 for females, and from 0.48 to 1.10 for males. Mean $FCF \pm SE$ was 0.69 ± 0.02 and 0.67 ± 0.02 for females and males, respectively. The overall Mean $\pm SE$ FCF was 0.68 ± 0.02 . Generally females had larger FCF than males. Based on a total of 476 gut samples of *G. dembecha*, the fish was found to ingest a wide spectrum of food items, ranging from various types of phytoplankton to zooplankton, and to sand particles and detritus. The predominant food items, in terms of frequency of occurrence, were *Melosira*, *Tetraedron*, *Amphora*, *Nitzschia*, *Cymbella*, *Microcystis*, *Fragillaria*, *Cosmarium*, *Suririella*, *Navicula* and *Daphnia*. Numerically, *Nitzschia*, *Tetraedron*, *Cosmarium* and *Melosira* dominated the food of *G. dembecha*. The contribution of *Daphnia* was low. Moreover, the fish had ingested detritus, and sand grains. Stomach content samples (n=121) of *C. gariepinus* showed that *C. gariepinus* feeds on a variety of items of both plant and animal origin ranging from phytoplankton to zooplankton, to insects and fish. Macrophyte shoots and detritus were also among the most frequently found items. The predominant food items in terms of frequency of occurrence were crustaceans, followed by insects and fish. Numerically as well, crustaceans (98%) were the most important items followed by insects (0.028%) and fish (0.0045%). *Mesocyclops* were the most numerous genera in the diet of *C. gariepinus* (37%) followed by *Thermocyclops* (31%), *Daphnia* (14%) and *Cerodaphnia* (14%). Monthly variation, both in frequency of occurrence and numerical abundance, was also noted in the gut contents of *G. dembecha* over the period of investigation. Diatoms contributed the highest number in 4 of the 6 sampling months (January to April); while Cyanophyta (40%) in May and Chlorophyta (60%) in June contributed the highest number. Monthly variation among the major food groups was observed in *C. gariepinus* in the present study. Insects were encountered in greater number of stomachs in the months of January (57%), March (55.56%), April (75) and May (83.33) while Crustacea appeared more frequently in February (77.78%), March (55.56%) and June (77.78%). Fishes were absent entirely in April and June. All the size

groups of *C. gariepinus* ingested all the major food items. This suggests that *C. gariepinus*, at all sizes, is an indiscriminate feeder in Lake Hayq. However, the relative contribution of items of *C. gariepinus* varied with fish size. The contribution of insects decreased with increasing fish size, whereas the contribution of zooplankton increased with increasing size.

Key words: Condition factor, food and feeding habits, Lake Hayq, length-weight relationship, *G. dembecha*, *C. gariepinus*

1. INTRODUCTION

Studies on the biology of an organism provide important information about its ecology. Feeding behavior, reproduction, growth and mortality are the important aspects of the biology of an organism that are the subject of several researches.

Studies on the diet composition and natural feeding of fish are important for various reasons. First, these studies permit the identification of the trophic relationships present in aquatic ecosystems, identifying feeding composition, structure and stability of food webs (Post, 2000; Abdel-Aziz, 2007). Second, they constitute the basis for the development of successful fisheries management program (Oso and Fagbuaro, 2006). Third, these studies are important in community ecology because the use of resources by organisms has a major influence on population interactions within a community (Mequilla, and Campos, 2007). And Finally, data on different food items consumed by fish may eventually result in identification of stable food preferences and in creation of trophic models as a tool to understand complex ecosystems (Lopez-Peralta and Arcila, 2002).

Length-weight relationships also give information on the conditions and growth patterns of fish. It provides the health and general well being of a fish as related to its environment (Bagenal and Tesch, 1978; Reynold, 1968, cited in Olurin and Aderibigbe, 2006). The condition factor or simply the well being of fish, which is a derivative of the length-weight relationship, measures the corpulence of the fish. The condition factor varies between species and within the same species with sex, age and other variables. It is important for a number of reasons. For instance condition factor is employed to compare populations living under similar or different levels of food availability, density and climate (Demeke Admassu, 1990). It is also used in determining the timing and duration of gonadal development and of growth pattern (Demeke Admassu, 1990). The feeding activity of fishes over time could also affect their condition factor. It is, therefore, apparent that knowledge of the condition factor of fishes is a necessary prerequisite to demographic analysis of a fish population.

Food and feeding habits of fish in Ethiopia have been studied by a number of researchers (e.g. Getachew Tefera, 1987; 1993; Elias Dadebo, 1988; 2000; Demeke Admassu and Elias Dadebo, 1997; Demeke Admassu, 1998; Tesfaye Wudneh, 1998; Leul Teka, 2001;

Lemma Abera, 2007). These studies mainly focused on very few economically important species such as Nile tilapia, *Barbus spp.*, Nile perch, and the African catfish. These are small number of species compared to the 152 species (Abebe Getahun, 2007) which inhabit the 7334 Km² of lakes and 7185 km of rivers of Ethiopia (FAO, 2001). Research on the other species is limited only to the description of diversity in relation to the different lakes and rivers which they inhabit.

Research on small sized fish, which are not commercially important, has never received much attention. The only researches conducted were on the small barbs of Lake Tana (Eshete Dejen, 2003) and the genus *Garra* of the different rivers and lakes of Ethiopia (Krysanov and Golubstov, 1993 and Driessen, 2002; Stiassny and Abebe Getahun, 2007). Krysanov and Golubstov (1993) investigated the karyology of three Ethiopian species of the genus. Driessen (2002) studied the feeding potential based on the ecomorphological studies on *Garra* of Lake Tana. Apart from the above mentioned studies, detailed study on the biology of the genus *Garra* was conducted by Akewake Geremew (2007) who studied four species of the genus from Lake Tana.

One of the lakes in Ethiopia, where we find species of the genus, is Lake Hayq. There is little or no information available on the species composition and the biology of the genus in this lake. The other species of fish from this lake is the African catfish, *Clarias gariepinus*.

Relatively more researches have been conducted on the biology of *C. gariepinus* in Ethiopia due to its commercial importance. According to Abebe Getahun (2007) *C. gariepinus* is the fourth commercially important fish species next to *Oreochromis niloticus*, *Labeobarbus spp.*, and *Lates niloticus*. The existing literature on some aspects of the biology of the species include Elias Dadebo (1988; 2000), Tesfaye Wudneh (1998), Leul Teka (2001), and Lemma Abera (2007) in Lakes Awassa, Tana, Langano, and Babogaya respectively. The utilization of *C. gariepinus* from Lake Hayq is very low when compared to *Oreochromis niloticus*. Information on the biology of the species in the lake is lacking.

As established in the above paragraphs, information on aspects of the biology of *Garra* spp. and *C. gariiepinus* are scarce for Lake Hayq. Therefore, the present study is designed to generate crucial information on the food and feeding habit, length-weight relationship, condition factor and sex ratio of *C. gariiepinus* and *Garra* spp. for sustainable utilization, management and conservation of the species.

General objectives:

- To generate baseline information on some aspects of the biology of *Garra dembecha* and *Clarias gariiepinus* which are important for sustainable exploitation, management and conservation of the fish resource of Lake Hayq.

Specific objectives:

- To study sex ratio of *G. dembecha* and *C. gariiepinus*
- To assess the condition of *G. dembecha*. and *C. gariiepinus* by analyzing length weight relationship and condition factor.
- To determine the food and feeding habit of *G. dembecha*. and *C. gariiepinus*

The results from this study will provide basic information upon which rational exploitation and management of *G. dembecha* and *C. gariiepinus* fishery can be made.

2. LITERATURE REVIEW

2.1 *G. dembecha*.

G. dembecha is a member of the family Cyprinidae and is represented by 165 species (Fishbase, 2009), 17 being from Africa (Abebe Getahun, 2007). Species of the genus are distributed from Borneo, China and Southern Asia through the Middle East, Arabian Peninsula and East Africa to West Africa. Most *Garra spp.* occur in freshwaters, but one species *G. tibanica*, (Trewavas, 1941), later synonymized with *G. quadrimaculata*, was reported from brackish water (Akewake Geremew, 2007).

Most species of *Garra* occur in swift flowing rivers and mountain streams, where they adhere to the surface of the underwater gravel and rocky substrates mainly by the mental adhesive disc modified from the lower lip and also by horizontally extended paired fins. Most are nearly uniformly brownish to blackish, with sparse, insignificant markings. An unusually colorful species found in streams of the Rakhine State in Myanmar, with contrasting yellow and dark brown vertical bars was reported by Kullander and Fang (2004). *G. dembecha* is characterized by its deeper body, short and deep caudal peduncle, dark dorsal and ventral body, and by its very long gut.

The genus *Garra* has been reported from 16 countries of Africa (Abebe Getahun, 2000). Currently the Ichthyological provinces and sub-provinces in Africa where the presence of the genus was reported include Nilo-Sudan, the Upper and Lower Guinea, the Zaire, the Quanza, the East Coast and the Abyssinian provinces.

Among the 17 species of *Garra* recognized in Africa, 11 are found in Ethiopia, 7 being endemic to the different rivers and lakes of the country (Stiassny and Abebe Getahun, 2007). According to Stiassny and Abebe Getahun (2007) the Ethiopian species of the genus occupy a wide range of habitats, from severely degraded to pristine, at altitudes ranging from 1500 m to over 3000 m asl, in water temperatures ranging from 12°C to 32°C, and with pH values ranging from 6.1 to 8.9. The overall distribution of species in Ethiopia declines from north to south. This pattern is consistently followed by the distribution of *Garra* in which about 75 % of the species are found in the Abbay (including Lake Tana) and Tekezze basins, and rivers of the north-western highlands (Stiassny and Abebe Getahun, 2007).

The small size of the species of this genus is probably the reason for their little utilization. The only report of their use for human consumption in Ethiopia is from Dek, an island in Lake Tana. The other place where these fishes are eaten is India. Hora (1956 in Coad, 2006) described these fishes as oily.

Other importance of the species of *Garra* is in the aquarium fishery. *G. ceylonensis* (Sundrabaranthy *et al.*, 2005), *G. pingi pingi* (Anon, 2007 cited in Akewake Geremew 2007) and *G. cambodgiensis* (Pornsopin *et al.*, 2004) are among the recent additions to the aquarium fish trade. “Doctor Fish”, the name given to *G. rufa*, is used in Turkey to treat a disease known as psoriasis by feeding on plaques on skin, usually on feet.

Although the gut length of different species of *Garra* varies according to the dominant food type, they are generally omnivores. They feed on a wide variety of diet including attached algae, phytoplankton, zooplankton, detritus and insects (Driessen, 2002). Roberts (1990 in Akewake Geremew, 2007) also reported that *G. allostoma* in the Niger basin is an insectivore. The diet of *G. dembecha* in Lake Tana included 20 genera of cyanobacteria, diatoms, and green algae associated with detritus and silt suggesting their bottom feeding habit (Akewake Geremew, 2007). Food is typically scraped off the substrate with sharp, keratinized jaw margins, and then sucked into the mouth by alternating dilation and contraction of the buccopharynx (Stiassny and Abebe Getahun, 2007). *Garra* have no stomach and the oesophagus leads directly to the intestine, from which it is separated by a sphincter.

Only one report exists on the presence of sexual dimorphism in *Garra*. Coad (2006) reported the presence of prominent tuberculation in males of Iranian species. However, other researchers stated the absence of sexual dimorphism in Ethiopian and other African species (Krysanov and Golubstov, 1993; Stiassny and Abebe Getahun, 2007). According to Stiassny and Abebe Getahun (2007), 75% of the body can be occupied by the gonads when ripe. Ripe females carry between 400 and 1000 ovarian eggs (average diameter 1.77 mm; Abebe Getahun, 2000).

2.2 *Clarias gariepinus* (Burchell, 1822)

C. gariepinus (Burchell, 1822) is a widespread freshwater benthic species, found from Turkey, the Middle East, and throughout Africa (Spataru *et al.*, 1987). It inhabits natural lakes, impoundments, fish ponds, streams, and natural ponds in both shallow and deep waters. Eventhough some of these habitats are subject to seasonal drying, the species is capable of living there due to the presence of accessory breathing organs (de Graff, 1996).

Bruton (1978) found that *C. gariepinus* smaller than 200 mm inhabit well-vegetated inshore areas whereas larger catfish inhabit more open and deeper habitats. Clay (1979) reported that recruitment from the shallow inshore areas to offshore occurs between 150 to 220 mm. *C. gariepinus* is known for its high temperature preference. It was found that juvenile *C. gariepinus* prefer a temperature of 30-35 °C (Clay, 1979).

Clariid catfishes have emerged as one of the most important groups of farmed fish in the world. *C. gariepinus* has long been considered as one of the most suitable species for culture. This species is known for its high growth rate, resistance to handling and stress, relatively low requirements for water quality, amenability to high stocking densities, excellent meat quality and preference amongst consumers in many African countries ([Hecht *et al.*, 1996](#)). During the last two decades or so the species has been introduced to Europe, Asia and Latin America and has also been recognized as the most suitable one for aquaculture throughout its distributional range ([Hecht *et al.*, 1996](#)). Its global aquaculture production increased from 138 tones in the year 1985 to 47, 428 tones in 2007 (FAO, 2009). The capture fishery for the species has also increased from 14,886 tones in 1985 to 44,124 tones in 2007 (FAO, 2009).

Although most researchers accept *C. gariepinus* as an omnivore, there are people who doubt this assertion. Groenewald (1964), who compared *C. gariepinus* with rainbow trout, a true carnivore, suggested that the plant and detritus materials, which are frequently

found in the stomachs of specimens, are ingested by accident. He argued that the intestine of *C. gariepinus* is that of a typical carnivore. This assertion is supported by Spataru *et al.* (1987) and Elias Dadebo (1988). But Bruton (1978) and Willoughby and Tweddle (1978) argued that *C. gariepinus* is in fact an omnivore, as its various anatomical adaptations suggest. Both groups of researchers, however, agree on two points, that *C. gariepinus* is an opportunistic feeder; virtually eating anything (the presence of a small crocodile in one stomach of *C. gariepinus* was reported by Bell-Cross (1974 in Willoughby and Tweddle, 1978) and that it is a “clumsy” predator, as Groenewald (1964) puts it.

Bruton (1979) suggested that *C. gariepinus* is a euryphagic, an organism feeding on a wide variety of organisms according to their availability. Clay (1979) showed that *C. gariepinus* exclusively feeds on fish when they are abundantly available. This is also supported by Merron (1993) who showed that *C. gariepinus* engages in pack hunting which starts when the drawdown of annual flood levels result in numerous small sized fish species.

C. gariepinus has a remarkable array of anatomical adaptations that made it capable of an euryphagy. These adaptations allowed the species to feed on a wide variety of diet and size ranges from a minute zooplankton to a fish half its own size (Bruton, 1979). The diet of the species include small crustaceans, insects, mollusks, oligochaetes and other fish (Groenewald, 1964; Bruton, 1978 and 1979; Tesfaye Wudneh, 1998, Elias Dadebo, 2000). Fish, particularly tilapia, have been found to be important prey of *C. gariepinus* in some waters (Elias Dadebo, 1988 and 2000).

C. gariepinus has a wide, sub-terminal and transverse mouth which is capable of considerable vertical displacement for engulfing large prey or large volume of water during filter feeding. The teeth are numerous, small and backwardly directed. It has a wide, rounded caudal fin typical of fishes which ambush their prey. It has abundant sensory organs on the body, head, lips and barbules. The later adaptations made *C. gariepinus* to depend less on sight and allowed it to be a nocturnal feeder (Bruton, 1979).

Bruton (1979) noted 4 modes of feeding in *C. gariepinus*: foraging, shoveling, surface feeding and formation feeding (pack hunting) and pointed out that the first two are performed by individuals, the third by individuals or by groups, and the fourth by groups.

An ontogenic shift in feeding is evident in *C. gariepinus*. Importance of food items change according to the size of the fish (Bruton, 1979). Insects and crustaceans were found to be important food items for fish less than 20 cm. Crustaceans and fish are found much frequently in the length range of 20- 30 cm. Fish were found to be the most important food items for *C. gariepinus* larger than 30 cm (Bruton, 1979). This shift, however, is evident when there is abundant prey fish. When fish were less abundant, crustaceans were found to be important food items for larger fish whereas insects were found to be important for fish less than 30 cm (Bruton, 1979).

Sexual dimorphism is evident in *C. gariepinus*. The male and females of *C. gariepinus* can be easily recognized as the male has a distinct sexual papilla, located just behind the anus. This sexual papilla is absent in females (de Graaf *et al.*, 1995). *C. gariepinus* shows a seasonal gonadal maturation which is usually associated with the rainy season. The maturation processes of *C. gariepinus* are influenced by annual changes in water temperature and photoperiodicity, and the final triggering of spawning is caused by a rise in water level due to rainfall (de Graaf *et al.*, 1995).

There is no parental care for ensuring the survival of the catfish offspring except by the careful choice of a suitable site. Development of eggs and larvae is rapid and the larvae are capable of swimming within 48-72 hours after fertilization at 23-28 °C (de Graaf *et al.*, 1995).

3. DESCRIPTION OF THE STUDY AREA

Lake Hayq ($11^{\circ}15'N$; $39^{\circ} 57' E$), one of the highland lakes of Ethiopia, is located some 430 km north of Addis Ababa in the Amhara Regional State, South Wollo Administrative Zone at an altitude of 2030 m (Fig. 1). It is a crater lake with surface area and maximum depth of 22.8 km² and 81 m, respectively (Molla Demilie *et al.*, 2007). The lake is located in the northeastern highlands at the western margin of the Afar triangle. It has a closed drainage system within the watershed of the Awash River basin (Molla Demilie *et al.*, 2007). There is no surface exit and the river that flows into the lake is Anchercah River. It also receives water from some seasonal streams (Molla Demilie *et al.*, 2007). Some physico-chemical characteristics of the lake are given in Table 1.

The area is characterized by a sub-humid tropical climate with an average annual rainfall of 1167 mm and a mean annual temperature of around 18 °C. The rainfall in the area is bimodal. The major rainfall occurs during summer from July to September and the lowest from February to May (Fig. 2). The water becomes cold during January, February, July and November and it gets warm during April, May, August and September (Molla Demilie *et al.*, 2007). Data from the National Meteorological Agency of Ethiopia show that mean annual maximum air temperature of the area was above 24 °C and the mean annual minimum temperature was below 14 °C (Fig. 3).

Pankhurst (1967 in Baxter and Golobitsh, 1970) reported that the small volcanic hill on which the monastery of St. Istefanos Abuna Eyesus Moa is located was an island. Now the monastery is connected to the mainland by a narrow saddle. Morandini (1940 cited in Baxter and Golobitsh, 1970) measured a maximum depth of 88.8 m. Currently the maximum depth of the lake is 81 m (Molla Demilie *et al.*, 2007). This shows a lake level reduction of 7.8 m during the last 60 years.

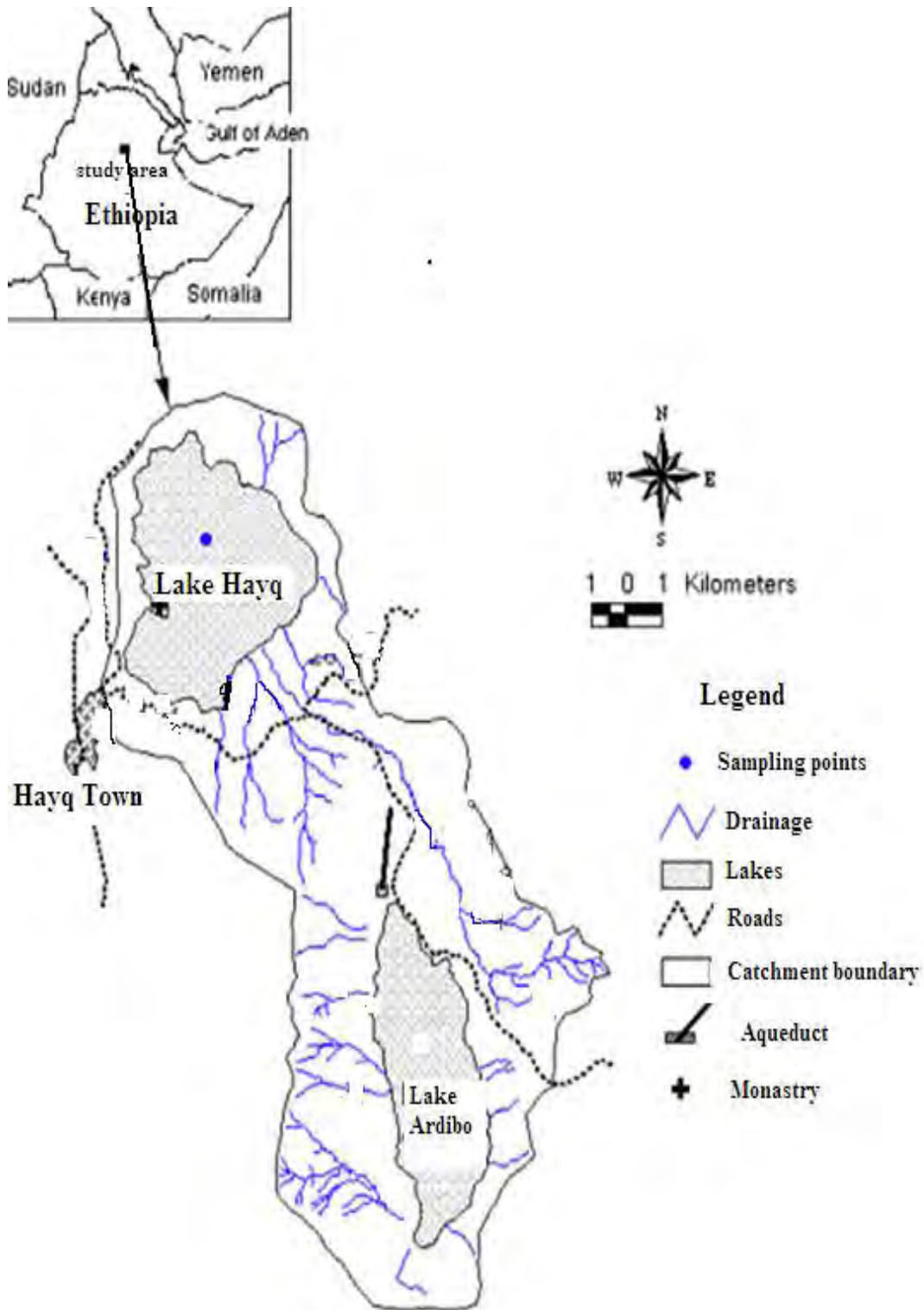


Figure 1. Map showing Lakes Hayq and Ardibo (adapted from Molla Demlie *et al.*, 2007). The sampling points are indicated by black dots.

Table1. Morphometry and limnological parameters of Lake Hayq (Baxter and Golobitsh 1970; Elizabeth Kebede *et al.*, 1992; Molla Demilie *et al.*, 2007, Tadese Fetahi unpublished data).

Parameter	Value
Max	
Length (north-south)	6.7 km
Max Width	6.0 m
Perimeter	21.7 km
Area	22.8 km ²
Max. depth	81 m
Mean depth	37.37 m
Volume	0.87 km ³
Average slope of basin	3 ⁰ 45 ¹
Secchi depth	1.24
Euphotic depth (Z_{eu})	4.85m
pH	9.1
Conductivity	900.6
Salinity	0.828 gL ⁻¹
Alkalinity	9.550 meqL ⁻¹
DO (mg/l)	3.84
DO (%)	53.39
Chlorophyll a	12.5-22.9 μ gl ⁻¹
Na ⁺	4.261 meqL ⁻¹
K ⁺	0.292 meqL ⁻¹
Ca ⁺	0.600 meqL ⁻¹
Mg ⁺	5.917 meqL ⁻¹
Cl ⁻	1.429 meqL ⁻¹
SO ₄ ⁻	0.063 meqL ⁻¹

The lake level was consistently declining starting from the mid 1970s (Molla Demilie *et al.*, 2007). This is attributed to the increased water diversion both from tributary streams and from the lake for local irrigation. However, starting from the late 1990s the level of the lake is consistently rising due to the sustained free flow of the Ardibo lake water through the newly constructed aqueduct into Lake Hayq (Molla Demilie *et al.*, 2007).

According to Baxter and Golobitsh (1970), chemical stratification was not pronounced, although there appeared to be some accumulation of silica, phosphate, and ammonia in the depths. The predominant cation (in terms of equivalents) is Magnesium and Calcium (Molla Demilie *et al.*, 2007). The predominance of magnesium and calcium is partly related to the geology of the area, which is characterized by basic Volcanics, mainly basalt (Molla Demilie *et al.*, 2007). The predominant anions are carbonate and bicarbonate, as in almost all Eastern African lake waters (Baxter and Golobitsh, 1970). Generally, the total dissolved solid (TDS) in the lake is below 790 mg^l⁻¹ which is lower by the standard of closed crater lakes in the Ethiopian rift and escarpment; often with very high ionic concentrations (Molla Demilie *et al.*, 2007). Baxter and Golobitsh (1970) reported that thermal stratification is similar to that in other Ethiopian lakes of comparable depth. The lake is also remarkable for the unusual clarity of its water (Baxter and Golobitsh, 1970).

As reported by Elizabeth Kebede *et al.* (1992) the phytoplankton community is composed of blue green algae (*Microcystis spp.*, *Merismopedia tenuissima*, *Chroococcus spp.*), diatoms (*Navicula spp.*, *Nitzschia spp.*, *Fragillaria spp.*) and green algae (*Tetraedon minimum*, *Chodatella subsala*, *Peridinium inconsoicuum*, *Coelastrum astrodeum*, *Oocystis spp.*). The dominant species are *Microcystis spp.* which constitute approximately 90% of the phytoplankton biomass. Zooplankton community of the lake is composed of Copepods, Cyclops and Cladocerans. The dominant species of rotifers in the lake is *Anuraepsis fissa* (Green and Seyoum Mengistou, 1991). Defaye (1988) reported that *Thermocyclops ethiopiensis* and *Mesocyclops aequatorialis*, cyclopoid copepods, live in Lake Hayq. Elizabeth Kebede *et al.* (1992) have identified ciliates of which *Halteria sp.*, *Cyclidium* and *Lagynophrya sp.* are the dominant members.

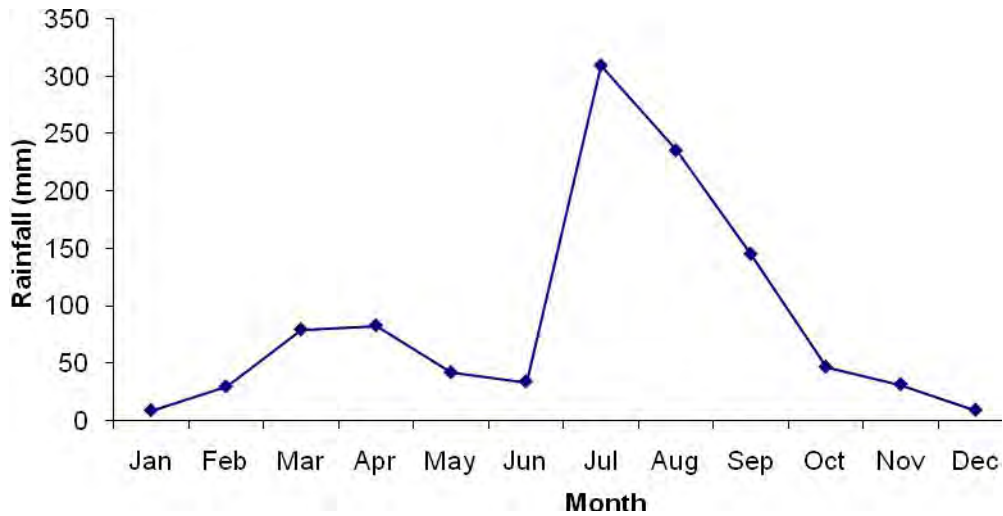


Figure 2. Mean monthly rainfall (mm) of Lake Hayq for the period 2006-2008 (Data from the National Meteorological Agency of Ethiopia).

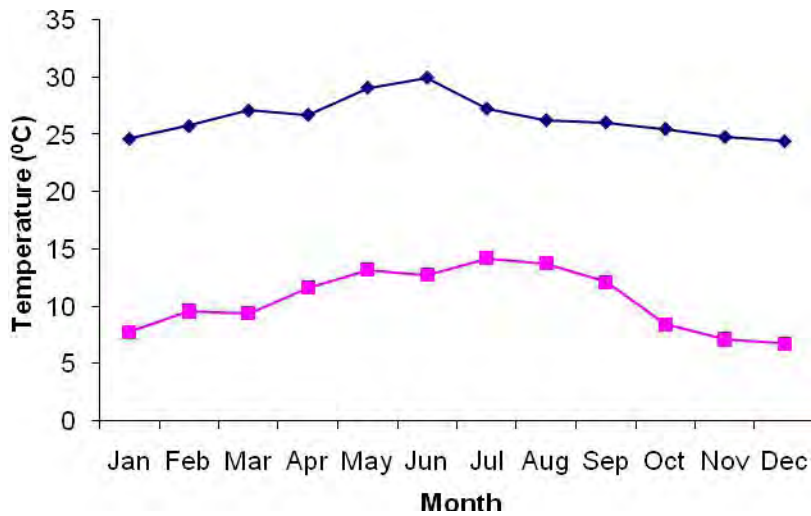


Figure 3. Mean maximum and mean minimum air temperature (°C) of Lake Hayq area for 2006-2008 (Data from the National Meteorological Agency of Ethiopia).

The fish fauna of Lake Hayq predominantly comprises *O. niloticus* which was introduced by the Ministry of Agriculture in 1978 (Elizabeth Kebede *et al.*, 1992). The original inhabitant of the lake was catfish, *C. gariepinus* (Baxter and Golobitsh, 1970). The other inhabitant of the lake is common carp *Cyprinus carpio* which was introduced into the lake, according to the local people, recently by flooding from a nearby lake, Lake Ardibo. This species has established itself in the lake and now, according to the local people, is increasing in number. *Garra spp.* are also found in the lake. We were able to determine one species of the genus, *G. dembecha*.

Mass fish kills have been reported from in Lake Hayq, which occurs in the months of May and December (Elizabeth Kebede *et al.*, 1992; Kebede Alemu, 1995). The authors have attributed the kill to cold weather and O₂ depletion.

The lake is threatened by a number of factors including overfishing, catchment degradation, encroachment, siltation and water withdrawal (Seyoum Mengistou, 2006). The road construction that is being undertaken currently is a source of concern among stake holders, as it resulted in the clearing of the surrounding vegetation and restructuring of the slopes surrounding the lake. This situation creates a favorable condition for soil erosion in the rainy season and the washed soil is dumped directly into the lake. The other threat associated with the road construction is the campsite built near the shore of the lake. It is possible that toxic substances could be dumped into the lake from this camp.

Water is withdrawn from the lake for various purposes including for irrigation of the farms surrounding the lake. Grazing of the macrophyte vegetation by cattle is also a problem, for it interferes with reproductive activity of fishes. Overfishing, a major problem in many lakes is also a problem in this lake. The local gears used by the fishermen selectively capture young fishes that are not reproductively mature (personal observation). This condition is feared to result in overfishing.

4. MATERIALS AND METHODS

4.1 Field sampling and measurement

Samples of *G. dembecha* and *C. gariepinus* were collected monthly between January 2009 and June 2009 using hook - and - line and gill nets of stretched mesh sizes 3, 5,8,10 and 12cm. Pieces of tilapia were used as bait for the hooks and nets were set parallel to the shoreline in the afternoon (about 05:00 pm) and lifted in the following morning (about 7: 00 am). In addition, *C. gariepinus* caught by fishermen were also sampled. Immediately after capture, total length (TL) and total weight (TW) of each specimen were measured to the nearest 0.1 cm and 1g, respectively. Each specimen was then dissected and its sex determined by inspecting the gonads. The stomach was checked if it contained any food. If it was empty, this was recorded, whereas stomachs with contents were preserved in 5% formaldehyde solution. As *G. dembecha* does not have a true stomach, the gut was removed and preserved in 5% formaldehyde solution. Preserved samples were then transported to the Department of Biology, Addis Ababa University for further laboratory analysis.

4.2 Estimation of sex-ratio

The number of female and male *C. gariepinus* and *G. dembecha* caught was recorded for each sampling occasion. Sex-ratio (male: female) was then calculated for each month, for different length classes and for the total sample. Chi-square test was employed to test if sex ratio varied from one - to – one in monthly samples, in various size classes and in the total sample.

4.3 Length - Weight relationship and Condition factor

4.3.1 Length - Weight relationship

Length-weight relationship of *C. gariepinus* and *G. dembecha* was calculated using least squares regression analysis as in Bagenal and Tesch (1978) separately for the sexes as follows:

$$TW = a * TL^b,$$

Where, TW = Total weight in grams,

TL = Total length in centimeters,

a and b = intercept and slope of the regression line, respectively.

4.3.2 Condition factor

The condition factor (well-being) of each fish was determined by computing Fulton condition factor as in Bagenal and Tesch (1978). The condition factor of individual fish was calculated and then monthly mean values were determined for each sex separately. Fulton condition factor was calculated as:

$$FCF = \frac{TW}{TL^3} * 100$$

Where, FCF = Fulton condition factor

TW = Total weight in grams

TL = Total length in centimeters

Significance of differences in length-weight relationships and of differences in condition factors of *C. gariepinus* and *G. dembecha* between sexes, sampling periods, and size groups were tested using ANOVA.

4.3 Food and feeding habit

4.3.1 Stomach content analysis (*C. gariepinus*)

Preserved stomach content of *C. gariepinus* was transferred into a petri dish. Larger food items were identified by eye whereas small-sized food items were microscopically examined using a WILD type stereoscope (magnification 6X to 50X), and each food item was identified to the lowest taxon possible using description, illustrations and keys in the literature (Macan, 1959, 1976; Borror and Delong, 1964; Harding and Smith, 1974; Edington and Hildrew, 1981; Defaye, 1988). In addition, smaller food items, such as phytoplankton, were examined at high magnifications (100X to 400X) under a compound inverted research microscope. After identification, a list of items found in the stomach was prepared, and each item counted whenever appropriate. Counting was performed using the whole stomach content for the majority of the samples. In some cases, however, counting was done from a sub-sample of 10 ml stomach content. All counts were converted to number per total volume of stomach content.

4.3.2 Gut content analysis (*G. dembecha*)

The composition of the content of the gut of *G. dembecha* was determined. Identification of the gut contents was made using wild type microscope at magnifications of 20X for zooplankton, and using an inverted microscope at high magnifications (100X to 400X) for phytoplankton to the lowest possible taxa using descriptions in the literature (Macan, 1959, 1976; Borror and Delong, 1964; Harding and Smith, 1974; Edington and Hildrew, 1981; Defaye, 1988).

4.3.3 Determination of relative importance of food items

The relative importance or contribution of each food item to the diet of *C. gariepinus* and *G. dembecha* was determined using the standard methods, i.e., the frequency of occurrence method and percent composition by number (the numerical analysis) (Hynes, 1950; Hyslop, 1980). Brief description of each method is given below:

a. Frequency of occurrence

The number of stomach samples in which one or more of a given type of food item was found was expressed as a percentage of all non-empty stomachs examined. This was considered as the proportion of the population that feeds on that particular food item.

b. Percent composition by number

The number of food items of a given food type that were found in all stomachs was recorded. The total numbers of individuals of each food item was then expressed as a percentage of the total number of all food items (Bagenal and Tesch, 1978). This estimated the relative abundance of that food item in the diet.

4.3.4 Estimation of fish- size and food habit relationship

To study whether there is ontogenetic shift in the food habit of *C. gariepinus*, results from each method were plotted against length of fish. Food items were grouped into major taxonomic groups for this purpose. Fish size and food habit relationship was not estimated for *G. dembecha* because of the very narrow size range of the sample.

4.3.5 Estimation of feeding periodicity

Seasonal difference in food habit of *C. gariepinus* and *G. dembecha* was studied from the frequency of empty stomachs, and also from results on relative contribution of major items as determined from frequency of occurrence and numerical abundance methods.

5. RESULTS

5.1 Size composition of the sample

A total of 580 (248 females and 332 males) specimens of *G. dembecha* were collected during the study. The total length of the fish ranged from 80 to 133 cm for females and from 80 to 140 mm for males. The corresponding total weight ranged from 6 to 29 grams for females, and from 6 to 45 grams for males.

As shown in [Figure 4](#), the greater proportion of the sampled female and male fish were 104 and 123 mm in length. The peak was between 114 and 123 mm for both sexes. This length group alone was about 42% for females and 55% for males in the total sample. Fish below 94 mm and over 134 mm TL were least represented in the sample (Fig.4).

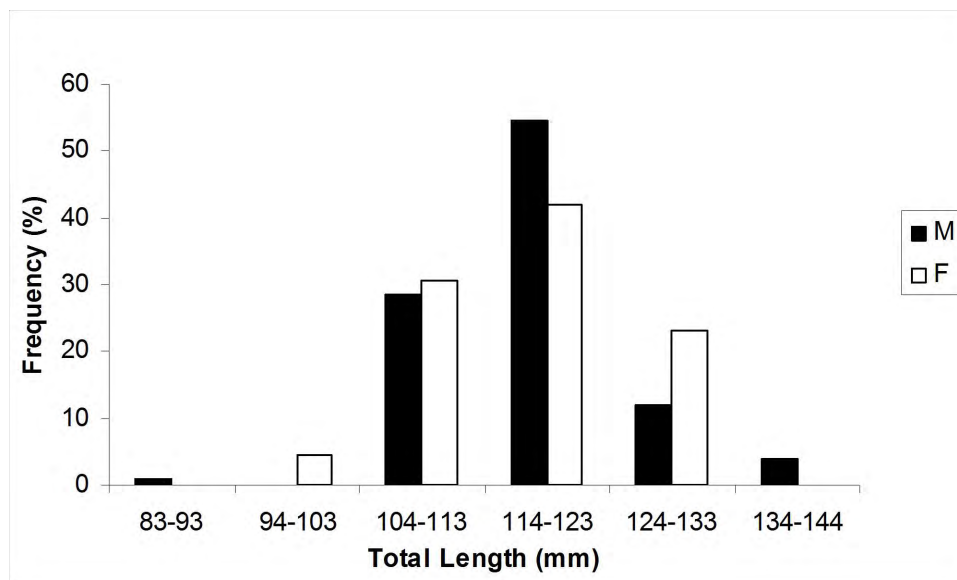


Figure 4. Length-frequency distribution of *G. dembecha* from Lake Hayq

A total of 121 (61 female and 60 male) specimens of *C. gariepinus* were collected during the study. The total length of the fish ranged from 25 to 77 cm for females and from 20.5 to 50 cm for males. The corresponding total weight ranged from 75 to 3500 grams for females and 75 to 825 grams for males.

The greater proportions of the sampled females were in the size class of 31-35 cm. For males the greater proportion of size was in the class 26-30 cm. These length groups alone were about 31% for females and 21.7% for males in the total sample. Fish over 50 cm TL were least represented in the sample whereas fish below 20 cm were not caught at all (Fig. 5).

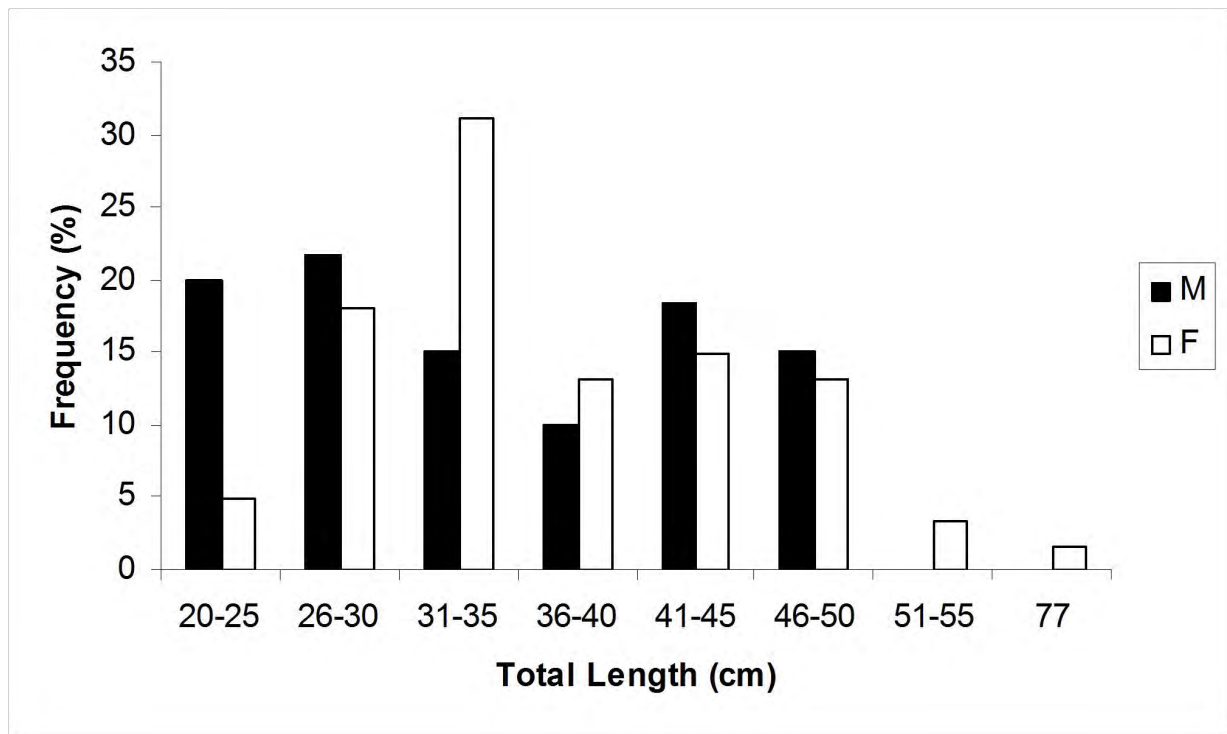


Figure 5. Length-frequency distribution of *C. gariepinus* from Lake Hayq

5.2 Sex ratio

Sex ratio results for *G. dembecha* are presented in Table 2. The ratio was significantly different from 1:1 (X^2 , $p < 0.05$) for three of the six sampling months. It was found that males outnumber females in all size classes except in the size class 124-133 mm (Table 3). Female preponderance over males was observed only in the June sample. The overall sex ratio (1.33:1) was significantly different from 1:1 showing a preponderance of males (Table 2).

Table 2. Monthly number of males and females and sex ratio (male: female) of *G. dembecha* in Lake Hayq (* = significant at 5% level).

Month	M	F	Ratio	X ²
January	48	47	1.02:1	0.092
February	60	51	1.18:1	2.70
March	95	41	2.31:1	23.4*
April	8	4	2.00:1	1.33
May	100	40	2.50:1	25.7*
June	21	65	0.32:1	22.5*
Total	332	248	1.33:1	12.1*

Table 3. Ratio of male and female *G. dembecha* by size class. (* = significant at 5% level).

Size class	M	F	Ratio	X ²
83-93	3	0		
94-103	0	11		
104-113	95	76	1.25:1	2.11
114-123	181	104	1.74:1	20.8*
124-133	40	57	0.70:1	2.97
134-140	13	0		

The present study showed that sex ratio of *C. gariepinus* was not significantly different from 1:1 (X^2 , $p>0.05$) for all sampling months (Table 4). Generally female preponderance was observed (1.02:1). Males outnumbered females in the size classes 20-25, 26-30, 41-45 and 46-50 while female preponderance was observed in the rest of the size classes (Table 5). Also female preponderance was observed in February, May and June, while males outnumbered females in March and April. Equal number of females and males were caught in January.

Table 4. Monthly number of males and females and sex ratio (male: female) of *C. gariepinus* in Lake Hayq.

Month	M	F	Ratio	X^2
January	17	17	1:01	0.00
February	11	14	0.79:1	0.36
March	12	4	3:01	2.00
April	7	5	1.4:1	0.33
May	9	12	0.75:1	0.43
June	4	9	0.44:1	1.92
Total	60	61	0.98:1	0.01

Table 5. Ratio of male and female *C. gariepinus* by size class. (* = significant at 5% level).

Size class	M	F	Ratio	X ²
20-25	12	3	4:01	5.40*
26-30	13	11	1.18:1	0.17
31-35	9	19	0.56:1	3.60
36-40	6	8	0.75:1	0.29
41-45	11	9	1.22:1	0.20
46-50	9	8	1.13:1	0.53
51-77	0	3		

5.3 Length - Weight relationship and condition factor

Length - Weight relationship

The Length-weight relationship of *G. dembecha* in Lake Hayq was computed separately for males and females and then for the combination of the sexes. Length-Weight relationship of *G. dembecha* was curvilinear and statistically highly significant (ANOVA, P<0.05). The equations separated by sex were as follows:

Males: $TW = 0.011x TL^{3.144}$, $R^2=0.901$, $n=332$

Females: $TW = 0.012x TL^{3.109}$, $R^2=0.867$, $n=248$

Comparison of the slope (b) of the two equations showed no significant difference between the sexes (t-test, p>0.05). Therefore, an equation combined for the sexes was fitted and shown in Figure 6. The equation was fitted for length range of 80 to 140 mm and weight range of 6 to 45 gm.

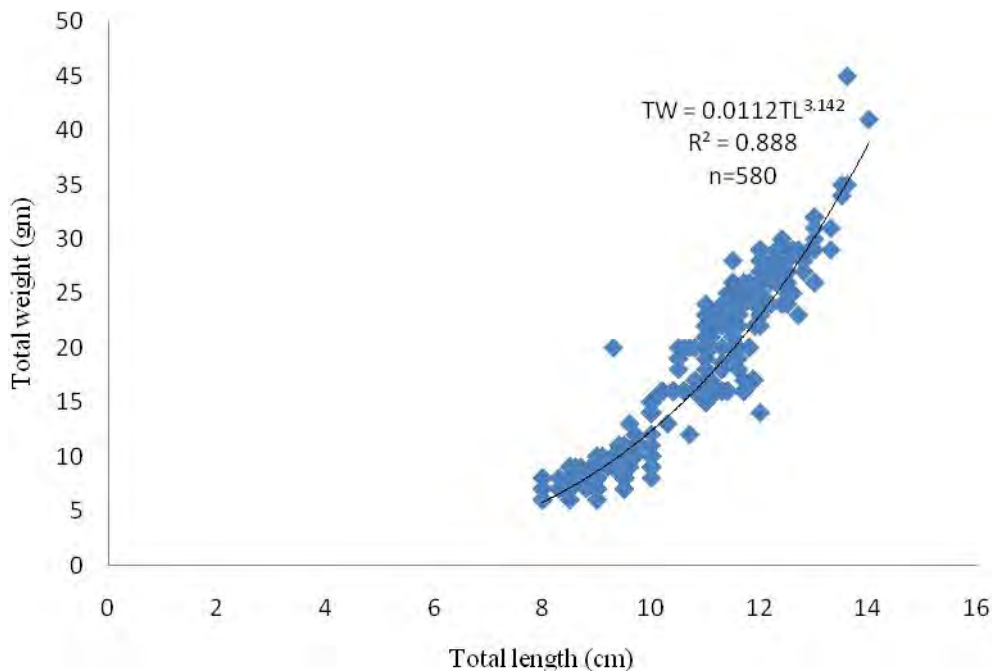


Figure 6. Length-weight relationship of *G. dembecha* in Lake Hayq.

As discussed above for *G. dembecha*, Length-Weight relationship for *C. gariëpinus* was computed separately for the sexes. Length-weight equations for females and males *C. gariëpinus* were as follows:

Males: $TW = 0.005x TL^{3.038}$, $R^2 = 0.946$, $n=60$

Females: $TW = 0.002x TL^{3.274}$, $R^2 = 0.948$, $n=61$

Length-Weight relationship of *C. gariëpinus* in Lake Hayq was found to be curvilinear and highly significant (ANOVA, $P < 0.05$). Comparison of the slope (b) of the above two equations showed no significant difference between the sexes (t-test, $P > 0.05$). Therefore, an equation combined for the sexes was fitted and shown in

Figure 7. The equation was fitted for length range of 20.5 to 77 mm and weight range of 75 to 3500 gm.

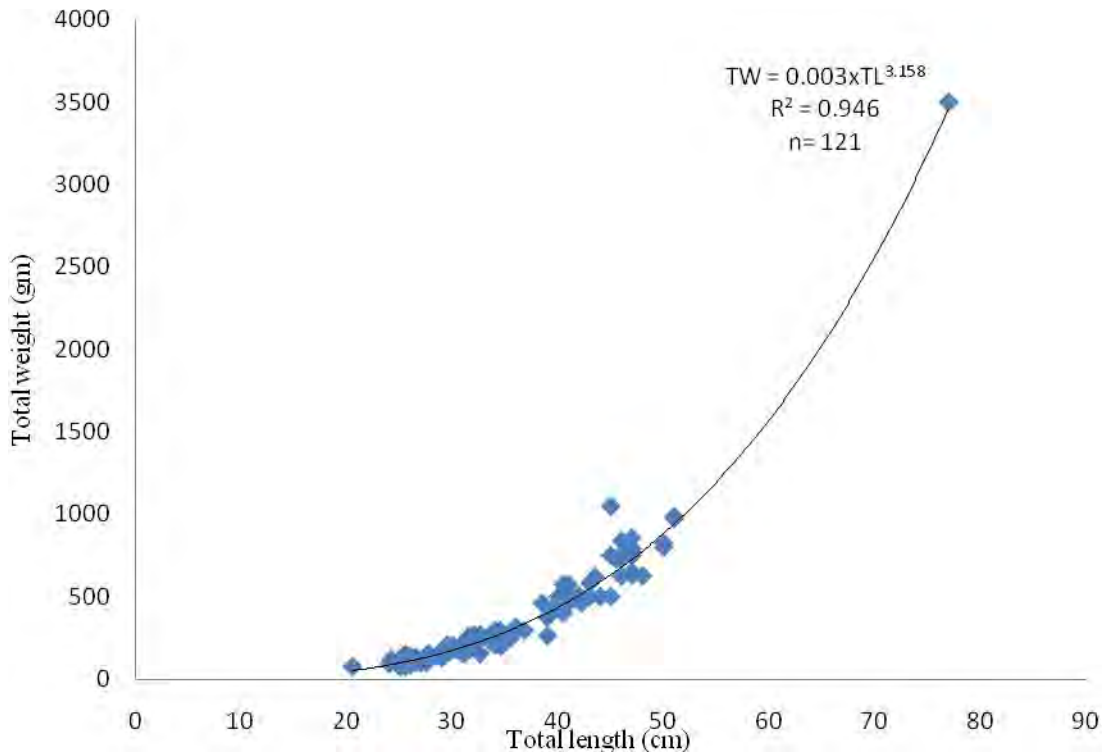


Figure 7. Length-weight relationship of *C. gariiepinus* in Lake Hayq.

Condition factor

Fulton condition factor (FCF) values of *G. dembecha* ranged from 0.8 to 1.73 for females and from 0.82 to 1.84 for males. Mean $FCF \pm SE$ was found to be 1.25 ± 0.02 and 1.33 ± 0.01 for females and males, respectively. The overall Mean $FCF \pm SE$ was 1.30 ± 0.01 .

Monthly Fulton condition factor values (Mean \pm SE) of *G. dembecha* ranged from 1.02 ± 0.01 (in January) to 1.53 ± 0.03 (in June) for males (Table 6), and from 0.85 ± 0.04 (in May) to 1.53 ± 0.02 (in March) for females (Table 6).

In the present study significant variation between sexes and between sampling months was observed (ANOVA, $P < 0.05$). Generally, males had higher mean FCF values than females. The sex by month interaction was insignificant (ANOVA, $P > 0.05$). This finding also suggests that the temporal variation in FCF was similar for both sexes (Fig. 8). Higher FCF values were recorded in March, and lower values were recorded in January for males and May for females (Table 6).

Table 6. Fulton Condition Factor (Mean \pm SE) of *G. dembecha* in monthly samples from Lake Hayq.

Month	M	n	F	n
January	1.02 \pm 0.01	48	1.01 \pm 0.02	47
February	1.24 \pm 0.01	60	1.20 \pm 0.02	51
March	1.53 \pm 0.01	95	1.53 \pm 0.02	41
April	1.48 \pm 0.06	8	1.44 \pm 0.07	4
May	1.38 \pm 0.03	100	0.85 \pm 0.04	40
June	1.49 \pm 0.03	21	1.10 \pm 0.05	65
Total	1.33 + 0.01	332	1.25 + 0.02	248

Fulton condition factor (FCF) values for *C. gariiepinus* ranged from 0.50 to 1.15 for females and from 0.48 to 1.10 for males. Mean FCF \pm SE was 0.69 \pm 0.02 and 0.67 \pm 0.02 for females and males, respectively. The overall Mean \pm SE FCF was 0.68 \pm 0.02.

Monthly Fulton condition factor (FCF) values (Mean \pm SE) of *C. gariiepinus* ranged from 0.57 \pm 0.03 (in April) to 0.81 \pm 0.08 (in January) for females (Table 7), and from 0.52 \pm 0.03 (in April) to 0.73 \pm 0.02 (in March) for males (Table 7).

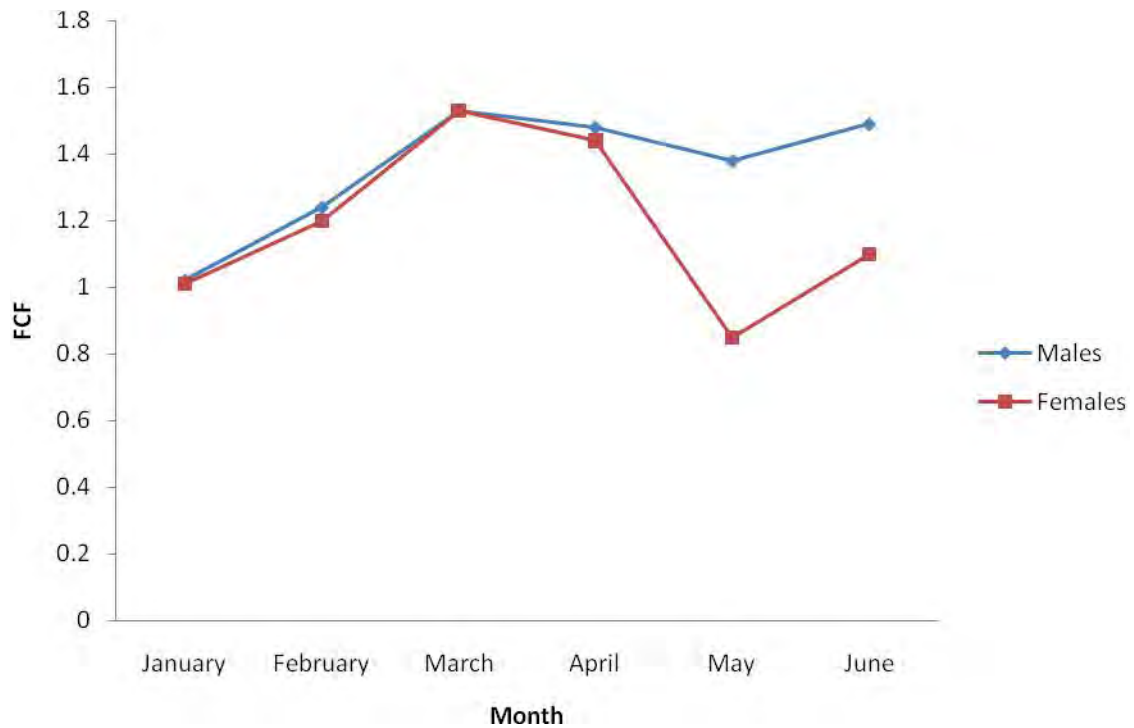


Figure 8. Monthly variation in mean Fulton Condition Factor of female and male *G. dembecha* from Lake Hayq.

Although mean FCF of females was slightly larger in some months, sex based difference in FCF was insignificant (ANOVA, $P > 0.05$). There was significant difference in FCF among sampling months (ANOVA, $P < 0.05$) where as the interaction was found to be insignificant (ANOVA, $P > 0.05$). This suggested that, within the sampling period, monthly variation in FCF of *C. gariepinus* was similar. Thus, for both sexes, mean FCF tended to decrease from January to April, and increased in May to decrease in June (Fig. 9)

Table 7. Fulton Condition Factor (Mean \pm SE) of *C. gariepinus* in monthly samples from Lake Hayq.

Month	Males	n	Females	n
January	0.68 \pm 0.08	17	0.81 \pm 0.08	17
February	0.73 \pm 0.02	11	0.79 \pm 0.01	14
March	0.64 \pm 0.05	12	0.72 \pm 0.04	4
April	0.52 \pm 0.03	7	0.57 \pm 0.03	5
May	0.69 \pm 0.02	9	0.68 \pm 0.02	12
June	0.52 \pm 0.07	4	0.55 \pm 0.04	9
Total	0.7 \pm 0.02	60	0.67 \pm 0.02	61

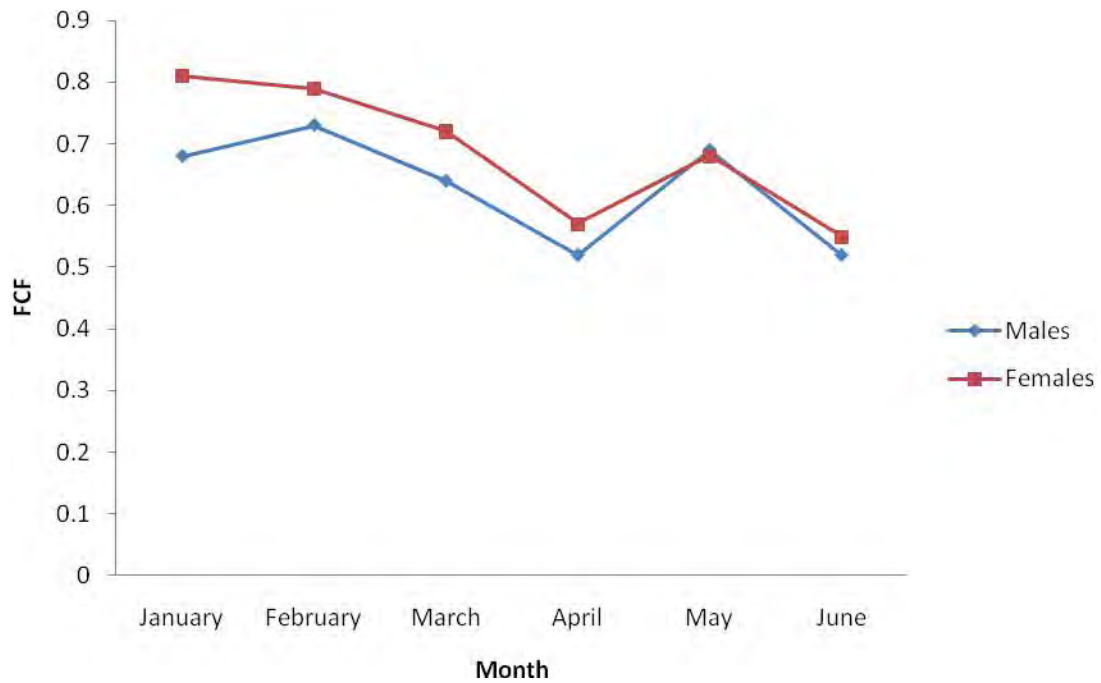


Figure 9. Monthly variation in mean Fulton Condition Factor of female and male *C. gariepinus* from Lake Hayq.

5.4 Food and feeding habits

A total of 476 gut samples of *G. dembecha* varying in length between 8.3 and 14 cm TL were examined for food composition. No food item was found in 169 (35.6%) of the sampled fish and the list of items observed in the remaining gut contents is presented in Table 8. Microscopic examination of these items showed diverse items of phytoplankton, zooplankton, detritus and sand grains (Table 8).

The groups of phytoplankton were Bacillariophyta, Cyanophyta and Chlorophyta. *Melosira sp.*, *Nitzschia*, *Amphora* and *Cymbella* are the common genera within Bacillariophyta. *Microcystis sp.* was the most frequently encountered species within Cyanophyta, whereas *Cosmarium* and *Tetraedron* were the dominant genera within Chlorophyta. Zooplankton was represented only by one genus of Cladocera, *Daphnia*.

Table 8. List of items identified from gut of *G. dembecha* from Lake Hayq.

Food items (group/genus)

Cyanophyta

Anabaena

Merismopedia

Lyngbya

Mycrocystis

Bacillariophyta

Amphora

Cyclotella

Navicula

Fragillaria

Melosira

Cymbella

Nitzschia

Surirella

Stephanodiscus

Chlorophyta

Botryococcus

Cosmarium

Tetraedron

Oocystis

Peridinium

Zooplankton

Daphnia

Unidentified filamentous Algae

Sand Grains

Detritus

Detritus, unidentified filamentous algae and sand grains were abundantly observed. The muddy appearance of the gut contents are attributed to the large proportions of these items.

Out of 121 stomachs of *C. gariiepinus* examined, 58 (47.9%) were empty the rest contained food items from various taxonomic groups, unidentified items, detritus, fish scales and eggs (Table 9). Thus, the food of *C. gariiepinus* in Lake Hayq was diverse which consisted items of both plant and animal origins.

The plant food was made up of phytoplankton, particularly *Melosira* sp. and filamentous algae, and macrophytes which were represented by shoot, roots, fruits and seeds. *Microcystis* sp. was also encountered in smaller quantities. Items of animal origin were quite diverse and included fish, amphibians, insects, nematodes, and zooplankton (Table 9).

In addition, fish eggs, detritus, unidentified fragments of animal parts and sand grains were also encountered frequently in the stomach content of the fish (Table 9). *O. niloticus* and *Garra* spp. were the fish species ingested by *C. gariiepinus*. Various developmental stages of insects belonging to Odonata, Hemiptera, Coleoptera, Diptera, and Ephemeroptera were also ingested by the fish. Zooplankton groups ingested by the fish included Copepoda and Cladocera (Table 9).

Table 9. A List of items identified from stomachs of *C. gariepinus* from Lake Hayq

Taxon (Food item)

Pisces

Oreochromis niloticus

Garra spp.

Amphibians

Frog

Insecta

Odonata

Hemiptera

Corixidae

Micronecta

Coleoptera larvae

Diptera

Chironomid larvae

Ephemeroptera

Arachnida

Spiders

Nematoda

Zooplankton

Copepoda

Cladocera

Algae

Melosira sp.
Microcystis sp.
Filamentous algae
Macrophytes (shoots, roots, fruits and seeds)
Fish eggs
Amphibian eggs

Detritus
Sand grains
Unidentified animal fragments

5.4.1 Relative contribution of food items

a. Frequency of occurrence

From the frequency of items in the gut content of G. dembecha, it is evident that detritus and sand grains make up the bulk of the ingested items, 86% and 61%, respectively. Diatoms are the next frequently ingested items, followed by Chlorophyta (Table 10).

Among the diatoms, Melosira and Amphora contributed 60.8% and 48.8%, respectively. These were followed in descending order of

occurrence by *Nitzschia*, *Cymbella*, *Cyclotella*, *Fragillaria*, *Surirella*, *Naviculla* and *Stephanodiscus*.

Tetraedron was the most frequently ingested Chlorophyta, contributing 56.8%. The next frequently found Chlorophyta was *Cosmarium*, followed by *Botriococcus*, *Oocystis*, *Peridinium* and *Pediastrum*. The frequency of the Chlorophyta ranged from 0.8 to 56.8% (Table 10).

Cyanophyta was represented more frequently by *Microcystis sp.* which contributed 47.2%. This is followed by *Lingibya* and *Anabaena* (Table 8).

The only zooplankton genus ingested by *G. dembecha* is the Cladoceran, *Daphnia*. It was found that *Daphnia* was ingested by 31.3% of the fish examined (Table 10).

The food group appearing in most stomachs of *C. garipepinus* was Crustacea (60%) followed by insects (46%), Fish (26%) and phytoplankton (20%).

Table 10. Relative importance of different items present in the gut of *G. dembecha* from Lake Hayq.

Food item	Frequency (%)	Number (%)
<i>Nitzschia</i>	48	74.32
<i>Tetraedron</i>	56.8	9.83
<i>Cosmarium</i>	36.8	7.86
<i>Melosira</i>	60.8	2.82
<i>Cyclotella</i>	39.2	1.10
<i>Microcystis</i>	47.2	1.01
<i>Cymbella</i>	47.2	0.69
<i>Amphora</i>	48.8	0.57
<i>Navicula</i>	32.8	0.46
<i>Surirella</i>	34.4	0.31
<i>Fragillaria</i>	39.2	0.27
<i>Oocystis</i>	12	0.23
<i>Botriococcus</i>	13.6	0.23
<i>Lyngbya</i>	8.8	0.20
<i>Daphnia</i>	31.3	0.08
<i>Stephanodiscus</i>	8	0.06
<i>Anabaena</i>	0.8	0.01
<i>Peridinium</i>	0.8	<0.01
<i>Pediastrum</i>	0.8	<0.01
<i>Merismopedia</i>	3.2	<0.01
Sand	61	
Detritus	86	
Filamentous algae	16	

Among the Crustacea, *Mesocyclops* was the most frequently ingested genus accounting for 52%, followed by *Daphnia* (50%), and *Thermocyclops* and *Cerodaphnia* each

contributing 46%. The crustacean appearing in less number of stomachs was *Moina* (20%) (Table 11).

Among insects, Hemiptera represented by two families Corixidae (26%) and Micronecta (6%), was the most frequently occurring class. These were followed by Ephemeroptera (24%), Coleoptera (20%) and Diptera represented by Chironomidae (12%) (Table 11).

In addition, macrophytes (24%), detritus (20%), sand grains (44%), fish eggs (10%), insect eggs (10%), a single frog and spiders which occurred in one individual were among the diversified diet of *C. gariiepinus* in Lake Hayq (Table 11).

Algae were represented by the diatom *Melosira* sp. and the blue green alga *Microcystis* sp. which occurred in 16% and 12%, respectively of the stomachs examined.

b. Percent composition by number

Excluding detritus and sand grains, Nitzschia was the most abundant, accounting for 74.3% of the total food item of the diet of G. dembecha of Lake Hayq. It is followed by Tetradron and Cosmarium both from Chlorophyta. Melosira, Cyclotella and Microsystis sp. are also ingested in relatively high numbers (Table 10). Daphnia accounted for 0.08% of the total food items (Table 10).

Numerically, zooplankton were the most important food items ingested by *C. gariiepinus* in Lake Hayq. They accounted for more than 98% of the total food ingested by the species. *Mesocyclops* was the genus contributing the highest number to the diet of *C.*

garipepinus (37%) followed by *Thermocyclops* (31%), *Daphnia* (14%) and *Cerodaphnia* (14%) (Table 11).

The other groups were represented by insignificant numbers compared to zooplankton. The next important food items were the insects which accounted for only 0.028% followed by fish 0.0045% (Table 11).

Table 11. Relative importance of different items present in the stomach of *C. gariepinus* from Lake Hayq.

Food Item	Frequency (%)	Number (%)
Fish	26	0.0045
Vertebrates		
Frog	2	<0.001
Coleoptera	20	0.011
Ephemeroptera	24	0.011
Hemiptera		
Corixidae	26	0.001
Micronecta	6	0.001
Odonata	6	0.001
Diptera		
Chironomidae	12	0.003
Insect eggs	10	0.025
Nematoda	6	0.0017
Fish eggs	10	0.081
<i>Microcystis</i>	12	
<i>Melosira</i>	16	0.29
<i>Mesocyclops</i>	52	37.94
<i>Thermocyclops</i>	46	31.84
<i>Daphnia</i>	50	14.34
<i>Daphinosoma</i>	40	5.14
<i>Cerodaphnia</i>	46	9.24
<i>Moina</i>	22	1.03
Macrophytes	24	

Detrius	20
Sand	44

5.4.2 Fish- size and food habit relationship

The relationship between *G. dembecha* size (TL) and its food could not be shown in this study because of the very narrow range of fish size in the sample.

The relationship between C. gariepinus size (TL) and its food, based on the frequency of major food item groups (fish, insects and crustacea), is presented in Figure 10. All the groups of food items were ingested by all size classes, except insects which were absent in the size class 51-77 cm. Even though almost all groups were ingested by all size classes, their importance varied with size class. For example, insects and fish were important for the size class 20-25 cm, whereas fish appeared to be the most important food for the size class 26-30 cm. Insects and crustacean were equally important for the size class 36-40 cm (Fig. 10).

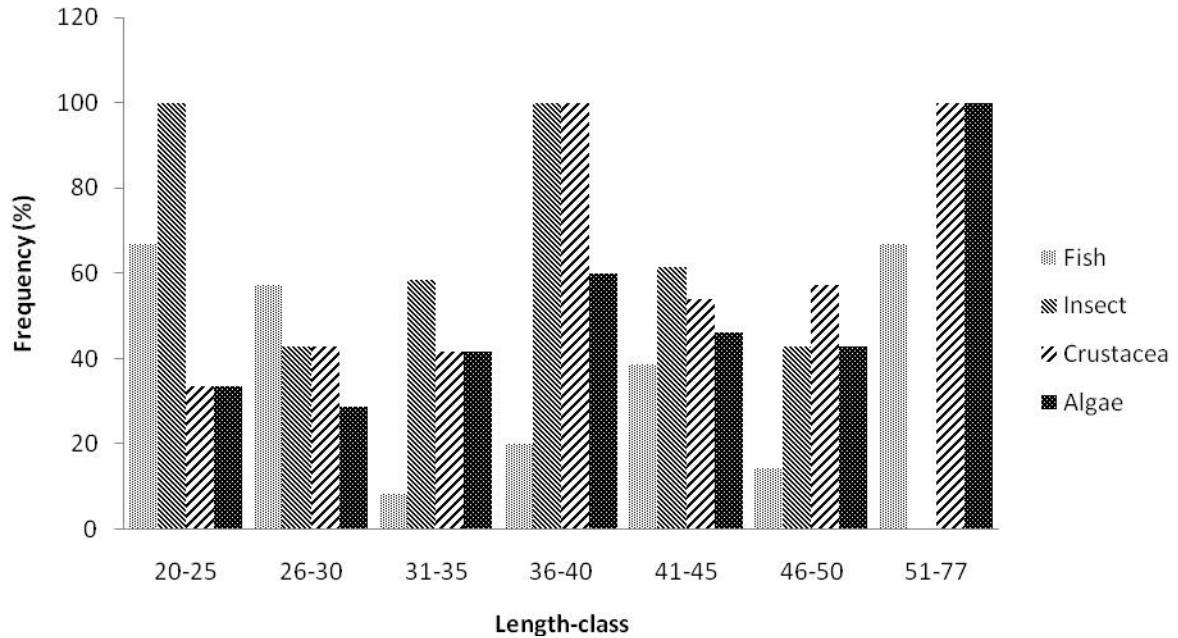


Figure 10. The relationship between *C. gariiepinus* size (TL) and its food based on the frequency of major food items

5.4.3 Feeding periodicity

In general, specimens of *G. dembecha* with empty guts, which accounted for about 35.6% of the total, occurred in all sampling months, but they were more frequent in April (83%) and February (43%). The frequency was lowest in January (2%) (Fig. 11 a).

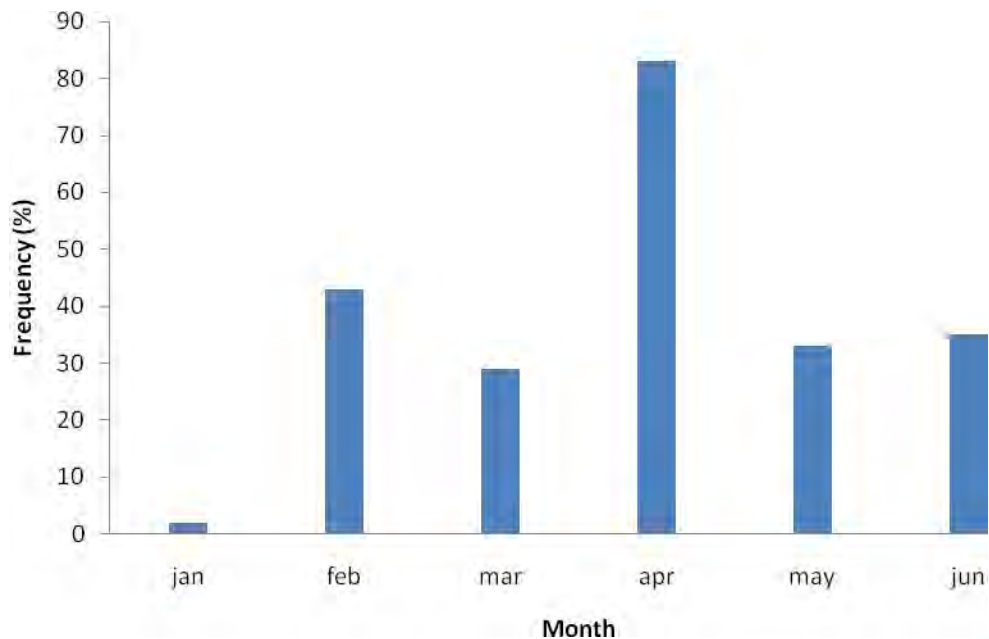
Specimens of *C. gariiepinus* with empty stomach were encountered in all sampling months. February (54%) and March (43%) are the months with the highest number of empty stomachs. As in *G. dembecha*, the lowest number of fish with empty stomachs for *C. gariiepinus* was recorded in January (Fig. 11 b).

Differences in frequency of major groups of food items are evident in *G. dembecha*. Bacillariophyceae were encountered in all guts of fish in three sampling months, February, April and May. Low frequency of diatoms was recorded in June (Fig.12a). Cyanophyta

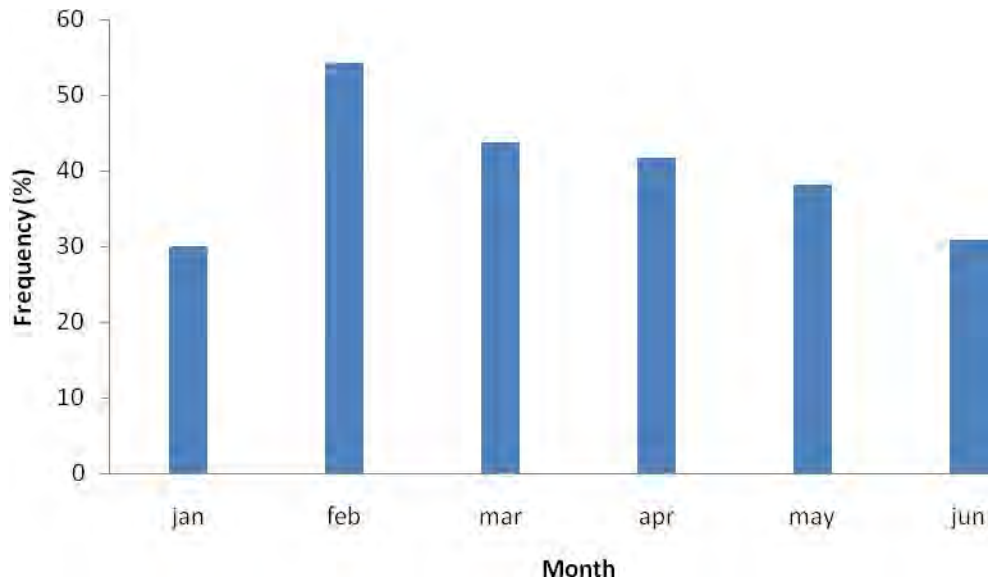
were found in all guts in April, May and June. Low frequency of Cyanophyta was recorded in March (Fig. 12a). Low frequency of Chlorophyta was also recorded in March, while all guts contained Chlorophyta in June and April (Fig. 12a). No zooplankton was ingested in January, whereas all guts were found to contain *Daphnia* in June (Fig. 12a).

Monthly variation in numerical abundance was observed in *G. dembecha* in this study. Diatoms contributed the highest number in 4 of the 6 sampling months (January to April); while Cyanophyta (40%) and Chlorophyta (60%) contributed the highest number in May and June, respectively (Fig 12 b). Relatively higher number of *Daphnia* was encountered in May (26.9%). Chlorophyta contributed larger number than Cyanophyta in January, February and June, whereas the reverse occurred in March, April and May (Fig 12 b).

Monthly variation among the major food groups was observed in *C. gariepinus* in the present study. Insects were encountered in greater number of stomachs in the months of January (57%), March (55.56%), April (75) and May (83.33) while Crustacea appeared more frequently in February (77.78%), March (55.56%) and June (77.78%). Fishes were not ingested in April and June (Fig 13).



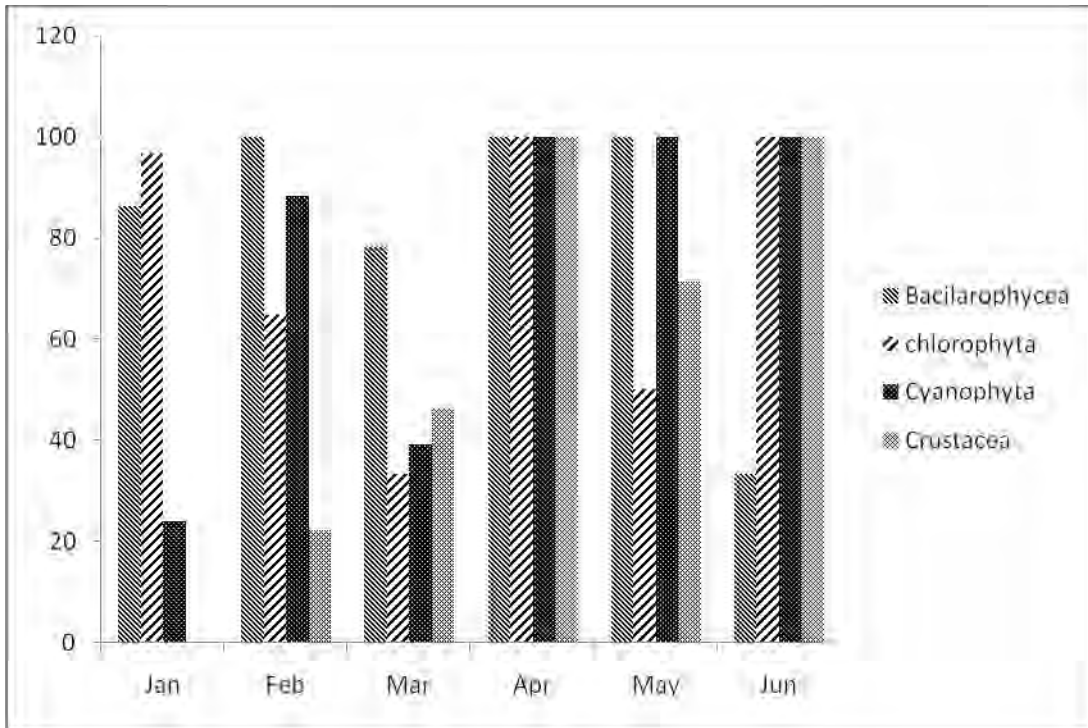
a)



b)

Figure 11. Frequency of *G. dembecha* (a) and *C. gariepinus* (b) from Lake Hayq with empty gut and stomach, respectively.

a)



b)

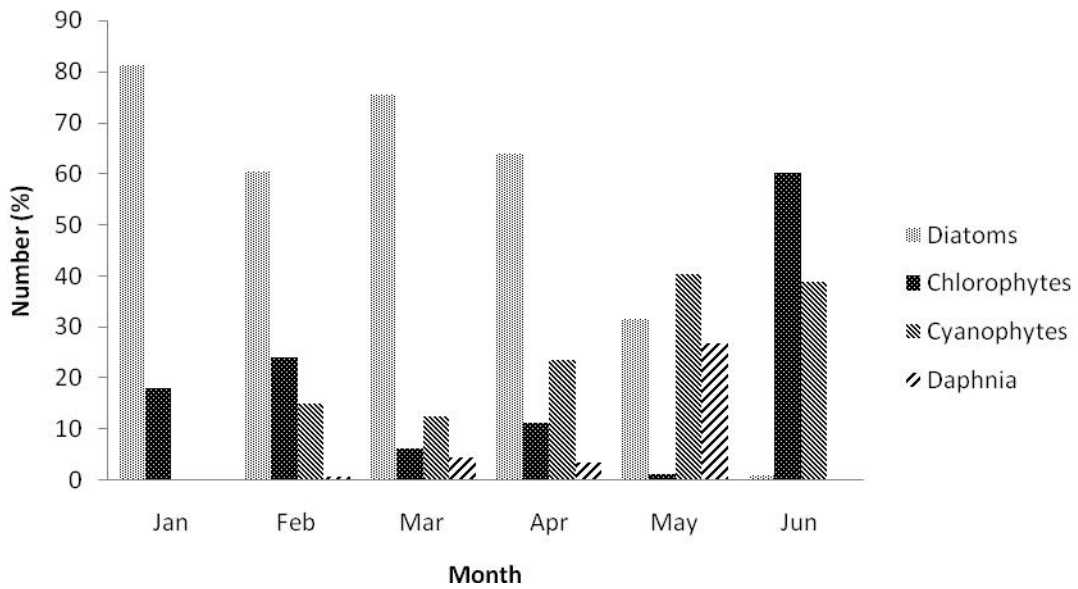


Figure 12. Monthly variation of major food items ingested by *G. dembecha* in Lake Hayq based on (a) frequency of occurrence and (b) numerical abundance methods.

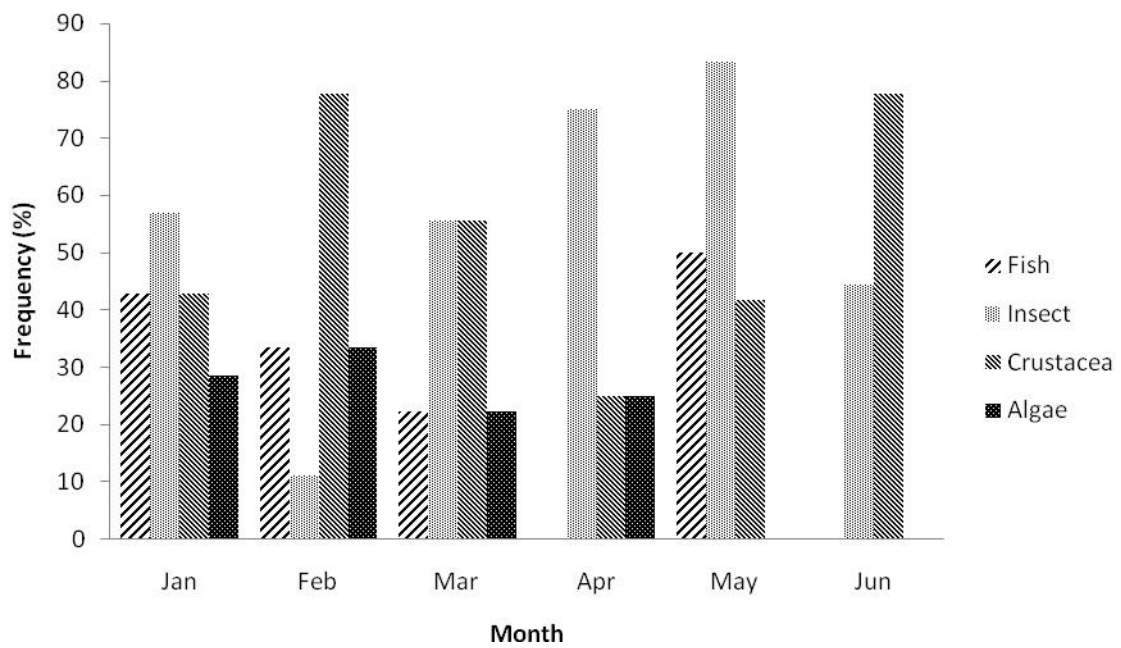


Figure 13. Monthly variation of major food items ingested by *C. gariepinus* in Lake Hayq based on frequency of occurrence.

6. DISCUSSION

Preponderance of males over females was observed in *G. dembecha* in all the sampling months except June in this study. The overall sex ratio was (M: F) 1.33:1, which significantly deviates from the expected 1:1 ratio. This agrees with the results for the same species in Lake Tana (Akewake Geremew, 2007). According to Demeke Admassu (1994) biased sex ratio in *O. niloticus* may be attributed to different factors such as sexual segregation during spawning, behavioral differences between the sexes, gear type and fishing site. More data is necessary to draw concrete conclusion as to which factor contributed more to this biased sex ratio for this species in this study.

Preponderance of female over males was observed in 3 sampling months: February, May and June, while males outnumbered females in March and April. Equal number of females and males were caught in January. The overall sex ratio (M: F) for *C. gariepinus* in this study was 0.98:1, which is almost equal to the expected 1:1 ratio. This result agrees with results for the same species in Lake Awassa (Elias Dadebo, 1988), and in Epe lagoon, Nigeria (Fafioye and Oluajo, 2005), but contradicts with the findings of Leul Tekla (2001) in Lake Langano, and of Lemma Abera (2007) in Lake Babogaya. The data obtained from this study does not allow us to make any concrete conclusion as to what caused this biased sex ratio in sampling months. However, the same factors mentioned above namely, sexual segregation during spawning, activity differences, gear type and fishing site (Demeke Admassu, 1994) might account for this biased sex ratio in sampling months.

The relationship between total length and total weight of *G. dembecha* was significant (ANOVA, $p < 0.05$) and curvilinear. The regression coefficient for males, females, and for the the sexes combined was 3.144, 3.109 and 3.142, respectively. This result shows that *G. dembecha* of Lake Hayq may grow isometrically. The regression coefficient obtained in this study is slightly lower than the value calculated for the same species in Lake Tana (3.16) (Akewake Geremew, 2007). It is also lower than *G. tana* (3.21) and higher than *G. regressus* (3.10) from Lake Tana (Akewake Geremew, 2007).

The relationship between total length and total weight of *C. gariepinus* in Lake Hayq was significant (ANOVA, $p < 0.05$) and curvilinear. Total length and total weight of *C.*

garipepinus in Lakes Awassa (Elias Dadebo, 1988), Lake Langano (Leul Teka, 2001), Lake Babogaya (Lemma Abera, 2007) were related in the same fashion. The coefficient of regression obtained in the present study ($b=3.27$ for females, $b=3.03$ for males and $b=3.16$ for the whole sample) was close to 3. This finding is in agreement with the theoretical 'cube law' (Bagenal and Tesch, 1978) indicating that the fish may grow isometrically in the lake. The result is slightly higher than values calculated for the same species in Lake Babogaya (2.92) (Lemma Abera, 2007), Lake Langano (2.91) (Leul Teka, 2001) and Lake Awassa (3.04) (Elias Dadebo, 1988). Comparable result was found for *C. garipepinus* in Elephant Marsh, Malawi (Willoughby and Tweddle, 1978).

The mean FCF of *G. dembecha* in the present study was 1.33 for males and 1.25 for females. The overall mean FCF for the population was 1.30. Mean FCF of the same species in Lake Tana was 1.42 (Akwake Geremew, 2007). This shows that *G. dembecha* in Lake Tana are in a better condition than those in Lake Hayq. Workiyie Worie (2009) found that *O. niloticus* of Lake Tana had higher FCF values than the same species in Lake Hayq. This difference could be attributed to the difference in the productivity of the two lakes. The absence of information in this aspect for Lake Hayq made it difficult to form any concrete conclusions.

Generally, males of *G. dembecha* appear to be in a better condition than females. According to Wootton (1990) this situation is to be expected, as reproduction is more energetically costly for females. FCF was found to be significantly different (ANOVA, $p<0.001$) between months. It was lowest in May for females, and in January for males. Akewake Geremew (2007) attributed low FCF values of *G. dembecha* in Lake Tana in the month of January to low temperature and poor availability of food. This seems to be the case in Lake Hayq as the lowest water temperature was recorded in January (Kebede Alemu, 1995; Tadesse Fetahi, unpublished). Other reasons for the seasonal fluctuation in FCF include feeding rate, degree of parasitization and reproductive activity (Getachew Teferra, 1987; Zenebe Tadesse, 1988; 1997; 1999; Demeke Admassu, 1990; Alemayehu Negassa and Abebe Getahun, 2003). The low FCF value in May for females could be

attributed to the high parasitic infestation in this month. More than 67% of the sampled fish were infected with *Ligula intestinalis* (personal observation).

The mean FCF of *C. gariepinus* in the present study was 0.67 for males and 0.69 for females. The overall mean FCF for the population was 0.68. The mean FCF of the same species was 0.70, 0.61 and 0.64 in Lakes Awassa(Elias Dadebo, 1988), Langano (Leul Teka, 2001) and Babogaya (Lemma Abera, 2007), respectively. *C. gariepinus* in Lake Hayq, therefore, appears to be in a better condition than the species in those lakes.

Length-weight equations fitted for a fish population can be used to determine one variable from the other. As a result comparing equations fitted for different fish populations in different environments can give us additional evidence as to which population is in a better condition and growing better. Thus, the equation fitted for the present study was compared with that of Elias Dadebo (1988) and Leul Teka (2001). For example a 30 cm fish weighs 190 g in Lake Awassa, 169.3 g in Lake Langano and 175.9 g in Lake Hayq. In addition, a 90 cm fish weigh 5400 g in Lake Awassa, 4200 g in Lake Langano and 4493 g in Lake Hayq. From these comparisons we can fairly conclude that *C. gariepinus* in Lake Hayq grows at a faster rate than those in Lake Langano, but at a slower rate than those in Lake Awassa. This could be the result of differences in the availability and quality of food between the lakes (Workiye Worie, 2009).

The low contribution of fish to the diet of *C. gariepinus* in Lake Hayq could be the cause of the lower condition observed in Lake Hayq than that in Lake Awassa. Leul Teka (2001) suggested the same reason for the lower condition of *C. gariepinus* observed in Lake Langano. Generally piscivores grow faster than non- piscivores (Wooton, 1990).

FCF was significantly different (ANOVA, $p < 0.001$) between months for *C. gariepinus*. The lowest FCF was recorded in June and the highest in January. Similar results were reported for the species in Lake Langano (Leul Teka, 2001) and Lake Babogaya (Lemma Abera, 2007). Seasonal fluctuation in FCF could be attributed to factors such as

temperature, food quality and quantity, spawning activity, etc (Zenebe Tadesse, 1988; 1997; 1999; Demeke Admassu, 1990).

Eventhough FCF was not significantly different (ANOVA, $p > 0.001$) between sexes, females appear to be in a better condition than males. Similar results were observed in Lakes Awassa (Elias Dadebo, 1988), Langano (Leul Teka, 2001) and Babogaya (Lemma Abera, 2007). This might be due to the large number of eggs in females. Bruton (1979) reported that the weight of mature testis is small and has little effect on Length- weight relationship, whereas mature ovaries may constitute up to 12% of total body weight.

A variety of organisms of both plant and animal origin constitute the diet of *G. dembecha* in Lake Hayq. Similar results were reported by Akewake Geremew (2007) for the same species in Lake Tana. He emphasized on the importance of detritus to the diet of the species and asserted that the empty appearance of the food items such as diatoms suggest their detrital origin. *Microcystis* from blue green algae, *Tetraedron* and *Cosmarium* from green algae *Melosira*, *Navicula* and *Amphora* from diatoms were the most important food of *G. dembecha* based on the frequency of occurrence (Table 10). *Daphnia* was the only genus of animal origin. Diatoms were the most important food items in the diet of *G. dembecha* occurring in 75% the guts analyzed and *Daphina* was the least important (31.3%). Green algae occurred in 71% while blue greens occurred in 59% of the fish investigated. Detritus and sand grains each accounted for 86 and 61%.

The brownish color of the gut in *G. dembecha* could be the result of the large amount of sand grains and detritus in the diet, suggesting their bottom feeding habits. This is supported by the ventrally positioned mouth of the species (Abebe Getahun, 2000). Their bottom feeding habits can also be supported by the long intestine the species possesses. Generally bottom feeders tend to possess long intestines (Fryer and Illes, 1972).

The contribution of zooplankton to the diet of *G. dembecha* in Lake Hayq is very low. In contrast to the findings of Akewake Geremew (2007), who reported 6 genera of zooplankton in the diet of the same species in Lake Tana, only one genus of cladocera,

Daphnia, was found in the present study. About 12 genera of zooplankton were reported by Workiye Worie (2009) in the diet of *O. niloticus* in the same lake. The reasons for the absence of other genera of zooplankton in the diet of *G. dembecha* in Lake Hayq in the present study are unknown.

In this study slight variation in the composition of the diet of *G. dembecha* between months was observed (Fig. 12 a and b). All the major groups were found, in different frequencies and numbers, in all sampling months with the exception of *Daphnia* which was absent in January. This variation in the frequency and abundance of the major food groups could be the result of changes in the availability of food items in the lake. It is known that environmental factors such as temperature, rainfall, pH, etc affect the production of phytoplankton which in turn affects the production of zooplankton. In many fish species, it was observed that, selection of food is governed by availability than preference of a particular species (Njiru *et al.*, 2004). This might be the case in *G. dembecha* of Lake Hayq.

C. gariepinus in Lake Hayq feeds on a variety of organisms and items of both animal and plant origin. Diversified food items from phytoplankton (*Melosira sp.*) to macrophyte shoots and from crustaceans to higher vertebrates (fish) were identified in this study. Similar results were found in Lakes Sibaya, South Africa (Bruton, 1979), Kinneret, Israel (Spataru *et al.*, 1987), Awassa (Elias Dadebo, 1988; 2000), Tana (Tesfaye Wudneh, 1998), Langanu (Leul Teka, 2001) and Babogaya (Lemma Abera, 2007).

Zooplankton were found to be the most important food item for *C. gariepinus* in Lake Hayq based on both frequency of occurrence and numerical abundance. Based on frequency of occurrence insects were the second most important food items followed by fish. This trend is also shown using numerical abundance. Similar results were reported in Lakes Sibaya, South Africa (Bruton, 1979), Kinneret, Israel (Spataru *et al.*, 1987) Langanu (Leul Teka, 2001) and Babogaya (Lemma Abera, 2007). In contrast to these results, fish were the most important food for *C. gariepinus* in Lake Awassa both numerically and in frequency of occurrence (Elias Dadebo, 2000). The low contribution

of fish to the diet of *C. gariepinus* in Lake Hayq may be related to the relatively low abundance of fish in the lake than other lakes. The highest occurrence of fish in the diet was recorded in May which is just after the peak breeding season of *O. niloticus* in the lake (Workiyie Worie, 2009). This finding is in agreement with previous findings which suggested that the species is an inefficient piscivore and feeds on fish when they are abundant (Groenewald, 1964; Tesfaye Wudneh, 1998; Leul Teka, 2001).

The study showed that, in addition to the above mentioned groups, the species had also ingested other food items in varying quantities. Macrophyte pieces (shoots, roots), detritus, sand grains, insect and fish eggs and nematodes were among the items occasionally found in the stomach of *C. gariepinus*. Eventhough macrophyte pieces (shoots, roots), detritus and sand grains appear in the stomachs more frequently, their nutritional value or importance to the species is controversial among authorities. Some authors suggested that these items are ingested accidentally as the fish tries to feed on other organisms associated with macrophytes or sediments (Groenewald, 1964; Spataru *et al.*, 1987; Elias Dadebo, 2000). Bruton (1978) and Willoughby and Tweddle (1978) argued that *C. gariepinus* is an omnivore. The description of the species as an indiscriminate feeder seems to be accepted by most workers. The findings of this study also suggest that this species is an indiscriminate feeder in Lake Hayq.

Spiders and a single frog were found in the stomach of the species. Arachnids and frogs were also found in the diet of *C. gariepinus* in Lake Sibaya, South Africa (Bruton, 1979). A frog, *Leptodactylus ocellatus*, was found ingested by the same species in a river at the Brazilian Atlantic Rain Forest (Vitule *et al.*, 2008). In Lake Babogaya frogs are frequently used as bait to catch *C. gariepinus* by the local people (personal observation). Insects, fish and amphibian eggs were also among the different items discovered in the diet of *C. gariepinus* in Lake Hayq.

In the present study slight monthly variations were observed in the major food groups ingested by the species in Lake Hayq. The same reasoning given to *G. dembecha* could

explain this variation. The availability of food items, which is determined by environmental factors, could be the cause of this monthly variation.

The major food items were ingested in all length groups except in the 51-77 group cm in which insects are totally absent. Leul Teka (2001) and Lemma Abera (2007) reported that larger fish ingested more and more fish than smaller fish. Similarly, Corbet (1961) showed that *C. gariepinus* in Lake Victoria feeds mainly on ostracods and insects when young but they tend to feed progressively more on fishes, as they grow older. In addition, Munro (1967) also reported that insects are more important in the diet of small *C. gariepinus*.

In this study, however, the smallest and largest size groups had ingested relatively equal number of fish. The reason for this finding in the present study is unknown. But in this study more insects were ingested by smaller sized fish than larger ones. This is probably due to the fact that large *C. gariepinus* inhabits deeper parts of the lake, whereas small ones live in shallow waters among macrophytes where densities of benthic organisms are usually high (Bruton, 1978; Elias Dadebo, 1988; 2000 and Leul Teka, 2001).

About 48% of the fish were found to be with empty stomachs, and even those found with contents in their stomachs were on average less than half full. Regurgitation or digestion could be one of the reasons for the high incidence of empty stomachs. Since the fish were caught by the gill nets or hooks in the night and collected the next morning, the contents might have been lost by the above processes (Elias Dadebo, 1988; 2000; Leul Teka, 2001; Lemma Abera, 2007). The other reason given for the incidence of high empty stomachs is spawning activity (Leul Teka, 2001; Lemma Abera, 2007). There is no information on the breeding season of *C. gariepinus* in Lake Hayq. However, if the breeding season of *C. gariepinus* is similar with other lakes, then the above reason might hold true in Lake Hayq. In Lakes Awassa and Babogaya the species breeds intensively between February and June (Elias Dadebo, 1988; 2000; Lemma Abera, 2007). In these months high empty stomachs were recorded in Lake Hayq. Therefore, spawning activity might be the other reason for the incidence of empty stomachs in Lake Hayq.

7. CONCLUSION AND RECOMMENDATION

Based on findings of the present study the following conclusions and recommendations are forwarded.

Conclusions:

- *G. dembecha* males outnumber females in the total sample.
- *C. gariepinus* sex ratio is almost equal to the ideal 1:1 ratio.
- The relationship between TL and TW was found to be highly significant and curvilinear in both species.
- The length-weight coefficient (*G. dembecha*=3.142 and *C. gariepinus*=3.16), which is closer to 3, indicates that the two species in Lake Hayq grow isometrically.
- Male *G. dembecha* were in a better condition than females; and the mean FCF for the population was found to be 1.30.
- Female *C. gariepinus* were in a better condition than males; and the mean FCF for the population was found to be 0.68.
- *G. dembecha* in Lake Hayq feed on a variety of food items of both animal and plant origin. The most important food items diatoms followed by green algae and blue green algae. In addition, the species also feeds on one genus of zooplankton, *Daphnia*.
- *C. gariepinus* in Lake Hayq feeds on a variety of food items of both animal and plant origin. Crustaceans were found to be the most important food items ingested

by the species followed by insects and fish. The species also feeds on plant materials.

- All size groups of *C. gariepinus* feed on all the major food items and the species can be considered as an indiscriminate feeder in Lake Hayq.

Recommendations:

- In this study it was attempted to generate crucial data on some aspects of the biology of *G. dembecha* and *C. gariepinus*. Other aspects like fecundity and breeding season should be studied to give us full information on the ecology of both species.
- The composition, nutrient content and digestibility of the diet of both species in the lake should be studied.
- Productivity and seasonal dynamics of phytoplankton and zooplankton in the lake are areas which require further investigation.
- We have observed parasite infestations in both species. The identification and degree of infestations of the parasites are other areas which require further investigation.
- It has been known that macrophytes provide shelter for the breeding fish; are hiding places for fish; improve oxygen conditions in water and also serve as a food source and ultimately they improve fish production. Research is required for further understanding of macrophytes and their contribution to fish production and water quality in Lake Hayq. However, macrophytes in Lake Hayq have been intensively grazed by cattle along the lake shore, especially during dry seasons (personal observation). Therefore, the concerned body should take measures to

conserve macrophyte beds and fishing in macrophyte beds should also be regulated because it interferes with fish breeding and feeding.

7. REFERENCES

- Abdel-Aziz, N. E. and Gharib, S. M. (2007). Food and feeding habits of round Sardinella (*Sardinella aurita*) in El- Mex Bay, Alexandria, Egypt. *Egyptian J. Aqu. Res.* **33**: 202-221.
- Abebe Getahun (2000). Systematic study of the African species of the genus *Garra* (Pisces: Cyprinidae). Ph. D. Thesis, City University of New York.
- Abebe Getahun (2007). An overview of the diversity and conservation status of the Ethiopian fresh water fish fauna. *J. Afrotrop. Zool.* **Special issue**: 87-96.
- Akewake Geremew (2007). Taxonomic revision, relative abundance and some aspects of the biology of some species of the genus *Garra*, (Hamilton, 1822) in Lake Tana, Ethiopia. M.Sc. Thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa. 100 pp.
- Alemayehu Negassa and Abebe Getahun (2003). Breeding season, length-weight relationship and condition factor of introduced fish, *Tilapia zillii* Gervais 1984 (Pisces: Cichlidae) in Lake Ziwai, Ethiopia. *SINET: Ethiop. J. Sci.* **26**: 115-122.
- Baxter, R.M. and Golobitsh, D.L. (1970). A note on the limnology of Lake Hayq. *Limnology and Oceanography* **15**: 144-149.
- Bagenal, T.B. (1978). Aspects of fish fecundity. **In**: *Ecology of Freshwater Fish Production* (Gerking, S.D., ed.). Blackwell Scientific Publications, Oxford.
- Bagenal, T.B and Tesch, F.W. (1978). Age and growth. **In**: *Methods for Assessment of Fish Production in Freshwaters* (Bagenal. T.B, ed.). IBP. Hand book No.3, Blackwell, Oxford, England. pp. 101-136.

- Borror, D.J. and DeLong, D.M. (1964). *An introduction to the study of insects*. Holt, Rinehart and Winston, Inc. London. 819 pp.
- Bruton, M. N. (1978). The habitat and habitat preference of *C. gariepinus* (Pisces: Clariidae) in a clear coastal lake (Lake Sibaya, South Africa). *J. Limno. Soc. Sth. Afr.* **4**: 81-88.
- Bruton, M. N. (1979). The food and feeding behaviour of *Clarias gariepinus* (Pisces, Clariidae) in Lake Sibaya, South Africa, with its emphasis on its role as a predator of cichlids. *Trans. Zool. Soc.* **35**: 47-114.
- Clay, D. (1979). Population biology, growth and feeding of African catfish (*Clarias gariepinus*) with special reference to juvenile and their importance in fish culture. *Arch. Hydrobiologia Supp.* **87**: 453-482.
- Coad, B. W. (2006). Freshwater fishes of Iran: Species accounts-Cyprinidae- *Garra*. <http://www.briancoad.com>.
- Corbet, P.S. (1961). The food of non-cichlid fishes on the Lake Victoria Basin, with remarks on their evolution and adaptation to lacustrine condition. *Proc. Zool. Soc. Lond.* **136**:1-101.
- de Graaf, G. and Janssen, H. (1996). Artificial reproduction and pond rearing of the African catfish *Clarias gariepinus* in sub-Saharan Africa – A handbook. No 362. Rome: FAO Fisheries Technical Paper. 73pp.
- Defaye, D. (1988). Contribution a la connaissance des crustaces copepodes d’Ethiopie. *Hydrobiologia* **164**: 103-147.

- Demeke Admassu (1990). Some morphometric relationships and the condition factor of *Oreochromis niloticus* (Pisces: Cichlidae) in Lake Awassa. *SINET: Ethiop. J. Sci.* **13**: 83-96.
- Demeke Admassu (1994). Maturity, Fecundity, Brood size and sex ratio of Tilapia (*Oreochromis niloticus* L.) in Lake Awassa. *SINET: Ethiop. J. Sci.* **17**: 53-96.
- Demeke Admassu (1998). Age and growth determination of tilapia, *Oreochromis niloticus* L. (Pisces: Cichlidae) in some lakes in Ethiopia. Ph.D dissertation School of Graduate Studies, Addis Ababa University, 115pp.
- Driessen, S. (2002). Feeding potential of some non-barbus fish in Lake Tana, Ethiopia. Msc. Thesis. Wageningen University, Department of animal Science, experimental zoology group.
- Edington, J.M. and Hildrew, A.G. (1981). *A Key to the Caseless Caddis larvae of the British Isles: with notes on their ecology*. Freshwater Biological Association Scientific Publication No. 43. Department of Zoology and Comparative physiology, University of London, Titus Wilson and Son Ltd., London.
- Elias Dadebo (1988). Studies on the biology and commercial catch of *Clarias mossambicus* Peters (Pisces: Clariidae) in Lake Awassa, Ethiopia. M.Sc. Thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa. 73 pp.
- Elias Dadebo (2000). Reproductive biology and feeding habits of catfish *Clarias gariepinus* Burchell (Pisces: Clariidae) in Lake Awassa. Ethiopia. *SINET: Ethiop. J. Sci.* **23**: 231-246.
- Elizabeth Kebede, Getachew Teferra, Taylor, W.D. and Zinabu G/Mariam (1992). Eutrophication of Lake Hayq in the Ethiopian Highlands. *J. plankton Research* **14**: 1473-1482.

- Eshete Dejen (2003). Ecology and potential for fishery of the small barbs (Cyprinidae, Teleostei) of Lake Tana, Ethiopia. Ph.D. Thesis, Agricultural University, The Netherlands.
- Fafioye, O. O. and Oluajo, O. A. (2005). Length-weight relationships of five fish species in Epe lagoon, Nigeria. *Afri. J. Biotec.* **4**: 749-751.
- FAO (2001). FAO fisheries and Aquaculture-Ethiopia, profiles home. <http://www.hotads.net> firms.com. Retrieved date, 20 July 2008.
- FAO (2009). Fisheries and Aquaculture-Fact sheet search- *Clarias gariepinus*. <http://www.fao.org/fishery/culturedspecies/en>
- FishBase (2009). Worldwide Web electronic publication. <http://www.issg.org>. Retrieved date 4/16/2009.
- Fryer, G. and Iles, T. D. (1972). The Cichlid Fishes of the Great Lakes of Africa: Their Biology and Evolution. Oliver and Boyd, Edinburgh. pp. 6-72.
- Getachew Teferra (1987). Food, nutrition and digestive efficiency in *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Awassa, Ethiopia. Ph.D dissertation, University of Waterloo, Canada, 109pp.
- Getachew Teferra (1993). The composition and nutritional status of the diet of *Oreochromis niloticus* in Lake Chamo, Ethiopia. *J. Fish Biol.* **42**: 864-874.
- Green, J. and Seyoum Mengistou (1991). Specific diversity and community structure of Rotifera in a salinity series of Ethiopian inland water bodies. *Hydrobiologia* **209**: 95-106.

- Groenewald, A. A. V. J. (1964). Observation on the food habits of *C. gariepinus* Burchell, the South African fresh water barbel (Pisces: Clariidae) in Transvaal. *Hydrobiologia* **23**: 287- 291.
- Harding, J. P. and Smith W. A. (1974). *A key to the British freshwater Cyclopid and Calanoid Copepods*. Freshwater Biological Association scientific Publication No. 18. Titus Wilson and Son Ltd. London. 54 pp.
- Hecht, T., Oellermann, L. and Verheust, L. (1996). Perspectives on clariid catfish culture in Africa. *Aquat. Living Resour.* **9**: 197-206.
- Hynes, H. B. N. (1950). The food of freshwater Sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungiteus*), with a review of methods used in studies of the food of fishes. *J. Anim. Ecol.* **19**: 36 -58.
- Hyslop, E.J. (1980). Stomach content analyses- A review of methods and their application. *J. Fish. Biol.* **17**: 411-429.
- Krysanov, E. Y and Golubstov, A. S. (1993). Karyotypes of three *Garra* species from Ethiopia. *J. Fish. Biol.***42**: 465-467.
- Kullander, S. O. and Fang, F. (2004). Seven new species of *Garra* (Cyprinidae: Cyprininae) from the Rakhine Yoma, southern Myanmar. *Ichthyol. Explor. Freshwaters* **15**: 257-278
- Kebede Alemu (1995). Age and growth of *Oreochromis niloticus* (Pisces: Cichlidae) in Lake Hayq, Ethiopia. *M.Sc. Thesis*, Addis Ababa University, Addis Ababa, Ethiopia, 84 pp.

- Leul Teka (2001). Sex Ratio, Length-weight relationship, Condition factor and the food habit of Catfish *Clarias gariepinus* (Burchell) in Lake Langano, Ethiopia. M.Sc. Thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa. 64 pp.
- Lind, O.T. (1974). *Hand Book of Common Methods in Limnology*. The C.V. Mosby Company, Saint Louis.
- Lopez-Peralta, R.H. and C.A.T. Arcila, 2002. Diet feeding composition on fish species from the southern continental shelf of Colombia. *Naga* **25**: 23-29.
- Macan, T.T. (1959). *A Guide to Freshwater Invertebrate Animals*. Longmans, Green and Co. Ltd., London. 118 pp.
- Macan, T. T. (1976). *A key to British Water Bugs (Hemiptera-Heteroptera): With Notes on Their Ecology*. Freshwater Biological Association Scientific publication no.16. Titus Wilson and Son Ltd.Londone.77 pp.
- Mequilla, A. T. L.and Campos, W. L. (2007). Feeding relationships of dominant fish species in the Visayan Sea. *Science Diliman* **19**: 35-46.
- Merron, G. S. (1993). Pack-hunting in two species of catfish, *Clarias gariepinus* and *C. ngamensis*, in the Okavango Delta, Botswana. *J. Fish Biol.* **43**:575-584.
- Molla Demlie, Tenalem Ayenew and Stefan W. (2007). Comprehensive hydrological and hydrogeological study of topographically closed lakes in highland Ethiopia: The case of Hayq and Ardibo. *Journal of Hydrology* **339**: 145– 158.
- Munro, J. L. (1967). The food of a community of East African fresh water fishes. *J. Zool. Lond.* **151**: 389-415.

- Njiru, M., Okeyo-Owuor, B., Muchiri, M. and Cowx, I. G. (2004). Shifts in the food of Nile tilapia, *Oreochromis niloticus* (L.) in Lake Victoria, Kenya. *Afr. J. Ecol.* **42**: 163-170.
- Oso, J. A., Ayodele, I. A. and Fagbuaro, O. (2006). Food and feeding habits of *Oreochromis niloticus* (L.) and *Sarotherodon galilaeus* (L.) in a Tropical Reservoir. *World J. Zool.* **19**: 35-46.
- Olurin, K. B. and Aderibigbe, O.A. (2006). Length-weight relationship and condition factor of Pond reared juvenile *Oreochromis niloticus*. *World J. Zool.* **1**: 82-85.
- Post, D.M., M.E. Conners and D.S. Goldberg, (2000). Prey preference by a top predator and the stability of linked food chains. *Ecology*, 81: 8-14.
- Pornsopin, P., Unsrisong, G., Kantiyawong, S., Muller-Beleke, A. and Horstgen-Schawark, G. (2004). Induced spawning and early development of stonelapping minnow, *Garra cambodgiensis*. Proceeding Subsession, 5d: exploring and sustaining aquatic systems. International Research on Food Security, natural Resource Management and Rural Development, Humboldt-Universitat Zu Berlin
- Seyoum Mengistou (2006). Status and challenges of aquatic invertebrate research in Ethiopia: A review. *Ethiop. Biol. J. Sci.* **5**: 75-115.
- Spataru, P., Viveen, W. J. A. R. & M. Gophen. (1987). Food composition of *Clarias gariepinus* (= *C. lazera*), (Cypriniformes, Clariidae) in Lake Kinneret (Israel). *Hydrobiologia* **144**: 77-82.
- Stiassny, M. L. J. and Abebe Getahun (2007). An overview of labeonin relationships and the phylogenetic placement of the Afro-Asian genus *Garra* Hamilton, 1922 (Teleostei: Cyprinidae), with the description of five new species of *Garra* from Ethiopia, and a key to all African species. *Zool. J. Linnean Soc.* **150**: 41–83

- Sundrabaranthy, T. V., Endrisinghe, V and Dematawewa, C. M, B. (2005). Breeding and larva rearing of threatened, endemic fish stone sucker, *Garra ceylonensis* (Bleeker). *Aquaculture Reaserch* 36:196-201.
- Tesfaye Wudneh, (1998). Biology and management of fish stocks in Bahir Dar Gulf, Lake Tana, Ethiopia. Ph.D. dissertation, Wageningen Agricultural University, Wageningen. 142 pp.
- Vitule, J. R. S., Umbria, S. C. and Aranha, J. M. R. (2008). Record of native amphibian predation by the alien African catfish in the Brazilian Atlantic Rain Forest. *Pan-Amer. J Aqua. Sci.* **3**: 105-107.
- Willoughby, N. G. and Tweddle, D. (1978). The ecology of the catfish *Clarias gariepinus* and *Clarias ngamensis* in the Shire Valley, Malawi. *J. Zool.* **186**: 507-534.
- Wootton, R. J. (1990). *Ecology of Teleost Fishes*. Fish and Fisheries series 1. London, Chapman and Hall. 104 pp.
- Workiye Worie (2009). Some aspects of the biology of Nile tilapia, *Oreochromis niloticus* L.1758 (Pisces: Cichlidae) in Lake Hayq, Ethiopia. M.Sc. Thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa. 78 pp.
- Zenebe Tadesse (1988). Studies on some aspects of the biology of *Oreochromis niloticus* L. (Pisces. Cichlidae) in Lake Ziway, Ethiopia. M.Sc. thesis. School of Graduate Studies, Addis Ababa University, Addis Ababa. 78 pp.
- Zenebe Tadesse (1997). Breeding season, Fecundity, Length-weight relationship and condition factor of *Oreochromis niloticus* L. (Pisces: *Cichlidae*) in Lake Tana, Ethiopia. *SINET: Ethiop. J. Sci.* **20**:31-47.

Zenebe Tadesse (1998). Food and Feeding Ecology of Tilapia, *Oreochromis niloticus* L. and effects of diet on the lipid quality of fish in some Lakes in Ethiopia. Ph. D. dissertation, School of Graduate studies, Addis Ababa University, Addis Ababa. 139 pp.