Current status and trends of fishes and fishery of a shallow rift valley lake, Lake Ziway, Ethiopia

A Thesis Submitted to

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Presented in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Zoological Sciences (Fisheries and Aquatic Sciences)

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Addis Ababa, Ethiopia

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Current Status and Trends of Fishes and Fishery of a Shallow Rift Valley Lake, Lake Ziway, Ethiopia

By

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A Thesis Presented to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Biology (Fisheries and Aquatic Sciences Stream)

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DEDICATION

This work is dedicated to the fishermen of Lake Ziway.

ABSTRACT

Current status and trends of fishes and fishery of a shallow rift valley lake, Lake Ziway, Ethiopia

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Lake Ziway is an economically important lake in the country. However, the physico-chemical parameters of the lake seem to be threatened by anthropogenic and climatic factors, which in turn affect biotic factors as reflected in fish catch. A study was made to assess the status and trends of fishes and fishery during October 2012 to September 2014 in Lake Ziway. Conductivity and pH showed more or less no change during the last two decades as the mean values ranged from 361.5±9.7 to 484.51±15.3 μS/cm and 8.03±0.2 to 8.37±0.1, respectively. Dissolved oxygen content has higher values around the northern part of the lake at the inlet of Meki River (5.71±0.6) and Ketar River (6.01±0.5).

Ten fish species were identified with low species diversity for the lake (H′ value of 1.67). The composition of the fishes has undergone some changes as compared to the last few decades. For instance, *Carassius auratus and Labeobarbus microterolepis* were not cought in this study. Inaddition, *Cyprinus carpio*, which was never reported inearlier catch earlier, attained the highest relative frequency (25.19 %) in this study, next to *Oreochromis niloticus* (27.88 %), and then followed by *Carassius carassius* (20.71%) and *Clarias gariepinus* (20.51%). Canonical Correspondence Analysis (CCA) showed that the average abundance of *C. carpio*,

C. carassius and *C. gariepinus* were positively correlated with nutrients, whereas the abundance of *Labeobarbus ethiopicus* and *Labeobarbus intermedius* had negative correlation with most of the physico-chemical variables.

Some biometric measurements (length-weight relationship, condition factor, and sex ratio) were examined for the fishes. The length-weight relationship in *Barbus paludinosus, C. carassius, C. carpio*, *L. intermedius, C. gariepinus, Tilapia zillii* and *O. niloticus* were curvilinear and statistically highly significant ($P < 0.05$). Fulton Condition Factor values (mean ± SD) of the fishes were 1.26±0.19 (*B. paludinosus*), 1.52±0.14 (*C. carpio*), 2.13±0.57 (*C. carassius*), 1.73±0.38 (*L. intermedius*), 0.76±0.21 (*C. gariepinus*), 1.9±0.35 (*T. zillii*) and 1.83±0.21 (*O. niloticus*) for both sexes. Females were more numerous than males for all commercially important fish species except *C. gariepinus*, and the ratio was significantly different from the hypothetical distribution of 1:1 ($X^2 > 4$).

The frequency of ripe *C.carpio* as well as GSI values were generally high during February through to June and peaking between March and May sugesting that fish resources were intensivelly in breeding condition. Fecundity, for *C. carpio* of fork length from 32 cm to 46 cm, ranged from 75,645 and 356,743 eggs with a mean of 210,538. Fecundity was significantly ($P < 0.05$) related to fork length to total weight as well as to gonad weight. The relationship between fecundity and fork length was curvilinear whereas that between fecundity and total weight and that between fecundity and gonad weight were linear.

The fish catch of Lake Ziway currently declined from 3180 tons in 1997 to 1157.14 tons in 2014. Most of the threats resulted from the anthropogenic impacts on the lake. Increased pressure in fishing was a problem in the lake. Currently, plenty of pumps are abstracting fresh water from the lake by state and private commercial farms throughout the year that are critically impacting the water level of Lake Ziway. As a result, the lake ecosystem is being affected by catchment degradation and siltation. The study suggested that if nutrient levels continue to increase and water levels continue to decline, further changes in fish composition can be expected in the lake, especially with a shift towards fish that are mainly turbidity-tolerant species such as *C. carpio*.

The study showed that the fishery sector has been of critical importance to the economy and to the social well-being of the fishermen in the study area. However, current harvest trends and fishery conditions put these attributes of the production at risk. It is threatened with problems of open access to the resources, pollutions, marketing, and lack of technology. Hence, appropriate management is an urgent requirement that could assist in sustainable exploitation of the resources, so that the resource could contribute to food security in the study area in particular and in the country in general.

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CHAPTER 1: GENERAL INTRODUCTION

The Ethiopian economy is heavily dependent on the agricultural sector. The agricultural sector suffers from poor cultivation practices and frequent drought, but recent joint efforts by the Government of Ethiopia and donors have strengthened Ethiopia's agricultural resilience, contributing to a reduction in the number of Ethiopians threatened with starvation (EEP, 2014).

Being the dominant sector, agriculture contributes about 46.3% of the total gross domestic product (GDP), 60% of exports, and 80% of total employment (EE, 2015). The country depends on the inland waters for the supply of fish as a cheap source of animal protein. It can also indirectly contribute by providing revenue for purchasing food for deficient areas (Dawit Garoma *et al*., 2013a).

The country has a number of lakes and rivers with substantial quantity of fish stocks. There are 10 major lakes with a total area of 7,400 km^2 and a combined length of 7,185 km of major rivers (Brook Lemma, 2012). Many artificial water bodies have also been stocked with fish for fishery (Brook Lemma, 2012). Most of the lakes are located in the Ethiopian Rift Valley, which is part of the Great East African Rift Valley system (Fig. 1.1).

The natural resource of the Rift Valley has immense economic and cultural values. These lakes are considered as centers of biodiversity, corridors of countless migratory birds; and are used in ameliorating the effects of drought and protein shortage for the population in the region (Zinabu Gebremariam, 1998; 2002; 2003). The Ethiopian Rift Valley Lakes have also proved their importance to scientific research (Zinabu Gebremariam and Elias Dadebo, 1989; Tudorancea and Taylor, 2002; Zinabu Gebremariam, 2003). In fact, they are the most studied water bodies in Ethiopia. Lake Ziway, for instance**,** is probably among the most studied of the lakes in Ethiopian Rift Valley, with respect to limnology and fish biology. In addition, Lake Ziway is one of the lakes in the rift valley used for multiple purposes like irrigation, fishing, domestic water supply, transportation, recreation and supply of fresh water to Lake Abijata through the out flowing Bulbula River. Although its importance is in the wide range of purposes, the fishery and all other related issues are not updated and even most scientific issues are poorly understood for proper management of the lake.

1.1. Formation and location of Lake Ziway

The Ethiopian Rift Valley floor, along which many of the lakes are aligned, is of tectonic origin created by volcanic and faulting activity that formed various volcano-tectonic depressions in the floor of the rift (Di Paola, 1972). According to Tamiru Alemayehu *et al*. (2006), the floor of the Rift Valley within the bounds of Ethiopia consists of three major water basins from North East to South West: Awash basin with Koka, Beseka, Gemari, and Abhe; Central Ethiopian Rift Valley basin with Ziway, Langano, Abijata and Shala; and Southern basin with Hawassa, Abaya, Chamo and Chew-Bahir as the most important lakes under each category (Fig. 1.1). During the pluvial period Lakes Langano, Abijata and Shala were united with Lake Ziway to form a large lake, which had a northern outflow into Awash River, and later they got isolated by faulting (Gasse and Street, 1978).

Lake Ziway (also known as Zway, Zwai, Zeway and Zuai in the literature; Makin *et al.*, 1975) belongs to the Central Ethiopian Rift. It is the third largest lake in the Ethiopian part of the Rift Valley and fourth in the country in termes of surface area. It lies in a shallow down-faulted basin (Gasse and Street, 1978) flanked in the east by a large basalt field with sandy or rocky shores (Schroder, 1984).

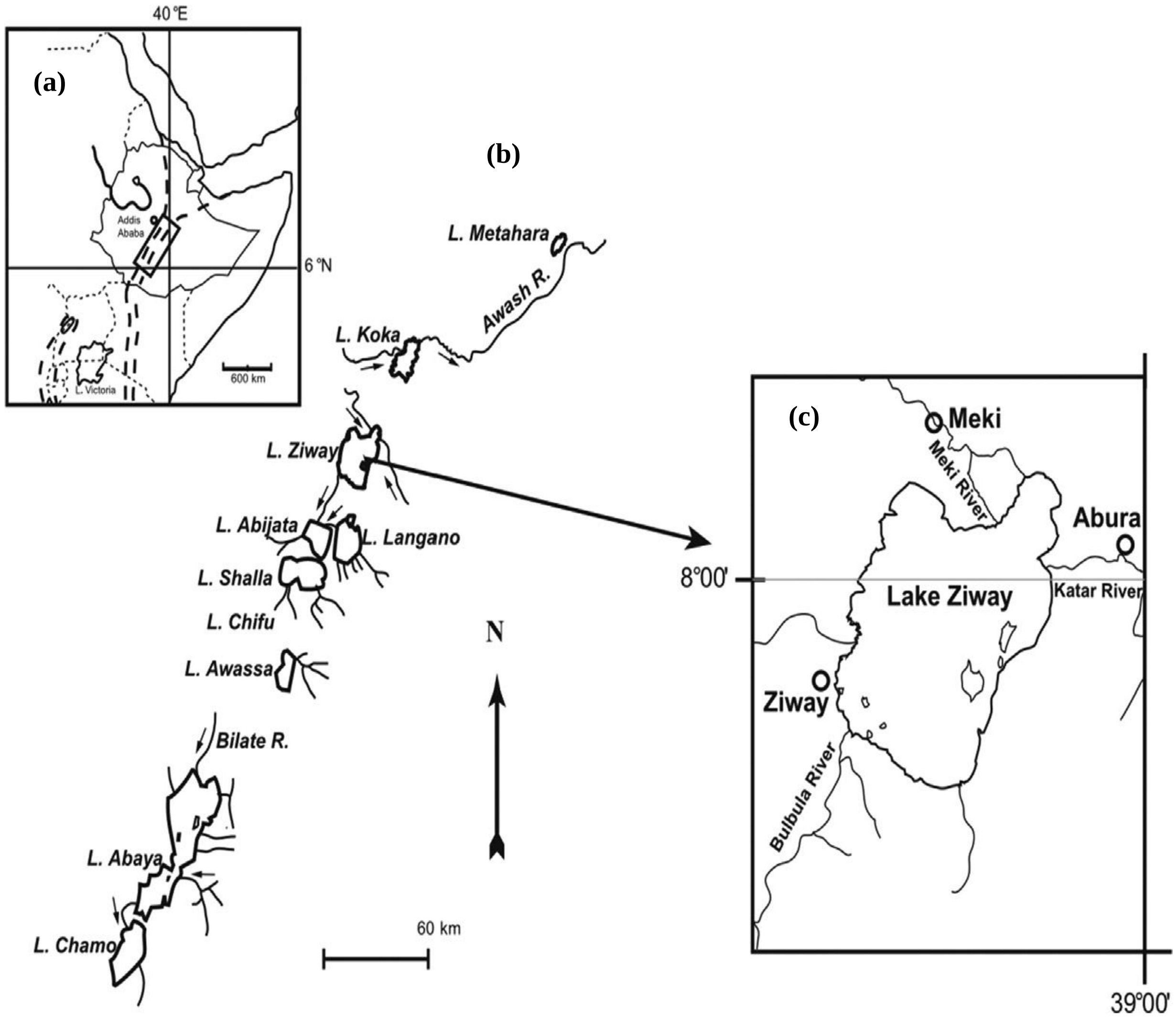

Fig.1.1. **(a)** Location of Ethiopia in the Horn of Africa, **(b)** Location of Ethiopian Rift Valley Lakes and **(c)** Lake Ziway (Source:Yared *et al*.,2014b)

Lake Ziway is bordered by two administrative zones of Oromia Regional State. The Western part belongs to East Shoa Zone while the Eastern part belongs to Arsi Zone (Fig. 1.1). The Western shore is shared by two districts, namely, Adami Tullu Jiddo Kombolcha (A. T. J. Kombolcha) and Dugda. The Eastern shore belongs to only Ziway Dugda (Z. Dugda) district. On the average, the lake is located at an elevation of 1650 meter above sea level at $7^0$89' - $8^0$05'

N latitude and $38^0 72'$ - $38^0 92'$ E longitude located at about 163 km south of Addis Ababa. The lake is shallow and has an open water area of 434 km^2 and shoreline length of 137 km, a maximum depth of 8.9 m and an average depth of 2.5 m (Von Damm and Edmond, 1984). The maximum length and width of the lake is 32 km and 20 km, respectively (LFDP, 1997).

There are two main feeder rivers to L. Ziway; namely, Meki originating from Gurage Mountains in the north-west and Ketar from the Arsi Mountains in the east; and it has one outflow in the south through Bulbula River, draining into Lake Abijata (Fig. 1.1). Lake Ziway contains five main Islands: Tullu Guddo (4.8 km^2), Tsedecha (2.1 km^2), Debresina (0.3 km^2), Funduro (0.4 km^2) and Gelila (0.2 km^2). Debresina and Gelila have only a few inhabitants, the other three are inhabited by several hundreds of people (Yared Tigabu, 2003).

1.2. Climate of Lake Ziway and the surrounding area

Rainfall in Ethiopia is erratic and subject to large spatial variability, which is largely determined by altitude. The rainfall pattern is largely influenced by the annual fluctuation of the inter-tropical convergence zone, which results in rainy season (with most of the rainfall occurring from June to September) and dry season (October to March) (Adamneh Dagne, 2010). There is also a short rainy periods originating from moist south-easterly winds mostly in April - May (Adamneh Dagne, 2010). The present meteorological data also show that comparable trends to that documented by Adamneh Dagne (2010).

However, the lake region in general is arid and even during the rainy seasons dry periods of several weeks are common. The meteorological data of National Meteorological Agency show that the rainfall occured between June and September. In addition, according to the data obtained from National Meteorological Agency, during the study period the mean monthly minimum air temperature ranged from 11.9 to 16.4 ^{0}C, while the maximum mean monthly air temperature varied from 24.6 to 29.8 ^{0}C (Fig.1.2). Monthly total rainfall also varied from 1.9 mm (November 2013) and 249 mm (July 2014) (Fig.1.2).

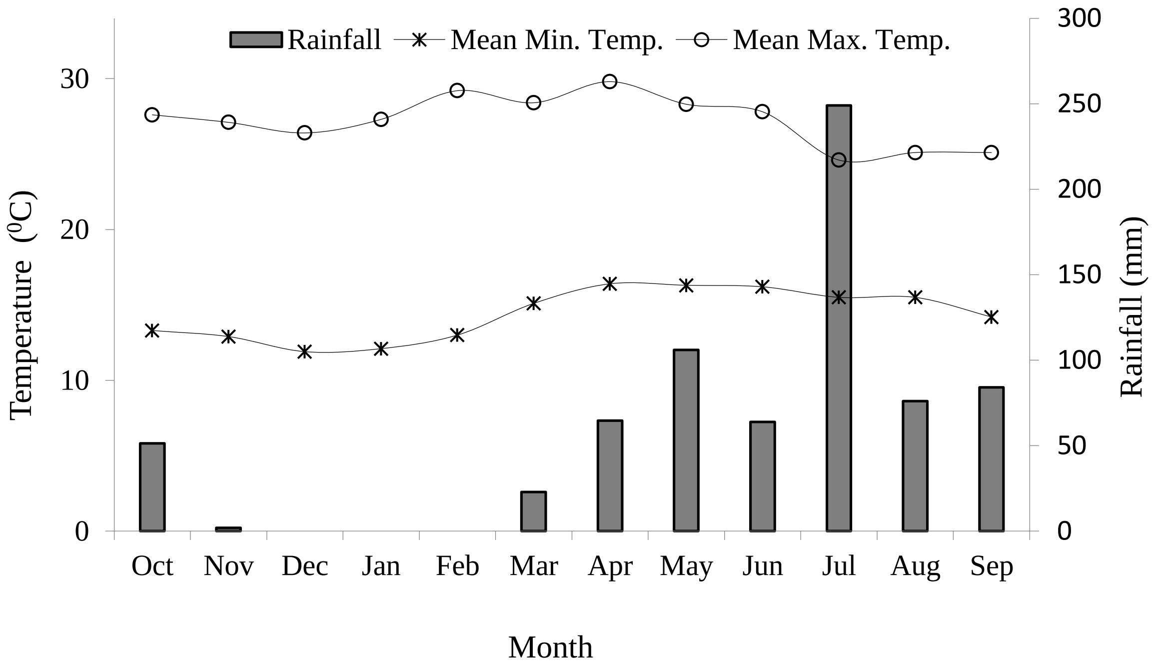

Fig.1.2. Monthly total rainfall; mean minimum and maximum air temperature of the lake region (From October 2013 to September 2014) (Source: National Meteorological Agency).

The weather in the lake region is frequently windy to stormy (Schroder, 1984). Due to the large surface area of the lake and the shallow depth slight wind action can cause complete mixing of the lake. Strong wind-induced water currents, especially in the afternoon is a common phenomenon in Lake Ziway, which is also indicated in Wood *et al*. (1978) who found no strong thermal stratification in the lake.

The water budget of Lake Ziway is regulated by superficial inflows, outflows, evaporation and precipitation mainly from the distant uplands as the precipitation in the lake area is inadequate to maintain the lake level (Dagnachew Legesse *et al*., 2001). An earlier report indicates that Lake Ziway receives 0.42 and 0.44 km^3 of water via Rivers Ketar and Meki, respectively, and losses through Bulbula River about 0.21 km^3 and through evaporation 0.2 km^3 water per year per 100 km^2 of lake area (Wood and Talling, 1988). According to a later report by Tenalem Ayenew (2003), the annual inflows from Meki and Ketar Rivers into Lake Ziway were 264.5 and 392 million m^3, respectively, and indicated that there was considerable reduction of inflows from those rivers into Lake Ziway. It also indicated that the inflow into the lake has an annual deficit of 74 million m^3 over the overall water loss from the lake. There is an increasingly uncontrolled water abstraction from the inflowing rivers and the lake for irrigation, domestic and industrial uses in Ziway town and the surroundings and loss through evaporation from the lake (Girum Tamire and Seyoum Mengistou, 2014).

1.3. Biodiversity of Lake Ziway watershed

1.3.1. Plankton (Phytoplankton and Zooplankton)

A total of 122 phytoplankton species were identified by Tsegaye Miheretab (1988) of which 50 species were blue green, 41 green algae and the rest 31 diatoms, dominated by *Lyngbya limnetica*, *Microcystis aeroginosa* and *Synechoccus elongates*. Later study by Elizabeth Kebede and Willen (1998), reported 67 taxa. According to Girma Tilahun (2006), although *Microcystis* spp dominated the phytoplankton community of Lake Ziway, the number of phytoplankton species was only 58, different from the previous studies (Getachew Beneberu, 2005). Primary production and biomass of the lake have also been studied by Girma Tilahun

(1988), Zinabu Gebremariam *et al.* (2002), Getachew Beneberu (2005) and Girma Tilahun (2006) with a wide range of values.

In Lake Ziway 59 species (49 rotifers, 7 cladocerans and 3 cyclopoid copepods) of zooplankton were recorded (Adamneh Dagne, 2010). *Brachionus angularis, Filinia novaezealandiae,* and *Trichocerca ruttner* were the dominant rotifer species in the lake. Cladocerans of the lake include *Ceriodaphnia cornuta, Diaphanosoma excisum, Alona diaphana, Moina micrura* and *Daphnia* (Adamneh Dagne, 2010).

1.3.2. Fishes

There are seven indigenous fish species in the lake comprising *Barbus paludinosus, Garra dembecha, G. makiensis, Labeobarbus ethiopicus, L. intermedius, L. microterolepis* and *Oreochromis niloticus* (Golubtsov *et al.*, 2002; Abebe Getahun, 2010; Jacobus *et al.*, 2012). Of these, *L. ethiopicus, G. makiensis* and *L. microterolepis* were reported as endemic to the lake (Golubtsov *et al*., 2002 and Abebe Getahun, 2010). The lake also harbors five exotic fish species (*Tilapia zillii, Cyprinus carpio, Carassius carassius* and *Carassius auratus)* which were introduced to enhance its production, and *Clarias gariepinus* that slipped into the lake accidentally (Abebe Getahun and Stiassny, 1998; Golubtsov *et al.*, 2002). Therfore, the lake has several important fish species for fisheries.

1.3.3. Reptiles and Birds

Very few reptile species are commonly found in the lake and its inflowing rivers. Most ubiquitous reptile observed in the lake is the Nile monitor lizard (*Varanus niloticus*). The Lake supports over 20,000 water birds (Yared Beyene *et al*., 2014a), which are inhabitants of the lake.

Fig.1.3. Common birds at Lake Ziway. **(a)** Great White Pelicans (*Pelecanus onocrotalus*), **(b)** Hamerkop (*Scopus umbretta*), **(c)** Sacred Ibis (*Threskiornis aethiopicus*) and **(d)** Marabou stork (*Leptoptilos crumeniferus*).

The most common species are *Pelecanus onocrotalus*, *Scopus umbretta*, *Threskiornis aethiopicus* and *Leptoptilos crumeniferus* (Fig.1.3). The lake's ecosystem serves as breeding and wintering ground and as a migration stopover habitat for several resident and migratory bird species. It is one of the best sites in Ethiopia to see a diversity of bird species. However, most of the area around Lake Ziway has now been cleared for farmland; especially by large scale irrigated fields and floricultures. Therefore, the expansion of intensive agriculture (producing fruits, vegetables and flowers) and the indoor residual spraying program for malaria control has introduced pesticides and fertilizers into the ecosystem, and a decline in water birds and fish has been also noted in recent years (Yared Beyene *et al*., 2014b).

1.3.4. Mammals

In Lake Ziway, hippopotamus (*Hippopotamus amphibius*) is common in most parts of the lake (Fig. 1.4). A reasonable number of hippopotamus are commonly seen in and/or near the macrophytes on which they graze.

Fig.1.4. *Hippopotamus amphibius* around at littoral zone of Lake Ziway.

1.3.5. Macrophytes

Lake Ziway has an extensive area of littoral macrophytes including emergent, submerged and floating that are used for construction, animal feed, building of rafts for fishing. The shoreline of Lake Ziway (nearly 100%) has a ring of emergent macrophytes, which is dominated by reeds (Fig. 1.5). A pronounced reed belt is found in the northern part of the lake where the two rivers join the lake (Adamneh Dagne *et al*., 2008). Both the shallowness and the freshwater of the lake might favor the macrophytes which is not the case in the other nearby lakes (e.g. Langeno and Shala) which are saline and/or deeper.

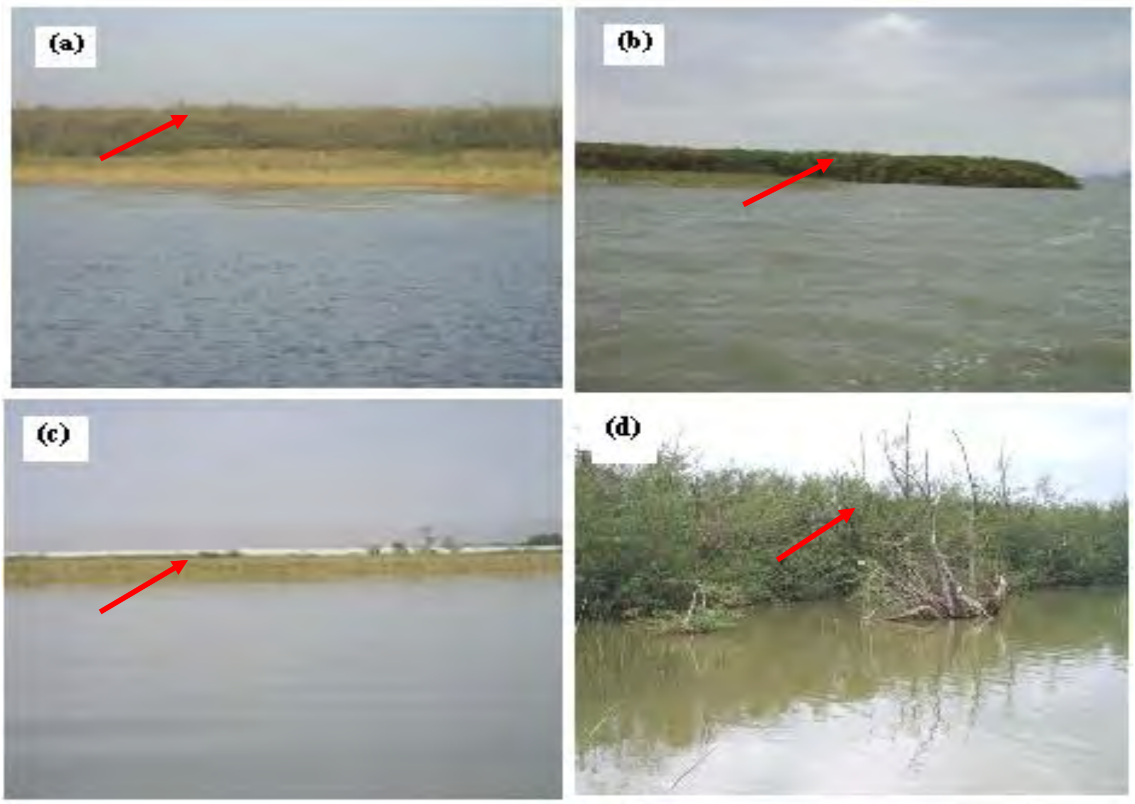

Fig.1.5. Macrophytes on the shore of northern part of the lake **(a)** *Aeschynomene elaphroxylon* and **(b)** *Cyperus papyrus*; and on southern part **(c)** *Arundo donax* and **(d)** *Aeschynomene elaphroxylon*

The lake is also unique in its macrophyte coverage compared to the nearby Rift Valley lakes. According to Girum Tamire and Seyoum Mengistou (2012), the most common emergent macrophytes in Lake Ziway are *Phragmites* sp., *Typha angustifolia*, *Scirpus* sp., *Cyperus papyrus*, *Arundo donax* and *Paspalidium qeminatum.* The common submerged and floating plants are *Potamogeton* sp. and the water lily *Numphaea coerulea*. Nevertheless, this extended macrophyte cover is endangered by the expansion of irrigated agriculture along the shore and even when the shore level recedes during the dry season the macrophytes are burnt (Girum Tamire and Seyoum Mengistou, 2014) to claim more space for horticultural crops.

1.3.6. Other invertebrates

The lake also contains bottom fauna that comprises gastropods (*Anisus natalensis, Biomphalaria sudanica, Bullinus forskahlii, Lymnea natalensis* and *Mellanoides tuberculata*), different kinds of insects, spiders, ostracods, and nematodes (Martens and Tudorancea, 1991; Alemayehu Negassa and Padanillay, 2008). Six ostracod species of which *Limnocythere thomasi thomasi* Martens (subspecies endemic to Lake Ziway) and *Gomphocythere angulata* Lowndes (common within the East African range) were reported Adamneh Dagne, 2010). Recently, most species reached their lowest density during the main rain when the turbidity was generally high (Adamneh Dagne, 2010). The benthic community of Lake Ziway in general is reported by Tudorancea and Taylor (Tudorancea and Taylor, 2002 Table 6.1)

1.4. Fishery

Almost all the fish consumed in Ethiopia are collected from the wild using artisanal methods. The current total fish production potential of the country is estimated to be around 51,481 tons annually for the main water bodies, of which only around 38,400 were exploited very recently (Fig.1.6) (FAO, 2014). According to Brook Lemma (2012), although there are some form of fisheries practiced in most freshwater bodies in Ethiopia, commercial fishery is concentrated at Lakes Tana, Chamo, Ziway, Abaya, Koka, Langano, Hawassa and Turkana. The major fish supply to the major cities and towns in Ethiopia are captured from the Rift Valley lakes (40%) and Lake Tana (50.2%) in the north (Tesfaye Wudneh, 1998) and the remaining percentage going to reverine fisheries. For instance, the rivers and floodplains in Gambela Region are estimated to have annual fish yield potentials of 15,000 to 17,000 tons (Hussien Abegaz, 2010), while the rivers and floodplains in Benishangul Gumuz Region are estimated to have potentials of 2,400 tons per year (Alayu Yalew, 2012).

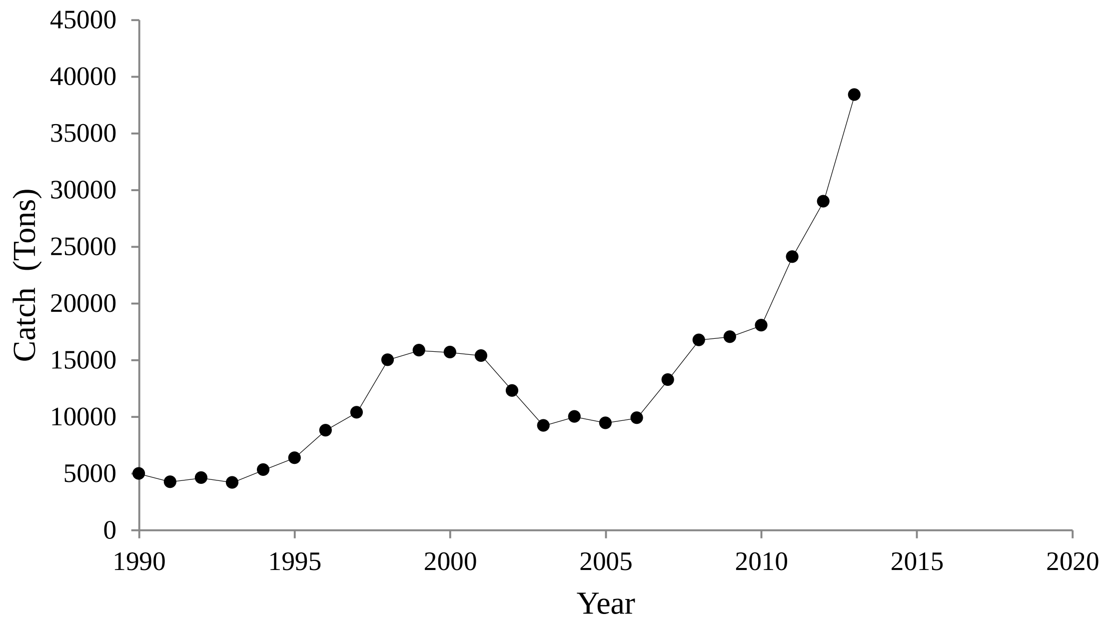

Fig.1.6. Trends of total fish catch of the country from 1990 to 2010 (Federal Ministry of Agriculture and website of the Central Statistics Office, cited by Brook Lemma, 2012 and from 2011 to 2013 (FAO, 2014).

Lake Ziway had a high fish yield potential of 3000 to 6680 tons per year (FAO, 1982). The fisheries activity in the lake was intensified through funding acquired from Lake Fisheries Development Project (LFDP) with the European Union (EU). The fisheries production has been the second largest from the Rift Valley lakes, which accounted for 3180 tons, next to Lake Chamo that produced 4500 tons per year (LFDP, 1998). However, the annual fish catch of the lake shows different trends at different times (Fig. 1.7).

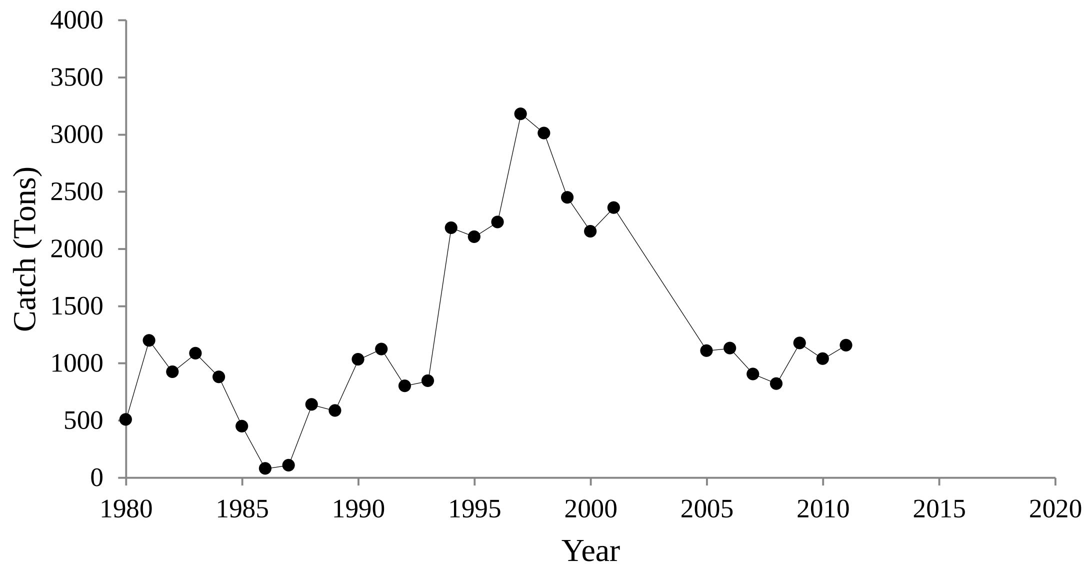

Fig.1.7. Trends of total fish production of Lake Ziway from 1980 to 2010 (Source: LFDP, 1998; Felegeselam Yohannes, 2003; Mathewos Hailu, 2011; Brook Lemma, 2012).

According to Yared Tigabu (2003), there was a continuous decline in the annual catch of some fish species like *O. niloticus* from the lake since 1997, but on the other hand an increase of *C. gariepinus* was observed in the fishermen catches since 2010 (Mathewos Hailu, 2011). In the same way, very recently increase in the catches of *C. carpio* was recorded (Lemma Abera *et al*., 2014a).

The fishermen use wooden boats for beach seining and rafts for gillnet and long-lines, while motorized boats are used for collecting catch from reed-boat fishermen in some areas. The number of beach seines, a common fishing gears at the lake, rose from about 39 in 1983 to over 116 in 1995 (LFDP, 1997). The number has, however, fallen to 68 in 2009/2010 (Mathewos Hailu, 2013). The number of gillnets has also decreased drastically from 2470 in 1995 to 104 in 2009/2010. In contrast to beach seine and gillnet the number of hooks utilized in long-lines has increased from none in the early 90's to 56,070 in 2009/2010 (Mathewos

Hailu, 2013). Long-lines are meant to catch large-sized *C. gariepinus*. The increase in long-line fishery is associated with low labor and capital investment requiring only one person and just a raft, while using a beach seine requires three or more persons to operate with a wooden boat. The use of illegal fishing gear, such as beach seine with smaller mesh size, has been fairly widespread and poorly monitored. Recent studies have shown that 96% of nets operating in the lake are under the recommended mesh size (Mathewos Hailu, 2013).

1.5. Justification and research questions

Freshwater ecosystems have been subjected to various environmental and human induced changes throughout the globe for centuries (Alfred, 2002) and they are the most endangered ecosystems in the world. The changes associated with environmental degradation range from loss of biodiversity to complete loss of ecosystems (Brook Lemma, 2003; Tenalem Ayenew and Dagnachew Legesse, 2007). In recent years, the establishments of increasing human populations as well as intense agricultural practices in catchments have resulted in significant degradation and loss of pristine ecosystems (Petra *et al*., 2008). Interventions in fisheries management so as to meet the increasing demand for fish has resulted in overexploitation particularly the commercially important fish species (Hilborn *et al*., 1995). Furthermore, introduction of exotic species has also been practiced to enhance fisheries and filling the available niche in ecosystems (Welcomme, 1988).

Although, Ethiopia has high production potential and composition of fish fauna, rigorous fishery investigation has been carried out only in a few of the numerous freshwater bodies. The territory of Ethiopia seems to be among the regions of African continents which are least explored for the ichthyofauna (Golubstov *et al*., 1995). Knowledge on composition, population structure, distribution and population of the Ethiopian ichthyofauna as well as biology and production of the fish species is far from being complete, and relatively a large number of small, medium and even some large rivers have not been well studied and explored (Abebe Getahun, 2005).This is particularly the case with the fish fauna of inland waters of Ethiopia in general and in Lake Ziway in particular. One of the main factors in water pollution around Lake Ziway is the unwise utilization of agrochemicals especially that of pesticides and 100% of the irrigated horticulture farmers utilize different type of agrochemicals. The pesticides are applied more than 20 times during three months of cultivation (Mathewos Hailu *et al.*, 2012). The nearby growing town of Ziway also contributes some urban wastes via run off.

Fish production has become a victim of change in lake water level and water chemistry. The decline in lake volume damages the breeding grounds of fish species that spawn in littoral vegetations of the lake, particularly, *O. niloticus* commercially the most important species.

The open access characteristic of the fishery in the area increases the number of fishermen, which in turn leads to stock depletion (Felegeselam Yohanes, 2003). Benson (2012) also confirmed that in Lake Victoria the decline in fish catch has been attributed to channeling, destruction of riparian vegetation, agricultural and industrial pollution, hydrologic alterations, illegal methods of fishing (e.g. use of nets of small mesh sizes) amongst others.

Hence, to sustain the development of the fishery in the lake different fishery research activities were conducted on the taxonomy (Golubtsov *et al.*, 2002, Stiassny and Abebe Getahun, 2007), biology (Zenebe Tadesse, 1988; Eyualem Abebe and Getachew Tefera, 1992; Demeke Admassu, 1998; Demeke Admassu and Ahlgren, 2000; Alemayehu Negassa and Abebe Getahun, 2003; Daba Tugie and Mesert Taye, 2004; Elias Dadebo and Daba Tugie, 2009;

Lemma Abera and Alemu Lemma, 2011; Mathewos Hailu, 2013; Lemma Abera *et al.*, 2014a), ecology (Zenebe Tadesse, 1988), stock assessment (LFDP, 1996, 1998; Felegeselam Yohannes, 2003; Gashaw Tesfaye, 2006), and fish health (Eshetu Yimer, 2003; Lemma Abera, 2012) and some socio-economic issues (Mberengwa and Zelalem Bacha, 2011; Dawit Garoma, *et al*., 2013a and b; Megerrsa Endebu *et al*., 2013; Assefa Mitike and Lemma Zemedu, 2015).

Although several studies were conducted on Lake Ziway on various aspects, the changes on the lake are fast and hence the information on the lake gets obsolete quickly. Therefore, regular updating, monitoring and control are essential and this study becomes important and relevant for better management and sustainable use of the resources. The following are the research questions posed:

1. How does the variation in physico-chemical factors influence the fish community structure of the lake?
2. What are the current species composition, distribution and relative abundance of the fishes in Lake Ziway?
3. What is the biology of the fishes that were not assessed yet in the lake?
4. What does the present and previous decadal distribution of fishes indicate in relation to environmental changes in the lake?
5. How is the current situation of the fisheries compared with previous periods?
6. What are the alternative livelihood sources and the fishery activities of the fishermen?
7. What are the existing threats to the fish production of Lake Ziway?
8. What management options should be implemented to reverse the declining trend of the fish stock of Lake Ziway?

1.6. Objectives of the study

1.6.1. General objective

The general objective of the study is to generate scientific information on the statu and trends of the fish and fishery of Lake Ziway that could assist in suitable exploitation and development of management strategies for the lake, so that the resource could sustainably contribute to food security in the country.

1.7.2. Specific objectives

- To assess the variations in some physico-chemical factors that influence the fish community structure of the lake.
- To update the species composition, distribution and relative abundance of the fishes.
- To estimate length-weight relationship, condition factor and sex ratio of the fishes.
- To determine breeding season, size at maturity and fecundity of the exotic fish (*C. carpio*).
- To assess the trends of the catch levels, species composition of catches and fisheries compared with previous work.
- To review the alternative livelihood sources and the fishery activities of the fishermen around the lake.
- To identify the existing constraints that affect the fish production of the lake.

1.7. Thesis outline

This dissertation deals with fish species composition, distribution and abundance with physico-chemical interaction, some biology of fishes, status and trends of fishes and fishery; and some socio-economic issues of the lake fishery. It has six main chapters: The first chapter outlines the general introduction like formation and location of the lake, climate and biodiversity issue, the fisheries activity in general and justification with research questions that would be answered in the course of this research.

The second chapter deals with the species composition, distribution and abundance in relation to some physico-chemical factors that influence the fish community structure of the lake. The third chapter deals with some biology of the fishes that includes the detailed studies of reproductive biology of *C. carpio*. The finding from this chapter has been published in Global Journal of Fisheries and Aquaculture; and also in Global Journal of Agricultural Research and Reviews.

The fourth chapter discusses the historical changes in species composition by comparing data from this study with earlier reports including the current fish and fishery status of the lake. In this chapter changes in some environmental factors that affect the production of fish are also discussed. The fifth chapter investigates the alternative livelihood sources of the fishery community; participation of household member towards livelihood activities; the major constraints of the fisheries and marketing system of fishes in the area. Finally, the last chapter concludes the major findings of the whole work and suggests some management options and research gaps for further studies.

CHAPTER 2: FISH SPECIES COMPOSITION, DISTRIBUTION AND RELATIVE ABUNDANCE IN RELATION TO SOME PHYSICO-CHEMICAL FACTORS IN LAKE ZIWAY

2.1. Introduction

Aquatic organisms are fundamental components in the ecological processes of shallow lakes (Scheffer *et al*., 1993). The functions of these organisms in lake ecosystems is related to their species composition, distribution and abundance which in turn depend on various environmental factors such as light, water temperature, substrate composition, disturbances and quality of the lake water (Duarte *et al*., 1986; Wetzel, 2001; Jafari *et al*., 2003).

Hence, fishes provide ecosystem services in the form of supplying food to community that are also essential for ecosystem function and resilience. These regulating services include top-down effects regulating population dynamics and nutrient availability in or near sediments, and carbon exchange (Cecilia and Monica, 1999). Linking services include active transport of nutrients, carbon and energy between the pelagic and bottoms; and the littoral (Cecilia and Monica, 1999).

The relationship between environmental factors and the distribution of organisms within aquatic environments has received considerable attention. Fishes are one of the dominant macro faunal components of aquatic biota, and the studies have focused on their distribution patterns (Daniel *et al*., 2013). The relative importance of each factor differs according to the species and knowledge of aquatic habitat use by fishes, which is important for the improvement of conservation policies with a view to preserving ecologically importance.

Some studies on Lake Ziway have confirmed decline in phytoplankton biomass and net annual loss of water from the lake (Tenalem Ayenew, 1998; Girma Tilahun, 2006; Adamneh Dagne *et al*., 2008; Getachew Beneberu and Seyoum Mengistou, 2009), change on hydrological status of the lake (Alemu Dribssa, 2006; Tenalem Ayenew and Dagnachew Legesse, 2007) and even change on some ecology of fish (Abebe Getahun, 2001; Golubtsov *et al*., 2002; Golubtsov and Mina, 2003; Mathewos Hailu, 2011). All these have shown evidence of undesirable changes that have occurred in the lake. However, the role of nutrient in the functioning and structuring of the lake system and the impact of such changes on fish and vice versa, have not been investigated so far.

Additionally, the fishery biologists, particularly those working in tropical countries, traditionally have tended to consider fish in isolation, as a natural renewable resource, rather than as integral components of the aquatic ecosystem interacting with other components of the system (Leveque, 1995 in Vijverberg *et al*., 2012). This attitude has led to various ecological changes, like food web; therefore, a better understanding of the role of fish distribution in the functioning of ecosystems should be a precondition.

In addition, quantitative assessments of fish species composition based on experimental fisheries are scarce for Ethiopian lakes. The best quantitative information is for L. Tana (e.g. Eshete Dejen *et al*., 2003, 2006, 2009; de Graaf *et al*., 2006, 2008) and for L. Abaya (Schroder, 1984). Hence, assessing the taxonomic composition, distribution and abundance of fishes is also important in the determination of the status of the fishes in the lake.

Thus, Lake Ziway is among such freshwaters that have received no adequate attention on the management of the fishery in general especially in recent years when fish distribution of the lake are considered to be scarce. Hence, the importance of fish exploration of Ethiopian freshwater systems on one hand and the absence of adequate study on fish composition, distribution and relative abundance on the other, justifies this study on Lake Ziway. Therefore, this chapter attempts to assess the variation in physico-chemical factors that influences the fish community structure of the lake and to update the species composition, distribution and relative abundance of the fishes in the lake.

2.2. Materials and Methods

2.2.1. Site selection

Before starting regular sampling program a reconnaissance survey was conducted together with the research advisors to fix the sites. Hence, a total of six sampling sites were selected based on geographical proximity and/or habitat similarity (river mouths neighboring floodplains, depth and distance to shore), their distance from human settlements and anthropogenic effect (Fig.2.1). Global Positioning System (GPS) was taken to demarcate the locations of the sampling sites, which are presented in Table 2.1.

This type of categorization is helpful to note the influence of human impacts on the distribution and abundance of fishes in the lake. Based on these, the detailed characteristics of each site are described as follows:

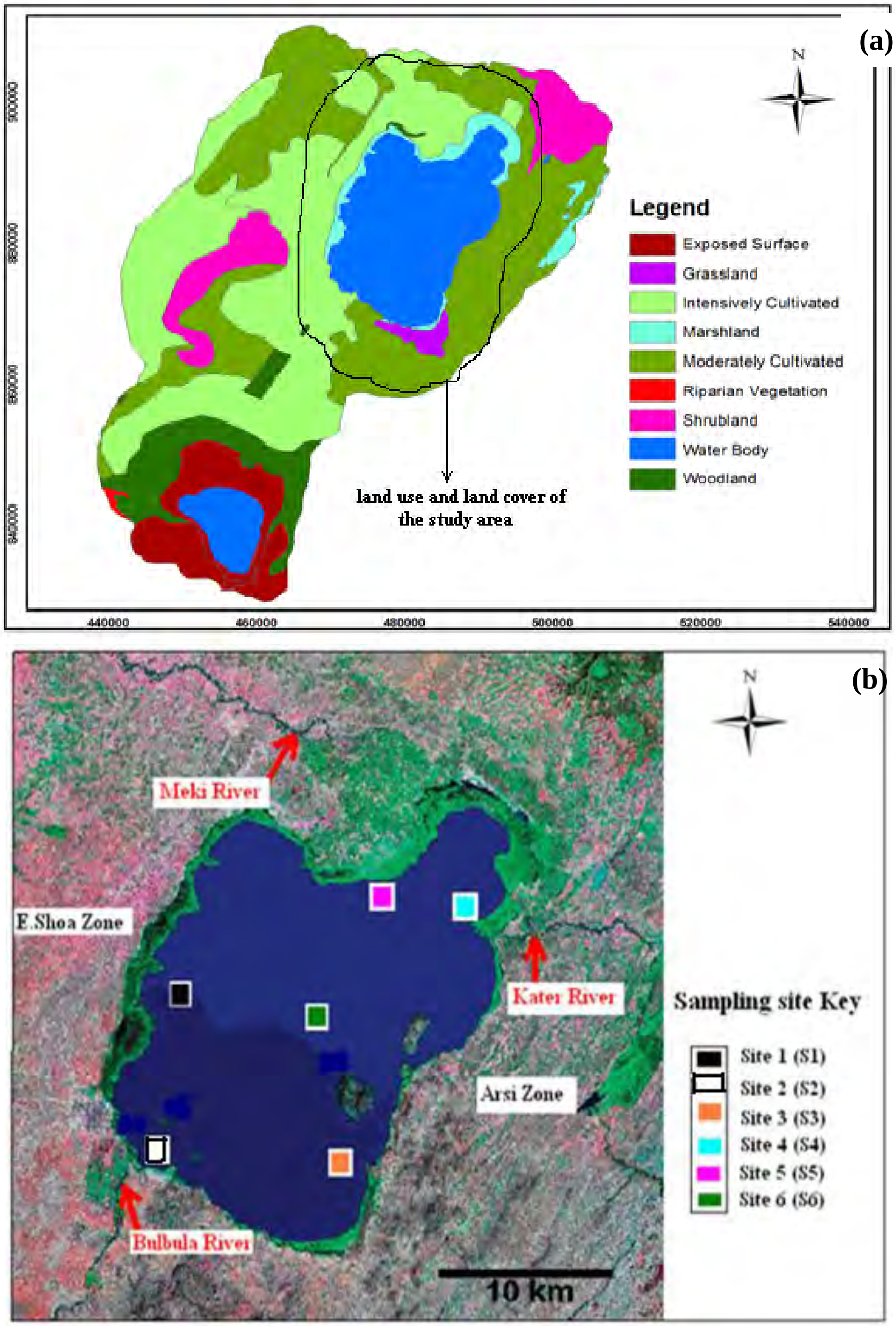

Fig.2.1. **(a)** Land covers of the study area (Salim Nigussie, 2013) and **(b)** Lake Ziway satellite image with the sampling sites indicated.

Table 2.1. Some characteristics of the sampling sites

Location of the study site		Relative location	Designation
Latitude	Longitude		
$07^0$54.79' N	$038^0$144.111'E	Western part of the lake	Site 1 (S1)
$07^0$54. 053' N	038^0 144.11'E	Southern part (Bulbula River mouth)	Site 2 (S2)
$07^0$55' N	$038^0$52.086'E	Eastern part of the lake	Site 3 (S3)
$08^0$05. 379' N	038^0 56.459'E	Northern part (Ketar River mouth)	Site 4 (S4)
$08^0$04. 6000' N	038^0 53.509'E	Northern part (Meki River mouth)	Site 5 (S5)
$07^0$55. 49' N	038^0 52.934'E	Center of the lake	Site 6 (S6)

Site 1: The site is located in the western part of the lake and the shoreline is characterized by intensive cultivation (Fig.2.1) with horticulture and field crops including flower farm. The sampling site was far from Ziway town, the flower farm and spots of horticulture cultivation (on the average about within a distance of at 0.5 to 7 km offshore at depths of 1.5 to 2.9 meter). The vegetation cover around the shoreline is degraded (Fig. 2.1).

Site 2: The site is located around the river mouth of Bulbula in the area between intensively and moderately cultivated shorelines (Fig. 2.1), with a distance of 1.5 km from the tip of the mouth of River Bulbula. The depth was between 1.5 to 2.3 m. The riverbed is mostly composed of mud.

Site 3: It is located on eastern part of the lake in Z.Dugda district in between Yerera (shoreline of the lake) and Tulu Gudo Island. The sampling site was distantly away from the shore of the lake on average about within a distance of 1.5 to 5 km at a depth of between 1.5 to 3.10 meter and the vegetation cover around the shoreline is almost conserved woodland (Fig. 2.1).

Site 4: It is located around the river mouth of Ketar with a distance of 1.5 km from the tip of the mouth of Ketar River. As is the case with the other sites, the area is also characterized as moderately cultivated; however, the vegetation cover is relatively denser with shrub and marshland (Fig. 2.1). The depth was between 1.5 to 3.20 m. The riverbed is mostlycomposed of mud and gravel.

Site 5: The site is located at the northern part of the lake and characterized by high human interference with horticulture and field crop activities next to site one (Fig. 2.1). The sampling site was far away from Meki town, and the horticulture activities are within a distance of 0.5 to 5 km and the water depth was 1.5 to 2.9 meter.

Site 6: It is located almost at the center of the lake at a depth of 3.2 to 4.8 meters (Fig. 2.1). The site was characterized by the activities of some fishermen using gillnets and long-lines.

2.2.2. Field sampling and measurements

2.2.2.1. Physico-chemical parameters

Physico-chemical parameters of the water were measured monthly from each site for two consecutive years (October 2012 to September 2014). Temperature, pH and conductivity of the lake were measured *in situ* during sampling periods at each sampling site. Temperature and pH were measured using a portable digital pH meter (Hanna 9024) and conductivity was measured using conductivity meter (Elmetron-model of CC411). Transparency was measured with a Secchi disc of 20 cm diameter. Depth was also recorded at each sampling station.

Water samples were collected from each site in dark plastic bottles, washed with acid and rinsed with distilled water several times in duplicates for nutrient analysis. Water samples for Chlorophyll-*a* determination were taken by the Schindler sampler from all sites.These samples were transported on ice to the laboratory.

2.2.2.2. Fish parameters

Parallel to the physico-chemical sampling, every month the fishes were collected at all sites using variety of fishing gears, which included gill nets of various mesh sizes (6, 8, 10 and 12 cm stretched mesh size), monofilament nets with various stretched mesh sizes (5 mm to 55 mm stretched mesh size) and multiple long-lines with hooks of different size (9,10,11 and 12). The gears were set in the afternoon (4:00 pm) and were collected in the following day (7:00 am) (Fig. 2.2).

Fig.2.2. **(a)** Making fish gear, **(b)** nets setting and **(c)** collecting the nets from the lake

Immediately after capture, total length (TL), fork length (FL) for fork-tailed species, and total weight (TW) were measured to the nearest 1cm and 1g, respectively. Finally, the fish samples were put in plastic jars containing 10 % formalin and labeled with all necessary information. For further identifications, the fishes were transported to Fisheries Laboratory, Ziway Fishery Research Center and Department of Zoological Sciences, Addis Ababa University.

2.2.3. Laboratory studies

Nitrate was measured with sodium salicylate method, ammonium with indo-phenol blue (APHA, 1995), and soluble reactive phosphate (SRP) with ascorbic method (APHA, 1999). Nitrite concentration was determined by the reaction between sulfanilamide and N-naphthyl-(1)-ethylendiamin-dihydrochloride (APHA, 1995).

The preserved specimens were soaked in tap water for many days to wash the formalin away. Then, they were transferred to 75 % ethanol before species identification was conducted. The specimens were identified to species level using taxonomic keys of Shibru Tedla (1973), Golubtsov *et al*. (1995); Witte and Wim (1995); Stiassny and Abebe Getahun (2007); Redeat Habteselassie (2012) and figures from Fishbase. Finally the species were labeled and deposited at the Fisheries Laboratory, Department of Zoological Sciences, Addis Ababa University and Ziway Fishery Research Center (Fig 2.3).

Fig.2.3. Fish specimens deposited at Ziway Fishery Research Center

2.2.4. Species description

Originally (both at the sites and in laboratory) the fish specimens were sorted out into groups based on their general appearance. Then this sorting was further extended to smaller number of specimens for the dominant morphotypes. All the morphotyes with few specimens were used for species description without sorting them into smaller number and some characteristics of the species were included in formal species description.

2.2.5. Data analysis

Prior to conducting Canonical Correspondence Analysis (CCA), Detrended Correspondence Analysis (DCA) was employed to check the response of the species data matrix (dependent set) to the environmental data matrix (independent set) using CANOCO for windows 4.5 version software followed by Pearson's correlation in order to explain the relationships between biological assemblages of species and the environmental variables using PAST software. Therefore, CCA was used because the species data showed unimodal response to the environmental variables. According to Leps and Smilauer (1999), Redundancy analysis (RDA) or linear method should be used only if the length of the longest gradient is shorter than 3. Redundancy analysis was also performed to observe the relation of species abundance data to environmental factors. Principal components analysis (PCA) was employed to observe the difference among the study sites with respect to their physico-chemical properties. The PCA was carried out using correlation because the variables were on different scales.

Species abundance at each sampling station was presented as a numerical contribution by each species. This was determined by calculating the percentage of each species represented in the total catch for each station. Fish species diversity in the lake was computed using Shannon and Wiener Diversity Index following Shannon and Wiener (1963). Descriptive statistics were also used to analyze the remaining collected data using SPSS software (SPSS V.19.0).

2.3. Results

2.3.1. Physico-chemical parameters in the study sites

The nutrients displayed relatively more variation among sites than did the physical parameters during the sampling periods (Table 2.2). Daytime temperature of the studied sites ranged from 20.78 ^{0}C to 24.11 ^{0}C whereas pH ranged from 8.03 to 8.37. Dissolved oxygen varied from 3.46 to 6.01 mg/l. Low dissolved oxygen was measured at sites categorized as heavily impacted sites. Conductivity varied from 361.50 to 484.51 µS/cm. Soluble Reactive Phosphate varied from 38.20 to 64.73 µg/l and nitrite ranged from 18.62 to 40.38 µg/l. Relatively an extremely high value of nitrate 61.66 µg/l was recorded in the western part of the lake (S1). Ammonium ranged from 64.17 to 258.92 μg/l and the mean values of Chl-*a* ranged from 37 to 54.50μg/l (Table 2.2). The minimum and maximum mean values of Sechi depth readings were between 17.85 to 22.12 cm and the detailed descriptions for each sampling site are given in Table 2.2.

Table 2.2. Pooled mean and standard error values of physico-chemical variables of the study sites (From October, 2012 to September, 2014).

	Sites					
Parameters	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Temperature (^{0}C)	23.46±0.5	24.11±0.6	23.65±0.7	20.78±0.4	22.29±0.7	23.93±0.1
Secchi depth (cm)	19.98±0.7	22.12±0.9	21.4±0.5	18.79±0.2	17.85±0.3	21.58±0.7
Nitrite (μg/L)	40.38±0.7	30.67±0.2	23.57±0.2	30.81±0.4	30.03±0.3	18.62±0.2
Nitrate (μg/L)	61.66±10.6	44.41±5.5	42.81±2.6	30.1±4.7	52.32±9.5	33.01±14.1
Ammonium (μg/L)	124.55±1.1	112.6±8.8	130.3±4.7	64.17±11.9	258.92±9.4	125.23±0.3
SRP (μg/L)	59.19±36.3	50.34±3.9	64.73±4.7	43.75±24.5	42.64±4.1	38.2±19.1
Dissolved Oxygen(mg/l)	3.46±0.1	3.76±0.1	4.15±0.3	6.01±0.5	5.71±0.6	4.39±0.6
Chl- *a* (μg/L)	50±0.9	54.5±2.3	49±8.9	42.5±7.9	37±6.4	44.5±5.3
pH	8.03±0.2	8.23±0.1	8.3±1.3	8.29±0.3	8.09±0.1	8.37±0.1
Conductivity (μS/cm)	484.51±15.3	396.6±5.7	361.5±9.7	376.95±23	404.8±25.9	366.7±1.9

Axis 1 and Axis 2 of the principal component analysis explained 78.1% of the total variance (Fig. 2.4) regarding the sites versus physico-chemical association where the first axis and second axis contributed 48.3% and 29.8% of the variation, respectively. The result of the analysis discriminates Site 1 from the others (by Axis 2), owing to higher value of Nitrate

(0.88), Conductivity and Nitrite (0.87 each) which had highest loading factor on the axis; and positively correlated with the axis (Table 2.3). Site 4 and 5 showed relatively high value of dissolved oxygen and are negatively correlated (-0.99) with the first axis (Fig. 2.4 and Table 2.3). Secchi depth Temperature, Chl-*a* and pH were positively correlated (0.8, 0.86, 0.91 and 0.94, respectively) with Axis 1 and had the highest loading factors (Table 2.3). Site 5 was different from others by having relatively higher ammonium (Fig. 2.4).

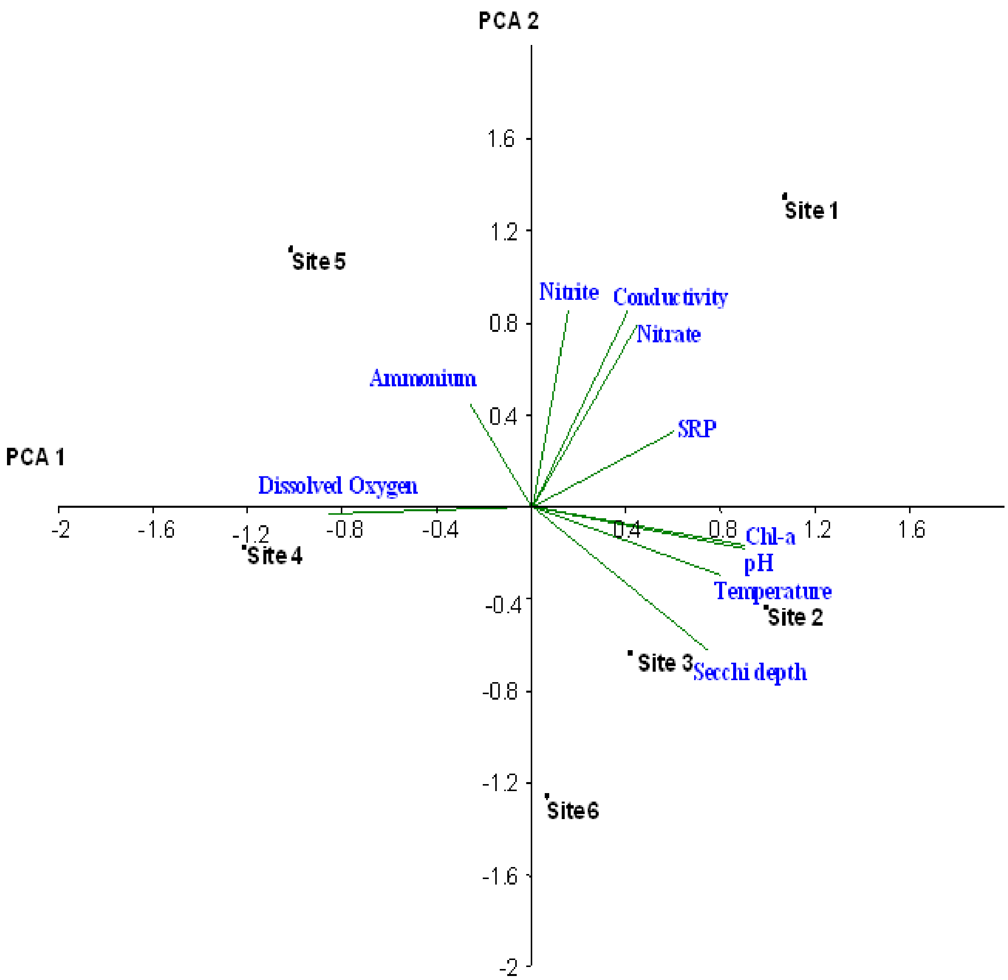

Fig.2.4. Principal component analysis ordination diagram of the physico-chemical factors at the study sites.

Table 2.3. Correlation coefficient of the environmental variables used in this study with the first two principal component axis (strong correlations are marked bold)

Environmental variable	Canonical coefficients	
	Axis 1	**Axis 2**
Temperature	**0.86**	-0.19
Secchi depth	**0.80**	-0.59
Nitrate	0.15	**0.88**
Nitrite	0.40	**0.87**
Ammonium	-0.27	-0.42
SRP	0.62	0.29
Dissolved Oxygen	**-0.99**	-0.05
Chl-*a*	**0.91**	-0.13
pH	**0.94**	-0.14
Conductivity	0.34	**0.87**

2.3.2. Fish species descriptions

I. *Barbus paludinosus* (**Peters, 1864)** (Fig. 2.5):

Diagnosis: Body depth 3.4 to 4 times in total length. Head length is 3.6 to 4 times in total length. Eye diameter is 3.5 to 4 times in head length. Two pair of barbels; anterior half diameter of eye, posterior ¾ to once eye diameter. Lateral lines complete with 34 to 39 scales.

Description:. Dorsal fin with III 7 rays; equally distant from anterior border of eye and caudal fin base, originating well behind vertical of ventral fin base; last simple ray bony and strongly serrated, as long as or a little shorter than head.

Distribution: The species was widely distributed in the whole sampling sites of the lake.

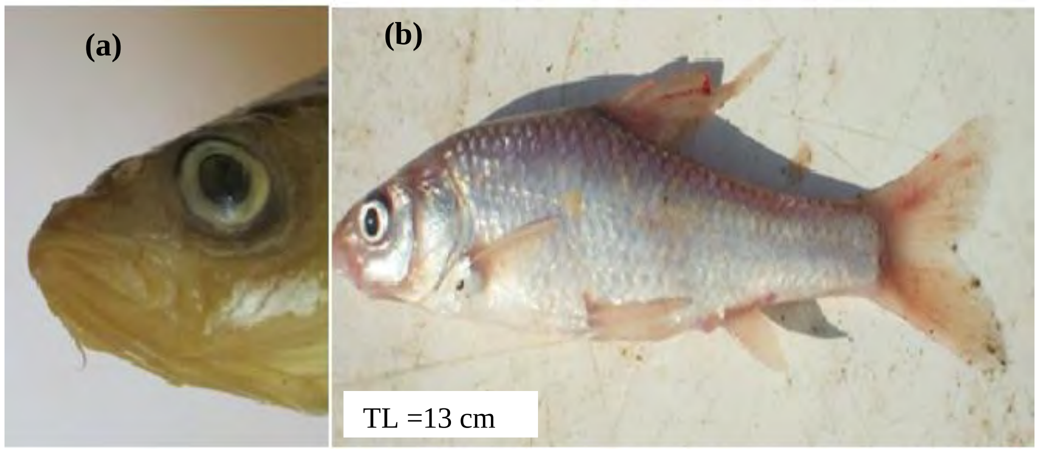

Fig.2.5. **(a)** Ventro lateral view of the mouth and **(b)** Lateral view of *Barbus paludinosus*

II. *Carassius carassius* (Linnaeus, 1758) (Fig. 2.6):

Diagnosis: No barbels present; anal fin with branched rays. Caudal fin bluntly lobed. Snout well rounded. 33 lateral line along 31-36 scales.

Description: the leading ray of the dorsal fin is weak and the fin is convex in shape, caudal fin bluntly lobed. Juveniles have a black spot at the base of the tail, which disappear with age. Young fish are golden-bronze but darken with maturity, until they gain a dark green back, deep bronze upper flanks. One distinguishing characteristic is a convexly rounded fin, as opposed to goldfish hybrids which have concave fins.

Distribution: The fish was found in all the sampling sites.

Fig.2.6. Lateral view of *Carassius carassius*

III. *Cyprinus carpio* (**Linnaeus, 1758)** (Fig. 2.7):

Diagnosis: The spines on both dorsal and anal fins are strongly serrated. Dorsal spines 3 to 4, dorsal soft rays 17 to 23; anal spines 2 to 3; anal soft rays 5 to 6. Caudal fin with 3 spines and 17-19 rays.Dorsal fins outline concave anteriorly. There are strongly serrated spines in the dorsal and anal fins; anal fin with 5 branched rays. Lateral line with 32 to 38 scales.

Description: Body elongated and somewhat compressed. Body length about four times body height. The lips are thick and two pairs of barbels at angle of mouth, shorter ones on the upper lip. In Lake Ziway there are sub-species either with a normal scale similar to other cyprinids or with large and thick scales (Fig.2.7.b). The sub-species have very variable in form, squamation, development of fins and color.

Distribution: The fish was distributed in all the sampling sites

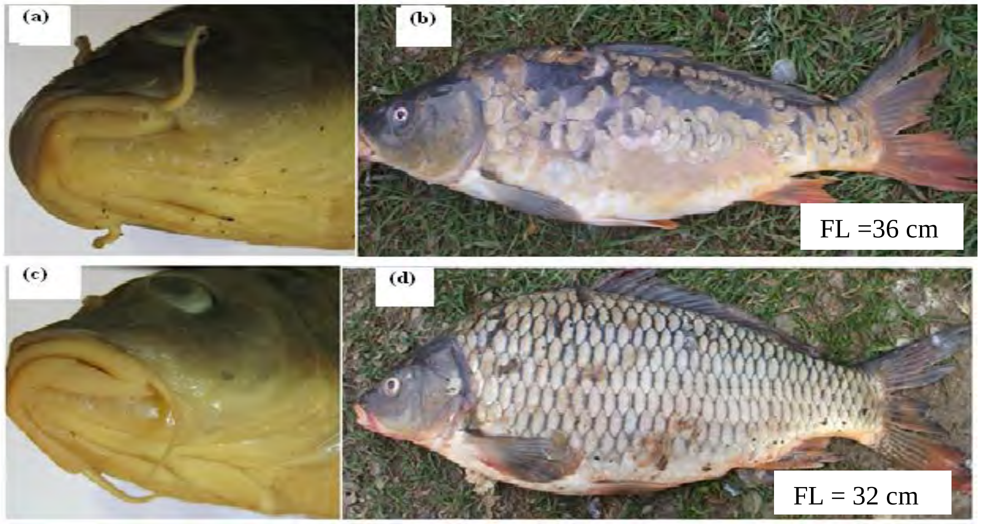

Fig.2.7. **(a)** Ventral view of the mouth and **(b)** *Lateral* view of *Cyprinus carpio specularis* (Large and thick scales); and **(c)** Ventral position of the mouth and **(d)** *Lateral* view of *Cyprinus carpio communis* of normal scale similar to other cyprinds

IV. *Garra dembecha* (**Stiassny and Abebe Getahun, 2007)** (Fig. 2.8):

Diagnosis: Dorsal fin having III, seven rays inserted well in advance of pelvic fine, 5.5 scales from lateral line to dorsal fin origin. 37 to 38 scales in lateral line. Pelvic fin pointed, not reaching the anus, shorter than head length. Two pairs of barbels; maxillary barbels usually about the same length as rostral pair.

Description: The fish has weakly developed disc; predorsal region partially scaled anterior to dorsal fin and postpelvic region asquamate. Chest is naked, whereas belly and post pelvic regions are scaled, with some of the belly scales embedded beneath skin. Dorsal profile slightly convex. Eyes positioned medially on head. Has narrow mouth with well developed rostral cap covering the upper jaw. Caudal fin deeply forked. Vent distant from anal fin.

Distribution: The species was relatively distributed in shallow part of the lake.

Fig.2.8. (a) Lateral view and (b) Ventral view of the mouth of *Garra dembecha*

V. *Garra makiensis* (Boulenger, 1902) (Fig. 2.9):

Diagnosis: Two pairs of barbells (maxillary and rostral). Some scales on belly; distance from vent to anal fin 10 -16 % of distance between anal and pelvic fin insertions; eye either median, or posterior in large specimens.

Description: Well-developed, large papillate disc; scaled predorsal and postpelvic regions; chest and belly with a few non-overlapping scales; vent located very close to anal fin.

Distribution: The species was found in the first four sites of the lake.

Fig.2.9. **(a)** Lateral views and **(b)** Ventral position of the mouth of *Garra makiensis*

VI. *Labeobarbus ethiopicus* (**Zolezzi, 1939)** (Fig. 2.10):

Diagnosis: Dorsal fin with 3 to 4 unbranched rays and 6 to 8 branched rays; anal fin with 3 to 4 unbranched and 5 branched rays; pectoral fin with two unbranched and 14 to 15 branched rays.

Description: Easily distinguished by the large number of lateral line scale (46-52 in lateral line). The last unbranched ray in the dorsal fin is ossified as a smooth spine, and two pairs of well-developed barbells are present.

Distribution: The species was caught mostly in the center of the lake.

Fig.2.10. Lateral view of *Labeobarbus ethiopicus*

VII. *Labeobarbus intermedius* (Ruppell 1836) (Fig. 2.11):

Diagnosis: Eyes small, about 14 % in head length. Barbells small, 2 pairs on the upper jaw only covered with cycloid scales. 30-36 scales in the lateral line. Body depth is shallow and 19-32% of the standard length.

Description: Mouth terminal and protractile.. Dorsal fin originates immediately above the pelvic fin. Dorsal and anal fin short, the former with a sharp spine and the latter base shorter.Moderately developed dorsal spines are present. No adipose fin. Fresh specimens show extremely variable color but the most common color color is light yellow.

Distribution: The species was widely distributed in all sampling sites of the lake.

Fig.2.11. **(a)** Side view of the mouth and **(b)** Lateral view of *Labeobarbus intermedius*

VIII. *Clarias gariepinus* (Burchell, 1822) (Fig. 2.12):

Diagnosis: *Clarias gariepinus* has scale-less slimy skin. Head is highly flattened dorso-ventrally. The skull bones above and on the sides are casque shaped. It is easily distinguished by the lack of adipose fin. The species has very long dorsal and anal fins.

Description: Eyes are relatively small, about 6.9% of head length, and are laterally placed. The head is large, depressed, and heavily boned. The mouth is quite large and sub-terminal in position. Four pairs (nasal, maxillary, outer mandibular and inner mandibular) of barbells are found around the mouth. There are two nostrils very close to the origin of nasal barbells.The species have small pointed teeth in large bands on the upper and lower jaws. *C. gariepinus* has long dorsal and anal fins that extend to the origin of caudal fin, each terminate in lobe.The dorsal fin has ranged from 63-70 soft rays and anal fin has 49-54 soft rays. Pectoral fins are very strong with spines that are serrated on the outer side.

Distribution: The species is distributed in all the study sites of the lake.

Fig.2.12 Lateral view of *Clarias gariepinus*

IX. *Oreochromis niloticus* (Linnaeus, 1757) (Fig. 2.13):

Diagnosis: The species has single dorsal fin with many spines. Lateral line divided into upper and lower sections, with 31 scales. There are only one nostril on each side of the snout. Faint traces 8 dark vertical bars on the flanks and the caudal peduncle. Gill rakers are 27 or 28 on the lower half of the first gill arc.

Description: Head naked. Snout rounded. Protuberance are absent on the dorsal surface of snout. The mouth part is moderately large and terminal. Outer jaw contains several teeth in 4 series rows. Eyes are visible from the dorsal only (supero-lateral). Body somewhat compressed laterally. Scales are cycloid. Lateral line interrupted. Dorsal with XII11-XVIII12; anal III8-III9. Caudal fin truncated with 8-10 faint Vertical bars.

Distribution: The species was widely distributed in the first five sampling sites.

Fig.2.13. Lateral view of *Oreochromis niloticus*

X. *Tilapia zillii* (Gervais, 1948) (Fig. 2.14):

Diagnosis: Upper profile of head not convex; lower pharyngeal bone about as long as broad, and with anterior lamella shorter than toothed area; median pharyngeal teeth not broadened Body brownish-olivaceous with an iridescent blue sheen; lips bright green. Chest pinkish. This species has greyish caudal fins with dots on entire caudal fin.

Description: Dorsal fin with 14-16 spines and 10-14 soft rays; 8-11 lower gillrakers; dark longitudinal band appears on flanks when agitated. Outer jaw teeth bicuspid and non-spatulate, inner jaw teeth and posterior pharyngeal teeth tricuspid; micro-gillrakers present. Six to seven dark vertical bars cross two horizontal stripes on the body and caudal peduncle.

Distribution: Distributed in the whole sampling sites of the lake except at the center.

Fig.2.14. Lateral view of *Tilapia zillii*

2.3.3. Fish species distribution

A total of ten species of fishes in the Families Cyprinidae, Clariidae and Cichilidae were identified from the different sites in the lake (Table 2.4). The species were *Barbus paludinosus, Carrasius carassius, Cyprinus carpio, Garra dembecha, Garra makiensis, Labeobarbus ethiopicus* and *Labeobarbus intermedius* from the Family Cyprinidae, *Clarias gariepinus* from the Family Clariidae and *Oreochromis niloticus* and *Tilapia zillii* from the Family Cichilidae. The status (presence/absence) of the species from the sampling sites is provided in Table 2.4.

Table 2.4. Fish species identified from the study sites of Lake Ziway (Present (+), Absent (-))

		Sampling Sites					
Family	**Fish species**	S1	S2	S3	S4	S5	S6
Cyprinidae	*Barbus paludinosus*	+	+	+	+	+	+
	Carassius carassius	+	+	+	+	+	+
	Cyprinus carpio	+	+	+	+	+	+
	Garra dembecha	+	+	+	-	-	-
	Garra makiensis	+	+	+	+	-	-
	Labeobarbus ethiopicus	-	+	-	+	-	+
	Labeobarbus intermedius	+	+	+	+	+	+
Clariidae	*Clarias gariepinus*	+	+	+	+	+	+
Cichilidae	*Oreochromis niloticus*	+	+	+	+	+	+
	Tilapia zillii	+	+	+	+	+	-

2.3.4. Composition of fishes

A total of 7741 fish specimens were recorded from the three families during the study period (Table 2.5). The species were *B. paludinosus*, *C. carassius*, *C. carpio*, *G. dembecha*, *G. makiensis*, *L. ethiopicus* and *L. intermedius* from the family Cyprinidae (50.73 %); *O. niloticus* and *T. zillii* from the family Cichilidae (28.76 %); and only *C. gariepinus* from the family Clariidae which accounts 20.51% (Fig. 2.15).

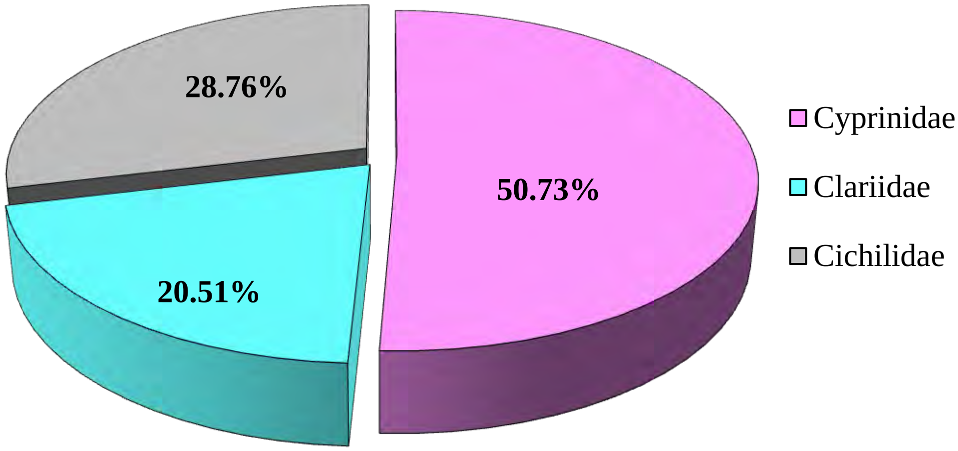

Fig. 2.15. Composition of fish at family level in the lake (%)

At species level, *O. niloticus* was the dominant fish species from the Family Cichilidae as well as the whole species from the lake and it accounts to 27.88 % of the total catch. *Cyprinus carpio* was the second dominant species which accounts to 25.19 %. *Carassius carassius* and *C. gariepinus* were almost equally represented in the catch with 20.71 % and 20.51 %, respectively (Fig. 2.16). The remaining fishes were each less than 3% of the total catch of fishes encountered in the lake (Fig. 2.16).

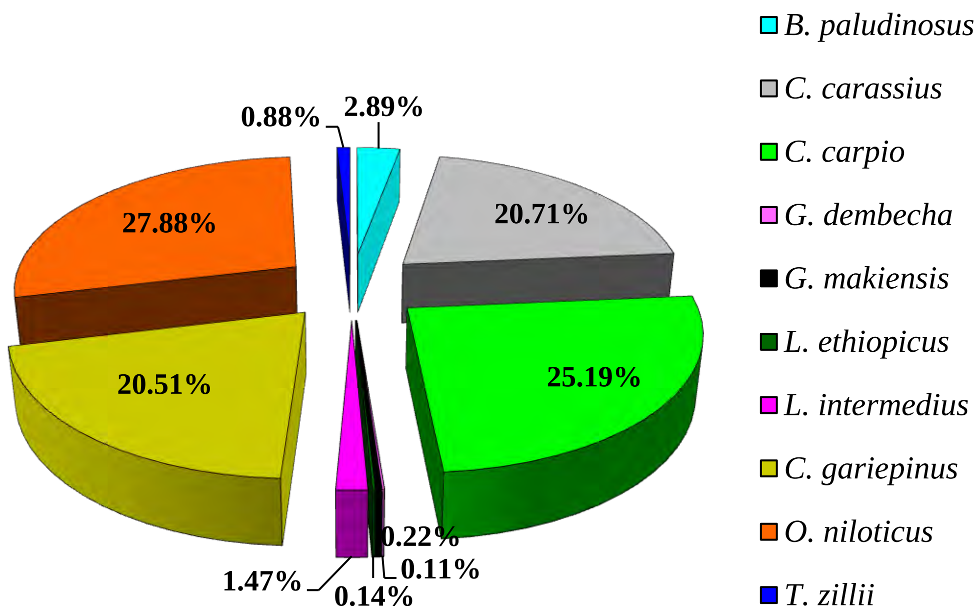

Fig.2.16. **F**ish species composition by number (%)

2.3.5. Numerical abundance

The catch proportion as well as numerical abundance from the three families that exist in the lake, *O. niloticus*, *C. carpio, C. carassius* and *C. gariepinus* each as a group contributed to the bulk of the fishes (Table 2.5) The details of the remaining species based on thye study sites were described in Table 2.5.

Table 2.5. Relative abundance of fish species caught from different sites from Lake Ziway (October 2012 - September 2014)

Family	**Fish species**	**Sampling Sites**													
		S1		**S2**		**S3**		**S4**		**S5**		**S6**		**Grand Total**	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
Cyprinidae		**799**	**43.61**	**718**	**52.83**	**716**	**43.68**	**652**	**53.09**	**745**	**61.53**	**297**	**57.77**	**3927**	**50.73**
	B. paludinosus	45	2.51	64	4.71	51	3.11	21	1.71	38	3.14	5	0.97	224	2.89
	C. carassius	367	20.46	251	18.47	345	21.06	278	22.64	291	24.03	71	13.81	1603	20.71
	C. carpio	377	20.09	359	26.42	293	17.89	332	27.04	406	33.53	183	35.6	1950	25.19
	G. dembecha	2	0.11	4	0.29	2	0.12	0	0	0	0	0	0	8	0.11
	G. makiensis	4	0.22	8	0.59	3	0.18	2	0.16	0	0	0	0	17	0.22
	L. ethiopicus	0	0	4	0.29	0	0	2	0.16	0	0	5	0.97	11	0.14
	L. intermedius	4	0.22	28	2.06	22	1.34	17	1.38	10	0.83	33	6.42	114	1.47
Clariidae		**392**	**20.89**	**266**	**19.57**	**299**	**18.53**	**250**	**20.35**	**220**	**18.17**	**161**	**31.32**	**1588**	**20.51**
	C. gariepinus	392	20.89	266	19.57	299	18.53	250	20.35	220	18.17	161	31.32	1588	20.51
Cichilidae		600	35.5	375	27.6	623	38.04	326	26.55	246	20.31	56	10. 9	2226	28.76
	O. niloticus	569	33.77	362	26.64	606	37.00	325	26.47	240	19.82	56	10.9	2158	27.88
	T. zillii	31	1.73	13	0.96	17	1.04	1	0.08	6	0.49	0	0	68	0.88
	Total	**1791**	**100**	**1359**	**100**	**1638**	**100**	**1228**	**100**	**1211**	**100**	**514**	**100**	**7741**	**100**

Of the total specimens that were collected, 4547 (58.7 %) were caught during the wet season (April to September) and the remaining 3194 (41.3 %) specimens were caught during the dry season (November to March) (Table 2.6).

In the wet season, a total number of 1152 specimens of *C. carpio* were collected from all the sites. *Cyprinus carpio* was the most abundant in number next to *O. niloticus* (1424) in the lake (Table 2.6 and 2.7). The number of specimens of *C. gariepinus* and *C. carassius* was 872 and 856, respectively. Even though the abundance of *T. zillii* was small in number, the catch was relatively high in wet season (Table 2.6 and 2.7). *Barbus paludinosus* and *L. ethiopicus* also had better catch in wet season and the remaining, *G. makiiensis* and *G. dembecha*, account less in wet season than dry season (Table 2.6 and 2.7). Seasonally, the catches of the commercially important fishes (*O. niloticus, C. carpio, C. gariepinus* and *C. carassius*) were dominant in abundance in the wet season. The difference in catches between wet and dry season were found to be statistically significant (Table 2.7).

In the dry season, the total number of *C. carpio* and *C. carassius* from all the sites were 798 (24.98 %) and 747 (23.39 %), respectively. The remaining commercially important fish species (*O. niloticus* and *C. gariepinus*) that contributed during the dry season were 22.98 % and 22.42 %, respectively (Table 2.6).

Table 2.6. The contribution by number of each fish species in the total catch during wet and dry seasons in the lake

Fish species	Seasons																	
	Wet								Dry								Overall	
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**Total**	**%**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**Total**	**%**	**Total**	**%**
B. paludinosus	22	31	28	9	25	2	117	2.57	23	33	23	12	13	3	107	3.35	224	2.89
C. carassius	194	148	168	150	152	44	856	18.83	173	103	177	128	139	27	747	23.39	1603	20.71
C. carpio	232	223	168	210	229	90	1152	25.34	145	136	125	122	177	93	798	24.98	1950	25.19
G. dembecha	2	0	1	0	0	0	3	0.07	2	2	1	0	0	0	5	0.16	8	0.11
G. makiensis	2	1	1	0	0	0	4	0.09	2	7	2	2	0	0	13	0.41	17	0.22
L. ethiopicus	0	4	0	1	0	3	8	0.17	0	0	0	1	0	2	3	0.09	11	0.14
L. intermedius	1	10	12	8	2	16	49	1.07	3	18	10	9	8	17	65	2.03	114	1.47
C. gariepinus	231	183	143	144	132	39	872	19.18	161	83	156	106	88	122	716	22.42	1588	20.51
O. niloticus	436	252	422	165	145	4	1424	31.32	133	110	184	160	95	52	734	22.98	2158	27.88
T. zillii	29	11	16	1	5	0	62	1.36	2	2	1	0	1	0	6	0.19	68	0.88
Total	**1149**	**863**	**959**	**688**	**690**	**198**	**4547**	**100**	**644**	**494**	**679**	**540**	**521**	**316**	**3194**	**100**	**7741**	**100**

Table 2.7. Seasonal variation in the relative abundance of fishes in Lake Ziway at 0.05 level of significance of Chi-square (X^2) test. ∗ means significant

Families	**Species**	**Total catch**	**Wet season**	**Dry season**	**X^2**
Cyprinidae	*B. paludinosus*	224	117	107	0.45
	C. carassius	1603	856	747	7.41*
	C. carpio	1950	1152	798	64.27*
	G. dembecha	8	3	5	0.5
	G. makiensis	17	4	13	4.77*
	L. ethiopicus	11	8	3	2.27
	L. intermedius	114	49	65	2.25
Clariidae	*C. gariepinus*	1588	872	716	15.33*
Cichilidae	*O. niloticus*	2158	1424	734	220.62*
	T. zillii	68	62	6	46.12*
	Total	7741	4547	3194	236.48*

2.3.5.1. Abundance of fish species in relation to environmental variables

The RDA ordination of the species-environmental association indicated that nitrate, conductivity, nitrite, SRP, Chl-*a*, temperature and pH were negatively correlated with the first axis. Secchi depth and dissolved oxygen were positively correlated to *L. ethiopicus* and *L. intermedius* with the the axis, which contributed 88.4% of this variance (Fig. 2.17 and Table 2.8). The remaining environment factors and fish species were negatively correlated with this axis (Fig.2.17; Table 2.8).

Table 2.8. Result of redundancy analysis of abundance of the fishes and physico-chemical associations including eigenvalues and percentage variance explained by the first two axes, as well as the correlations between environmental variables and the axes (strong correlations are marked bold)

Variables	**Canonical coefficients**	
	Axis 1	**Axis 2**
Eigenvalues	0.884	0.093
Cumulative percentage variance of species-environment relation	0.884	0.977
Temperature	-0.0289.	-0.4912
Secchi depth	0.0263	**-0.7482**
Nitrate	**-0.5869**	0.3866
Nitrite	**-0.6302**	0.5450
Ammonium	0.1152	**0.5620**
SRP	**-0.9191**	-0.335
Dissolved Oxygen	0.3718	0.4955
Chlorophyll-*a*	-0.4406	-0.4658
pH	-0.0853	-0.4518
Conductivity	-0.4804	0.3651

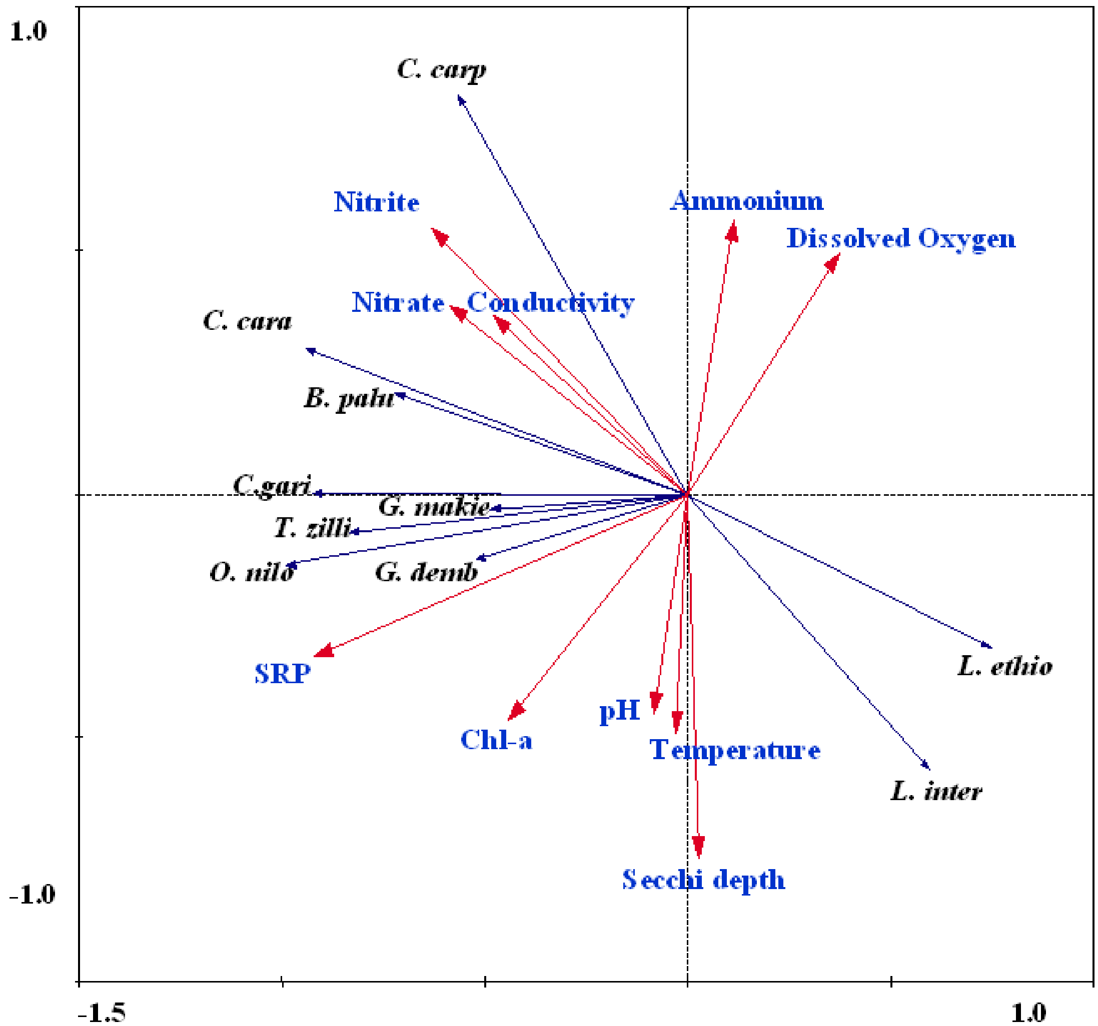

Fig.2.17. Biplots of the first two axes of correspondence analysis showing the association of fish species numerical abundance and environmental variables (Abbreviation: *L.ethio.* - *Labeobarbus ethiopicus*, *L.inter*.- *Labeobarbus intermedius*, *B.palu*.- *Barbus paludinosus*, *G.makie*.-*Garra makiensis*, *G.demb*.- *Garra dembecha*, *O.nilo*.- *Oreochromis niloticus*, *C.carp*.-*Cyprinus carpio*, *C.cara*.- *Carassius carassius* and *C.gari*.- *Clarias gariepinus* and SRP - Soluble Reactive Phosphate)

The second axis was positively correlated with the environmental variables nitrite, nitrate and conductivity that were associated with relatively high abundance of the two carp species (*C. carpio* and *C. carassius*) (Fig 2.17; Table 2.8). The remaining fish species (*O. niloticus, T. zillii*, *C. gariepinus* and the two *Garra* species) were negatively correlated with the two axes of the environmental variables such as Chl-*a*, SRP, pH and temperature.

2.3.5.2. Diversity index

Three families and 10 species were recorded in the total of 7741 fish specimens collected during this study period (Table 2.5). The Shannon-Wiener diversity index differed, with higher diversity being observed in the southern part of the lake around River Bulbula (S2), while the open water (S6) and the northern part of the lake (S4 and S5) contributed relatively less number of species diversity (Table 2.9).

Table 2.9**.** Shannon Weiner diversity index, H', value and number of fish species, N, in the lake

	Sites					
	S 1	**S 2**	**S 3**	**S 4**	**S 5**	**S 6**
N	9	10	9	9	7	7
H'	1.5472	1.6681	1.5473	1.5213	1.5142	1.5127

2.4. Discussion

2.4.1. Physico-chemical situation of the lake water

Water quality testing is an important part of environmental monitoring. When water quality is poor, it affects not only aquatic life but also the surrounding ecosystem. This section discusses some of the parameters that affect the quality of water in the lake, which are indicated in Table 2.2.

The physico-chemical parameters of the lake water at the six sampling stations markedly differ (Table 2.2). Site 4 (Around Ketar River mouth) and Site 5 (Around Meki River mouth) were different from other sites and were characterized by having higher dissolved oxygen and less Secchi depth (Table 2.2 and Fig. 2.4). Site 1 (Western part of the lake) was characterized by having higher nitrate, nitrite and conductivity. Site 2 (Bulbula river mouth) and Site 3 (Eastern part of the lake) were again characterized by having high level of Chl-*a* and temperature (Table 2.2 and Fig.2.4).

In the present study, the results obtained for conductivity and pH as the mean ± SE values ranged from 361.5±9.7 to 484.5±15.3 μS/cm and 8.03±0.2 to 8.37±0.1, respectively, were comparable with the values (410 μS/cm and 8.5, respectively) reported by Elizabeth Kebede *et al*. (1994) and very recentlly by Girum Tamire and Seyoum Mengistou (2012). Hence, the pH values of the lake water in the sampling sites are within the range of 8 to 8.4, and it is suitable for normal biological activity set as 6.5 - 8.5 by the European Economic Community (EEC, 1980).

The mean minimum nitrate value (30.1 μg/l) was higher than previously reported values for the same lake (28μg/l; Girma Tilahun, 1988), indicating an eutrophication trend with time.

However, nitrate varied more than soluble reactive phosphate suggesting that it may be a limiting factor for phytoplankton growth inaddition to silitation in Lake Ziway. Talling and Talling (1965) highlighted that nitrogen was the limiting nutrient for phytoplankton growth in tropical African lakes. The high concentration of dissolved oxygen was satisfactory for fish production (EEC, 1980). Dissolved oxygen content has higher values in the area at the inlet of Meki (5.71±0.6) and Ketar Rivers (6.01±0.5) (Table 2.2). High circulation of water in the river as compared to other sampling sites in the lake is the possible reason for such high oxygen values. Offem *et al*. (2009) reported similar findings in Cross River, Nigeria.

On the other hand, Secchi depth is considerably low even when compared with some recent results. For example, Adamneh Dagne *et al*. (2008) have reported that the Secchi depth of the lake was between 20 and 35 cm, which was higher than the result obtained in this study (ranged from17.85 to 22.12 cm). Even, higher range of Secchi depth reading (0.4-1.06 m) was reported by Girma Tilahun (1988) in earlier times. The declining trend in Secchi depth reading shows that turbidity in the lake is increasing, which can be attributed to catchment degradation, siltation and perhaps introduced bottom-stirring fish such as carp becoming more and more abundant in the lake (Table 2.5). IBC (2005) has also reported that vegetation around the shore of the lake was being harvested for different purposes in many of the sites. Even now at the lake side residents have continued with this practice (Personal observation) that may further increase the turbidity of the lake. Elias Dadebo *et al.* (2013) have reported very recently that large quantities of detritus drain into Lake Ziway with run-off during the rainy season from the catchment area increasing the proportion of decomposing plant and animal materials. In addition to blocking out the light needed by submerged aquatic vegetation, phytoplankton and burying fish eggs and benthic organisms, suspended sediment can carry nutrients and pesticides throughout the water system, damage gills, and interfere with the ability of fish to find food (Barnes *et al.*, 1998). Hence, with all this evidence, that the low transparency of the lake could potentially affect fish production in the lake.

Soluble reactive phosphate was high in the lake ranging from 38.2 ± 19.1 to 64.73 ± 4.7. The value of phosphate is higher than previously reported for the same lake, which was 5.5 to 16.2 μg/L (Girma Tilahun, 1988). The high concentration of phosphate in the littoral site of the lake could be due to influx of pollutants and organic matter from lakeshores. In addition, when phosphorus remains in the sediments it is generally not available for use by algae; however, various chemical and biological processes can allow sediment phosphorus to be released back into the water. For example, bottom-feeding fish such as carp (currently becoming the dominant fish) can stir up bottom sediments, releasing phosphorus back into the water (Mansor *et al*., 2012). Also previously, Girma Tilahun (1988) reported low concentration of phosphate under high phytoplankton biomass. The phytoplankton biomass in the present study was very low, so the high concentration of phosphate in the present study can also be due to lower phytoplankton biomass.

The farm lands located near the shore use fertilizers which are rich in nutrients, especially phosphates and nitrates (Personal observation). Beside this, other contributions from the activities of fishermen, detergents and fish offal could be high. Fish offal is rich in nutrients, and hence can increase the concentration of SRP. Based on qualitative observation, that the decomposition of fish does not result in net nutrient release to the lake except in so far as the dead fish are subsequently grazed by piscivorous birds, which subsequently release their droppings into the lake (NIWR,1985). As discused in chapter 1, *Pelicans* and *Marabou storks* are the dominant bird species in Lake Ziway, which feed on fish offal and release their droppings for the conribution of nutrent increment to the lake.

Chlorophyl-*a*, varied during the study period from 37±6.4 to 54.5±23 μg/l. The mean biomass was relatively high at the littoral sites (S1, S2 and S3). Hence, the littoral area has high phytoplankton biomass, which could be because of immediate nutrient input from the surrounding. In general, low value of Chl-*a* was found during the present study as compared to previous results. For example, high phytoplankton biomass of 150-212 mg Chl-*a* m^{-3} was reported for the same lake by Girma Tilahun (1988). Zinabu Gebremariam *et al*. (2002) reported a mean value of 82.4 with ranges of 23-224 μg/l of Chl-*a* for Lake Ziway, again much higher than the values recorded in this study.The decline in Chl-*a* in the present study as compared to previous results also can be attributed to turbidity. The increment in turbidity was reflected by the low Secchi depth measured during the study period as compared to previous records.

2.4.2. Distribution and composition of sample sfishes

10 species of indigenous and exotic fishes were collected from Lake Ziway (Table 2.4). Twelve fish species have been recorded from the lake as described in the previous chapter, while *C. auratus* and *L. microterolepis* were not encountered during this study. Among the species that have been currently captured *C. carpio, C. carassius, C. gariepinus* and *O. niloticus* are commercially important fishes. *Oreochromis niloticus* was the major species of the sample accounting for 94 % in previous studies (Schroder, 1984). However, the contribution of the fish has gradually declined to 89.3 % of total catch in 1994, 50.9 % in 2010 and 42 % in 2010 (Mathewos Hailu, 2013); and 31 % in 2012 (Lemma Abera *et al*., 2014b)

and 27.88 % in this study. On the contrary, the catch composition of *C. gariepinus* was 8.1 % in 1994 and increased to 41.8 % in 2010 (Mathewos Hailu, 2013) and currently decreased to 20.51 % (Fig. 2.16).

During this study, Cyprinidae clearly dominated the fish composition of the lake as had previously been observed in the study area (Viverberg *et al*., 2012). From this family the catch of *C. carpio* and *C. carassius* is increasing in Lake Ziway and this condition may be due to a high tolerance of these fishes to turbidity variation of the lake. Particularly, the former species is appearing to be an important commercial catch in all landing sites, since the last three years (See Chapter 4).

2.4.3. Numerical abundance of fishes

During this investigation almost all species of fishes were identified from the southern part of the lake (Site 2) (Table 2.5). One of the possible reasons for less diversity of the species could be the effect of flow variability on fish assemblage due to the two rivers (Meki and Ketar Rivers) on the northern part of the lake.

Water shade fluctuation observed was up to 500 m during the study period. The water drawdown was mainly due to irrigation and other domestic use. The delayed onset of rains also contributed to the change in water level. The floodplain showed that fish breeding nests were left exposed whenever the water level reduced and affects some of the diversity of the fishes of Lake Ziway, thus confirms reports elsewhere (Inogwabini, *et al.*, 2009). Because of these, resilient fishes and very tolerant species such as cyprinids survive in such area, which has also been compiled by Abebe Getahun and Stiassny (1998). In general, in many tropical water bodies variability in diversity increases from upstream to downstream reaches (Moyle, 1982). Similarly, on this study more species are caught around the northern side of the lake (Site 2).

The genus *Garra* is apparently highly tollerant and found in large numbers even in streams that hardly flow and where there is slight pollution (Abebe Getahun and Stiassny, 1998). However, small number of *G. dambecha* and *G. makiensis* were captured during study (Table 2.5). In addition, from the three species of *Labeobarbus* that were reported previously, only two species, namely, *L. ethiopicus* and *L. intermedius* were collected (Table 2.4). *Labeobarbus microterolepis* is not cought in this during this stud and this could be due to the gears were not set at bottom site.

Seasonal and spatial variations in the fish fauna of the lake during the study period support findings of Jackson and Harvey (1997), that various fish communities exhibit some patterns in migration and hence show defined variation in the space they occupy over time and space. Seasonal differentiation is evident in that higher number of species and specimens were caught during wet seasons of the study period, this is due to the fishes were in breeding time that high chance to captured with fishing gears. This is in agreement with results of Assefa Tessema *et al*. (2012) in the country and Welcomme (1985), Benedict (2009) and Benson (2012) elsewhere. In the study site (S1, S2 and S3) the proportion of fishes that were caught was high as compared to other sites. This was due to the availability of floodplain. Floodwaters are important because the flooding of lateral plains increase the area of food rich habitat and shelter from predators. They also provide ideal site for fish to develop and grow (Welcomme, 1979) unless the area was degraded and polluted.

Wetlands and vegetated near shore habitats are required by fishes to complete their life cycle (spawning and nursery spaces) and for foraging. These habitats contain a diversity of submergent, emergent, and floating aquatic vegetations that provide shelter, food and protection from predators (Welcomme, 1985). At the study sites, particularly during the dry seasons, such habitats get shallow and eventually dry up if the dry season persists. During such period, there are varieties of fish predators such as birds, and fishermen also tend to converge to such places exerting high mortality.

In addition, currently *T. zillii* was not abundant in the lake (Table 2.5). In previous studies, it was even more abundant than *O. niloticus* (Alemayehu Negassa and Padanillay, 2008). This might be due to their habitat preferences. Lowe-McConnell (1987) pointed out that substrate-spawners with macrophyte feeding habit, such as *T. zillii*, are more dependent on shoreline habitat with dense vegetation than are the mouth brooders with their microphagous feeding and more pelagic habitat, (e.g. *O. niloticus*), especially in waters rich in plankton. However, currently the situation is changed and the catch of *T. zillii* from Lake Ziway has decreased. This is may be due to ecological changes on the shore of the lake in particular, such as decreasing phytoplankton production due to silitation and degradation of shoreline vegetation.

2.4.3.1. Abundance of fishes in relation to environmental variables

Abundance of fish species in the lake were probably affected by changes in physico-chemical properties of the lake. Some parameters were correlated significantly with the abundance of fish species (Table 2.8). Similar trend was highlighted by other authors (Schoener, 1988; Whitefield, 1990) who suggested that physico-chemical parameters influence the aquatic system.

Except *L. ethiopicus* and *L. intermedius* the remaining fish species were found in relatively nutrient-rich sites (Fig. 2.17). *Labeobarbus ethiopicus* and *L.intermedius* preferred areas where there is high dissolved oxygen and relatively clear water (Fig. 2.17). According to Balakrishna *et al.* (2013), oxygen availability throughout the year is influenced by other chemicals present in the water, biological processes, and temperature. Hence, the fishes were restricted to sites where there was relatively better oxygen availability. However, *C. gariepinus, C. carassius,* and *C. carpio* were relatively found in both nutrient-rich sites (S1and S3). The occurrence of these fishes in the lake seems not to be affected by differences in the nutrient condition among sites, and their ability to colonize these varied sites indicates their potential to adapt to diverse trophic conditions.

In addition to increase in nutrient concentration, further reduction in water level may create conducive environment for the fishes (*C. gariepinus, C. carassius,* and *C. carpio*). On the other hand, *O. niloticus* and *T. zillii* were almost restricted to sites where there was relatively higher concentration of Ch-*a*. Since the fishes concentrated in the littoral zone of the lake due to their habitat and relatively high concentration of Ch-*a* in the littoral site of the lake could be due to flood of pollutants around the area and organic matter from lakeshores.

As can be learned from the case of similar lakes such as Lake Naivasha, which is one of the world's top ten important bird areas (Njenga, 2004), such trends will lead to severe ecological consequences unless prompt mitigation is taken. Currently, Lake Naivasha is encountering many adverse changes that are associated with enrichment of nutrients from run-off, horticulture and other sources around the lake region (Jimoh *et al*., 2007). Consequently, rapid proliferation of water hyacinth, excessive increase in algal biomass and reduced transparency are already observed in the lake (e.g. Mironga *et al*., 2012). It is evident that such changes are a huge threat to fisheries, ecological integrity of lakes and public health of lake-side communities.

Seyoum Mengistou (2013) tried to assess the possibility of invasion of water hyacinth in Lake Ziway using three nutrient loading models and found that the first two models indicated that phosphorous loading levels were below the growth requirement for the plant while the last model predicted that it was already twice more than growth requirement for the plant. *Pistia stratiotes* was observed around Bulbula, the site closest to the floriculture industry. *Pistia stratiotes* is one of the worst invasive floating macrophytes and is well known for invading new habitats within a short period of time under high nutrient loading. Malefia Tadele (2009) has also reported high nutrient enrichment at this site, which was attributed to the untreated effluents from the farms, and is in agreement with the result of this study; and as personal observation, that affects the fish production (eg. massive fish kill at the site very recently).

2.4.3.2. Fish species diversity in Lake Ziway

Larger and shallow lakes are potentially expected to have a wider range of habitats than smaller lakes (Toivonen and Huttunen, 1995). However in Lake Ziway, higher turbidity, fluctuations in water level and other factors seem to limit the fish diversity to mainly turbidity-tolerant species, for example the two carp species and *C. gariepinus*. The fish species diversity of Lake Ziway was low (H′ value in between 1.51 to 1.67 on different sites) compared with some published data of similar works on lake (H' value in between 1.9 to 2.4) (Sylvester and John, 2010). In general, low diversity is expected in lakes that have an outflow, because accumulated nutrients produced from different sources could be flushed out (Burlakoti and Karmacharya, 2004), although the effect on some species could be less pronounced.

In addition, the absence of significant heterogeneity among sites can induce lower diversity of fishes, which was also corroborated with physico-chemical data in this study (Table 2.2). Sylvester and John (2010) also reported that homogeneity of habitats favored lower diversity of fishes in water courses of Uganda. The lower fish diversity around the two inlets of the rivers was due to both lower fish abundance. On the other hand, relatively higher fish diversity was observed at the southern part of the lake (S2) around the outlet of Bulbula River, and this may be due to the relatively high densities of fishes.

The decline of the native fish species in Lake Ziway has been attributed to predation by the introduced *C. gariepinus*, other bottom feeder species like *C. carpio* and *C. carassius* that affect the breeding area, use of wrong and destructive fishing gears and to some extent destruction of spawning and nursery grounds through human encroachment. Ogutu-Ohwayo *et al.* (1991) and Ochumba *et al*. (1991) also confirmed this on their study on Lake Victoria and Kyoga, respectively. Hence, results of our study revealed that the native species of Lake Ziway may have now become threatened and others like *C. carpio* and *C. carassius* are now occurring in almost all parts of the lake and have increased in biomass. *Carassius auratus and L.microterolepis* were not cought in the study, because the gears used were surface set.

CHAPTER 3: SOME BIOLOGICAL ASPECTS OF FISHES IN LAKE ZIWAY

3.1. Introduction

Lake Ziway is home to three families of fishes: Clariidae, Cichlidae and Cyprinidae. Clariidae is represented by a single species *Clariasn gariepinus*, and Cichlidae by *O.niloticus* and *T. zillii*; and Cyprinidae by seven species as indicated in Chapter 2. Most of the fish species in the lake are a fast growing and hardy fish that can withstand adverse environmental conditions; and they have been successfully transplanted into freshwaters throughout the world (Welcomme, 1988; Seegers *et al*., 2003; Demeke Admassu *et al*., 2015a) and an important food fish in the country as well as in the world.

From the fishes that were described in Chapter 2, *C. carassius, C. carpio, C. gariepinus* and *O. niloticus*, are relatively more abundant and commercially the most important. Even though, some information on the fishes of Lake Ziway are described in the previous chapters, the biology of the fishes need to be investigated/updated for proper management of the resources.

Biologically, fish are said to be growing isometrically, where the weight increases with in proportion to the power of 3 of length body with constant specific gravity (Olurin and Aderibigbe, 2006) while allometric growth is assumed when the increase in any of the parameters (length or weight) is not as that of isometric growth. It is possible to estimate the weight or length of fish from either of each parameter that is available from a formula that takes into account the growth pattern (whether isometric or allometric). Additionally, Length-weight relationship gives the condition and growth patterns of fish. It provides important information concerning the structure and function of the fish populations (Lemma Abera *et al*., 2014a). Condition factor refers to the well-being of the fish (Blackwell *et al*., 2000). It is, therefore, an index reflecting interactions between biotic and abiotic factors to the physiological condition of fish. It is assumed that heavier fish reflect a healthier physiological state.

As discussed in Chapter 1, there were fishes that have been introduced into the lake for different purposes including enhancing fish production. For example, *C. carpio* was introduced into Lake Ziway in late 1980's by the staff of the Ministry of Agriculture with the intention of increasing fish production by introducing a benthos feeder into the system where the niche was not occupied by any of the indigenous fishes (FAO, 1997). Currently, the fish has become one of the most abundant fish species that often forms the basis of commercial fisheries and one of the most desired fish species by the local community among the commercially exploited fishes.

However, very little is known about *C. carpio* in Ethiopia and virtually nothing is known about the population in Lake Ziway. Thus, with an attempt to fill this knowledge gap, a study was conducted on some biometric measurements (length-weight relationship, condition factor and sex ratio) of the fishes and some reproductive biology (breeding season, size at first maturity and fecundity) of *C. carpio* of the lake to provide baseline information useful for sustainable exploitation and management of the fisheries.

3.2. Materials and Methods

3.2.1. Sample collection and measurements

Detailed fish sampling methods and some biometric measurements were given in Chapter 2 sections 2.2.2.2. In addition to these methods, specimens were dissected and the sexes determined by inspecting the gonads for some biological parameter analysis from January to

December 2013. A five-point maturity scale was used to describe stages of gonads (Holden and Raitt, 1974).

The ovaries of *C. carpio* were split longitudinally and turned inside out, to ensure the penetration of the preservative before storing in labeled jars (Bagenal and Tesch, 1978) and they were preserved in Gilson's fluid (Simpson, 1959). The preserved samples were then transported to the laboratories at Ziway Fisheries Research Center and College of Veterinary Medicine and Agriculture of Addis Ababa University for laboratory work.

3.2.2. Length-weight relationship and condition factor

The relationship between total/fork length and total weight of the fishes were calculated using least squares regression analysis (Bagenal and Tesch, 1978) as follows:

$TW = aFL^b$, for fork length,

$TW = aTL^b$, for total length

Where: TW - Total weight in grams

FL - Fork length in centimeters　　a - Intercept of the regression line

TL - Total length in centimeters　　b - Slope of the regression line

The condition or well-being of the species was determined by computing Fulton Condition Factor (Bagenal and Tesch, 1978), as follows:

$FCF = (TW / FL^3)\ 100$, for Fork length fish species

$FCF = (TW / TL^3)\ 100$, for Total length fish species

Where: FCF - Fulton condition factor FL - Total length in centimeters

TW - Total weight in grams TL - Total length in centimeters

3.2.3. Estimation of sex-ratio

The number of female and male individuals was recorded for each sampling occasion. Sex-ratio (female: male) was then calculated for each species of the total sample. Chi-square test was employed to test if sex ratio varied from one-to-one in the total samples for each species as in Demeke Admassu (1994).

3.2.4. Reproductive biology of *Cyprinus carpio*

3.2.4.1. Determination of breeding season

The breeding season of *C. carpio* was determined from monthly frequency of fish with ripe gonads and gonado-somatic index (GSI). The GSI for each fish was computed as the weight of the gonads in percent of total body weight as follows:

GSI = (Weight of gonad / Weight of fish) X 100

Where, GSI - Gonado-somatic index

3.2.4.2. Estimation of length of fish maturity (L_{50})

The average length at first maturity (L_{50}) has been defined as the length at which 50 % of the individuals in a given length class reach maturity (Willoughby and Tweddle, 1978). Thus, after classifying data by length class, the percentages of male and female *C. carpio* with mature gonads were plotted against length to estimate L_{50} graphycally (Tweddle and Turner, 1977).

3.2.4.3. Fecundity estimation

The fecundity of ripe gonads preserved in Gilson's fluid was estimated gravimetrically (Simpson, 1959). To estimate fecundity the preservative was replaced with water, and the eggs were washed repeatedly, decanting the supernatant. The fecundity estimate was then obtained by weighing the entire eggs, and two sub-samples of 1000 eggs, each of which were similarly dried. The eggs were counted and weighed using a sensitive balance. The total number was computed using the following ratio:

$$N/n = W/w, \text{ from which } N = (nW)/w$$

Where, N - Total number of eggs   n - Number of eggs in sub sample (=1000)

W - Weight of all eggs (g), and   w - Mean weight of the sub sample (g)

3.3. Results

3.3.1. Size composition of the sample

A total of 7705 specimens of the species of *B. paludinosus*, *C. carassius, C. carpio*, *L. intermedius*, *C. gariepinus, O. niloticus* and *T. zillii* were caught for the study of biological parameters (Table 3.1). The commercially important fishes (*C. carassius*, *C. carpio*, *C. gariepinus* and *O. niloticus*) contributed 99.53% of the total catch (Fig. 2.16 in Chapter 2). The length of the fish ranged from 7-13 cm for *B. paludinosus*, 14 - 46 cm for *C. carassius*, 13 - 48 cm for *C. carpio*, 17 - 44 cm for *L. intermedius*, 25 - 96 cm for *C. gariepinus,* 9 - 34 cm for *O. niloticus* and 10 -25 cm for *T. zillii* (Fig. 3.1 to 3.2).

The greater proportion of the sampled fish ranged in size classes between 15 - 19 cm, 25 - 34 cm, 25 -29 cm and 40 - 44 cm for *O. niloticus*, *C. carpio*, *C. carassius* and *C. gariepinus* respectively (Fig. 3.1 to 3.2). This length group alone was about 45% (*O. niloticus*), 28 % (*C. carpio*), 24.4% (*C. carassius*) and 17.4% (*C. gariepinus)* (Fig. 3.1 to 3.2). Fishes over 25, 40, 40 and 65 cm length were least represented for the fishes in the same order for *O. niloticus*, *C. carpio*, *C. carassius* and *C. gariepinus* (Fig. 3.1 to 3.2).

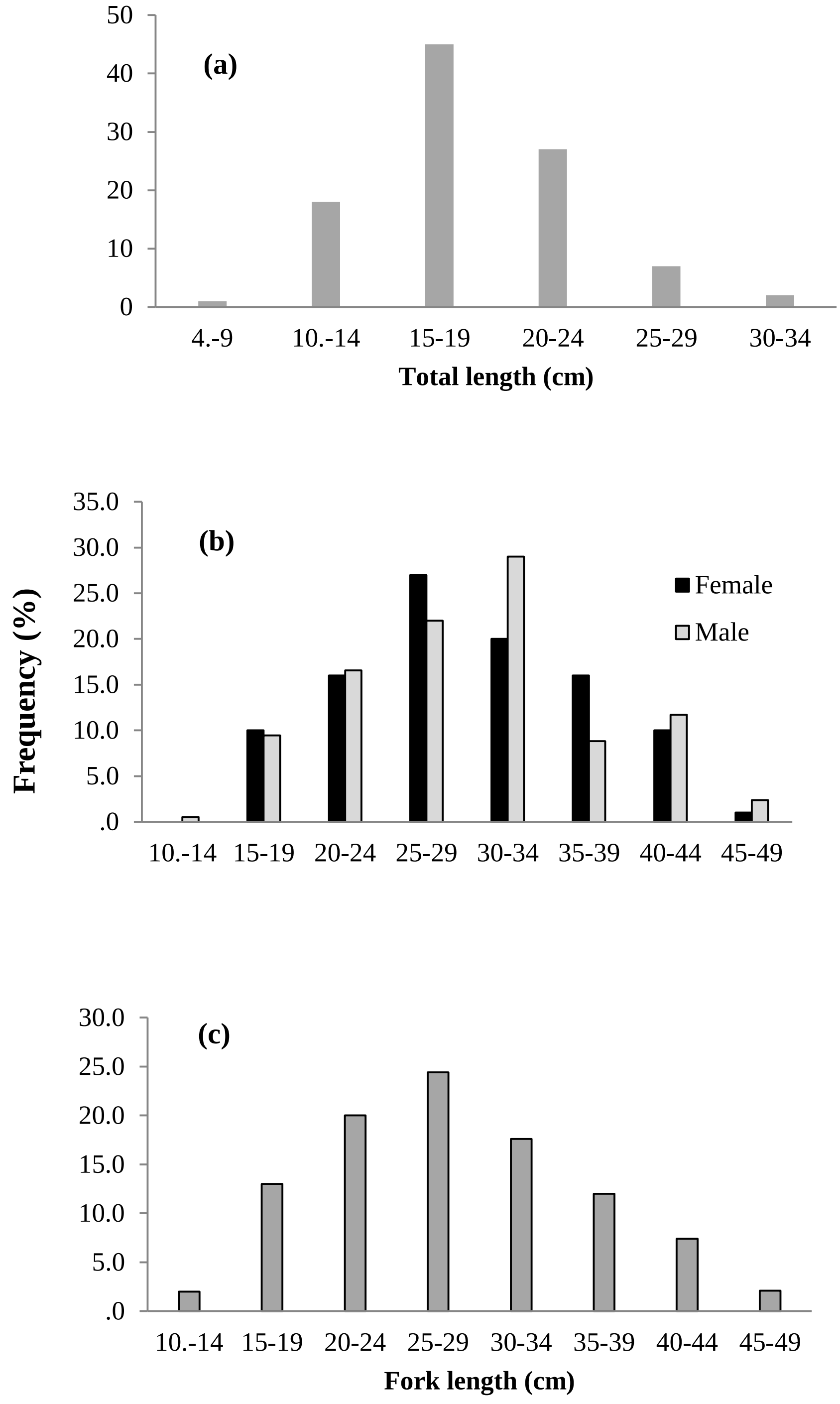

Fig.3.1. Length-frequency distribution of **(a)** *Oreochromis niloticus*, **(b)** *Cyprinus carpio* and **(c)** *Carassius carassius* sampled between October 2012 and September 2014 from Lake Ziway

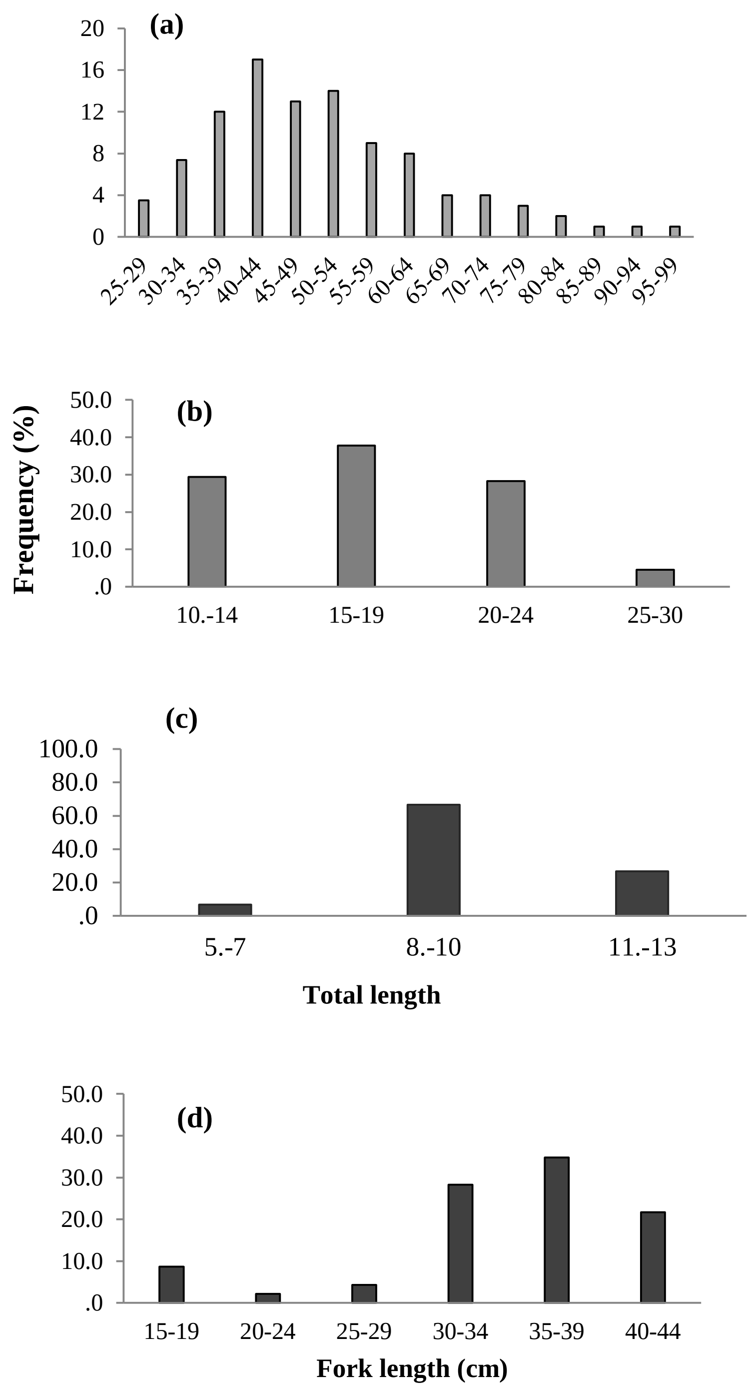

Fig.3.2. Length-frequency distribution of **(a)** *Clarias gariepinus*, **(b)** *Tilapia zillii* **(c)** *Barbus paludinosus* and **(d)** *Labeobarbus intermedius* sample between October 2012 and September 2014 from Lake Ziway

3.3.2. Length-weight relationship and condition factor

Length-weight relationship was determined for *B. paludinosus, C. carassius, C. carpio, L. intermedius, C. gariepinus, O. niloticus* and *T. zillii*, and it was curvilinear and statistically highly significant for each species ($P < 0.05$). The line fitted to the data was described by the regression equations shown in Figures 3.3 amd 3.4.

An equation combined for fish ranging in length from 9 - 34 cm (*O. niloticus*), 13 - 48 cm (*C. carpio*), 14 - 46 cm (*C. carassius*), 25 - 96 cm (*C. gariepinus*), 10 - 25 cm (*T. zillii*), 7 - 13 (*B. paludinosus*) and 17 - 44 cm (*L. intermedius*); and the corresponding total weight from 30 to 850 g. (*O. niloticus*) 57 to 2500 g. (*C. carpio*), 115 to 1859 g. (*C. carassius*), 250 to 5500 g. (*C. gariepinus*), 30 to 360 g. (*T. zillii*), 7 to 25 g. (*B. paludinosus*) and 160 to 995 g (*L. intermedius*) for both sexes was fitted and shown in Figures 3.3 amd 3.4.

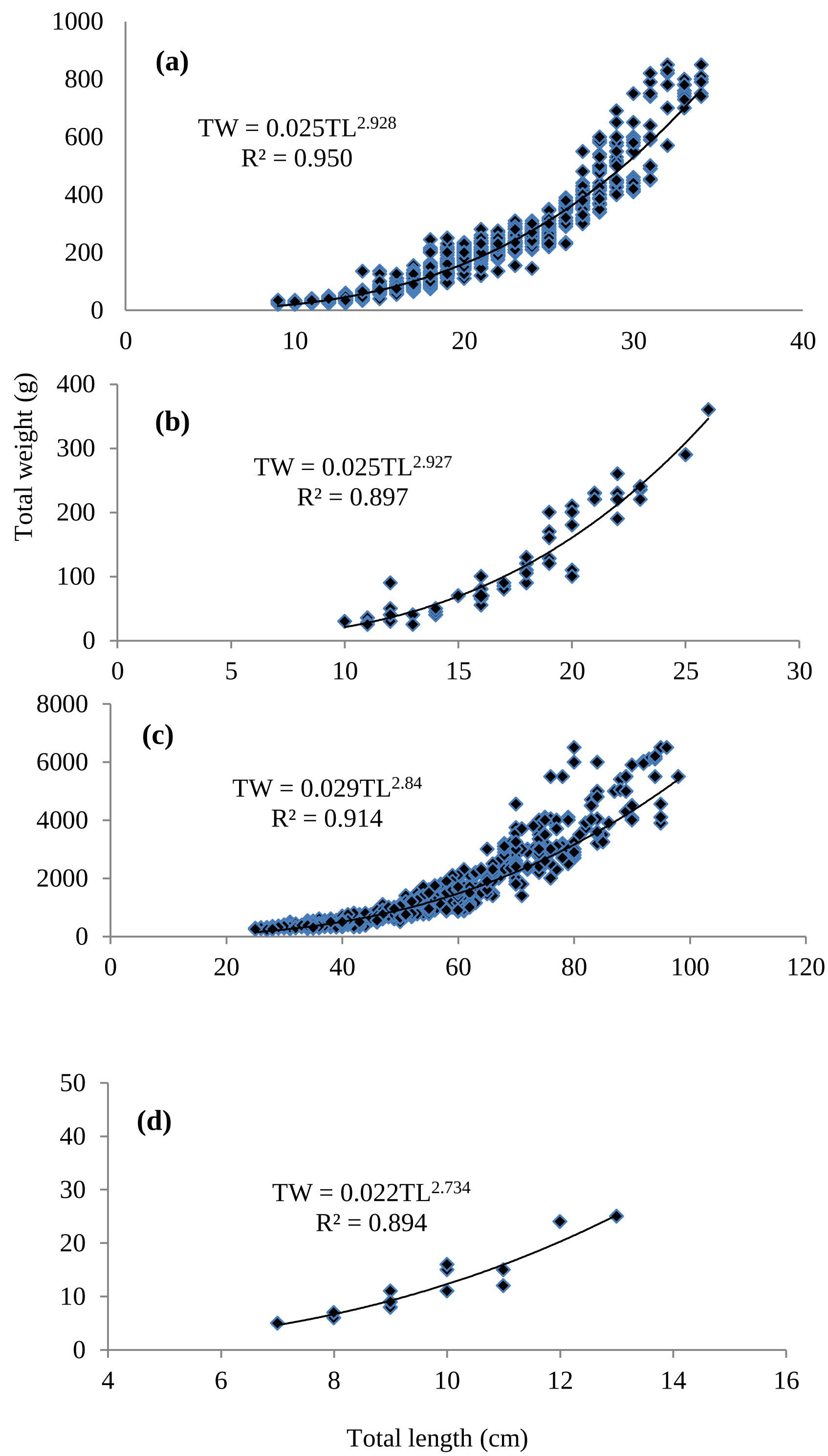

Fig. 3.3. Length-weight relationship of (a) *O. niloticus*, (b) *T. zillii*, (c) C. *gariepinus* and (d) *B. paludinosus* in Lake Ziway.

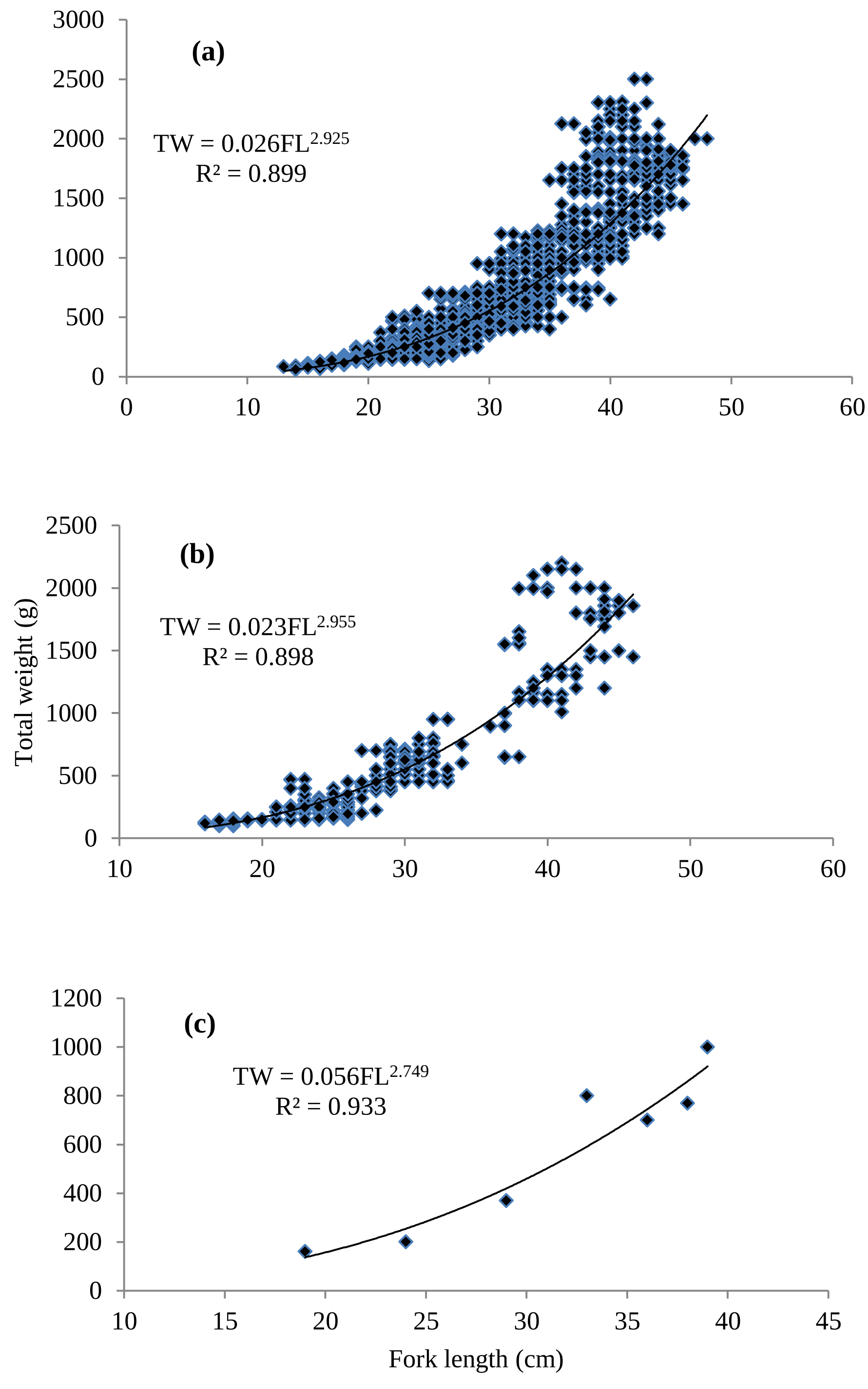

Fig.3.4. Length-weight relationship of (a) *C. carpio*, (b) *C. carassius* and (c) *L. intermedius* in Lake Ziway.

Fulton Condition Factor (FCF) values (mean ± SE) of the fishes were 0.76±0.21 for *C. gariepinus*, 1.82±0.21 for *O. niloticus*, 1.90±0.35 for *T. zillii*, 1.52±0.19 for *B. paludinosus*, 1.73±0.38 for *L. intermedius*, 2.12±0.57 for *C. carassius* and 1.52±0.14 for *C. carpio* for both sexes and for the separate sexes as shown in Table 3.1.

Table 3.1. Average Fulton condition factor (FCF) of both sexes of fishes from Lake Ziway

		FCF±SE		
Families	**Species**	**Female**	**Male**	**Total**
Cyprinidae	*B. paludinosus*	1.27±0.03	1.24±0.12	1.52±0.19
	C. carassius	2.14±0.32	2.12±0.13	2.12±0.57
	C. carpio	1.63±0.06	1.50±0.12	1.52±0.14
	L. intermedius	1.88±0.08	1.52±0.15	1.73±0.38
Clariidae	*C. gariepinus*	0.77±0.11	0.74±0.09	0.76±0.21
Cichilidae	*O. niloticus*	1.87± 0.09	1.70±0.12	1.82±0.21
	T. zillii	1.93±0.14	1.73±0.14	1.90±0.35

3.3.3. Sex -ratio

Sex ratio of the fishes are presented in Table 3.2. Females were more numerous than males for each commercially important fish species except *C. gariepinus* (Table 3.2). The ratio was significantly different from the hypothetical distribution of 1:1 ($X^2 > 4$). While, the sex ratio of the other fish populations was not significantly difference from 1:1 ratio (Table 3.2).

Table 3.2. Number of females, males and the corresponding sex ratios in samples of fish species from Lake Ziway (Oct. 2012 to Sept. 2014)

Families	Species	Total	Female	Male	Sex-ratio	Chi square
Cyprinidae	*B. paludinosus*	224	103	121	0.85:1	1.446
	C. carassius	1603	864	739	1.17:1	9.747*
	C. carpio	1650	1020	930	1.1:1	4.154*
	G. makiensis	17	6	11	0.55:1	0.818
	G. dembecha	8	3	5	0.6:1	0.5
	L. ethiopicus	11	4	7	0.57:1	0.818
	L. intermedius	114	53	61	0.87:1	0.561
Clariidae	*C. gariepinus*	1588	800	788	1.02:1	0.91
Cichilidae	*O. niloticus*	2158	1134	1024	1.11:1	5.607*
	T. zillii	68	29	39	0.74:1	1.471

3.3.4. Reproductive biology of *Cyprinus carpio*

3.3.4.1. Breeding season

Monthly variation in Gonado-somatic Index (GSI) of male and female *C. carpio* was evident (Fig. 3.5). Mean GSI values of females ranged from 13.97±0.05 (January) to 17.01±0.04 (April) and that of males ranged from 2.5 ±0.21 (December) to 6.02 ±0.14 (May) (Fig.3.5). GSI values varied significantly (ANOVA, $p < 0.05$) between sampling months in both females and males. Sex by month interaction, however, was not significant (ANOVA, $p > 0.05$) suggesting a similar pattern of seasonal fluctuation of GSI in both sexes. Mean GSI values of the males increased from January (2013) to the highest value in May (2013) and then decreased towards a minimum in December (Fig.3.5). Mean GSI values of the females increased from the lowest value in January to the highest in April (2013) and then decreased towards December as the same trends as of males (Fig. 3.5).

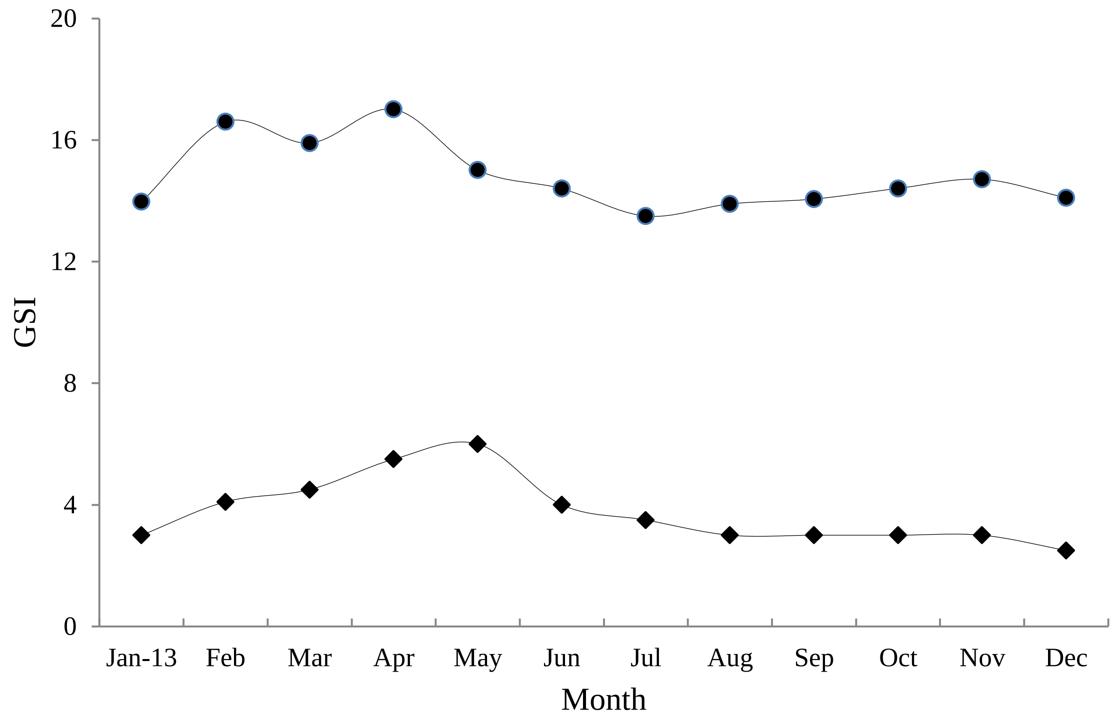

Fig.3.5. Seasonal variation in Gonado-somatic index (GSI) of female (•) and male (♦) *Cyprinus carpio* from Lake Ziway (January - December 2013)

The frequency of ripe female and male *C. carpio* ranged from 2-19% and 2-20%, respectively, with high frequency occurring between April and May (Fig. 3.6). The variation in GSI values was also reflected in monthly variation in the frequency of fish with ripe gonads (Fig. 3.5 and 3.6). Hence, lowest frequency of ripe fishes was recorded at times of lowest GSI values (Fig. 3.5). The result suggests that, while some fish in breeding condition may be present throughout the year their proportion was higher during February to May (Fig.3.6). This sugests that it is breeding time for the fish.

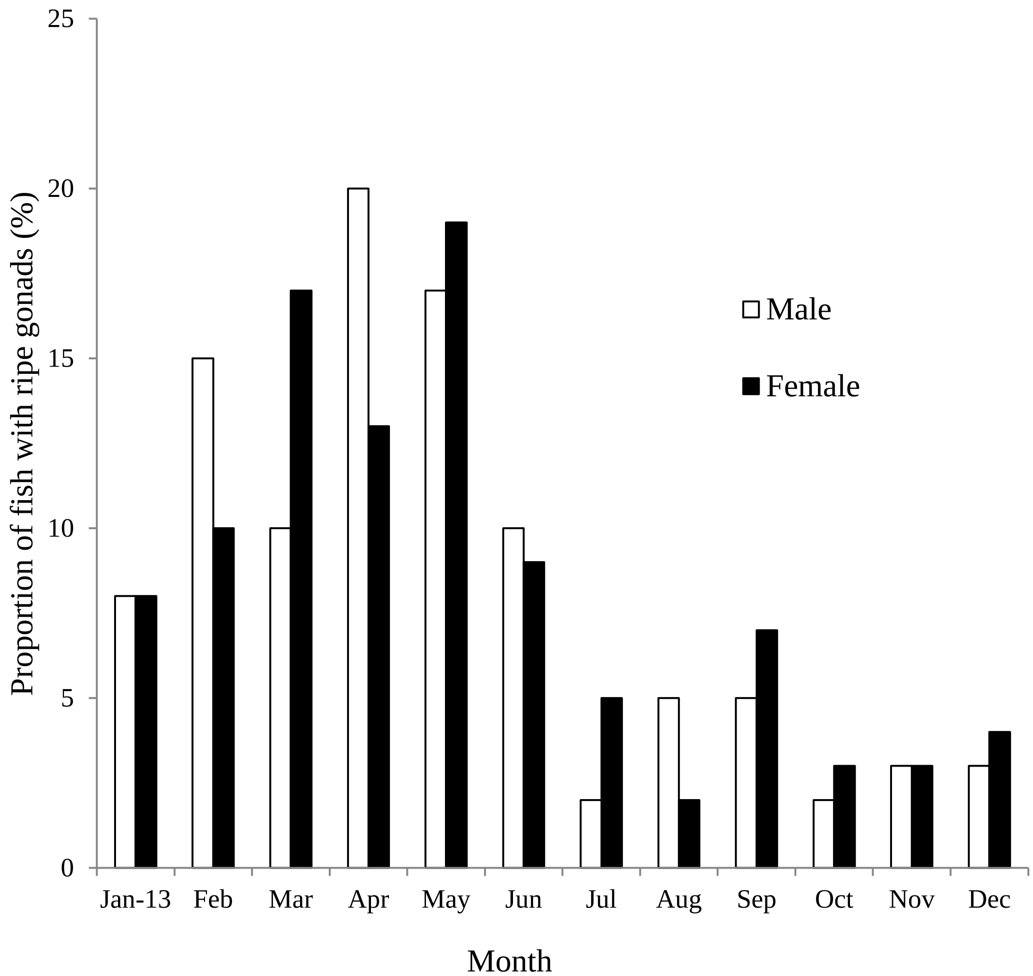

Fig. 3.6. Frequency of male and female *Cyprinus carpio* with ripe gonads in Lake Ziway during January - December, 2013.

3.3.4.2. Length at maturity

The smallest male found with ripe gonads was 16 cm FL and weighed 95 g., while the smallest female in breeding condition was 17 cm FL and weighed 100 g. Length of 50% maturity (L_{50}) was estimated to be 28.7 cm FL for females and 27 cm FL for males (Fig. 3.7).

On the average, males appeared to attain sexual maturity at a relatively smaller size than females.

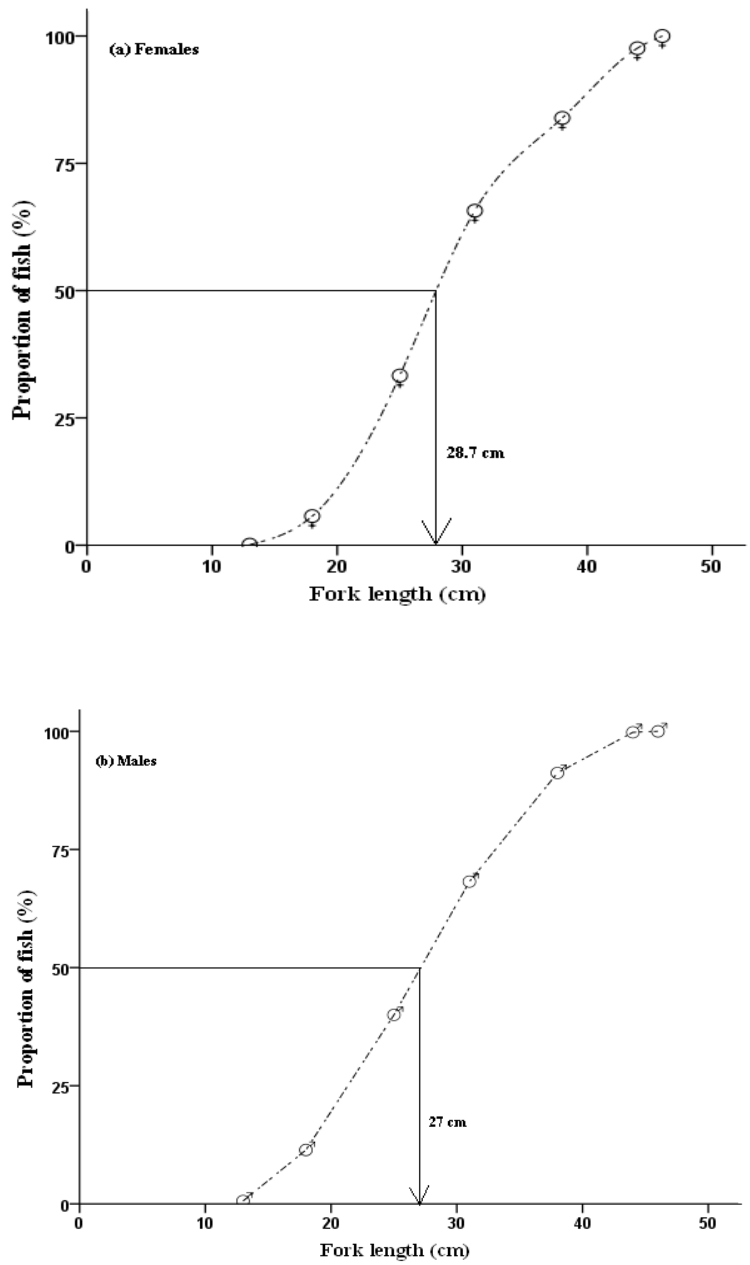

Fig. 3.7. The proportion in different length groups of females (a) and males (b) of *Cyprinus carpio* from the breeding seasons in Lake Zway.

3.3.4.3. Fecundity estimation

Fecundity was estimated for 93 ripe females of *C. carpio* whose fork lengths and total weights ranged from 32 to 46 cm and 600 to 2270 g, respectively. The estimated absolute fecundity ranged from 75,645 and 356,743 with a mean of 210,538. The relationship between fecundity and fork length, total weight and gonad weight were shown in Figs. 3.8, 3.9 and 3.10, respectivelly. Fecundity showed an increase with the increase in size of the fish and ovary weight (Figs. 3.8, 3.9 and 3.10).

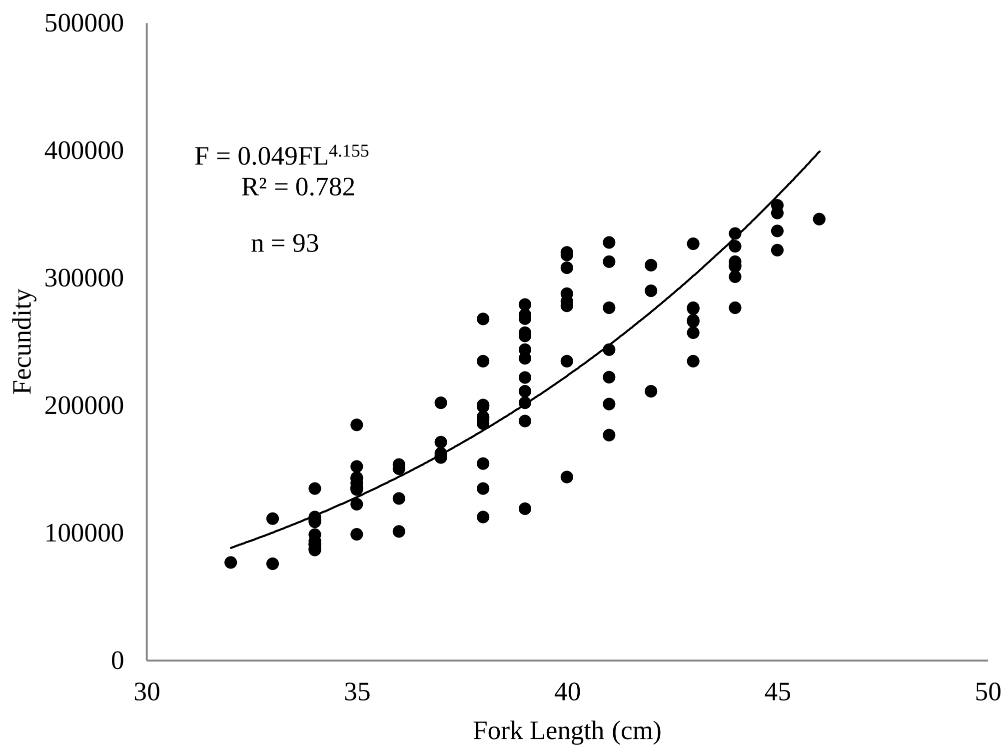

Fig. 3.8. Relationship between fecundity and fork length of *Cyprinus carpio* in Lake Ziway.

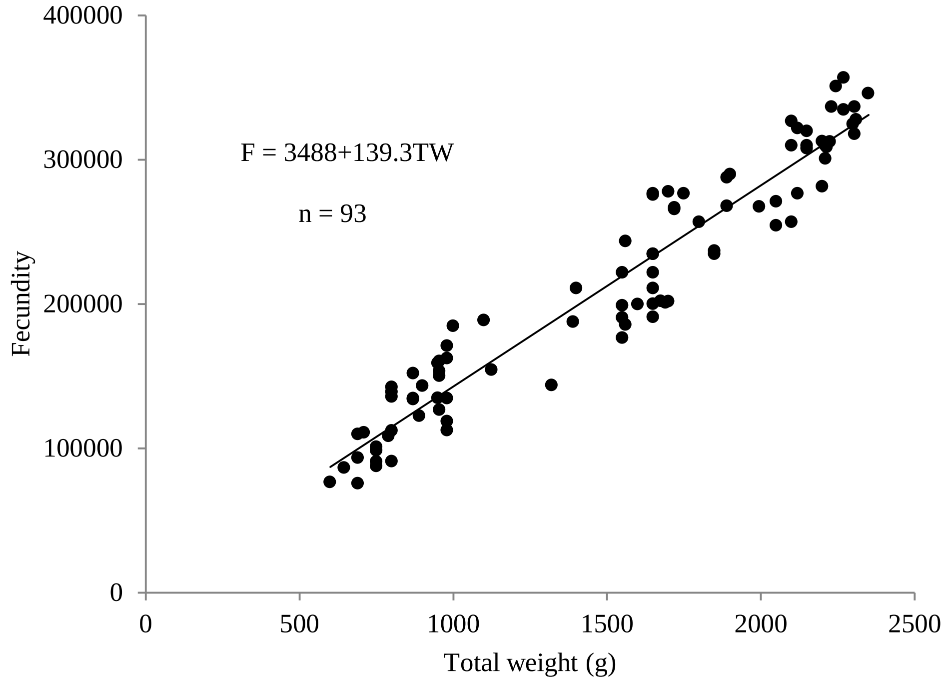

Fig. 3.9. Relationship between fecundity and total weight of *Cyprinus carpio* in Lake Ziway

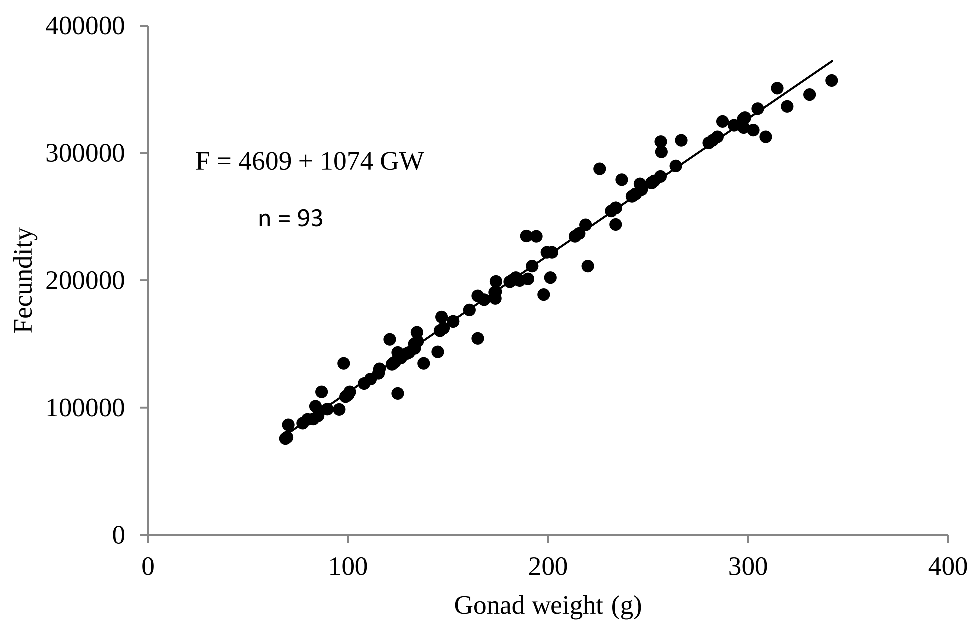

Fig.3.10**.** Relationship between fecundity and gonad weight of *Cyprinus carpio* in Lake Ziway.

3.4 Discussion

3.4.1. Size composition of the fishes

The largest *C. gariepinus* caught in the present study was 96 cm (TL) which was smaller than the size recorded for the same species collected with the same methodologies from Lake Langeno (104 cm; Leul Teka, 2001) and also from previous studies of Lake Ziway (117 cm; Daba Tugie and Meseret Taye, 2004). The largest *C. carassius*, caught in the present study was 46 cm (FL) which was similar to that recorded by Elias Dadebo and Daba Tugie (2009) for the species (47.8 cm) from the same lake. In earlier studies, the average size of *O. niloticus* landed by the commercial fisheries in Lake Ziway was 22 cm TL (Schroder, 1984). The length frequency distribution of *O. niloticus* in 1996 ranged from 12 to 40 cm with 83 % of the fish being between 16 and 24 cm TL (Mathewos Hailu, 2013). In this study, however, 73% of the fish were between 15 and 24 cm TL. In addition, the large-sized fish appeared in the catch of 1996 was between 35 and 40 cm (Mathewos Hailu, 2013), while the maximum length of *O. niloticus* landed in the present study was 34 cm, indicating that the size of the fish is decreasing over time.

The largest *T. zillii* caught in the present study was 25 cm (TL) which was smaller than the size recorded by Alemayeu Negassa and Abebe Getahun (2003) for the same species (32 cm). The declining trnds of length frequency for the fishes and the disappearance of large-sized fishes from the catch indicates that the fishery resource is vulnerable. These changes could be due to various reasons among which fishing pressure, use of reduced mesh size of fishing gears are the major ones.

3.4.2. Length-weight relationship and condition factor

The relationship between length and total weight for dominant fish species, *O. niloticus, C. carpio, C. carassius,* and *C. gariepinus* was curvilinear (Figures 3.3 and 3.4). In fishes, a length weight coefficient (b) of 3 describes isometric growth, that is the fishes retain the same shape and their specific gravity remains unchanged with growth in their life time (Ricker, 1975). The cofficient of *C. gariepinus* in this study is in agreement with Bagenel and Tesch (1978), and comparable to the value of b calculated for the same species in the same lake (2.84) in 2000 (Daba Tugie and Meseret Taye, 2004), but slightly lower than that of L. Awassa (3.04) (Elias Dadebo, 1988), L. Langeno (2.9) (Leul Teka, 2001) and L. Babogaya (2.93) (Lemma Abera *et al*., 2014a).

The length weight cofficient of *C. carpio* in this study was slightly higher (b = 2.93) than for the species found in Amerti Reservoir in the country (b = 2.92) (Mathewos Hailu, 2013). In addition, a 17 cm fish fork length of *C. carpio* would weigh 86.9 g in Amerti Reservoir, and 120 g in Lake Ziway. Hence, this may indicate that the condition of growth for the fish in Lake Ziway is better.

In addition, according to Mathewos Hailu (2013) the corresponding values of Fulton condition factor (FCF) of *C. carpio* for both sexes was 1.22 ± 0.14 in Amerti Reservoir; and 1.34±0.15 in Almus Lake in Turkey (Mehmet *et al*., 2007) and also 1.34±0.24 in Anzali Lake in Iran (Moradinasab *et al*., 2012). Currently in Lake Ziway the FCF value, 1.52±0.14 is better well-being than in Amerti, Almus Lake and Anzali Lake. Hence, such variations could arise due to difference in environmental factors, food availability and quality, feeding rate, degree of parasite and reproductive activity (Vostradovisky, 1973).

On the other hand, currently, mean FCF for *T. zillii* in Lake Ziway was 1.9 and this was lower than the value (2.06) reported by Alemayehu Negassa and Abebe Getahun (2003) for the same population. Thus, *T. zillii* in Lake Ziway is faced with poor environmental conditions than the previous years. The reason for this difference may be related to the differences in productivity of the lake due to anthropogenic impacts that changes food quantity and quality of the fishes. However, a detailed study is required to confirm this conclusion.

3.4.3. Sex-ratio

The overall sex ratio of *O. niloticus*, *C. carassius* and *C. carpio* was significantly different from 1:1 in the present study. Significantly, more female fishes were observed than males (Table 3.3). The unbalanced sex ratio found in the present study for these species was probably attributable to behavioral differences between the sexes, which might have made females more vulnerable to be caught in passive gears such as gill nets. In addition, this could be because of the difference in growth rate between the sexes where females attain larger size than males, for instance *C. carpio* species (Fig. 3.7). Other biological mechanisms such as differences maturity rates, mortality rates, or migratory patterns between the male and female sexes may also cause unequal sex ratios (Matsuyama *et al*., 1988). Also Elias Dadebo *et al*. (2003) reported the same phenomena of predominantly higher proportion of females in larger size classes in another cyprinid fish *Labeo horie* (Heckel) in Lake Chamo. According to Demeke Admassu (1994), for *O. niloticus,* preponderance of females has been attributed to sexual segregation during spawning activity, gear type and fishing site. Hence, the case may be the same for the Lake Ziway species; and further study is required to see if the same factors could be responsible for sex ratio.

3.4.4. Reproductive biology of *Cyprinus carpio*

Seasonal fluctuations in ripe fish and in GSI (Figures 3.5 and 3.6) suggest that *C. carpio* in Lake Ziway has a long breeding season extending from February through to September. Furthermore, since fish in breeding condition were present throughout the sampling year, some individuals may breed at other times of the year. Our finding agrees well with the general pattern of breeding seasonality of many fish species in the tropics (Fryer and Iles, 1972; Lowe-McConnell, 1982; Demeke Admassu, 1996; Zenebe Tadesse, 1997). Thus, for several tropical species, while some breeding may take place at any time, intensive breeding takes place during certain, often several, months of the year showing an extended period of breeding activity.

Several environmental factors could be responsible for the high breeding activity of *C. carpio* in Lake Ziway during the months of February to May 2013. The beginning of the rainy season, subtle change in temperature, rise in water level and the subsequent lowering of water conductivity were implicated as the triggering factors for spawning of many tropical fish species (Rinne, 1975; Dadzie and Okach, 1989; Elias Dadebo, 2000; Mathewos Hailu, 2013; Demeke Admassu *et al*., 2015b).

On the average, males appeared to attain sexual maturity at a relatively smaller size than females. In Asia and Far East, also *C. carpio* was found to attain maturity in ponds when six to eight months old, the males about two months earlier than the females and at a relatively small size (Alikunhi, 1966). Males attain maturity at a smaller size than females as reported in both temperate and tropical aquatic ecosystems (Tempero *et al*., 2006; Britton *et al*., 2007).

The estimated absolute fecundity ranged from 75,645 and 356,743 with a mean of 210,538 eggs, which was slightly higher than the same species in Amerti reservior (170,937; Matheows Hailu, 2013) and in Iranian water body (114,000; Yousewfian, 2011), but lower than that in New Zealand (299, 000 eggs; Tempero *et al*., 2006). High fecundity of *C. carpio* in L. Ziway could be due to its high body condition and growth as compared to the species in Amerti Reservoir, which in turn is a reflection of favorable biotic and abiotic factors. Fish in poor body conditions are reported to have lower fecundity than those in better condition (Lowe-McConnell, 1959; Demeke Admassu *et al*., 2015b). Fecundity increased in proportion to 4.16 power of the length and 0.98 power of the weight (Fig. 3.8 and 3.9). In many tropical freshwater fish species, fecundity increases in proportion to 2.81-3.96 power of total length (Lowe-McConnell, 1987). Bagenal and Tesch (1978) reported that the value of *b* (slope of the fitted line) is about 3 when fecundity is related to the length and about 1 when it is related to weight.

CHAPTER 4: ASSESSMENT OF THE FISHERIES AND SOME FACTORS THAT AFFECT FISH PRODUCTION OF LAKE ZIWAY

4.1. Introduction

Significant socio-economic developments have taken place around the Rift Valley Lakes since the 1980s and some effects on water level, water chemistry, macrophytes and fisheries were noted (Zinabu Gebremariam, 2013). Hence, given the fact that human activity is the major cause for the effects of the Ethiopian Rift Valley Lakes (Zinabu Gebremariam and Elias Dadebo, 1989; Zinabu Gebremariam, 1994; 1998 and 2003), it is adequate to take a quick assessment of the status of the human interference as an indicator to possible changes in water quality of the lakes.

Lake Ziway is located in an area with many agricultural activities but very few soil conservation efforts in its catchment area. The lake has been used for a variety of development activities such as fisheries, irrigated agriculture, livestock watering, vehicle washing, domestic water supply and sanitation; and most recently, and indoor flower farming. Although not as pronounced as that of the nearby Lake Abijata, lake level changes were reported for Lake Ziway by Dagnachew Legesee and Tenalem Ayenew (2006) and Tenalem Ayenew and Dagnachew Legese (2007).

In addition, extreme pumping of lake water for irrigation and reduction in lake volume has resulted in soil salinity, which is evident in the irrigation fields around Lake Ziway (Derege Hailu *et al*., 1996). IBC (2005) also reported that the situation of the lake ecosystem is being affected by catchment degradation, siltation, imbalance between water inflow and outflow and uncontrolled fishing practices. Share Floriculture Enterprise one of the most visible sources of effluent, was discharging its liquid wastes into the lake; there is also discharge from the irrigated fields around the lake as well as from Meki and Ziway towns, which end up in the lake (Personal observation).

It is worth mentioning that the effects of the effluent from the discharge are very worrying, given the toxic substances Dichlorodiphenyltrichloroethanes (DDTs), hexachlorocyclohexanes (HCHs), chlordanes, and heptachlorsthat it may contain (Yared *et al*., 2014b). There are several evidences of some undesirable changes that have occurred in the lake, such as decline in phytoplankton biomass (Getachew Beneberu and Seyoum Mengistou, 2009; also in this study as discussed in chapter 2), increase in dominance of toxin-producing blue-green algae such as *Microcystis* and *Cylindrospermopsis* spp. (Girma Tilahun, 2006) and imbalance between water inflow and outflow, which was mainly attributed to higher lake evaporation (Tenalem Ayenew and Dagnachew Legesse, 2007) and also other nutrient variations as discussed in chapter 2.

As described in Chapter 1, commercial fish production in Lake Ziway was intensified through the support acquired from Lake Fisheries Development Project and onwards, the fish stocks of the lake have declined for a variety of reasons. The long-term effect of all these on water quality and on food webs is complex and affects the fish production of the lake. Hence, based on the historical data available on environmental as well as water quality, it is possible to ascribe fishery changes in the lake to identifiable factors. Therefore, this study was undertaken to assess the status of fish and fisheries in relation to some long-term environmental impacts that were recorded earlier, which will help to suggest appropriate measures that will promote the conservation and sustainable utilization of the resources of the lake.

4.2. Materials and Methods

4.2.1. Catch and effort

Catch and effort data were recorded from the landing sites of the lake between October 2012 and September 2014. Data collection was done by the staff members of Ziway Fishery Research Center as well as the selected cooperative in each district (A. T. J. Kombolcha, Dugda and Z. Dugda). Total landing by species in kg, the number and type of gears used for fishing and the number of settings for each gear were recorded.. The number of gears in a community was monitored by the data collector responsible for it. Total effort per gear type was estimated based on the number of gears (gill net and hooks), settings (beach seine) and time (the number of days the gear was deployed in the month). The number of gears and settings in relation to fish catch in each gear were obtained through interviews with the fishermen.

These data were also used as raising factor in the estimation of annual yield. A review was also made on the long-term trend of fish production from various published research results and unpublished data collected by Ziway Fisheries Research Center.

4.2.1. Factors that affect the fish production

Some previous physico-chemical variables and nutrients that are directly related to the production of fishes were reviewed to assess the effects on the fish production. Monthly and yearly rainfall and temperature for the study area was obtained from National Meteorological Agency. Surface water level was measured by a standard calibrated vertical scale to referred surface level gauge located at GPS point of $07^0$55.195’N, $038^0$43.719’E and an elevation of 1639 masl.

4.3. Results

4.3.1. Species composition of catch

Six fish species were represented in the catch from the lake. The catch composition of the most commercially important fishes is estimated to be about 42.48 % *O. niloticus*, 27.06 % *C. carpio*, 16.39 % *C. carassius* and 14.08 % *C. gariepinus* (Table 4.4). The long-term trends of the species composition of the catch are described in Figure. 4.1.

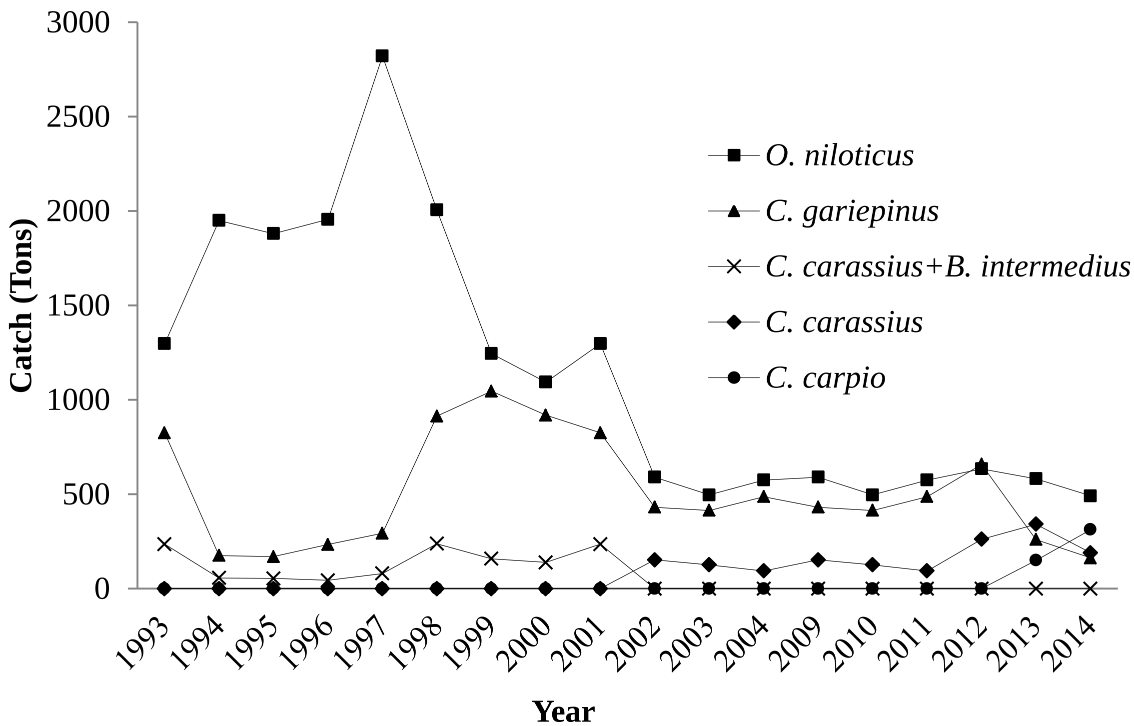

Fig. 4.1. Trends in species composition of catch from Lake Ziway (Source: LFDP, 1998; Felegeselam Yohannes, 2003; Mathewos Hailu, 2011; Brook Lemma, 2012, and the current study)

Catch composition has changed since 1997 with a decline in *O. niloticus*, but relatively a progressive increase in the proportion of *C. gariepinus* and *C. carassius*. Hence, the catch composition of *C. gariepinus* was 176 tons in 1994 and increased to 1046 tons in 1999 then decreased to 163 tons in 2014. Currently, contributions of *O. niloticus* is by far lower than previous years while the contribution of the carps has increased and became significat part of the landings (Fig. 4.1).

4.3.2. Catch

The estimated mean annual catch in tons per gear type for different years were summarized in Tables 4.1 - 4.4. The catch proportions of the fishes (*O. niloticus*, *C. gariepinus* and the two carp species) were also assessed. The total CpUE were 1156.71, 1555.72, 1333.82 and 1157.14 for the production year of 2010/11, 2011/12, 2012/13 and 2013/14, respectively (Table 4.1 - 4.4).

Catch proportion varied among species in different periods. For instance, the catch of *O. niloticus* and *C. gariepinus* were decreasing from 575.82 to 491.54 tons and 487.09 to 162.88 tons during 2010/11 to 2013/14, respectively. While, the total catch for the two carp species increased from 93.8 to 502.63 tons respectivelly (Table 4.1 - 4.4).

Although the number of beach seines decreased, the catch proportion of the gear is better as compared to others gear; it accounts to more than 74% of the total catch since 2010 to 1014 (Table 4.1- 44). Currently, the number of hooks utilized in long lines has increased, but the catch efficiency of the gear was not more than 5 % of the total. The long-lines used mainly to catch large-sized *C. gariepinus*. In general, the trend of catch decreased and even the latest statistics showed that in 2012/13 the fish catch was around 1333.82 tons while in 2013/14 it was 1157.14 tons, showing a decline of fish from the existing potential of 176.68 tons in just one-year (Tables 4.3 and 4.4).

Table 4.1. Catch percentage of fishes by species and gears in 2010/2011

	Total catch in metric tons				
Gear	*O. niloticus*	*C. gariepinus*	*C. carassius*	Total	Catch size with gears (%)
Gill net	65.69	30.68	10.27	106.64	9.22
Beach Seine	510.13	267.97	83.53	861.63	74.49
Long line	0	188.44	0	188.44	16.29
Total	575.82	487.09	93.8	1156.71	100
Species composition (%)	49.78	42.11	8.11		

Table 4.2. Catch percentage of fishes by species and gears in 2011/2012

	Total catch in metric tons				
Gear	*O. niloticus*	*C. gariepinus*	*C. carassius*	Total	Catch size with gears (%)
Gill net	80.25	15.92	19.98	1264.62	81.29
Beach Seine	554.00	467.59	242.16	116.15	7.47
Long line	0	174.95	0	174.95	11.25
Total	635.12	658.46	262.14	1555.72	100
Species composition (%)	40.83	42.33	16.85		

Table 4.3. Catch percentage of fishes by species and gears in 2012/2013

	Total catch in metric tons					
Gear	*O. niloticus*	*C. gariepinus*	*C. carassius*	*C. carpio*	Total	Catch size with gears (%)
Gill net	59.39	18.96	68.08	32.15	178.58	13.39
Beach Seine	504.43	146.47	274.12	117.85	1042.87	78.19
Long line	0	112	0	0	112.37	8.43
Total	563.82	277.43	342.2	150	1333.82	100
Species composition (%)	42.27	20.80	25.66	11.25		

Table 4.4. Catch percentage of fishes by species and gears in 2013/2014

	Total catch yield in metric tons					
Gear	*O. niloticus*	*C. gariepinus*	*C. carassius*	*C. carpio*	Total	Catch size with gears (%)
Gill net	80.06	14.91	28.42	46.73	170.12	14.7
Beach Seine	411.48	94.97	161.2	266.37	934.02	80.72
Long line	0	53	0	0	53	4.58
Total	491.54	162.88	189.62	313.1	1157.14	100
Species composition (%)	42.48	14.08	16.39	27.06		

4.3.3. Annual fish catch

The annual fish catch of the lake shows different trends with time (Fig. 4.2). The first fishing phase was before 1994, which was a period of fisheries where the catch has been stable with a mean annual catch of 780 tons. The possible reason for the stability was low number of active fishing gears in the lake. The second phase was the growth period between 1994 and 2000, which was a period when yield increased dramatically to 2500 tons which has exceeded the recommended (Mathewos Hailu, 2011), annual catch of 2163 tons. At this time additional and effective fishing gears were handed out to fishermen by the LFDP. The third phase was the period in which fish catch declined with an average of 1200 tons in 2010, and currently, in this study years the catch again decreased to 1157.14 tons.

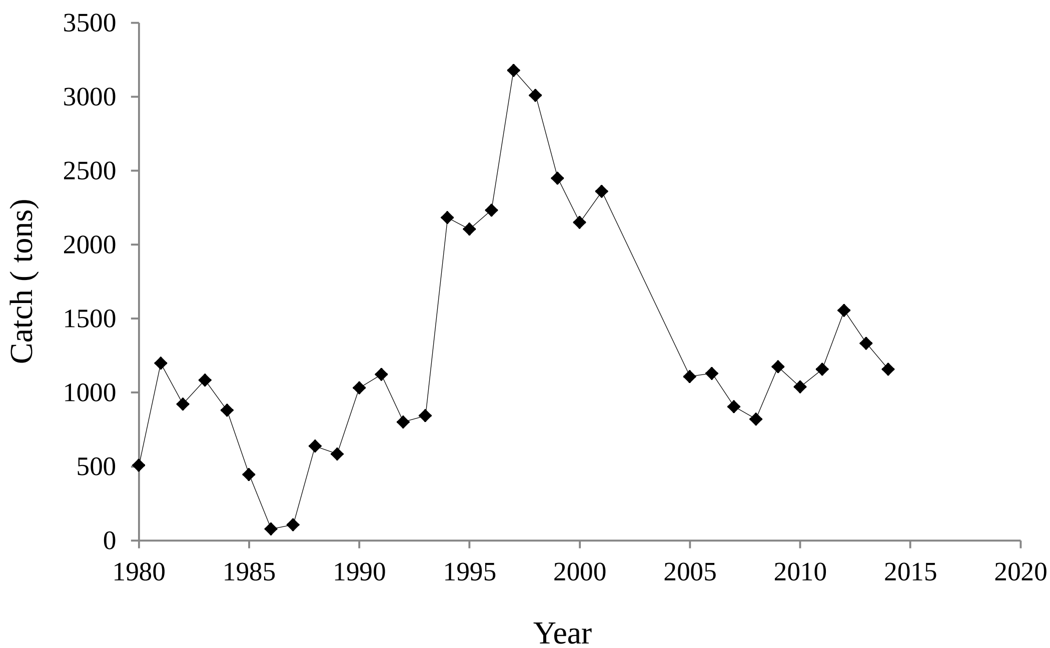

Fig. 4.2. Change in total anual fish catch from Lake Ziway between 1980 and the present (Source: LFDP, 1998; Felegeselam Yohannes, 2003; Mathewos Hailu, 2011, Brook Lemma, 2012, and the present study).

4.3.4. Factors that affect the fish production of Lake Ziway

4.3.4.1. Fishing gears

The fishing activity of Lake Ziway was operated by three types of gears: beach seines, gillnets and long-lines (Table 4.5); while hook-and-lines were utilized by occasional fishermen along the shoreline. The fishermen utilize wooden boats for casting beach seines and rafts for gillnets and long-lines. Steel boats were used only for collection of fishes from landing sites as well as for transportation. Beach seine was the most common fishing gear used, whose presence increased from about 116 in 1993-1995 to 5596 in 2001/02 (Table 4.5). During this study, the assessment done has indicated that the number of beach seines have decreased to 127 only (Table 4.5). The number of gill nets has also decreased drastically from 2470 in 1996 -1998 to 104 (2009/10) and then increased during this study period to 1445 (Table 4.5). The decrease in fishing gears in Lake Ziway are many among which may be decline in catch size and decline in fish sizes.

Table 4.5. Summary of fishing gears trend involved in Lake Ziway in different years (in number)

Years	Gill nets	Beach seines	Long-line (Hooks)	Reference
1993-1995	1,810	116	1,056	LFDP, 1996
1996-1998	2,470	124	1,413	Felegeselam Yohannes, 2003
2000-2001	1,098	5,596	399,995	Yared Tigabu, 2003
2009-2010	104	68	56,070	Mathewos Hailu, 2013
2012-2013	1,445	127	400,461	Current study

In contrast to beach seines and gill nets, the number of hooks utilized in long-lines has increased from 1,056 in 1993/95 to 399,995 in 2000/01. Again the number of the hooks decreased in 2009/2010 to 56,070 and currently the number increased and reached 400,461 (Table 4.5) to capture the number of *C.gariepinus*.

4.3.4.2. Rainfall and temperature

The fluctuation in air temperature and rainfall during the period 1982 to 2013 is shown in Figure 4.3. Lower average air temperature were recorded in 1982 (19.90 ^{0}C) and in 1983 (19.95 ^{0}C) and the highest (21.8 ^{0}C) in 2002 and onwards. In contrast, the highest rainfall was recorded during the time when temperature was low, namely in 1982, which amounted to 891 mm and the lowest (364 mm) was observed in 2002. In general, the total annual rainfall and average temperature of the area were negatively correlated (Fig. 4.3).

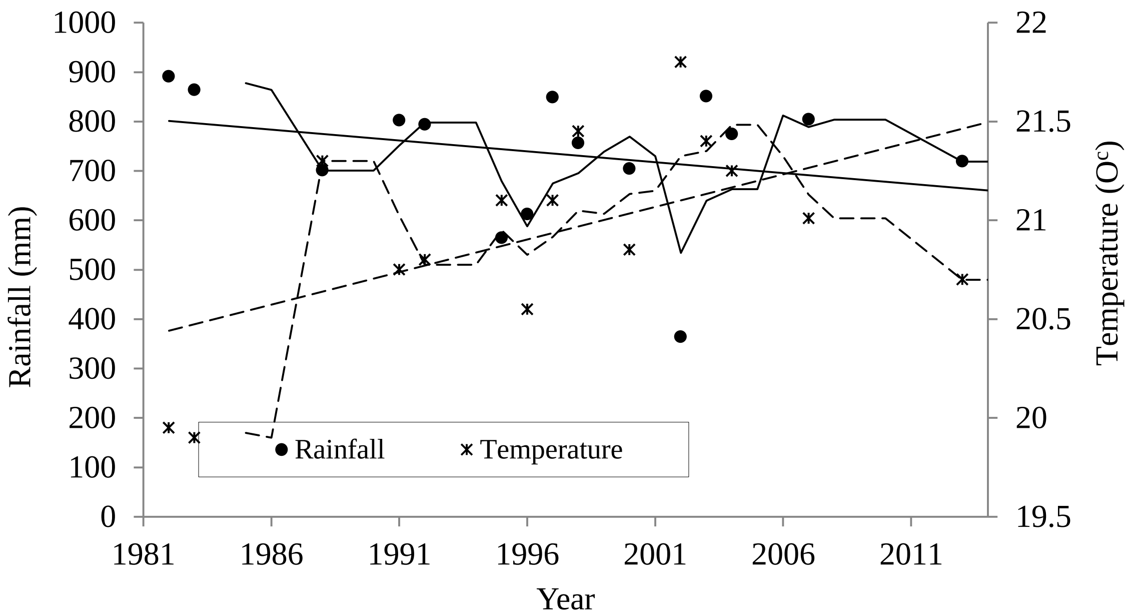

Fig.4.3. Total annual rainfall and average air temperature trends around Lake Ziway during the year 1982-2013 (Source: National Meteorological Agency).

Like other natural resources, Lake Ziway requires a particular water level and seasonal timing of flows to guarantee the sustainability of its ecosystem and biodiversity. Hence, rainfall is the major incentive for water level of the lake and when the rain starts, the lake water is rising and the shallow shores of the lake become fringed with submerged wetlands and floating vegetation (Personal observations).

4.3.4.3. Lake water level

In this study lake water level measurement is the height at which the water fluctuates at the same spot at different time. Within each year the water volume of Lake Ziway fluctuates following season changes with slight rise in wet seasons and decline in dry seasons (Fig. 4.4. 4.5 and 4.7). During dry seasons and low rainfall years of the study period, the discharge of the feeder rivers was low, 2.23 m^3/s (Meki River) and 3.19 m^3/s (Ketar River) and as a result reduced the surface area of the lake (Fig.4.5).

Fig.4.4. Mean yearly water level measurement of Lake Ziway (From1975 to 2014) (Source: Alemu Dribssa (2006) and the current study).

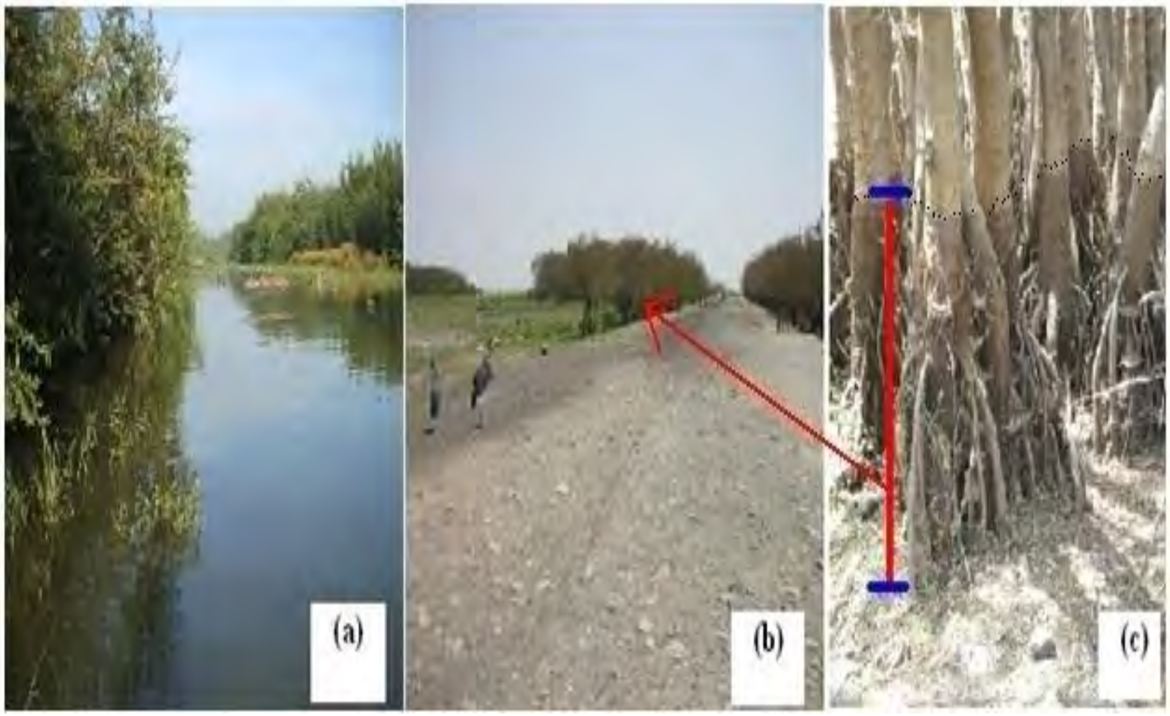

Fig.4.5. Lake water level fluctuations of **(a)** wet season and **(b** and **c)** dry season at the same spot during the year 2013/2014

Monthly distribution of the water level of the lake is described in Figure 4.7. The trend shows that high water level occurred since July and reached its peak in September for the whole cycle of the years and in contrast decreased in the dry seasons (Fig. 4.6 and 4.7).

Currently, plenty of pumps are abstracting fresh water from the lake by the state, investors and private commercial farms throughout the year (Fig. 4.6). Even during the rainy seasons water for horticultural crops is collected from the lake. Hence, the current irrigation practices in the upstream areas have considerably reduced the volume of the inflowing water from Meki and Ketar River and the lake itself, critically impacting the water level of Lake Ziway. As a result, the lake ecosystem is being affected by catchment degradation, siltation, imbalance between water inflow and outflow.

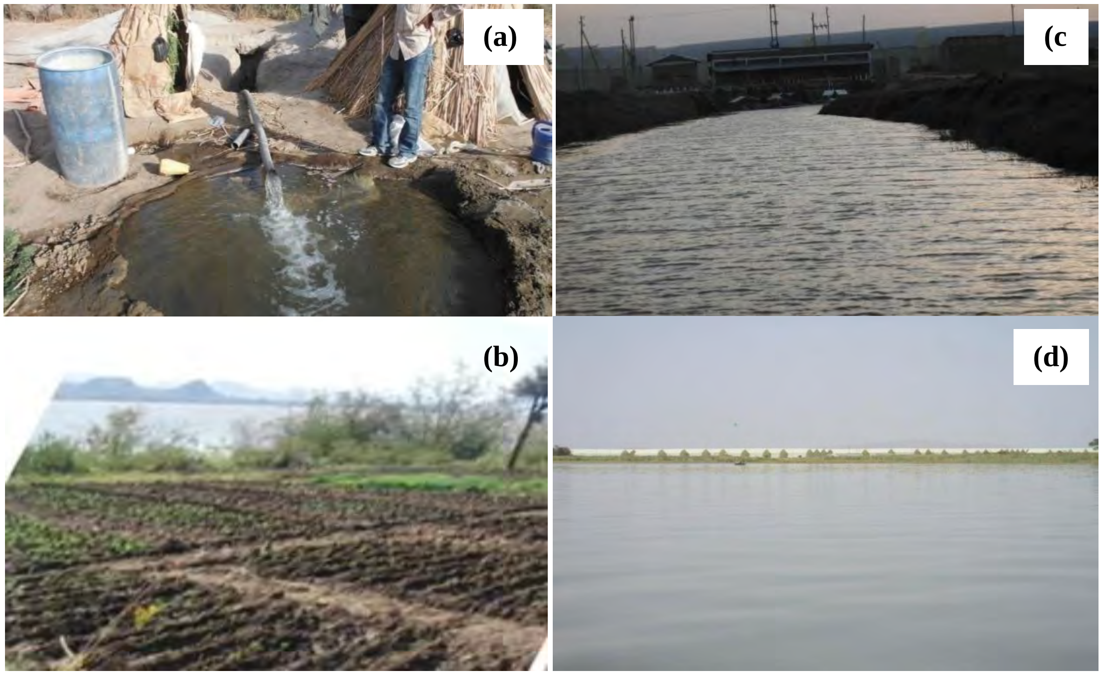

Fig.4.6. Some irrigation practices around the shore of the lake showing enhanced **(a)** abstraction, **(b)** horticulture activity, **(c)** and **(d)** drainage system and the green house of flower farm around the lake

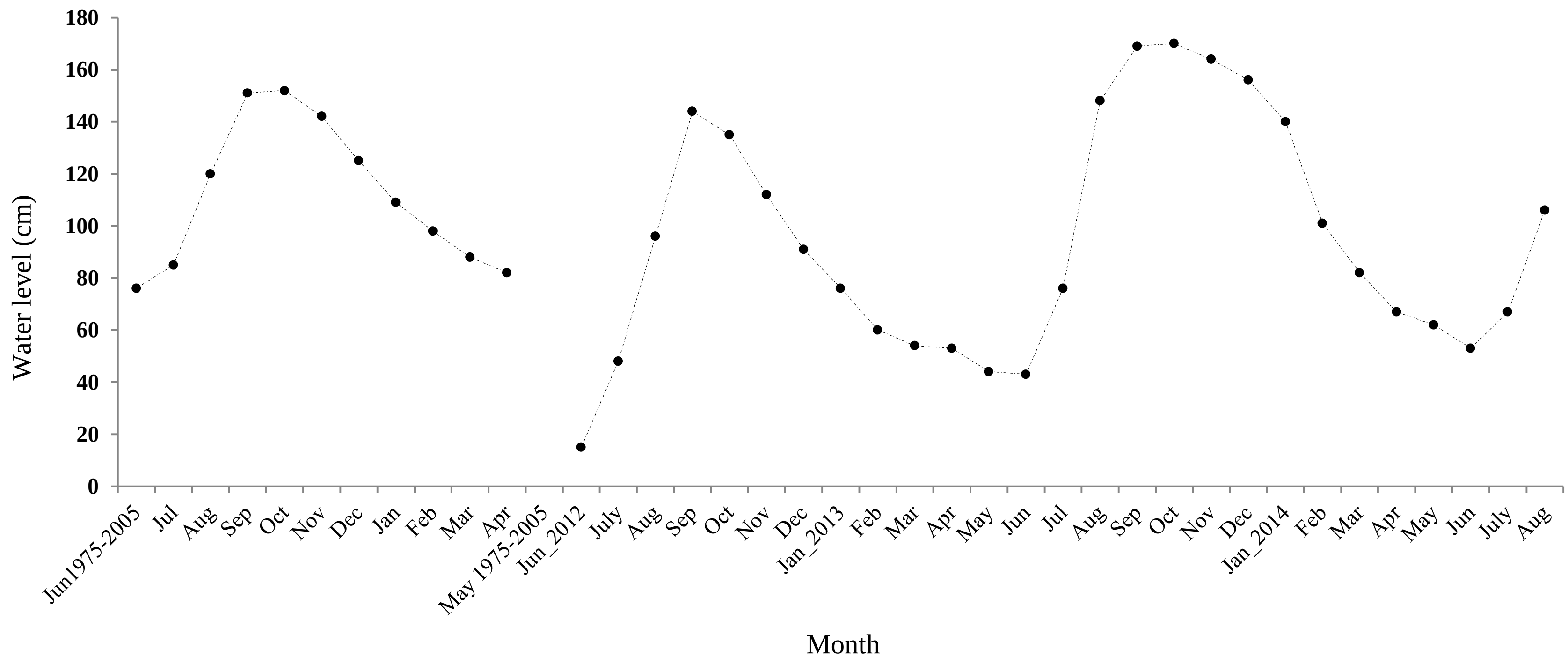

Fig.4.7. Mean monthly water level measurement of Lake Ziway (June 1975 - August 2014) (Source: Alemu Dribssa (2006) and the present study).

In addition, evaporation due to high temperature is one of the main factors for the decrease in the water level of the lake and the general trend is described in Figure 4.8. The trend of temperature increase was continual, which in turn must have increased the rate of evaporation and then affect the level of the lake (Fig.4.8).

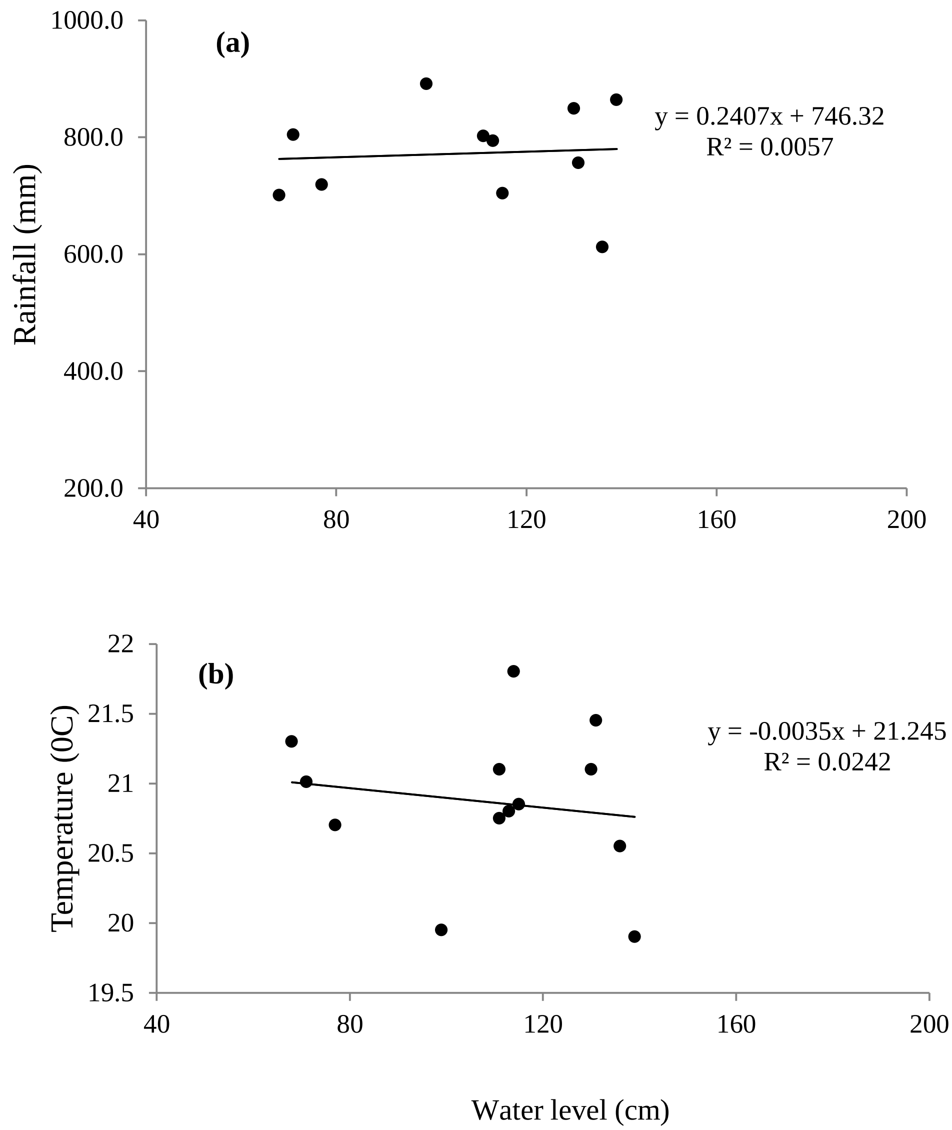

Fig.4.8.Relationship between water level of the lake versus **(a)** total rainfall and **(b)** temperature over the period (1982-2013) (Source: Alemu Dribssa (2006), National Meteorological Agency and the present study).

Fish catch versus water Level: Even if there were high anthropogenic pressures in Lake Ziway, abundant fish species were collected from the littoral zone of the lake (See Chapter, 2). Fig. 4.9 describes the correlations between fish catch and water level of the lake. Fishes belonging to the Family Cichilidae particularly the Nile tilapia thrives well in shallow areas with rich macrophyte vegetation cover. As indicated in Fig. 4.8, rainfall has significant importance for the water level of the lake. Hence, the catch of the particular fish species were increased as water level increased (Fig. 4.9), which in turn provides suitable spawning grounds for adults, and feeding and nursery grounds for the young. Currently also carp species, like *C. carpio*, have dramatically increased in the catch in the littoral zone of the lake (Fig. 4.1 and see in Chapters 2 and 3).

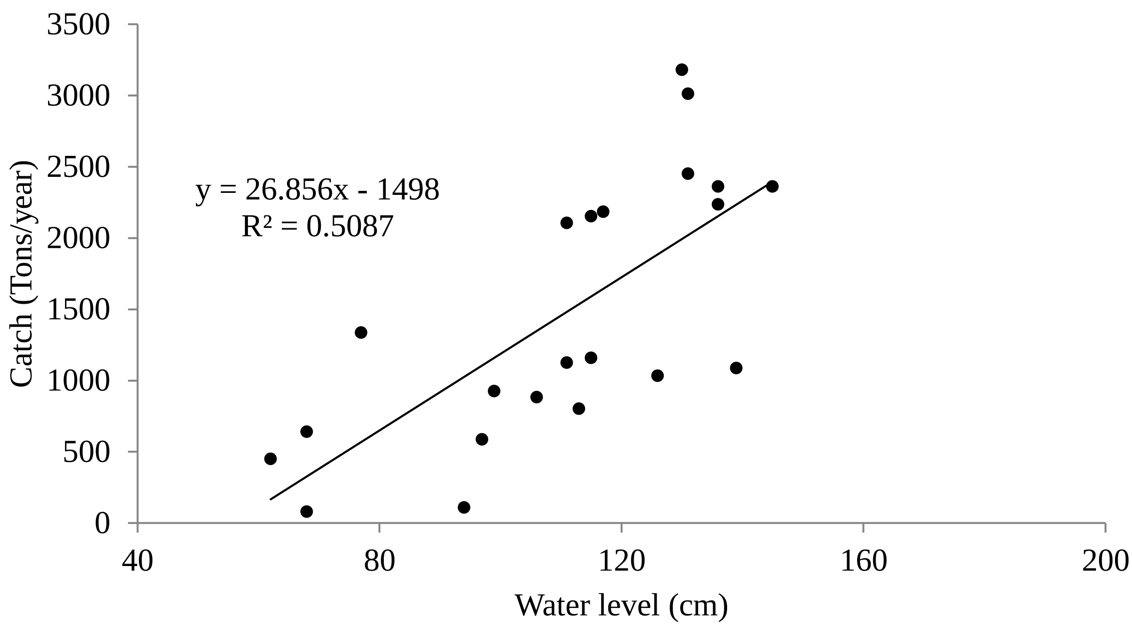

Fig.4.9. Relationship between water level and catch in Lake Ziway (1982-2014) (Source: LFDP, 1998; Felegeselam Yohannes, 2003; Mathewos Hailu, 2011; Brook Lemma, 2012 and the current study).

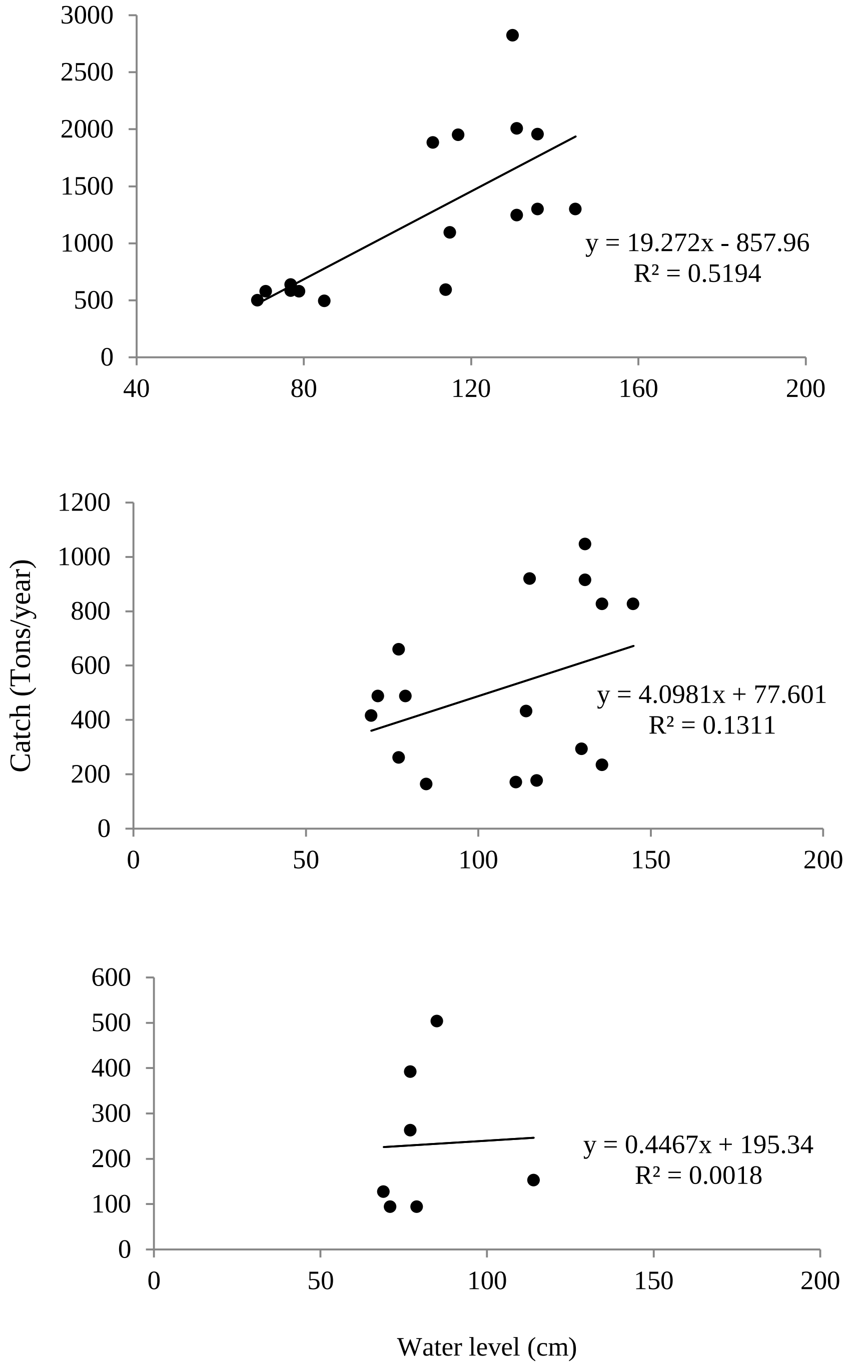

Fig. 4.10. Catch with species ((a) *O.niloticus*,(b) *C.gariepinus* and (c) Carp species) and water level since 1993 (Source: LFDP, 1998; Felegeselam Yohannes, 2003; Mathewos Hailu, 2011; Brook Lemma, 2012 and the current study).

Fig. 4.10 describes the relationship between fish species and water level of the lake. Family Cichilidae was observed to be more abundant in the catch when the lake level remained high between 1993 and 2001 (Fig.4.10). On the other hand currently, carp species, like *C. carpio* have dramatically increased in the catch in relation to water level decrease (Figure 4.10).

4.3.4.4. Water quality

Aside from problems related to decreasing water level of the lake, water abstraction started to induce salinity, due to loses of freshwater from the lake. Simultaneously, the application of agrochemicals (e.g Fig. 4.11) and fertilizers due to intensification of irrigation practices around the lake has increased and affected the water chemistry of the lake (Table 4.6).

Table 4.6. Trends in some physico-chemical factors of Lake Ziway

Parameters	**Unit**	**Amount**		**General trend**
		Previous	**Present study**	
Secchi depth	cm	40 -106 (Girma Tilahun, 1988)	17.8-22.1	Decreasing
pH	-	8.5 (Elizabeth Kebede *et al*., 1994)	8 - 8.4	Decreasing
D. Oxygen	mg/L	7.1 (Adamneh Dagne, 2010)	3.4 - 6	Decreasing
Chl-*a*	µg/L	150 - 212 (Girma Tilahun, 1988)	37 - 54.5	Decreasing
Nitrate	µg/L	28 (Girma Tilahun, 1988)	30.1 - 61.7	Increasing
SRP	µg/L	5.5-16.2 (Girma Tilahun, 1988)	38.2 - 64.7	Increasing
Ammonium	µg/L	36.4 (Elizabeth Kebede *et al*., 1994)	64.17- 258.92	Increasing
Conductivity	µS/cm	347- 400 (Girma Tilahun, 1988)	361.5 - 484.5	Increasing

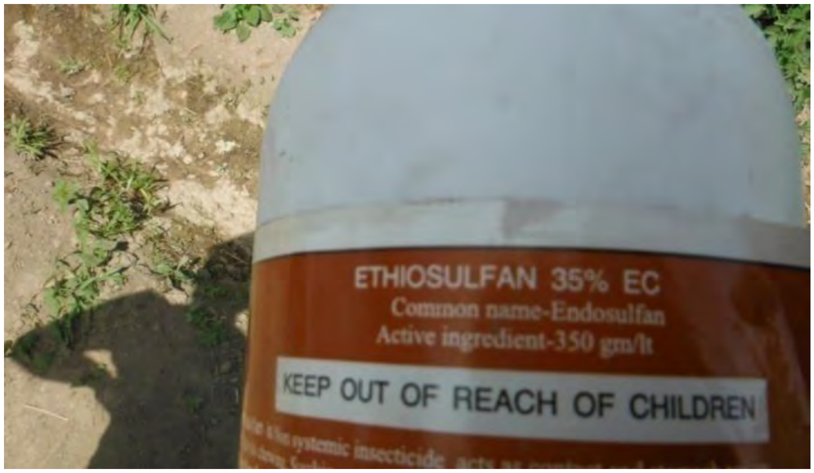

Fig.4.11. Chemicals that farmers commonly use for pest control around the lake.

With the clearing of the vegetation in the watershed for different purposes (Fig. 4.12), silt loads of the feeder rivers bringing impact on the limnological system and hydrological conditions of the lake (Table 4.6).

Fig. 4.12. Vegetation clearing around the shore of Lake Ziway for different purposes.

Hence, currently, the high concentration of SPR in the lake could be due to influx of pollutants and organic matter from the lake shores (Table 4.6). The farm lands located near the shore use fertilizers which are rich in nutrients, especially phosphates and nitrates, and hence can increase the concentration of SRP (Table 4.6).

As discussed in chapter 2, the increment in turbidity was measured by the low Secchi depth measured during the study period as compared to previous records (Table 4.6). The lower Secchi depth can be partly caused by the rising levels of silitation as conductivity increased. Also the major routes of entry of nitrogen into the lake was may be due to anthropogenic causes (municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes (including birds and fish (personal observation)) and discharges from car exhausts) and all these directly or indirectly affect the water quality of the lake. The detail interaction between nutrients in the lake was discussed in Chapter 2.

4.4. Discussion

4.4.1. Species composition of the catch

Lake Ziway is endowed with different kinds of indigenous and exotic fish species as discussed in the first three chapters of this thesis. Among these species *O. niloticus*, *C. gariepinus*, *C. carpio* and *C. carassius* are commercially important (Lemma Abera *et al*., 2014b). As discussed in Chapter 2, *O. niloticus* was the major contributer to the catch accounting for 94 % (Schroder, 1984 in Mathewos Hailu, 2011). However, the composition of *O. niloticus* has been gradually declining to 89.3% of total catch during 1994, 50.9 % in 2010 and reached to 42.5 % of the total commercial catch currently. In contrast, the catch composition of *C. gariepinus* was 8.1 % in 1994 (LFDP, 1997) and increased to 41.8 % in 2010 then currently decreased to 14.08 %. The catch composition of *C. carassius* and *C. carpio* are currently increasing and account to 16.4 and 27.1 %, respectively (Table 4.4).

The most abundant fishes (*O. niloticus*, *C. gariepinus*, *C. carpio* and *C. carassius*) were also the most widely distributed in different water bodies, as they are highly tolerant to a wide range of environmental conditions (Greenwood, 1966; Demeke Admassu *et al*., 2015a). In Lake Ziway, *O. niloticus* is one of the fish species that are abundantly found in the littoral zones during juvenile stage (Eyualem Abebe, 1984; Elias Dadebo, 1988; Eyualem Abebe and Getachew Tefera, 1992; Lemma Abera, 2012) and similar phenomenon has been observed in Lake Naivasha (Mavuti, 1983). Currently, the littoral zone is being affected due to different anthropogenic factors and the composition of the fishes changed and as a result there is a progressive increase in the proportion of *C. carassius* and *C. carpio.*

4.4.2. Catch

Over the years the total catch (tons/year) has been decreasing. It was 1156.71, 1555.72, 1333.82 and 1157.14 for the years 2010/11, 2011/12, 2012/13 and 2013/14, respectively (Table 4.1 - 4.4), which was by far lower than 3195 tons recorded in 1997 (Felegeselam Yohannes, 2003). Currently, the catch composition has changed with a decline in *O. niloticus*, but a progressive increase in the proportion of *C. carpio* and *C. carassius*. *Clarias gariepinus* had established themselves in the lake since the mid 90s (LFDP, 1997), but currently the contribution of the fish to the catch has decreased (Table 4.4 and figure 4.1). The decrease in catch trend since 2011 is due to an excessive increase in effort with gill nets, beach seines and number of hooks in long line (Table 4.5) as well as the number of fishermen as will be discussed in the next Chapter. This was because of an ever-increased fishing effort coupled with the decrease in the amount of fish caught in each trip (Table 4.1 - 4.5). The catch of Lake Tana was also by far lower than the previous production as reported by de Graaf *et al*., (2006) due to the same reasons.

The catch of *O. niloticus* and *C. gariepinus* decreased from 575.82 to 491.54 tons and 487.09 to 162.88 tons during 2011/12 to 2013/14, respectively. That of carps was increasing from 93.8 to 502.72 tons (Table 4.1 - 4.4 and Fig. 4.1). This could be due to overfishing of selected fish species with inappropriate gears and degradation of the catchment area that breeding of some fish species that take place. All these leads to decline in species like Nile tilapia.

Although, *O. niloticus* catch decreased, it is still the most dominant and the most preferred species in Lake Ziway as described in Chapter 2. In the early 1990s, the size of the fish was reportedly greater than the findings of this study (Table 4.1 - 4.4). Over the years, this size became less and less due to increased fishing pressure in which the minimum mesh size for gill nets was reduced from 10 to 8 cm. In this way the larger parent fish was caught, thus reducing the number of parent fish and the stress on the remaining population was increased, like carp species in the lake as discussed in Chapter 2.

4.4.3. Trends of fish catch in the lake

The problem of Lake Ziway fishery is that fishing is open to everyone who wishes to do so as source of income and food. Hence, the current annual fish production from Lake Ziway is declining due to overexploitation and reduction in the average size of catch that was reported after the introduction of improved fishing technologies by EU funded Lake Fisheries Development Project (LFDP, 1998). According to Yared Tigabu (2003), there was a continuous decline in the annual catch of some fish species, like *O. niloticus* from the lake since 1997, but on the other hand there was an increase in *C. gariepinus* population which was also observed from the fishermen catches since the period 2010 to some extent. Similarly very recently, there is increased catch of the two carp species particularly during the period of this study. According to Felegeselam Yohannes (2003), the average total annual catch in Lake Ziway was 2459.25 tons between 1994 and 2001, with a range of 2105-3180 tons. However, the current annual yield of the lake is much less than these estimates due to different anthropogenic impacts that will be discussed below in this section.

4.4.4. Factors that affect fish production

Lake Ziway experienced direct and indirect environmental stresses and the common factors that affect the production of the fishes are discussed below.

4.4.4.1. Fishing gears

Different fishing methods catch different types and sizes of fishes in the same area (Smith, 1994). Gill nets, beach seines and long-line were the most common fishing gears that were being used in Lake Ziway and the trends were different from time to time (Table 4.5). The decline in the number of beach seines was associated with decrease in catch, which led some fishermen to move Lakes Langano, Koka and Fincha (Personal observation). The recommended minimum beach seine mesh size in the cod end was 6 cm, minimum mesh size in the wings was 8 cm, and maximum allowed length 150 meters for Lake Ziway (LFDP, 1997). However, Megersa Endebu *et al*. (2013) reported that the beach seines operating currently are twice as long as the recommended length. About 56.3 % of the fishermen use beach seine whose wing mesh size is less than 8 cm and 42% of the fishermen use beach seine whose cod end mesh size is less than 6 cm.

The number of gillnets has also decreased drastically from on average 2470 between 1996 - 1998 (Felegeselam Yohannes, 2003) to 104 in 2009 - 2010 (Mathewos Hailu, 2013) and then increased to 1445 (2013/14) (Table 4.5). The decrease in gillnet could be due to the decrease in tilapia catch in the lake's fishery. In the management plan of Lake Ziway set during LFDP 1997, the minimum stretched mesh size of gillnet was 8 cm in the first year, 9 cm in second year and 10 cm thereafter, with maximum length of 60 m. (Megersa Endebu *et al.* ,2013). Also Megersa Endebu *et al.* (2013) reported that 41.9 % of gill net users were confirmed to use gill nets whose mesh size is less than 8 cm very recently.

The number of hooks utilized in long lines has increased from none in the early 90's (LFDP, 1993) to 400,461 in 2013/2014 (Table 4.5). The appearance of the long-line and its expansion was after the increase in *C. gariepinus* population, which was exotic to the lake. The increase in long-line fishery is associated with low labor and capital investment requiring only one person and just a raft, while using a beach seine requires three or more persons to operate with a wooden boat. Hence, employment of different gears in the fishery of the lake can have strong impacts on the fish community with regard to their size structure and composition. For example, progressive increase of fishing effort and reduction of mesh size will first reduce the stock of larger species and then begin to reduce the stock of smaller sizes with the danger of removing all those fishes of below breeding size.

4.4.4.2. Rainfall and temperature

The fluctuations in rainfall, water withdrawal for irrigation, deforestation and farming activities around the study area; and the decreasing lake water level, all have their own effect on the ecosystem of the lake. Similarly, on average the current higher air temperature, drought and reduced inflow of water had a negative impact on the ecology of the lake. Amare Mazengia (2008) has reported that the annual mean temperature around Ziway has increased over time. The variations in temperature might be as a result of climate change around the area.

In the present study, as discussed in Chapter 2 and 3, there have been instances when an increase in the total fish catch was recorded during the rains. Thus, rainfall and associated factors may act as cues for spawning by the fish so that offspring were produced at a time of better growth and survival. The role of rainfall in fish spawning is well documented (Fryer and Iles, 1972; Lowe-McConnell, 1982). The relation between rainfall and breeding activity has also been reported by Elias Dadebo (1988); Zenebe Tadesse (1988; 1997); Demeke Admassu (1994; 1996); Yirgaw Teferi (1997), Lemma Abera (2011; 2012); Lemma Abera *et al*. (2014a) in Ethiopia, and elsewhere (Fryer and Iles, 1972; Lowe-McConnell, 1982; Stewart,1988). Also the study from Queensland Australia (Meynecke *et al*., 2006) the overall catch of fishes increased during the rainy season. The significant positive relationship between annual catch and total rainfall has been also reported by Vance *et al*. (1985), Gammelsrod (1992), Chen *et al*. (1994), Galindo-Bect *et al*. (2000) and Staunton-Smith *et al*. (2004).

According to Whitfield and Harrison (2003) and Whitfield (2005), temperature has a major impact upon the richness and composition of fish in Africa. Similarly, in tropical coral reefs, the changes in fish community due to climate change effects have been reported (Parker and Dixon, 1998). Balston (2009) has shown that the long-term climate cycle may affect the life cycle stages of fishes by influencing climate variables such as rainfall, stream flow and temperature and hence nutrient availability and nursery habitat suitability in Australian waters. Spalding and Jarvis (2002) also reported that increase in temperature would have a measurable influence on the taxa of the tropical and subtropical environment.

4.4.4.3. Lake water level

Irrigated agriculture is a common practice around Lake Ziway, by pumping water from the lake and by diverting the rivers that flow into the lake (Fig. 4.6). Previously water abstraction from Lake Ziway was mainly by state farms, cooperatives and/or individuals (Tenalem Ayenew and Dagnachew Legesse, 2007). The irregular rainfall variability in the lake region and the increasing population with increasing demand for water use undoubtedly increase the pressure on the lake. Recently there are different agricultural activities near the lakeshore, which solely depend on irrigation by lake water abstraction with higher efficiencies than before. The blooming floriculture in Ethiopia mainly in the study area was also a major concern. The previous irrigated state farm near the shore of Lake Ziway was currently running a large scale horticulture and floriculture greenhouse complex (current data showed that more than 100 greenhouses with an area of 400-500 ha) by a private firm that may abstract mor water from the lake.

The water budget of Lake Ziway was regulated by superficial inflows and outflow, evaporation and precipitation mainly from the distant uplands as the precipitation and underground water flow in the lake area is inadequate to maintain the lake level (Alemu Dribssa, 2006). An earlier report indicates that Lake Ziway receives 0.42 and 0.44 km^3 of water via from Rivers Ketar and Meki, respectively, and losses through Bulbula River was about 0.21 km^3 and through evaporation of 0.2 km^3yr^{-1} in 100 km^2 lake area (Wood and Talling, 1988). However, a more recent estimate indicated much reduced inflows from those rivers into Lake Ziway. According to Tenalem Ayenew (2004), the annual inflows from Meki and Ketar Rivers into Lake Ziway were 264.5 and 392 million m^3, respectively. It has also been indicated that the inflow into the lake had an annual deficit of 74 million cubic meters over the overall water loss from the lake (Tenalem Ayenew, 2004).

An increasing water demand and uncontrolled water abstractions from the inflowing rivers as well as the lake for irrigation, outflow through River Bulbula, domestic use (drinking water supply to Ziway Town, watering cattle) and loss through evaporation from the lake and evapo-transpiration from the extensive vegetation which cover a greater portion of the littoral part are the major cause for the reduction. During the study period, on average, the highest precipitation was recorded in July, which lasted only for short period. Shore level fluctuations, receding in hundreds and even more meters in the fish landing sites were observed which had not recovered even after the main rainy season (Fig. 4.5).

The lake was also highly dominated by emergent macrophytes, which could be due to their high tolerance for water-level fluctuation (Van Der Valk and Davis, 1976). According to Jansen *et al*. (2007), the average water level of the lake had decreased by 0.5m since 2002 (Fig.4.5). One time depth measurement using echo-sounder at many points in this study indicated that the water level reduction is getting worse than the earlier reports. The maximum depth measured was 5.8 meter during this study time. The width of the lake is also shrinking (Fig. 4.5). A century ago, Blundell (1906) reported that the width of the lake was about 50 miles (80.46 Km) and it had receded to 20 km by 1992 (Hughes and Hughes, 1992) and currently we could not get this width due to like high irrigation activites. The good example that shows the effect of different pressure in the lake is Lake Haramaya, which dried up by the year 2000. Today it has completely disappeared with grasses gradually covering the sediments (Brook Lemma, 2011).

It was also reported that there is high lake evaporation, which was estimated at 890 million m^3 annually, contributing to imbalance between water inflow and outflow (Tenalem Ayenew and Dagnachew Legesse, 2007). There was also high seasonal variation in water level, which can be attributed to seasonal rainfall and temperature (Fig. 4.8). According to Alemu Dribssa (2006), lake level declines from November to June and then rises from July to October. The current trend is also the same in which it declines from November to June and then rises from July to October (Fig. 4.7).

Relationship between yield and lake water level: The current reduced water levels of Lake Ziway may degrade formerly productive nursing habitats of fishes and other aquatic life and reduce the resilience of ecosystems in terms of production and conservation of biodiversity. Due to relatively shortage of rainfall and increased withdrawal of water for irrigated agriculture from the Meki and Ketar Rivers and Lake Ziway over the past few years, the water level of the lake was critically lowered (Fig.4.8), this may impacting the fish reproduction as most of the breeding and nursery grounds were lost. In addition, there was an increase in population pressure continuously in the area which could greatly influence the lake. This impact can be in the form of land improvements that affect the balance between evapo-transpiration, surface runoff and groundwater recharge; and abstraction of water resulting in reduction of outflow and storage components of water balance. This also exerts impact on the fish production of the lake.

In general, the catch proportion of the fishes in the lake has declined as compared to the previous catch (LFDP, 1998; Felegeselam Yohannes, 2003; Mathewos Hailu, 2013). This was due to the great increase in the extent of irrigation schemes around the lake in recent years and water is being removed directly from the lakes and/or diverted from rivers that feed the lakes, organic matter accumulation from litters and siltation could further aggravate the condition (Lemma Abera *et. al*., 2014b). This condition may be a threat to the lake's biota in general and the fishery in particular. Hence, this calls for serious intervention.

4.4.4.4. Water quality

The physico-chemical and biological features of the lake were documented by various papers (Table 4.6). Currently the mean ranges of conductivity and pH of the lake during the study period were 361.5 - 484.5 μS/cm and 8 - 8.4, respectively (Table 4.6); these values were in the order of magnitude of the values recorded about decades ago in Talling & Talling (1965) and Girma Tilahun (1988). Zinabu Gebremariam *et al*. (2002) also reported that the conductivity of Lake Ziway shows little variation over a long time compared to other nearby Rift Valley Lakes. However, to some extent an increase in the conductivity (Table 4.6) in the present study may be explained by the concentration of ions accumulated from the river inflows and surface runoff from the agricultural areas around the lake. The higher the conductivity level, the lower the dissolved oxygen concentration that might affect the physiology of fish in the lake that contributes for the decreasing of fish production.

As described in Table 4.6, some of the physico-chemical trends of the lake water were changed. Some of them may affect the aquatic organisms, such as fish kills occurring at the outlets of the flower farm effluents (personal observation). Also evidence from other lakes in Ethiopia show that the longer term impact of human induced changes like deforestation increases the risk of flooding such as Hawassa Lake or even complete degradation of the lake like in the case of Haramaya (Brook Lemma, 2011).

According to Zinabu Gebremariam (1998), population pressures and urbanization significantly affect cities near lakes and the lakes themselves were among the greatest potential causes of change in water quality and quantity (e.g. L. Ziway). Therefore, the current population pressure around the lake, cause pollution and water scarcity, and in turn impairing fish population and future development of the resources.

Low phytoplankton biomass was found during the present study as compared with previous results. For example, high phytoplankon biomass of 150 - 212 mg Chl a - m^{-3} was reported by Girma Tilahun (1988) (Table 4.6). Zinabu Gebremariam *et al*. (2002) reported a mean value of 82.4 with ranges of 23-224 µg/L of Chl-*a* for Lake Ziway, again much higher than the values recorded in this study. This could be due to intensive human pressure on the lakeshore, the trophic status of Lake Ziway was thus bound to show change with time.

Relationship between catch and water quality: Different factors have been forwarded that could change the trophic state of a lake (e.g. nutrient, waste disposal, morphometric features, other biota, turbidity etc). One of the factors that affect phytoplankton biomass is turbidity. The major source of turbidity in the open water zone of most lakes is typically phytoplankton, but closer to shore; particulates such as clay and silt from shoreline erosion, re-suspended bottom sediments, and organic detritus from stream and/or wastewater discharges can contribute (Hecky *et al*., 1981). Bottom-dwelling fish may increase lake turbidity through bio-turbation and bottom-stirring activities (Brooks and Dodson, 1965 and references therein).

Variables such as phytoplankton biomass and production often are better predictors of fishery yield than physical, chemical and hydrological variables (Melack, 1976; Liang *et al*., 1981;

Hanson and Legget, 1982; Oglesby, 1982; Carline, 1986; Downing *et al*., 1990; Moreau and De Silva, 1991). Thus, the relation between chlorophyll-*a* and fishery yield identified in the study area is not a new finding; however, it is the first indication that the prevailing low phytoplankton biomass in the lake may be an important factor limiting fishery yields. Factors other than phytoplankton biomass and effort, such as fish assemblage characteristics (community composition, complexity of food webs, and efficiency of energy transference among trophic levels) may also have bearing on fishery yield (Fernando and Holcik, 1982).

CHAPTER 5: ASSESSMENT OF THE FISHERY ACTIVITIES AND ALTERNATIVE LIVELIHOODS OF FISHERMEN AROUND LAKE ZIWAY

5.1. Introduction

Mixed type of agricultural system is practiced in Ethiopian Central Rift Valley (Mekonnen Hailemariam and Lemma Abera, 2011). Livestock contributes to the households' economy in different ways in the area as a source of draft power, source of income, source of supplementary food, and means of transport. In addition, livestock is one means of security and coping mechanism during crop failures and other calamities (EARO, 2004). The types of crops produced are field crops, pulses, and horticultural crops. Among field crops maize, tef, and wheat are principal in terms of both area and yield, while haricot bean is a dominant crop among the pulses (personal observation). Onion, tomato, pepper and cabbage are important among horticultural crops; and papaya is the main vegetables (Bedru Beshir, 2004).

As described in Chapter 1, the area has also fishery resource from Lake Ziway and the lake fisheries have benefited from Phase I (1981-84) and Phase II (1991-98) fishery development projects assisted by the European Development Fund (EDF). Due to lack of appropriate management of the fishery of the lake, fish catch per unit effort and the average size of the fish caught have continued to show a declining trend, implying the fish stocks are getting depleted (LFDP, 1996; Felegeselam Yohannes, 2003; Chapter 4 of this study). The consequence may have direct impact on the livelihood of the fishermen of Lake Ziway.

Although there are considerable numbers of studies that have been done on fisheries in Lake Ziway, it seems the majority of them tend to focus on the biological aspects of the resource as described in Chapters 2 and 3, while others relate to management of fishery resources as described in Chapter 4. Based on these facts, very recently Megersa Endebu *et al*. (2013) updated some information on fisheries baseline of Lake Ziway that has been conducted some 20 years back in 1993 during Lake Fisheries Development Program (LFDP, 1993). In addition, a few studies have been carried out on the determinants of gross margin income generated through fishing activity to rural households (Dawit Garoma, *et al*., 2013a), the impact of fishery cooperatives on fishing activity of rural households (Dawit Garoma, *et al*., 2013b), fishermen's willingness to pay for fisheries management (Assefa Mitike and Lemma Zemedu, 2015) and the role of fishery in livelihood security of fishing communities (Mberengwa and Zelalem Bacha, 2011).

Hence, there is lack of studies that are specifically linked to fisheries activities and the alternative livelihoods sources of the fishermen of the lake. Therefore, this study was initiated with the purpose of investigating the alternative livelihood sources of the fishing community; the effect of fishery in the household livelihood, household distribution and participation towards livelihood activities; the major constraints on the fisheries and marketing system.

5.2. Materials and Methods

5.2.1. Selection of landing site and fishery cooperatives

Landing sites were selected on the shores that are used by fishermen to land their catches. However, there were several small landing sites through which a few fishermen bring out their catches. Totally 15 major landing sites were purposively selected during the survey with equal proportion from each district (Table 5.1).

Table 5.1. The selected landing sites with location for each district

Districts								
A. T. J. Kombolcha			**Dugda**			**Z. Dugda**		
	Location			Location			Location	
Kontola	07058.8N	038043.3'E	Ido Kalo	08004.1N	038044.7E	Burkitu	08021.3N	038093.1E
Korokonch	07055.5N	038042.7E	Koli	08004.8N	038045.5E	C. Minchi	08054.1N	039001.4E
Menafesha	07056.2N	038042.9E	M. Dalana	08005.8N	038046.3E	D. Chifa	08052.2N	039074.1E
Shallo	07058.2N	038043.5E	M. Kofe	08007.9N	038048.5E	Tsedacha	08055.4N	038093.4E
Woranto	07056.6N	038042.8E	M. Takiti	08007.8N	038049.2E	T. Guddo	08057.3N	03903.7E

5.2.2. Sample size determination

Arsham's (2005) mathematical formula, as indicated below, was used for sample size determination.

$$N = 0.25/SE^2;$$

Where N = Sample size

SE = Standard error; which was calculated by using confidence interval of 10 % and confidence level of 95%,

SE = 0.1/1.95 = 0.05, where 1.95 is constant

Accordingly, 100 fishermen households from fishery cooperative of each district were randomly selected based on the lists of fishermen obtained from the executive committee member of the cooperative of the three districts (Adami Tullu Jiddo Kombolcha (A. T. J.

Kombolcha), Dugda and Ziway Dugda (Z. Dugda)). Hence, a total of 300 fishermen were selected.

5.2.3. Questionnaire survey

Data were collected in the study area between July 2013 and June 2014 through semi-structured questionnaire interview (Appendix 1), visits to the landing sites and focus group discussion. In order to conduct the survey, a total of three enumerators (one for each district) who speak the local languages, Afan Oromo and Amharic, were recruited. The enumerators were also trained by the investigator before launching the survey to make them clear of the purpose of the survey and to familiarize them with the questionnaire. Then the questionnaire was pre-tested on a small number of respondents randomly selected from the study areas prior to its administration and the interviews were then conducted with a close supervision of the investigator.

The content of the questionnaire includes general questions related to household structure, age distribution, main livelihood sources of the fishermen, role of fishing, utilization patterns of fish products, household participation towards different livelihood activities, main constraints of the fishery and the marketing system (Appendix 1).

5.2.4. Focus group discussion and key informants

Focus group discussions were held in each study district after filling out the questionnaires by way of interview. Members of the focus group were purposively selected to make a total of four to six members for each district. The members included committee members of fishery cooperative, peasant association executive committee members, development agents, and the districts livestock development desk officers and individuals who were believed to be knowledgeable about the past history and the present status of the fishery of the lake.

The leading check list of issues to be discussed at the group discussions were prepared to guide the discussion with the focus group with special emphasis on policy issues, external support for the schemes, institutional and managerial issues, major problems and future plans to further the development of the fishery of Lake Ziway.

In addition, secondary data were collected from published and unpublished sources. Z. Dugda, Dugda and A. T. J .Kombolcha districts Agricultural Development Offices, Cooperative Promotion Offices, Livestock Development Agency Desks and Ziway Fishery Research Center were the important sources of data.

5.3. Results

5.3.1. Fishery cooperatives around Lake Ziway

Currently the majority of fishermen have been organized into fishermen cooperatives, in line with the policy of the Government. The Ministry of Agriculture has granted commercial fishing rights only to fishermen cooperatives, each of which has to pay in return for the privilege of exploiting the lake resource. During the study period, the members of the cooperatives were 517, and were organized in 14 cooperatives (Table 5.2), of which 100 from each district were randomly selected from all cooperative members of A. T. J. Kombolcha, Dugda and Z. Dugda in the selected cooperatives (Table 5.2).

Table 5.2. Fishermen cooperative members of in the selected cooperative in each district

Zone	District	Name of cooperative	Current No. of members
E. Shoa	A.T.J. Kombolcha	Ziway Batu	60
		Kontola	32
		Bochessa	31
		Abeyi Burkitu	18
		Abosa	26
		Sub Total	167
E. Shoa	Dugda	Melka Koffe	28
		Abono Gabriel	12
		Melka Fesasa	63
		Warabo	15
		Gotu Derara	10
		Sub Total	128
Arsi	Z. Dugda	Dibayu Chaffa	33
		Tsedecha	69
		Katar	32
		Tullu Guddo	88
		Sub Total	222
		Grand Total	517

5.3.2. Household structure

For the purpose of this study, the term household members, comprised all those who, at the time of survey, were physically residing in the same house with one person serving as the household head. Hence, Table 5.3 gives details on family size, age distribution and male to female ratio in the study areas. Average family size per household in A. T. J. Kombolcha, Dugda and Z. Dugda was 5.4, 4.9 and 3.3 persons, respectively. The average family size of

Z. Dugda was relatively lower than A. T. J. Kombolcha and Dugda by two persons (Table 5.3).

Table 5.3. Household size and age distribution in the study area

Districts									
	A.T.J.Kombolcha			**Dugda**			**Z. Dugda**		
Household characteristics									
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Household size	3	14	5.4	2	13	4.9	2	10	3.3
Male	1	9	3.1	1	7	2.7	1	6	1.8
Female	1	6	2.4	1	6	2.2	1	4	1.5
Household age distribution (%)									
Age < 12 years	21			17			14		
Age 12 -17	28			30			32		
Age 18 - 60	45			46			42		
Age > 60	6			7			12		

In general, males were in higher proportions as compared to females in all the study areas (Table 5.3). The research population of 42 % to 46 % of them were aged between 18 to 60 years, representing the highest proportion of the fishermen households. Almost 30 % of the households were aged between 12-17 years, while the rest are less likely to provide productive labor (less than 12 years of age and more than 60 years of age) and ranged from 6 to 21 % in all the study areas (Table 5.3).

5.3.3. Main livelihood sources of the fishing community

Almost in all the study areas, the livelihood of fishermen and their dependents relied mainly on incomes generated through fishing activities (Table 5.4). Hence, the households used fish as a source of food at home, for generating money and in turn with which they buy other food items. However, there are only a few communities whose livelihoods were not primarily based on fishery activities in A. T. J. Kombolcha District (Table 5.4).

Table 5.4. Ranking of livelihood sources based on their function in the study areas in percentage (Rank 1: highest priority; and Rank 4: least priority)

	Priority in the district											
Livelihood sources	**A.T.J Kombolcha**				**Dugda**				**Ziway Dugda**			
	1	2	3	4	1	2	3	4	1	2	3	4
Fishery	98	2	0	0	100	0	0	0	100	0	0	0
Livestock	0	19	35	46	0	25	58	37	0	36	40	29
Field crops	0	20	55	25	0	40	17	19	0	42	33	28
Horticulture	2	59	10	29	0	35	25	44	0	22	27	43

Households who practice production of horticulture through irrigation mainly produce onion, tomato and cabbage for retail purposes. Horticulture activity was mostly practiced in A. T. J. Kombolcha next to fishery. Whereas, in Dugda and Z. Dugda, most of the respondents cultivate field crops and livestock rearing as second and third means of livelihood next to fishery (Table 5.4).

In the area, livestock were reared for the use of draught animal power to cultivate the land for crop production and generate income through live animal sale, especially as a guarantee in case of risk when fish catch declined. Respondents also indicated that livestock, epecially cattle, were used as source of manure for fertilizing the homestead farmland and compaction of seedbeds for horticulture. Hide of the animal was used either as source of cash income or used as household furniture.

5.3.4. Role of fishing

The role of fishing was high in the study area as compared to other agricultural commodities (Table 5.4). Hence, fisheries provide resources for home consumption as well as additional income generation. In this study it was found out that both sale and consumption of fish had the higher value that accounts for 74, 70 and 55 % at A. T. J. Kombolcha, Dugda and Z. Dugda districts, respectively (Fig. 5.1). Fish product selling accounts to 26, 30 and 45% for A. T. J. Kombolcha, Dugda and Z. Dugda districts, respectively, for the purpose of buying other food items for home consumption and other purposes. The product was not common for consumption only except in A. T. J. Kombolcha district that accounts (2%) (Fig.5.1).

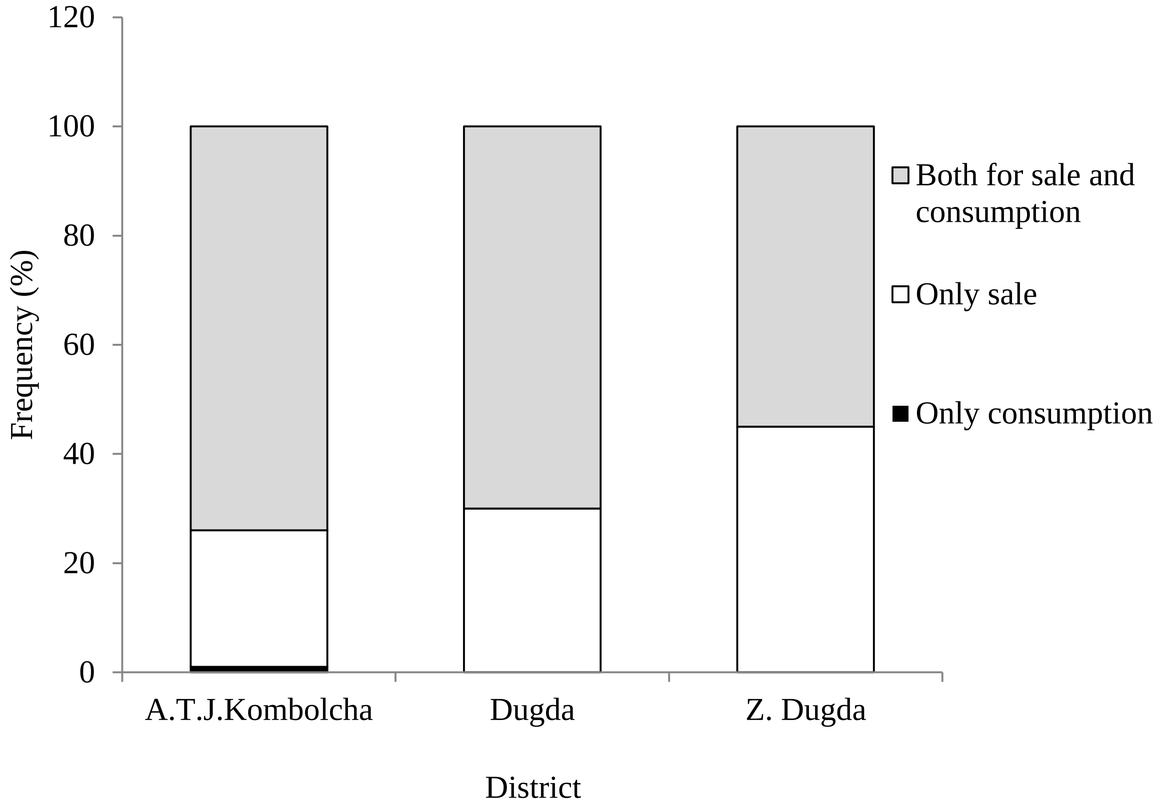

Fig. 5.1. The role of fishing in the study area.

5.3.5. Preference trends of fish products

Figure 5.2 shows the preparation of various forms of dishes of fish for household consumption in fishermen families. They partly consume fish as soup, half-done or locally known as "*Lebleb*", raw consumption of fillets, roasting after gutting, fillet cutlets, smoked fish and filleted dried fish, locally known as "*qwanta*" (Fig. 5.2). Among these dishes consumption of half-done and raw fillets were the most preferred ones followed by fish soup.

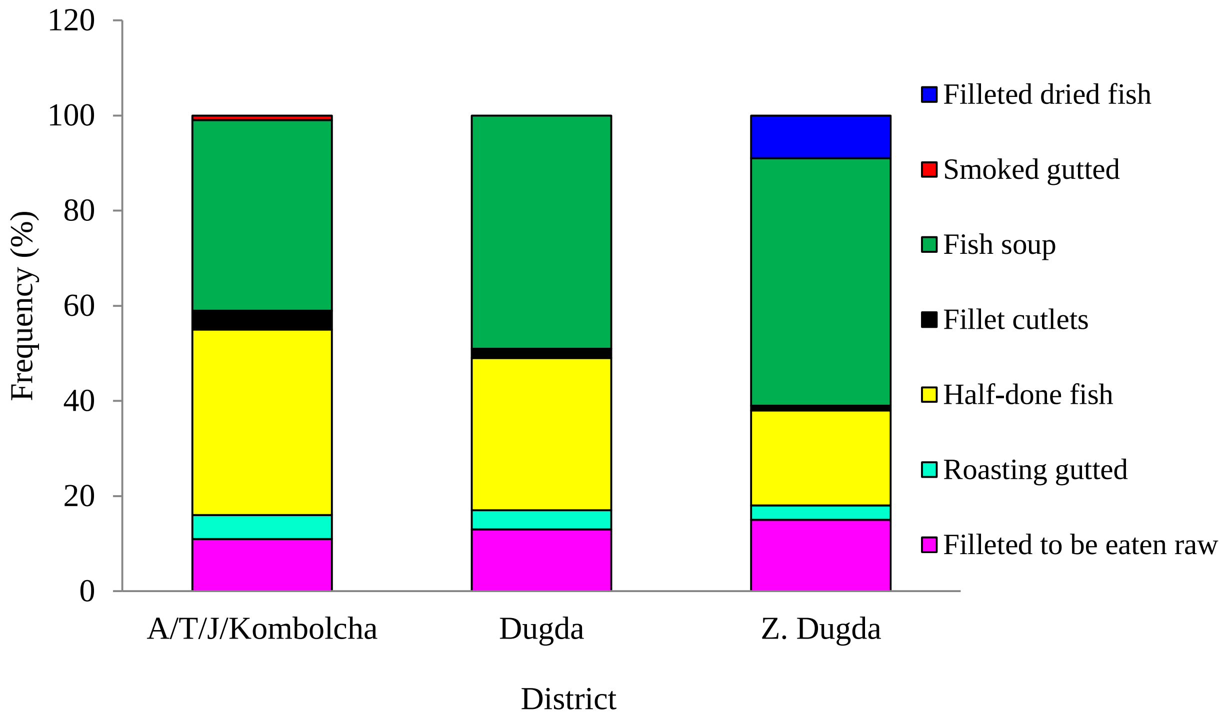

Fig.5.2. Preference trends of fish dishes from commercial fish species in the fishing community.

The respondents in the study area expressed their belief that fish soup was nutritious compared to other fish dishes. Smoked fish and filleted dried fish were described as the least preferred items by most of the households in the districts (Fig. 5.2). The households also stressed that consumption of any of the fish dishes generally depends on the availability of fish and the economic status of the family.

5.3.6. Household participation towards different livelihood

The summary of the occupational participation of the household in the study area were described in Figure 5.3. In the area, men were the ones doing most of the fishery activities due to the labor intensive nature of the work (Fig. 5.3). Field crops and horticultural production were done by boys and it accounts for 45% and 40 %, respectively. There was no participation of girls in fishery activities in the area and only 0.4 % of women participate in fishery in A. T. J. Kombolcha. Women and girls were highly responsible in livestock rearing activities and accounted to 40 % and 30 %, respectivelly.

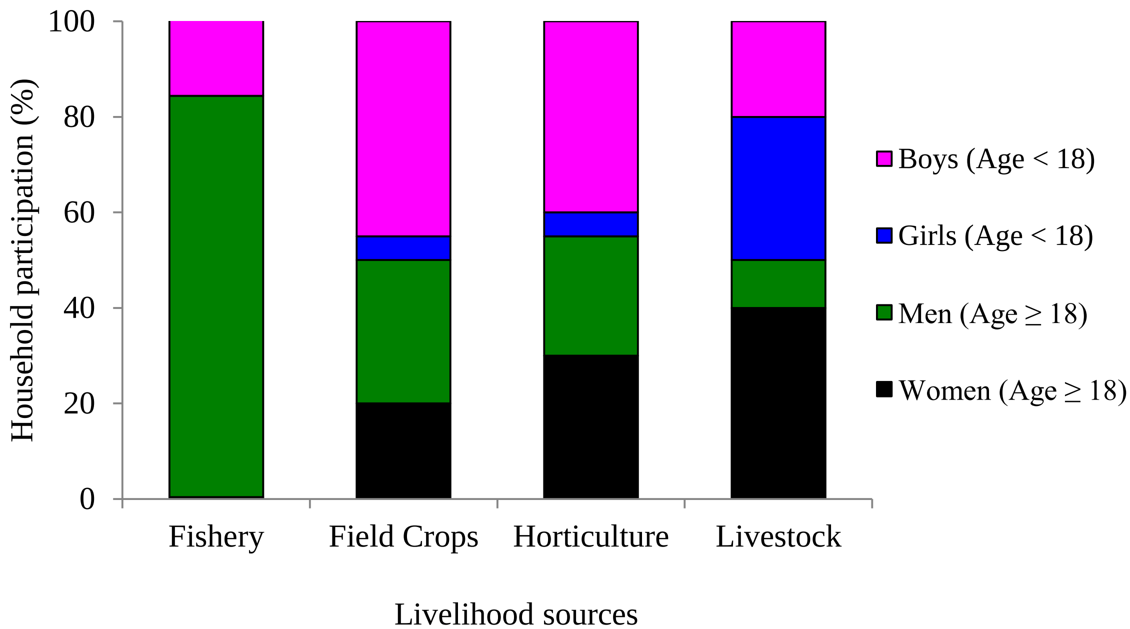

Fig.5.3. Participation of household members in various livelihood sources.

5.3.6.1. Household participation towards the fishery activities

In the study area boys followed by men were the ones doing most of the fishing and fish processing activities like gutting, filliting (Fig. 5.4). More than 78 % of the fishing activities in each district were done by men. Boys in A. T. J. Kombolcha share the highest proportion of the fishery activities and that seems to decline in Z. Dugda. The participation of women towards fishery activities is only in small amount in A. T. J. Kombolcha and no girls participated in the sector in the study area in general (Fig. 5.4). Regarding fish processing, the participation levels of boys was high in A. T. J. Kombolcha and Dugda than Z. Dugda district; in the contrary, men had a leading role in Z. Dugda (Fig. 5.4).

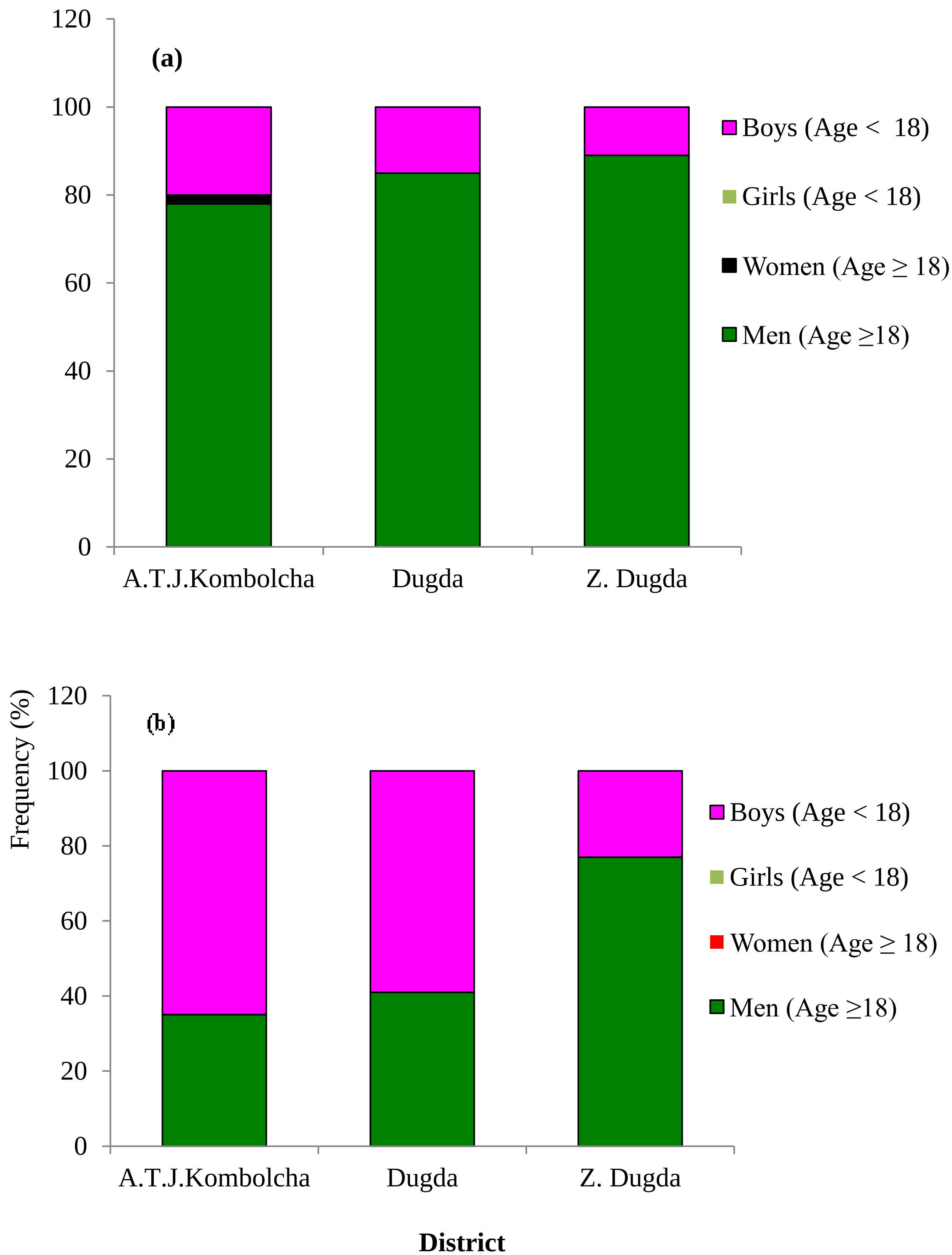

Fig.5.4. Participation of household members in **(a)** fishing and **(b)** fish processing.

5.3.7. Marketing system

5.3.7.1. Marketing of fish

Prices of whole fresh and filleted fishes of *O. niloticus*, *C. gariepinus*, *C. carpio* and *C. carassius* in the three districts of the study areas are presented inTable 5.5. There were variations in price between districts due to species difference, fish size and distance to access to market (Table 5.5). The price of fish is relatively higher in A. T. J. Kombolcha and Dugda where the landing sites are closer to the market at Ziway and Meki; and lower in the remote landing sites (Z. Dugda) (Table 5.5). *Oreochromis niloticus* obtained higher price than other fish species because of the higher demand from the customers. Again the price varies between seasons; the fish price was high during the Orthodox Christian Lent seasons and reduced in the non-fasting seasons. The price of both whole fish and filleted were relatively high in A. T. J. Kombolcha and Dugda district landing sites than Z. Dugda in all fish species as described in Table 5.5.

Quality of the product was also an important factor determining the price. Even though there was lack of processing technology at landing sites, fishermen indicated that cleaning the processing area at landing helped them to obtain the quality of products preferred by buyers. The price range for whole fish also varies according to their size of the fishes.

In general, currently the prices of fishes have increased in the study area due to less catch the fishes. All interviewees and the observations made have clearly indicated that there is an extreme shortage of supplies of fishery products in the market.

Table 5.5. Variation in price of whole and filleted fish at the landing sites of the three districts (July 2013 - June 2014) around Lake Ziway

Variables	Districts		
	A. T. J. Kombolcha	**Dugda**	**Z. Dugda**
Oreochromis niloticus			
Whole fish price (Birr/fish)	4 - 12	3 - 12	3 -10
Filleted (Birr/kg.)	30 - 70	28 - 70	26 - 65
Clarias gariepinus			
Whole fish price (Birr/fish)	5 - 24	4 - 22	3 - 20
Filleted (Birr/kg.)	15 - 40	13 - 35	10 -30
Cyprinus carpio			
Whole fish price (Birr/fish)	6 - 35	5 - 30	4 -28
Filleted (Birr/kg.)	26 - 48	26 - 45	24 - 42
Carassius carassius			
Whole fish price (Birr/fish)	3 -10	3 - 8	2 - 7
Filleted (Birr/kg.)	15 -28	15 - 26	15 -24

5.3.7.2. Market chain of fishes

A generic schematic fish market chain at the study site is presented in Fig. 5.5. Based on information gathered in the course of the field study there were no variation with the report of Brook Lemma (2012). The key actors along the chains include cooperative and private fishermen at landing and their assistants (Fig.5.5).

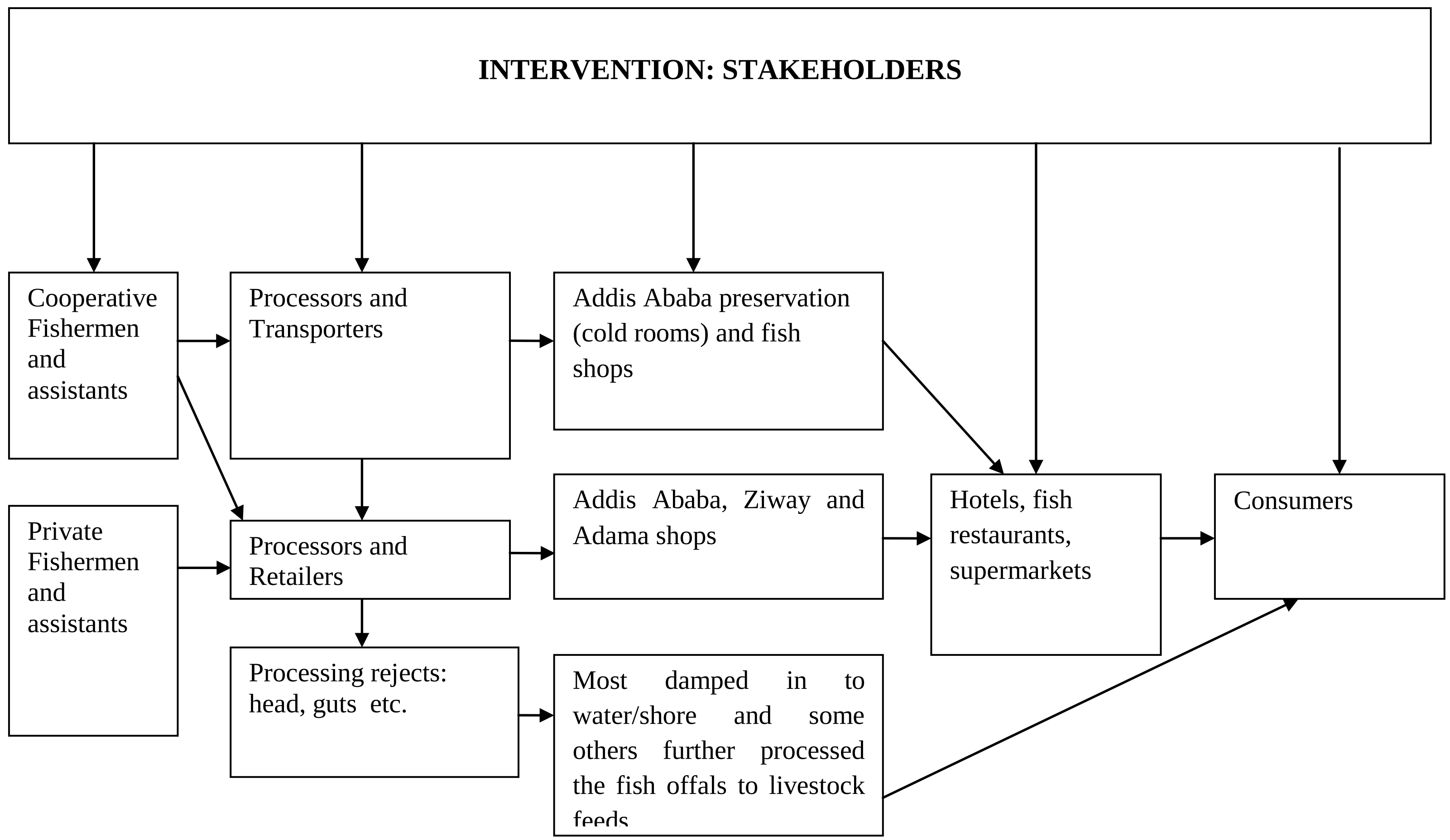

Fig. 5.5. Value Chains of the fishery products of Lake Ziway (adapted from Brook Lemma, 2012).

In the study area fish consumption and marketing starts at landing sites. The result of this study showed three basic routes of fish delivery to consumers (Fig. 5.5). The primary route is towards Addis Ababa preservation and fish shop. This is the major route of delivery *O. niloticus* is sold as fillet and gutted whole fish, while *C. gariepinus*, *C. carpio* and *C. carassius* as fillets only. In this route fishes are transported first to a temporary store present in Ziway and Meki towns and then distributed to hotels and supermarkets in Addis Ababa (Fig. 5.5). According to the information obtained from the fishermen and retailers there is high market demand for fillets of fish epecially *O. niloticus*, and the price also at landing site is higher for this fish being 26 to 70 Birr/kg and the remaining commercially important fish species also receive considerable demand (Table 5.5). Offals are damped in to shore and some others further processed to livestock feed.

The second route involves delivery of fish to markets in Addis Ababa, Ziway and Adama shops by processors and retailers (Fig. 5.5). In the area demand of fish is high towards fasting days (Wednesdays and Fridays as fasting days of the week) and fasting periods (55 days in March/April, 15 days in August).

5.3.8. Major constraints of the fishery sector

Open access to the resource and pollution were the most common problems on the landing sites of the two districts (A. T. J. Kombolcha and Dugda) (Fig. 5.6). Marketing constraints were faced by the fishermen mainly in Z. Dugda (42 %). Lack of regulations for the fishery was almost common understanding in all districts (Fig. 5.6). In the area, the market issues depend on physical access to landing points, numbers of retailers in the area and the amount of catch (personal observation). Low prices was paying to fishes, particularly due to the high cost of transportation and loss of quality because of limited options for conservation and time/distance to trading point's, were also major contributors for marketing problems.

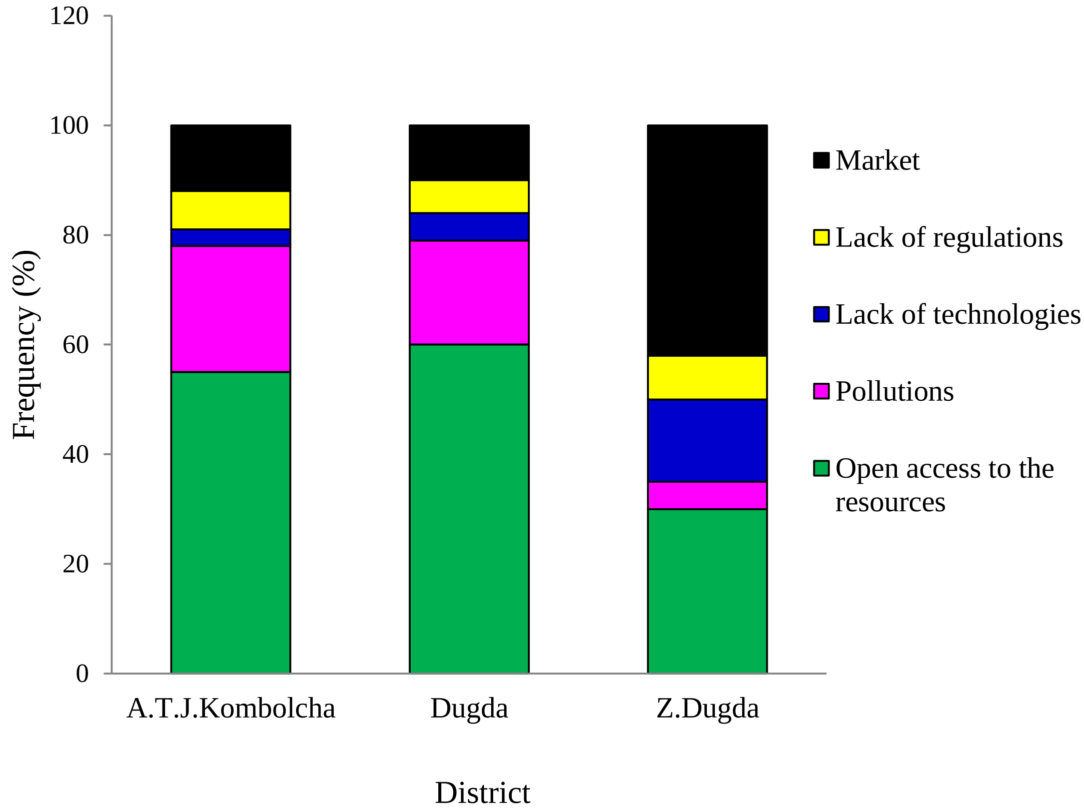

Fig.5.6. Major constraints of Lake Ziway fishery according to responses of fishermen.

Pollution of the lake is taking place due to improper farming methods and poor tillage systems, which contribute towards the erosion of top soils of the steep cultivated land around the catchment of eastern part of the lake. Urbanization and human settlement are amongst the most serious problems around the lake; associated industrial development was also problematic in Lake Ziway that intensifies pollution, especially in A. T. J. Kombolcha and Dugda districts (Fig.5.6), as also discussed in Chapters 2 and 4. Farming along the lakeshore not only disturbs lake shore ecology but also exacerbates siltation and increases turbidity as discussed in Chapters 2 and 4.

In Ziway Dugda, lack of technology was common as compared to other districts (Fig.5.6). In general, fishes from the lake were caught and transported by reed boats. These boats are old, inefficient (personal observation). Motors for boats are not easily available and it is one of the major technological problems. Floats and lead rope used with nets were also difficult to obtain for appropriate fishing practices.

In all the study areas, there was also critical shortage of cooling and processing facilities. There was no ice making plant in the area and because of this, fishes are easily spoiled at all stages of the process. This problem was more pronounced in Z. Dugda, due to the landing being far from some infrastructures as compared to the remaining districts (Fig. 5.6).

Based on the responses of key informants lack of institutional arrangement, like poor linkage and coordination between the large departments and the apparent absence of an effective line of communication with the field level, are among the serious problems to be faced by the sector in general.

5.4. Discussion

5.4.1. Major landing sites and fishery cooperatives around Lake Ziway

Lake Ziway has landing sites that are already scattered along the whole length of the shoreline, making the implementation of area closure difficult (LFDP, 1996). Totally, 43 landing sites were found in the three districts surrounding the lake (Megersa Endebu *et al.*, 2013). However, for this survey only 15 landing sites were purposefully selected (Table 5.1). Practically around the lake A. T. J. Kombolcha District has more landing sites than the other two (Dugda and Z. Dugda), because of its accessibility to market along the main road at Ziway and also other related infrastructures that assisted fishermen get quality fishes. There were some fishermen who were irregularly changing their landing sites as there is no restriction on fishermen movements

During the study period the members of the fishermen in the cooperative were a total of 167, 128 and 222 for A. T. J. Kombolcha, Dugda and Z. Dugda, respectively. Currently, the number of members has increased as compared to the previous studies (LFDP, 1996; Ignatius Mberengwa and Zelalem Bacha, 2011; Megersa Endebu *et al*., 2013) due to the initiative taken by the government through organization of micro-enterprises and promoting fishing as job creation. Members of the cooperatives were complaining about the importance of being a member because there is no advantage from it. This was due to the depletion of the fish stock in the lake and such micro-enterprise organizations have not considered the maximum sustainable yield of the lake rather they focused on job creation.

In Lake Ziway, there were also illegal fishermen (LFDP, 1993; 1996; Ignatius Mberengwa and Zelalem Bacha, 2011). According to Megersa Endebu *et al*. (2013), more than 50 % of the fishermen are not members of the cooperatives and are non-licensed fishermen, in which the number has increased from previous reports (LFDP, 1993).

5.4.2. Household structure

Average family size per household in A. T. J. Kombolcha, Dugda and Z. Dugda were 5.4, 4.9, and 3.3 persons, respectively (Table 5.3). Hence, the average family size of A.T. J. Kombolcha and Dugda were almost comparable to Z.Dugda (Table 5.3). The family size of the first two districts was comparable to the current national household size of the rural area of the countrty (5.0 persons) (CSA, 2014). On the other hand, the family size in this study was lower than that of Lemma Fixa (2004) who reported the average family size of 6.67 and

6.43 in Eastern Wolega of Ethiopia at Doni Kumbi and Bato Degaga District. Lemma Abera (2008) also reported average household size in East Shoa Zone of the three districts to be 6.14, 6.3 and 6.65 persons for Ada, Gimbichu and Boset, respectively, that shows higher than this finding.

In general, males were representing higher proportions in all the study areas (Table 5.3). This was found to be in agreement with the findings of Dawit Garoma *et al*. (2013c) in the same district; and contradicted with the general rural area of the country (CSA, 2014). The difference in sex ratio among the fishing communities and other agricultural systems is difficult to explain and needs further study to see if the same factors could be responsible for sex ratio results.

5.4.3. Main livelihood sources of the fishing community

Fish is the main food source for people or minor ethnic group living on the islands and surrounding of the lake; and in almost all the study areas, the livelihood of fishermen and their dependents mainly comes from fishing activities (Table 5.4). According to Sewmehone Demissie (2003), in Lake Tana, fish is the only food source for the group of people who have long tradition in eating fish and hippopotamus meat because of lack of access to farmland and then they cannot afford to use other types of food source. Animal protein is the most deficient or undersupplied nutrient in most rural communities diets of the country in general (Mekonnen Hailemariam and Lemma Abera, 2011), fish is the only and an important source of animal protein especially for the poor who cannot afford buying other animal protein sources, like in the study area. According to key informants and focus group discussions, the shortage of farmland and availability of fish in Lake Ziway are some of the major reasons contributing to the predominance of fishing in the study area. However, fishing is the major occupation of both the landless and those who engaged in farming activities as well, currently the productivity of the fishery is declining as indicated by catch stastics in Chapter 4, and therefore fishery alone cannot support the households.

5.4.4. Role of fishing

Like other agricultural products, fishing has both direct and indirect contributions to household livelihoods. Fishing is an important source of subsistence and income. Thus, it significantly contributes to the livelihood security for a large number of households in Africa (Bene, 2006). The direct contribution was that fish can be consumed at the household level; and the indirect contribution in the study area is that fishermen sell the product and in turn buy other food items for home consumption and other purposes.

In Lake Ziway area the percentage of fish consumed by a family from the total catch varies greatly. It is generally observed that the poor consume a lower proportion of their catch around Lake Ziway.Instead the fishing families' sell most of their fish catch to purchase cheaper food stuffs. The research in Lake Chad area (Bene *et al*, 2003), has shown the same result that the poorest households consume a lower proportion of their catch than better-off households. Hence, it can be concluded that fish constitutes some percent of the diet of the majority of the sample respondents and the revenue generated from the fish sale contributes to supplement the expenses of other types of food items and family needs.

5.4.5. Preference trends of fish products

The Ethiopian domestic fish consumption pattern around water bodies was not different from the global trend in which people with frequent contact with water bodies to consume fish.

Since, these people understand the value of fish as food (Brook Lemma, 2012). However, in this study area the consumption patterns differ with the product type of the fish, and all products of fish were not consumed by the majority of the households on daily basis (Fig.5.2).

Fish utilization in this country is very poor. This is very closely tied with old traditions and religious beliefs. Although the yearly fish production shown in Chapters 1 and 4 seems much, the consumption patern of person^{-1} year^{-1} (Federal Ministry of Agriculture) is extremely low as compared to the case in the Far East to WHO recommendation of 40 g capita^{-1} day^{-1}. It reaching 16.4 kg person^{-1} year^{-1} in 2005 or it can vary from less than 1 kg person^{-1} year^{-1} in some countries (e.g. Ethiopia, Brook Lemma, 2012) to more than 100 kg person^{-1} year^{-1} in some exceptional ones (FAO, 2009).

Ethiopians tend to rely on animal protein sources such as beef, mutton and chicken. With some Muslims, one can add to the list camels. They do not consume large quantities of fish, although there is no religious prohibition for the Christian and Moslem populations. Rather, this is a country with a strong tradition of livestock rearing and meat consumption. The Ethiopian Orthodox Church observes several fasting periods as well as fasting days every week, when meat is not consumed. Most Christians consider fish acceptable during those periods. At the household level the consumption pattern was defined as a combination of the types, quantities and frequencies of the product consumption (Mullins *et al*., 1994). These parameters are closely linked to household location and income classes in the fishing community members of the study area.

5.4.6. Household participation towards livelihood resources

The common livelihood sources of the fishing community were fishery and other agricultural activities (field crop and horticultural production with livestock rearing (Fig. 5.3). The results of this study indicate that women and girls were the ones doing most of the livestock activities, which accounts for 40 and 30 % for women and girls, respectivelly (Fig. 5.3).

The household participation towards livelihood resources studies conducted in the other districts like, Ada, Boset and Gimbichu indicated that women and girls take the highest proportion in livestock rearing. Livestock rearing by girls and women account to 60.2 % in Boset, 70.38% in Ada and 85.7 % in Gimbichu (Lemma Abera, 2008). Similarly, in southern Ethiopia, there is high involvement of women in livelihood diversification. Cash income from non-farm sources was important particularly for the poor households in order to offset low agricultural incomes (Assefa Mitike and Lemma Zemedu, 2015).

5.4.6.1. Household participation towards fishery activities

More than 78% of the fishing activities in all districts were done by men (Fig. 5.4). Among the three districts, in A.T.J. Kombolcha boys share the highest in the fishery activities next to men. The participation of women towards fishery activities is low in A.T.J. Kombolcha, and no girls participate in the remaining districts (Fig. 5.4). Brook Lemma (2012) also reported that the involvement of females in the fishery industry was very low following the poor development of the sector in Ethiopia.

From among those females, the majority of them were found in the processing section as observed in Bahir Dar Lake Tana Fishery (Brook Lemma, 2012). This is slightly different in Lake Ziway and Hawassa fishery, where males make fish processing such as filleting and packing. While the majority of females participated in the activity of livestock rearing, and they were involved in fishery related business like preparing food for the fishermen around the fish landing sites, cooking (roasting, making soup), selling bread, hot and soft drinks around the landing site. These services are not only for the fishermen but also for other consumers including tourists). In general, according to Brook Lemma (2012), the national trend in the involvement of females is very limited which does not exceed 10 %.

5.4.7. Marketing system

Regarding the existing fish marketing information system for fisheries/agriculture, the Ethiopian media, particularly, the national radio regularly announces market trends of various agricultural crops and coffee. People in the business and in many cases ordinary consumers also listen to this information, as most of these crops are part of the traditional foods daily consumed and habits of the public. In this respect, much attention is not given to the fishery business and in general terms fishery products do not make part of the traditional foods of Ethiopians. As a result, information on marketing system of the fish is not available in Ethiopia. Whatever people know about fish markets and prices is what they know through personal contacts using mobile phones. Because of this gap, there is no consistency in the value of fishery products in the study area in particular and the country in general.

The price of fish in the study area varies by fish species, type of product and market site (Table 5.5) like other agricultural commodities. Seasonal pattern of fish consumption affects fish marketing around Lake Ziway. Another aspect, which tends to impinge on the activity highlighted during focus group discussions, was the seasonality of the activity as dictated by demand. According to Gordon *et al*. (2007), consumption is heavily biased towards quite limited geographical areas (production areas and Addis Ababa) and also heavily weighted towards fasting days (Wednesdays and Fridays) and fasting periods (55 days in March/April, 15 days in August, as well as other periods which may be less widely observed). In addition, according to Reyntjens and Tesfaye Wudneh (1998), increasing scarcity (apparently reflecting both rising demand and supply constraints) has resulted in rising the prices for fish, so there is an increasing tendency for fish to be a luxury product consumed by higher income groups.

As discussed in previous chapters (2 and 4), tilapia is the dominant species caught and consumed in Ethiopia, although this does not hold true for all fishing areas in the country. According to Asche and Bjorndal (1999), fish consumption patterns reflect the local availability of fish type. Although fish consumption patterns vary from place to place in the study area, much of the landed fish is prepared into gutted and filleted forms at landing sites based on the market demand. According to FAO (2003), in Ethiopia most (about 73 percent) of the total fish landed is marketed fresh in nearby markets. The rest reaches distant consumers chilled or frozen (26 percent), or as dried, smoked and canned (1 percent) forms. Currently canning has ceased due to poor product quality and low demand.

The Ethiopian market has been growing steadily, and the volume of catch handled by FPME has declined, and the market share has fallen considerably to roughly 8 % of fish entering the marketing system nationally in 2007 (Gordon *et al*., 2007). Despite its superior facilities, the FPME has lost market share to smaller-scale more flexible operators, although unable to operate a cold chain and now the volume of catch handled by FPME is almost nil, due to the collapse of the enterprise. Hence, fish traded from Lake Ziway to Addis Ababa is a much more *ad hoc* trade, though cummulatively the volumes are quite significant (Brook Lemma, 2012).

5.4.8. Constraints

According to the survey and personal observations, fishing on Lake Ziway was predominantly artisanal and the fishermen use non-motorized traditional boats and gears that are mentioned in Chapter 4. The lake is also governed by open access to the resources. In addition, key informants revealed that some fishermen were using destructive fishing gears of small mesh sized beach seines. Personal observations also corroborated this. The small mesh size indiscriminately catches both the immature and mature fishes. This indiscriminate immature fish catch endangers the reproductive capacity of the stock that directly affects the resources of the lake as noted in the earlier chapters.

There was lack of regular fishery development plan at both federal and regional levels. These situations do not promote appropriate fishery practices and research activities. Another serious issue is the problem of pollutions that were directly related to different agricultural farms, especially flower farms, in which fishermen in A. T J. Kombolcha District complained about, due to the mass fish kill that occurred in 2011.

Lack of fishing gear technology is another constraint in which fishes from the water bodies are caught and transported by reed boats. These boats are old and inefficient. Floaters and lead rope used with nets are also difficult to obtain in the area as well as in the country in general.

There is critical shortage of landing, cooling and processing facilities that intensify the spoilage process. There are limited buyers at the area with limited capacity, which have impact on the price of fish and fishermen are forced to sell the product with cheap price before loss of the quality, because of limited options for preservation and improve the shelflife of fish products, especially in Z. Dugda District.

Access to adequate and sustainable infrastructure and facilities is one of the most essential factors affecting livelihood security of fishermen (Z. Dugda). In the study area, lack of electricity and inadequate transport system were identified by both key informants and focus group discussants as major challenges faced by fishermen. Except in some areas, which are near to Ziway and Meki towns, there is no electricity facility in many rural areas around the lake. Inadequate transportation is also particularly a serious challenge to the fishermen on the Island, who sometimes use their manual boats to market their product in Ziway and Meki towns. The majority of the fish caught were sold to traders usually at landing sites of the lake. Fish marketing is a critical stage as it tends to be greatly affected by preservation technology. Survey results revealed that the majority (92.9%) of the fish catch was sold whole fresh partly due to lack of fish preservation equipment. Focus group discussions indicated that the lack of refrigeration facilities has been a great obstacle as fishermen were forced to sell their catch at landing sites.

CHAPTER 6: GENERAL CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Lake Ziway has shown some undesirable changes in terms of some physico-chemical factors and shift in catch composition of fishe species. Soluble reactive phosphate and nitrate level of the lake increased in recent years but phytoplankton biomass (as chl-*a*) did not show corresponding increase. However, the nutrient level in the lake is still lower than that of most Ethiopian and similar African lakes. The Secchi depth reading and water level of the lake have shown declining trend.

The fish fauna of Lake Ziway is dominated by Cyprinids. Of the total 12 species recorded in the lake only 10 species were sampled with the three families. Seven species from Cyprinidae and the rest are included in the Families Clariidae and Cichlidae. Clariidae is represented by only one species (*C. gariepinus*) and Cichlidae by two species (*O. niloticus* and *T. zillii*). *C. auratus* and *L. microterolepis* were not encounterd during the study. *Oreochromis niloticus*, *C. carpio*, *C. carassius* and *C. gariepinus* were the most abundant in number, and commercially the most important fishes of the lake. Based on percentage composition, *O.niloticus* is relatively the most dominant fish in L. Ziway, which contributed to 27.88 % of the total catch. Among the Cyprinids, *C. carpio* and *C. carassius* contributed 25.19 % and 20.71 %, respectively, of the total fishes. *Clarias gariepinus* contributed 20.51 % of the samples from the lake. The remaining fishes were each less than 3% of the total number of fishes encountered.

Based on this study, the highest number of fishes were recorded around the mouth of the River Bulbula (Site 2) that contains 10 species, while in the northern part of the lake (S4 and

S5) contributed the least number of species. In addition, more number of fish specimens was caught in the wet season than the dry season. Abundance of fish species in the lake was also related to water quality of the lake. For instance, *C. gariepinus, C. carassius,* and *C. carpio* were r found in elatively nutrient-rich sites whereas *L. ethiopicus* and *L. intermedius* were found in the area where there is relatively high dissolved oxygen and relatively clear water.

From the length-weight relationship, it can be stated that the four dominant fish species (*C. carassius*, *C. carpio, C. gariepinus* and *O. niloticus*) show isometric growth and the length-weight relationships were also curvilinear. Of these, *O. niloticus* and *C. gariepinus* were in poor condition as compared to previous studies, while the two carp species were in better condition. The smallest sexually mature male *C. carpio* was 16 cm FL and the female was 17 cm FL, whereas the 50 % maturity length (L_{50}) was estimated to be 28.7 cm FL for females and 27 cm FL for males. Fecundity of *C. carpio* was found to be linear when related to fork length, total weight and gonad weight. The frequency of ripe fish as well as GSI values were generally high during February through to June and peaking in between March and May. Fecundity, for *C. carpio* of fork length from 32 cm to 46 cm, ranged from 75,645 and 356,743 eggs with a mean of 210,538.

The status of Lake Ziway fish yield has changed over time. Currently, the contribution of the two carp species (*C. carpio* and *C. carassius*) has increased and the contribution of *O. niloticus* and *C. gariepinus* has decreased. This is due to the increase in effort applied through time and other anthropogenic impacts exerted on the lake as discussed in Chapter 4. Fishing technology on Lake Ziway was not modern in its nature and only makes use of traditional boats of rafts and wooden manual boat. Long-lines, beach seining and gillnets were predominant fishing gears on the lake. Currentlly, the number of beach seines has decreased as compared to other gears that operated on the lake.

The major cause for the accelerated water quality changes in the lake was identified as human impact in the catchment of the lake. This includes land use changes, particularly removal of vegetation cover (through deforestation, animal grazing, etc.), irrigation, diversion of inflows and industrial use of the water were taken as the cause for the decline in water quality and quantity that directly have an effect on the current change in fish catch composition.

Fishing plays an important role in the livelihood sources of the community through both direct consumption and other income generation in the study area. However, it is constrained by several challenges like, open access to the resources, pollution and lack of technology, among others. Thus, if some or all of the challenges are tackled, fishing can be a pillar of economic activity in the study area and appropriate management is an urgent need to address the contribution of the fishery as a source of food, income and employment as ongoing activity. This can be done either by the government or by the fishing communities themselves or by both and may follow the following recommendations.

6.2. Recommendations

- With increase in nutrients and inorganic turbidity and more degradation in the catchment, fish species composition may continue changing in the future. Therefore, monitoring of fishes and management of nutrient inputs should be carried out on regular basis. The lakeshore should be restored with macrophytes and protected in order to control external nutrient loading. The current practice of Ziway Fisheries Resource Research Center with community based planting of mutually beneficial legume plants, like *Sesbania sesban* as animal feed should be continued for better management of the lake.

- The nutrient contribution from decomposition of macrophytes and other plant forms and from sediment recharge should be further investigated. In addition, the impact of inorganic turbidity on productivity of the aquatic organisms in general and fish in particular, needs further focused investigation. Hence, further detailed studies should be done to identify the nutrient sources in the lake ecosystem in general.
- There are indications of severe degradations of the lake basins particularly the water shade areas. The most threats to the lake are related to deforestation, irrigation and overgrazing by domestic animals in the lake basin. Therefore, sustainable utilization and conservation measures should be taken in and around the lake.
- The waste-disposal mechanisms of the adjacent businesses and/or residential areas should be investigated to establish the exact source and nature of the pollutants. Those people responsible for the pollution should be encouraged to implement appropriate mitigating measures as soon as possible.
- More detailed resource assessment of the lake water should be done, including sustainable abstractions and the special variability of water quality and quantity. Particularly, the potential impact of large-scale water abstraction for irrigation near the southern and western shore of the lake should be assessed in detail, with special attention to the impacts of drinking water, small-scale irrigation and Lake Ziway sustainability for the fishery industry.

- Proper irrigation scheduling, focusing on high value crops, using limited area and water, and detailed crop-water requirements study has to be made in irrigation fields to protect the over abstraction of the lake before affecting the resource of the lake.
- In Lake Ziway, large number of small sized fish of all species are being exploited and proper management actions are required to protect the immature fish. Particularly, capture size of the stock should be determined taking into consideration the size at first maturity of fishes (e.g. 28.7 cm FL of female *C. carpio*). Therefore, the fishery management plan such as prohibiting fishing on spawning ground during the breeding season is needed for the lake before the fishery resource is overexploited. In addition, high dependence on fishing activity has posed a serious threat to the fish resource. Thus, management tools like closed seasons, catch quota restriction, mesh size regulations, gear restrictions and limits on the number of fishers has to be for sustainable exploitation of the stocks.
- In the study area, currently the catches of the fishery are declining and therefore fishery alone cannot support the households. Thus, fishermen around the study area diversified and strengthen the livelihood source for better income generation.
- The development of aquaculture and other related alternative fisheries (Integrated-fish-horticulture-poultry farming and Aquaponics technology) to reduce the pressure on the natural system should be encouraged.
- The decline in the number of beach seine was associated with decrease in catch especially *O. niloticus* from the lake and this led some fishermen to move to Lakes Langano and Koka. If the situation continues, the case may be repeated to these water bodies and there is a need to control mesh size of the gears and such migration for fishing

- Promotion of credit arrangements should be given due attention to help fishermen access modern fishing equipment and maintain their fishing gears. Such credit can also be extended to complementary livelihood activities such as agriculture.
- Need to implement the existing regional as well as national fishery proclamation.
- Regular monitoring of the lake's limnology is needed in order to understand the trends of the lake water quality for mitigation measure.
- Based on the lesson from Lake Ziway, detailed studies and investigations are required on status and trends of fishes and fishery in rift valley basin in general due to high pressure of degradation of the area as well as ecological issues specially that of catchment of the lakes.

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APPENDIX 1: QUESTIONNAIRES

PART ONE: QUESTIONNAIRE TO BE FILLED BY FISHERMEN

I. PERSONAL INFORMAION

1. General Information

1.1. Date of interview ____

1.2. Name of the respondent___________________________________

1.3. Administrative zone ______________________________________

1.4. District ____

1.5. Name of the Village ______________________________________

2. Characteristics of Household head

2.1. Sex: 1. Male _________ 2. Female _____________

2.2. Marital status of the respondent

2.2.1. Single _______________

2.2.2. Married ______________

3. Age: (specify) _____________Year

4. No of dependants with age? (Specify)___________

II. LAKE ZIWAY FISHING INFORMATION

5. What are the sources of livelihood? ___________

5.1. Mention and rank them.

6. What is the role of fishing?

6.1. Only for consumption__________________

6.2. Only for sale_________________________

6.3. Both for sale and consumption __________

7. Main gear used:

7.1. Hand line __________________________

7.2. Long line __________________________

7.3. Gillnet ____________________________

7.4. Cast net ___________________________

7.5. Beach seines _______________________

7.6. Others (specify) ____________________

8. How many fish species are found in the lake?

8.1. Before Ten Years (> 2003 year) ________________

8.2. Between 2003 and 2013 year) __________________

9. What type of fish species preferred?

9.1. Rank them ____________________________________

9.2. Why ____

10. Do you process the product? Yes/No

10.1. If Yes, what and rank them______________

10.2. If No, why? __________________________

11. What is the preference trend of fishes dishes in the household?

11.1. Mention and rank them

12. Who perform the activities in the livelihood sources in the household? __________

13. Who perform the fishery activity in the household? (Focusing on the fishing and processing activities).__________________

14. How do you use your catch? ____________

15. Catch sold to:

15.1. Fish processing Enterprise _________

15.2. Consumer direct _________________

15.3. Local market ____________________

15.4. Others (specify) __________________

16. What is the most common commercial important fish species for your livelihood?

17. What is the price based on the most common products? ____________

18. Thinking about the catches when you first became involved with fishing compared with the catches now:

18.1. Increased___________

18.2. Decreased__________

18.3. Stay the same_______

18.4. No opinion_________

18.5. What do you think the reason for this? ___________

19. Do you think that the catches over the next 5 year wil?

19.1. Increased ___________

19.2. Decreased __________

19.3. Stay the same _______

19.4. No opinion _________

19.5. Why?______________

20. About those people who live around the lake, do you think that?

20.1. Everybody should be able to catch as much as they like?

20.1.1. Yes_____________

20.1.2. No _____________

20.1.3. No opinion ______

21. Do you think that there will always be enough fish catch for everybody?

21.1. Yes ____________

21.2. No ____________

21.3. No opinion_____

21.4. For what reasons do you think this? ________________

22. What are the most priority issues in Lake Ziway fisheries that need intervention?

22.1. Write the most important first and rank them ________

23. We have reached the end of our interview. Do you have any additional suggestions for the protection and proper use of Lake Ziway fishery?_________

PART TWO: ORGANIZATION/INSTITUTE INTERVIEW

Organization/Institute Name: ___________________

Date of interview: ____________________________

Name of the respondent/I/D: ____________________

PERSONAL INFORMAION

1. Sex: 1.1. Female ___________1.2. Male ___________

2. What is your current position? _____________________

3. How many years have you worked in your current position?

   3.1. Less than 5 years _________

   3.2. From 5 to 10 years _______

   3.3. From 10 to 15 years ______

   3.4. More than15 years _______

4. Are you a representative of which organization?

   4.1. The Ministry of Water and Energy

   4.2. The Ministry of Agriculture

   4.3. Ethiopian Institute of Agriculture Research

   4.4. Ethiopian Environmental Protection authority

4.5. Municipality

4.6. Irrigation Project

4.7. Water Supply Authority

4.8. Zone/Woreda Agriculture Offices

4.9. NGOs

4.10. Smallholder farmers

4.11. State Farm

4.12. Others (Specify) __________________

LAKE ZIWAY WATER QUALITY, QUANTITY AND FISHERY

5. Are there external factors that are out of your organizations thatn control Lake Ziway fisheries management? _________. If yes, describe and explain with respect to the following:

5.1. Natural factors: _____________________

5.2. Institutional factors, laws: _____________

5.3. Political factors, policies: _____________

5.4. Others (Specify): ____________________

6. In your opinion, is there a need to improve the fishery of Lake Ziway?

6.1. Yes ___________

6.2. No ____________

6.3. I don’t know ______

6.1.1. If yes, what steps should be taken to ensure? _____________

7. In your opinion, are there problems related to overfishing from Lake Ziway?

7.1. Yes ________________

7.2. No _________________

7.3. I don’t know ________

7.1.1. If yes, please describe them, and suggest what could be done to overcome these problems.

8. In your opinion, does your organization aware the communities in the area to protect and manage Lake Ziway for the production of fishes?

8.1. Yes ________________

8.2. No _________________

8.3. I don’t know _________

8.4. Based on the response of question No.8, Why? Explain your answer ____________

9. In your opinion, what are the main reasons why people are misusing the fishery resources in Lake Ziway?

10. In your opinion, who do you think is the most responsible organization for managing and protecting Lake Ziway Fishery?

10.1 The local communities

10.2. Government

10.3. Private sectors

10.4. Others (specify) ___________

11. What is the role of the concerned government body in the fishery management of Lake Ziway?

11.1. Passing legislations

11.2. Providing training on how to conserve the fishery of the Lake Ziway

11.3. Offering some financial and material incentives

11.4. Supporting fishermen cooperatives

11.5. Encouraging wetland management and conservation activities surrounding Lake Ziway

11.6. Others (Specify) _______________

12. In your opinion, do you think that the government is now successful in protecting Lake Ziway fishery and its surrounding?

12.1. Yes _____________

12.2. No ______________

12.3. I do not know ____

13. Are there some parts of Lake Ziway shoreline that are not allowed for local communities/cooperatives to use as landing site for fishing?

13.1. Yes _____________

13.2. No ______________

13.3. I do not know _____

13.1.1. If yes, which parts of the lake shoreline are not allowed?

14. Has your organization ever been involved in activities to ensuring the proper management of Lake Ziway fishery?

14.1. Yes _______________

14.2. No _______________

14. 3. I don't know ______

14.1.1. If yes, how was your organization involved? __________

15. What are the most priority issues in Lake Ziway fisheries that need intervention?

15.1. Write the most important first (Rank them) ________

16. What are the main concerns related to conservation of Lake Ziway at your organization?

17. What can be done to ensure the sustainable use of Lake Ziway fishery? (Rank)

18. We have reached the end of our interview. Do you have any additional suggestions for the protection and proper use of Lake Ziway fishery?_________

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 correctly acknowledged.

Name ______Lemma Abera Hirpo________________

Signature ___________________________________

Date of submission ___________________________