Feeding habits and Length-weight relationship of juvenile and adult Common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) in Lake Ziway, Ethiopia

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<td>ADC</td>
<td>Austrian Development Cooperation</td>
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<tr>
<td>APHA</td>
<td>American Public Health Association</td>
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<td>ANOVA</td>
<td>Analysis of variance</td>
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<td>DO</td>
<td>Dissolved oxygen</td>
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<td>EC</td>
<td>Electrical Conductivity</td>
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<td>FAO</td>
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ABSTRACT

The length weight relationships and feeding habits of juvenile and adult *Cyprinus carpio* and *Oreochromis niloticus* were studied from Lake Ziway, Ethiopia from April to August 2017. The juveniles were obtained using Beach seine net from three studying sites, and the adult fishes were purchased from catches of the landing fishermen. A total of 315 common carp (240 adult and 75 juveniles), and 365 Nile tilapia (170 adult and 195 juveniles) fish sample were collected ranging from 5.2 to 55 cm and from 2.5 to 30 cm TL, respectively. The corresponding TW ranges from 4.6 to 1610.2 g and 0.5 to 459.7 g, respectively. The relation between TL and TW of common carp was curvilinear with a strong relationship ($R^2=0.910$ juveniles; $R^2=0.962$ adults). The “$b$” value was 2.704 and 2.909 for juvenile and adults of common carp respectively which were closer to the isometric growth value ($b=3$). Similarly, the length-weight relationship of Nile tilapia was also curvilinear and showed strong relationship ($R^2=0.948$ juveniles; $R^2=0.979$ adults). The adult Nile tilapia had an isometric growth ($b=2.908$) while the juvenile showed allometric growth ($b=2.523$). From the total number of 75 juvenile and 240 adult of common carp, 4 (5.3%) and 60 (25%) fish samples had empty guts and the remaining 71 (94.5%) and 180 (75%) guts were observed with food, respectively. Whereas from 195 and 170 juvenile and adult Nile tilapia, 30 (15%) and 55 (26.5%) fish samples had empty stomachs while 165 (85%) and 115 (73.5%) were with foods, respectively. Fish samples that contained food in their stomachs were analyzed using frequency of occurrence and volumetric analysis methods. The major food items found in the stomach of juvenile common carp was zooplankton (34.24%), insects (26.34%) and detritus (25.82%) volumetrically while adult feeds on detritus (31.38%), macrophytes (30%) and insects (20%). The diet of adult Nile tilapia mainly depends on macrophytes (36.2%), phytoplankton (34.36%) and subsequently detritus (18.41%) while juvenile fed mainly on zooplankton (33.79%), phytoplankton (25.44%), insect (18.69%) and detritus (14.02%) volumetrically. In the diet of adult common carp, the contribution of insect was high from April to May while, detritus and macrophytes were high from June to August showing temporal variation in diet. The contribution of phytoplankton in the diet of adult Nile tilapia was high from April to May and low from June to August while, detritus and macrophytes were low from April to May and high from June to August. The contribution of zooplankton was high from June to August and low from April to May in the diet of juvenile Nile tilapia. However, there is no temporal variation in the contribution of insects in the diet of Nile tilapia except being relatively higher in June. The diet composition of this study shows that the two species are omnivore type which feeds on plant and animal origin. Schoener's index revealed significant dietary overlap between the two species, $\alpha=0.84$ (between juveniles) and $\alpha=0.63$ (between adults). However, there was no significant dietary overlap within species between juveniles and adults of common carp and Nile tilapia ($\alpha=0.52$) which indicate the presence of ontogenetic dietary shifts in both species. The presence of significant dietary overlap between the two species may be one of the causes for reduction of Nile tilapia stock in Lake Ziway. Further investigations are recommended for verification of the present findings and searching for alternative and complementary causes.

Keywords/phrases:

Dietary overlap, feeding habit, invasive fish, Lake Ziway, ontogenetic dietary shift, temporal variation
1. INTRODUCTION

Fishes are key elements in many natural food webs. They are often considered to control the structure of freshwater systems. Consumption of organisms by fish is a salient feature which can regulate trophic structure and thus influence the stability, resilience, and food web dynamics of aquatic ecosystems; moreover, these regulatory influences change as fish pass from one life stage to another (Carpenter et al., 1992; Post et al., 1997). They also can serve as environmental indicators (Tesfaye Wudneh, 1998).

Fishes also play an important role in the economy of developing and developed countries by contributing to animal protein intake, employment generation, household incomes and foreign exchange earnings (Rishikanta et al., 2015). To fill the gap in food limitations, the aquatic ecosystem can serve as an inexpensive source of fish protein (Tesfaye Wudneh, 1998). Aiming at increasing the fish production of water bodies, introductions of exotic freshwater fishes have been made to several man-made and natural water bodies in Ethiopia (Kassahun Asaminew et al., 2011).

On the other hand, invasive species pose one of the greatest threats to the biotic integrity of aquatic ecosystems, even though their effects on native fauna are highly variable and extremely difficult to predict (Lodge, 1994; Moyle and Cech, 1996). This is because environmental conditions vary and the processes by which species coexist are complex (Huisman and Weissing, 1999). Introduced species compete for space and food with native species. Hence, there could be diet overlap between exotic and native species, resulting in diet and habitat shifts with potentially negative consequences for native species (Persson and Greenberg, 1990; Petern and Case, 1996; Chase et al., 2002).

Common carp, native to Eastern Europe and Central Asia, was introduced to Ethiopia in 1936 for aquaculture purpose (Welcome, 1988; Henning et al., 2008; Troca, 2012). Since then, it has been stocked in various reservoirs and natural lakes to enhance fish yield by filling the available niche (Shibru Tedla and Fisha Haile-Meskel, 1981). Common carp was introduced into Lake Ziway in the late 1980s by Ministry of Agriculture with the intention of increasing fish production by introducing a macrophyte feeder into the system where the niche was not occupied by any of the
indigenous fishes (FAO, 1997). However, Cyprinus carpio (common carp) has been nominated as one of the 100 of the "World's Worst" invaders (Lowe et al., 2000).

Common carp has a versatile feeding behavior, characterized by opportunistic omnivorous feeding behavior (Colautti and Remes, 2001). Studies have reported that common carp feeds on a variety of food items including molluscs, zooplankton, aquatic vegetation, detritus, phytoplankton, insects, fish parts and ostracods (Maitland, 1992; Magalhaes, 1993; Colautti and Remes, 2001; Rahman et al., 2006; Saikia and Das, 2008; Elias Dadebo et al., 2015). Its diet composition may vary within a wide range of seasonal and spatial condition of the environments (Ali et al., 2010; Elias Dadebo et al., 2015). The food composition may also vary depending on the size of the fish, environmental condition and habitat types (Chakrabarti and Jana, 1991).

Oreochromis niloticus (Nile tilapia), on the other hand, is a native fish to Africa and it is the most dominant and the most preferred species in Ethiopia (Petra et al., 2008). It is distributed in almost all inland water bodies of Ethiopia and accounted about 60% of the capture fishery in the country (LFDP, 1997; Demeke Admassu, 1998). Several studies indicated that phytoplankton is the most consumed food item over the other food items in the diet of Nile tilapia (Zenebe Tadesse, 1988, 1999; Yirgaw Teferi et al., 2000; Alemayehu Negassa and Prabu, 2008; Filapos Engdaw et al., 2013; Workye Worie and Abebe Getahun, 2015). However, Tadesse Fetahi et al. (2018) recently reported that 64% of Nile tilapia diet originated from macrophytes in Lake Ziway, indicating the absence of consensus on the food and feeding habits of Nile tilapia as well as the possibility of diet competition between common carp and Nile tilapia. Kassahun Asaminew (2005) has also reported that there was a clear food competition between common carp and Nile tilapia in Lake Koka.

The study of the food and feeding habits of fish is a subject of continuous research because it constitutes the basis for the development of a successful management program on capture fishery and aquaculture (Shalloof and Khalifa, 2009). Moreover, studies on the natural feeding of fish enable to identify the trophic relationships present in aquatic ecosystems, identifying feeding composition, structure and stability of food webs in the ecosystem (Adeyemi et al., 2009; Otieno et al., 2014). The dietary study is also useful to understand ecosystem perturbation due to exploitation or introduction of exotic species. Food availability determines the wellbeing of fishes, as well as their reproductive potentialities in any aquatic ecological system and the weight

2
and size of fish, is a reflection of food availability in the aquatic ecosystem (Elias Dadebo et al., 2014). Quantitative and qualitative determination of the composition of the diet, their nutritive value and seasonal availability are the basic parts for an understanding of environmental impacts on the condition and growth of fish. Therefore, an understanding of fish diet and its influence on growth can be essential for understanding the ecological role and the productive capacity of fish populations (Bowen, 1982).

To sustain the development of the fishery in Lake Ziway, different fishery research activities were conducted on the taxonomy (Golubtsov et al., 2003; Stiassny and Abebe Getahun, 2007; Eshete Dejen et al., 2010), biology (Zenebe Tadesse, 1988; Eyualem Abebe and Getachew Tefera, 1992; Demke Admassu, 1998; Demke Admassu and Ahlgren, 2000; Alemayehu Negassa and Abebe Getahun, 2003; Elias Dadebo and Daba Tugie, 2009; Lemma Abera et al., 2014), ecology (Zenebe Tadesse, 1988; Alemayehu Negassa and Prabu, 2008; Mathewos Hailu, 2011; Lubaba Mohamed, 2017), stock assessment (LFDP, 1996, 1998; Felegeselam Yohanes, 2003; Gashaw Tesfaye, 2006) and fish health (Eshetu Yimer, 2003; Lemma Abera, 2012). However, there are no studies focusing on the diet overlap of juvenile and adult individuals of common carp and Nile tilapia and interestingly no study has been conducted on the feeding habits of the common carp in Lake Ziway. Lemma Abera (2016) recently reported that the contribution of common carp to total annual catch of the lake has dramatically increased from zero (0%) before 2012 to 25% in 2014. On the contrary, the contribution of Nile tilapia to the total catch has declined from 89.3% in 1994 to 27% in 2014 (Lemma Abera, 2016). The dramatic decline of this most commercially important fish species in the lake could be related to the dominancy of the exotic carp that potentially compete with tilapia for available resources. This study was therefore proposed to provide new insights on diet of juvenile and adults of common carp and Nile tilapia, and examine dietary overlap between the two species in Lake Ziway.
1.1. Research questions

- What are the diets of juvenile and adult common carp and Nile tilapia in Lake Ziway?
- Are there any differences in relative importance of food items between Nile tilapia and common carp, and between juvenile and adults of both species?
- Is there temporal variation in the feeding habit of juvenile and adults of Nile tilapia and common carp?
- Is there dietary overlap between Nile tilapia and common carp at both juvenile and adult stages?
- What are the length-weight relationships of juvenile and adults of common carp and Nile tilapia in Lake Ziway?

1.2. Objectives

1.2.1. General objective

To study feeding habit and the length-weight relationship of juvenile and adult common carp and Nile tilapia to enable put sustainable management and conservation of the fish resources of Lake Ziway

1.2.2. Specific objectives

- To identify the type of food items consumed by juvenile and adult common carp and Nile tilapia
- To compare the relative importance of food items on the diet of juvenile and adults of common carp and Nile tilapia
- To assess the temporal variations in the feeding habit of juvenile and adults of common carp and Nile tilapia
- To examine the dietary overlap between common carp and Nile tilapia at both juvenile and adult stages
- To determine length-weight relationships of juvenile and adults of common carp and Nile tilapia in Lake Ziway
2. LITERATURE REVIEW

2.1. Food and feeding habit of fishes

The study of fish feeding, characteristics of their feeding behavior, effects of various environmental factors and physiological status on feeding efficiency is the basic directions of ichthyological research (Moyle and Cech, 2000). Fishes are characterized by very high diversity of species adaptations, including feeding adaptations (Wooton, 1990). The composition of the consumed food, the width and variability of the food spectrum, the way of obtaining the food and dynamics of feeding may differ. Food habits of fish are highly variable and depend on a wide range of factors including the species and age of the fish, the availability of preferred food and the combination of fish species (Antony et al., 2014).

Studies on natural feeding of fishes are permit to identify the trophic relationships present in aquatic ecosystems, identifying feeding composition, structure and stability of food webs (Abdel-Aziz, and Gharib, 2007). Food and feeding habit of fish are also important biological factors for selecting a group of fish for culture in ponds to avoid competition for food among themselves and live in an association and to utilize all the available food (Dewan and Saha, 1979).

The study of the feeding habits of fish and other animals based on analysis of stomach content has become a standard practice (Hyslop, 1980; Zacharia and Abdurahiman, 2004). Stomach content analysis is widely used in the study of fish feeding habits and provides an important means of investigating trophic relationships in aquatic communities (Zacharia and Abdurahiman, 2004).

An understanding of how a species utilizes its food resource and how that changes ontogenetically is prerequisite to any examination of the impact of a predator on the structure of a prey assemblage (Adeyemi et al., 2009). Ontogenetic shifts in diet are very common in fish (Mohammad, 2015). Many factors are also responsible for these changes in diet, and can be divided into two categories: external factors (e.g. habitat, food supply, predation risk) and internal factors (e.g. anatomical structures, behaviour, physiological demands). In many species, dietary changes are associated with habitat shifts (Mohammad, 2015). The type and size of food
item consumed changes with age and size of the fish (Mohammad, 2015). This is mainly because fish can only feed on food items that can fit into their mouth and what their gut can digest.

The food habit of different fish also varies from month to month (Shukla and Patel, 2013). This variation might be due to changes in the composition of food organisms occurring at different seasons of the year. It has been documented that natural food material is not available in equal quantity throughout the year, and there is a clear fluctuation in it (Bhuiyan et al., 1999). It is important to emphasize that the effect of seasonality should always be considered in the studies on natural feeding of fish, because the temporal changes of biotic and abiotic factors alters the structure of the food web along the year and, as a consequence, the fish often shows temporal and seasonal diet shifts (Wootton, 1990).

2.2. Length-weight relationship of fishes

Length-weight relationship is an integral component in the study of fisheries science (Moata et al., 2005) and it is fundamental to understand life history and undergoing morphological comparisons between different fish species or between fish populations from different habitats (Mehmet et al., 2007). Gulland (1983) reported the importance of length-weight relationship as a factor in the biological study of fishes such as stock assessment and management. The establishment of length-weight relationship is fundamental for estimation of production and biomass determination of a fish population (Moata et al., 2005).

The relationship between weight (W) and length (L) typically takes the curvilinear form: \( W = a L^b \) or in the linear form: \( \log W = \log a + b \log L \), where \( a \) and \( b \) are constant parameters estimated by regression analysis. According to Pauly (2005), ‘\( b \)’ values may range from 2.5 to 3.5. If fish retains the same shape, it grows isometrically and the length exponent ‘\( b \)’ has the value \( b=3.0 \) (Pauly, 2005) and a value significantly larger or smaller than \( b=3.0 \) shows allometric growth pattern. A value less than \( b = 3.0 \) shows that the fish becomes lighter for its length and if greater than \( b = 3.0 \), indicates that the fish becomes heavier for its length as it grows.

Common carp \((Cyprinus carpio)\)

Carp are widespread across the world, but the extensive environmental damage that they cause makes them a part of the “100 World’s Worst Invasive Species” by the International Union for
the Conservation of Nature (IUCN) (Lowe et al., 2000). Carps are known to be an ecosystem engineer, which means that they modify and alter the state of the water bodies they inhabit (Weber and Brown, 2009). Common carp is native to Europe but has been widely introduced and is now found worldwide except for the poles (Froese and Pauly, 2002). It is probably the first fish species whose distribution was widely extended by the human introduction, since its introduction by the Romans from the River Danube throughout Europe (Balon, 1995). It also accounts for the world’s highest farm fish production (Abdelhamid et al., 2017).

Common carp exploit large and small manmade and natural reservoirs, and pools in slow or fast moving streams. However, they prefer larger, slower-moving bodies of water with soft vegetated sediments but they are tolerant and hardy fish that thrive in a wide variety of aquatic habitats (Pauly, 2005). They normally live in a preferred temperature range of around 15–32°C, but are able to survive in a wide range of temperatures, including ice-covered lakes (at about 2°C) and much warmer ponds (up to about 40°C) (Koehn et al., 2016). Carps are also able to tolerate poor quality water with low oxygen levels and water that is slightly salty (Banarescu and Coad, 1991). Juvenile carp are usually found strongly associated with aquatic plants in marsh areas or river backwaters for the first year of their life (McCrimmon, 1968).

Ecosystem alterations induced by common carp have great potential to influence native fish populations, but direct empirical evidence is limited. By reducing or eliminating aquatic macrophytes and disrupting substrates, common carp may indirectly reduce the abundance of other fishes through reductions in spawning and nursery habitats (Paukert et al., 2002). Additionally, increased turbidity, commonly associated with common carp populations, may alter piscivore and planktivore foraging behavior and reduce success (Reid et al., 1999), affecting fish condition, growth and survival. Thus, common carp may interact with and have effects on native fishes through multiple complex mechanisms.

On the basis of qualitative and quantitative analysis of gut contents, common carp is an omnivorous fish that can consume a wide range of food items like worms, molluscs, zooplankton, aquatic vegetation, plant debris, detritus, and insects (Colautti et al., 2001). The diversity of its diet makes this species resistant to food web change and capable of inhabiting a wide variety of habitats (Weber and Brown, 2011).
Rahman et al. (2009) stated that common carp primarily feeds on benthic macro-invertebrates (chironomids) and zooplankton, but the bulk of its diet consists of detritus. Common carp generally ignores phytoplankton, strongly selects benthic macro-invertebrates and weakly selects zooplankton (Mohammad, 2015). Cherry and Guthrie (1975) reported that detritus and zooplanktonic organisms such as cladocera, copepod and diptera constituted the large part of the monthly and annual food of common carp in waters they investigated. Karaca (1995) reported that the majority of the food found in the digestive tracts of common carp constitutes Chrysophyta from algae with 55.46% followed by benthic organisms with 16.17 % and copepod from zooplankton with 8.49 %. Among the animal based organisms which constitute 33.77 % of the total food consumed 56.72 % was zooplanktonic and 43.28 % was benthic organisms in Hirfanli dam, Turkey. Hana and Manal (1988) found eggs of other fish and small fish in the digestive tract of common carp. The feeding habit of common carp showed seasonal differences based on its diet availability (Mustafizur et al., 2010). Elias Dadebo et al. (2015) also reported that common carp mainly feed on detritus and macrophytes during the wet months whereas insects accounted the largest food volume in the dry months. However, the presence of benthic organisms and detritus in its digestive tract throughout the year confirms that the species feeds at the bottom of the water body (Mustafizur et al., 2010).

Diet of common carp also varies between adult and juvenile fish, with juveniles consuming more plankton and larger carp consuming more bottom-dwelling food (Chakrabarti and Jana, 1991; Adamek et al., 2003; Rahman et al., 2009). According to Rahman et al. (2009), common carp of up to 15.4 cm total length preferentially select zooplankton, while common carp larger than 18.9 cm total length avoid zooplankton. But, size of common carp has no significant effect on phytoplankton (Mohammad, 2015).

The allometric and isometric growth pattern of common carp was reported in different water bodies Mehmet et al. (2007) in Almus Dam Lake (Tokat- Turkey) and (Moata et al., 2005) in Morocco reported a ‘b’ value of 3.319 and 3.412, respectively and showed that common carp had a positive allometry growth pattern. Daniela et al. (2009) in Brazil and Elias Dadebo et al. (2015) in Lake Koka, Ethiopia also reported a ‘b’ value of 3.002 and 3.018, respectively and showed that common carp had isometric growth pattern.
Nile tilapia (*Oreochromis niloticus*)

Tilapia is considered to be the most important and second cultured fish species next to carp around the world (Abdelhamid *et al.*, 2017). These fishes were found throughout the Nile River basin (Njir *et al.*, 2004; Shipton *et al.*, 2008). In Ethiopia it is widely distributed in the lakes, rivers, reservoirs and swamps, and contributes about 60% of total landings of fish (LFDP, 1997; Demeke Admassu, 1998), but currently reduced to 49% (Gashaw Tesfaye and Wolff, 2014).

Due to its suitability to aquaculture, this species was introduced in many parts of Asia, Europe, North America and South America (Alemayehu Negassa and Prabu, 2008). Nile tilapia is an important fish in the ecology of tropical waters as well as aquatic systems in other subtropical regions (Offem and Omoniyi, 2007). This is mainly because it feeds mainly on algae and other plant materials as well as detritus making it a link between lower and upper trophic levels in the aquatic food webs. However, Nile tilapia has been observed to diversify its diet under different conditions to include detritus, small insects as well as some fish parts (Zaganini *et al.*, 2012). In addition the fish is capable of filter feeding by capturing food particles in the water column.

Depending on the food source, Nile tilapia feed either via suspension filtering or surface grazing, trapping plankton using mucus excreted from their gills (Fryer and Iles, 1972). It is reported that Nile tilapia from Lakes Hawassa, Ziway and Chamo mainly feed on phytoplankton, macrophytes and detritus (Todurancea *et al.*, 1988; Zenebe Tadesse, 1988; Yirgaw Teferi *et al.*, 2000; Alemayehu Negassa and Prabu, 2008).

The food composition differs depending on the season and also lake type (Getachew Tefera and Fernando, 1989). Nile tilapia feeds on both types of food, plant material and animal material; the proportion of phytoplankton was higher during dry months and macrophyte was higher in wet months (Zenebe Tadesse, 1988, 1998; Yirgaw Teferi *et al.*, 2000; Shalloof and Khalifa, 2009; Flipos Engdaw *et al.*, 2013). The seasonal variation on the feeding habit of Nile tilapia due to a seasonal succession of phytoplankton in some rift valley lakes of Ethiopia was also well explained (Yirgaw Teferi *et al.*, 2000).
Fish tend to show a preference for some food items over others within their environment. Selection of food items of fish also depends on the age or size of the fish, since smaller fish tend to select smaller food items and vice versa (Flipos Engdaw et al., 2013). Adult Nile tilapia was reported to feed on variety of food items including phytoplankton, macrophytes, planktonic and benthic invertebrates and detritus (Yirgaw Teferi et al., 2000; Oso et al., 2006; Alemayehu Negassa and Prabu, 2008) whereas juveniles are generally omnivorous feeding on zooplankton, insect larvae (Todurancea et al., 1988; Zenebe Tadesse, 1988; Flipos Engdaw et al., 2011) and phytoplanktons of which diatoms were the major dietary component (Zenebe Tadesse, 1988; Witte and Winter, 1995).

The slope of the regression line (b) of Nile tilapia in different water bodies was indicating isometric growth pattern of the fish; where its shape and specific gravity do not change as the fish grows in size (Elias Dadebo et al., 2014). The isometric growth pattern of Nile tilapia was reported in rift valley lakes of Ethiopia such as in Lake Hayq (b=2.95; Workye Worie and Abebe Getahun, 2002), Lake Hawassa (b=3.01; Demeke Admassu (1998), Lake Koka (b= 3.0541; Flipos Engdaw et al., 2013).
3. MATERIALS AND METHODS

3.1. Description of the study area

Lake Ziway (70° 52’ to 80° 8’ N Latitude and 70° 52’ to 38° 56’ E Longitude) is one of the freshwater Rift Valley Lakes of Ethiopia (Makin et al., 1975) and is situated at an altitude of 1636 meters above sea level with a surface area of 434 km² (Wood and Talling, 1988). Two main rivers, Meki from the north-west and Katar from the east flowing into the lake and it has an outflow through Bulbula River, draining into Lake Abijata.

3.1.1. The climate of Lake Ziway and the surrounding area

The rainfall pattern is largely influenced by the annual oscillation of the inter-tropical convergence zone, which results in the rainy season (with most of the rainfall occurring from June to September) and dry season (October to March) (Adamneh Dagne, 2010). The weather in the lake region is also frequently windy to stormy (Schroder, 1984). The mean monthly minimum air temperature in the region ranged from 11.2-13.5°C while the maximum ranged from 21.6-31.5°C and monthly total rainfall in the region also ranged from 2.1 mm to 24.5 mm (Lemma Abera, 2016).

3.1.2. Physical and chemical features

The water budget of Lake Ziway is regulated by superficial inflows, outflows, evaporation and precipitation (Dagnachew Legesse, 2001). An earlier report indicates that Lake Ziway receives 0.42 and 0.44 km³ of water via Rivers Katar and Meki, respectively and losses through Bulbula River about 0.21 km³ and through evaporation 0.2 km³ water per year in 100 km² of lake area (Wood and Talling, 1988). Later, according to Tenalem Ayenew (2002) the annual inflows from Meki and Ketar Rivers into Lake Ziway were 264.5 and 392 million m³, respectively, and indicated that there was a 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 m³ over the overall water loss from the lake. 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 yield
(Lemma Abera, 2016). Morphometry and limnological parameters of Lake Ziway are indicated in Table 1.

Table 1: Morphometry and limnological parameters of Lake Ziway

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>20 Km</td>
<td>Wood and Talling, 1988</td>
</tr>
<tr>
<td>Length</td>
<td>31 km</td>
<td>»</td>
</tr>
<tr>
<td>Mean depth</td>
<td>2.5 m</td>
<td>»</td>
</tr>
<tr>
<td>Maximum depth</td>
<td>9 m</td>
<td>»</td>
</tr>
<tr>
<td>Water temperature</td>
<td>18.9-27.3</td>
<td>Admneh Dagne, 2008</td>
</tr>
<tr>
<td>Rainfall</td>
<td>0-187.4</td>
<td>»</td>
</tr>
<tr>
<td>Secchi depth</td>
<td>17.8-22.1 cm</td>
<td>Lemma Abera, 2016</td>
</tr>
<tr>
<td>Turbidity</td>
<td>45.4-342 NTU</td>
<td>Admneh Dagne, 2008</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>28 -76 µg L⁻¹</td>
<td>Dessie Tibebe. 2017</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>5 mgL⁻¹</td>
<td>»</td>
</tr>
<tr>
<td>Conductivity</td>
<td>361.5 - 484.5 µScm⁻¹</td>
<td>Lemma Abera, 2016</td>
</tr>
<tr>
<td>pH</td>
<td>8-8.4</td>
<td>Lemma Abera, 2016</td>
</tr>
<tr>
<td>TP</td>
<td>0.311 mgL⁻¹</td>
<td>Dessie Tibebe. 2017</td>
</tr>
<tr>
<td>SRP</td>
<td>0.038-0.064 mgL⁻¹</td>
<td>Lemma Abera, 2016</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>0.030 -0.061 mgL⁻¹</td>
<td>»</td>
</tr>
<tr>
<td>NH₃-N</td>
<td>0.064-0.258 mgL⁻¹</td>
<td>»</td>
</tr>
</tbody>
</table>
3.1.3. Sampling sites

Three sites were selected by considering Lake Region where juvenile of common carp and Nile tilapia can dwell. The sampling sites are located in the littoral zone of the lake, site 1 (Wafeko) and site 2 (Bochessa) at the southwestern end and site 3 (Abiye) at the southern end (Fig 1). All three sites are characterized by extensive macrophytes including emergent and submergent vegetation with relatively larger coverage in Abiye. But their substratum is differing in which Wafeko and Bochessa are intermediate between sandy and muddy, and Abiye is muddy bottom.

![Figure 1: Map of Lake Ziway indicating sampling sites](image)

3.1.4. Biota in Lake Ziway

The phytoplankton community is dominated by blue green algae (*Microcystis* sp., *Lyngbya* sp., *Merismopedia* sp., *Chroococcus* sp., and *Anabaena* sp.), diatoms (*Navicula* sp., *Cymbella* sp., *Surirella* sp., *Nitzschia* sp., *Synedra* sp., and *Pinnularia* sp.) and green algae (*Scenedesmus* sp., *Spirogyra* sp., *Pediastrum* sp., *Cosmarium* sp. and *Botryococcus* sp.) (Alemayehu Negassa and Prabu, 2008). Zooplankton community of Lake Ziway is reportedly composed of 59 species (49 rotifers which are dominated by *Brachionus angularis*, *Filinia novaezealandiae* and *Trichocerca ruttner*, 7 cladocerans which include *Ceriodaphnia cornuta*, *Diaphanosoma excisum*, *Alona diaphana* and *Moina micrura*) and 3 cyclopoid copepods which are dominated by *Thermocyclops decipensis* and *Mesocyclops aequatorialis* (Adamneh Dagne, 2010).
Some 12% of the lake’s surface area is covered by macrophytes, which are distributed mainly in the littoral part of the lake (Girum Tamire and Seyoum Mengistou, 2012). The bottom fauna comprises chironomid larvae and gastropods (Anisus natalensis, Biomphalaria sudanica, Bullinus forskahlii, Lymnea natalensis and Mellanoides tuberculata), different kinds of insects, spiders, ostracods and nematodes (Martens and Tudorancea, 1991).

The fish community is composed of both native and introduced species. There are seven indigenous fish species in the lake comprising Enteromius paludinosus, Garra dembecha, Garra makiensis, Labeobarbus ethiopicus, Labeobarbus intermedius, Labeobarbus microterolepis and Oreochromis niloticus (Golubtsov et al., 2002; Jacobus et al., 2012). The lake also harbors five exotic fish species (Coptodon zillii, Cyprinus carpio, Carassius carassius, Carassius auratus) which were introduced to enhance fish production and Clarias gariepinus that slipped into the lake accidentally (Abebe Getahun and Stiassny, 1998; Golubtsov et al., 2002). The most important commercially fishes are Nile tilapia, common carp, crucian carp and catfish (Lemma Abera, 2016).

### 3.2. Field sampling and measurement

#### 3.2.1. Physico-chemical parameters

Dissolved oxygen, water temperature, pH, and conductivity were measured in situ using a Multi meter probe (model HQ40d) at all sampling sites. Turbidity was estimated using a turbido meter (T100 Oakaton). TDS was analyzed by filtering lake water sample and evaporating filtrates and residue on flask was measured as final weight using analytical balance (APHA, 1998). For the analysis of major inorganic nutrients water samples were collected from each site in dark plastic bottle. The collected water samples were put on the ice and transported to Limnology laboratory of Addis Ababa University, Ethiopia. All samples used for nutrient analyses were filtered through glass fiber filters (What man GF/F) except total phosphorus (TP), for which unfiltered water sample was used. Nitrate was measured with sodium salicylate method, ammonium with phenate method (APHA, 1995), and Soluble reactive phosphorus (SRP) and TP (after per sulfate digestion) by the ascorbic acid method (APHA, 1999).
3.2.2. Fish collection and measurement

Adult fish samples were obtained from catches of the fishermen. The commercial gillnets of the fishermen consist of different mesh sizes (6cm, 8cm, 10cm and 12cm stretched mesh sizes). In order to obtain juveniles, beach seine (3cm mesh size) was used at three sampling sites which were located in the shallow part of the lake. The fish samples were then taken to the Battu Fish and other Aquatic Life Research Center laboratory soon after capture for identification using keys developed by (Golubtsov et al., 1995, Redeat Habtesilassie, 2012), and for length-weight measurements. Total length (TL) and total weight (TW) of all specimens were measured and weighted to the nearest value of 0.1 cm and 0.1g, respectively. Then each fish was dissected and the sex and maturity stage of each sample was determined by visual examination of gonads using five point maturity scales as of Holden and Raitt (1974) and Babiker and Ibrahim (1979). Stomach containing food were transferred to a labeled plastic bag containing 5% formaldehyde solution and then brought to the fishery laboratory of Addis Ababa University for analysis.

3.3. Food and feeding habit

3.3.1. Gut content analysis

In the laboratory, the content of each gut of all specimens was transferred into a petri-dish to identify food items. Large food items were identified visually. However, smaller food items were examined under a dissecting microscope (LEICA L2) and a compound microscope (LEICA DME), and identified to the lowest possible taxa using descriptions and illustrations in the relevant literatures (Mammaril, 1978; Blomqvist, 1981). Then, the relative importance of each food items to the diet of the fish was estimated using the following established methods:

3.3.2. The relative importance of food items

a) Frequency of Occurrence (FO)

The number of gut samples in which a given food item was found was expressed as a percentage of all non-empty guts examined. This method gives an estimate of the proportion of the population that feeds on a particular food item (Hyslop, 1980). The method is advantageous to
illustrate changes in the diet with age and size, and to establish relative occurrence and requires less time (Hyslop, 1980; Bowen, 1983).

\[
\%\text{FO} = \frac{\text{The number of stomach in which a given food item is found}}{\text{The number of non-empty stomach examined}} \times 100
\]

b) Volumetric Analysis (%V)

The stomach content from each sample was diluted with tap water to a known volume. After thoroughly mixing the samples, one drop was taken on a microscope slide and food items that are found in the guts were grouped into different taxonomic categories. And the volumetric percentage of each prey item was estimated relative to all food items present in a drop by considering their size and number. A minimum of three drops per stomach were used to estimate the volumetric percentage of each food item in each fish sample. The volumetric percentage of each food items per drop was also estimated from 3 fields of visions at different parts of the cover slip by computing mean percentage of each food item from each field. The relative volume of each food item in a stomach was computed by multiplying the proportion of each food item in a drop by the total volume of the stomach content. The mean volume percentage of food items was calculated using the method of Wallace (1990).

\[
\%\text{V} = \frac{\text{Volume of one food item found in all specimen}}{\text{The volume of all food items in all specimens}} \times 100
\]

3.3.3. Differences in relative importance of food items between juvenile and adult common carp and Nile tilapia

To study whether there is diet variation in the food habit of juvenile and adults of common carp and Nile tilapia, relative importance of each food item was plotted against the total length of fishes. Fish samples were divided into juvenile and adult stage depending on their gonad development and size. Fishes (≤10cm TL) for both species had thread like (very thin) and flesh-colored gonads. Such features characterize immature gonad (Babiker and Ibrahim, 1979). Therefore, juvenile of fishes in the present study ranged from 5.2-10 and 2.5-10cm TL for common carp and Nile tilapia, respectively. For the sake of present study, the adult Nile tilapia and common carp include all fish whose size ≥10cm and ≥22cm TL, respectively. Although,
sexual maturity is different for a species in different environmental conditions, by referring relevant literature from tropical lakes, the aforementioned size class category becomes important. All adult fishes of both species in the present study had matured gonad and hence sexed.

3.3.5. Temporal variation in feeding habit of common carp and Nile tilapia

The monthly variation in the feeding habit was also studied by plotting the relative importance (%FO and %V) of major food items against sampling months.

3.3.4. Dietary overlap between common carp and Nile tilapia at both juvenile and adult stages

Dietary overlap between juvenile and adult stage of the same species, and between the two species at both juvenile and adult stages was calculated using, Schoener Diet Overlap Index (SDOI) (Schoener, 1970).\[\alpha = 1 - 0.5(\sum |Pxi - Pyi|);\] Where \(\alpha\) is percentage overlap, SDOI, between developmental stage x and y and species x and y, pxi and pyi are proportions of food category (type) i used by x and y. Values range from 0 (no food overlap) to 1 (complete overlap) with values greater than 0.6 being considered as biologically significant (Mathur, 1977).

3.4. Length-weight relationship

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

\[TW = aTL^b,\] where: TW - Total weight in grams \(a\) - Intercept of the regression line

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

3.5. Data analysis

Data generated from the stomach contents were analyzed using Microsoft Excel. Spatial variation in physico-chemical parameters were analyzed using One way ANOVA followed by multiple comparison tests.
4. RESULTS

4.1. Physico-chemical parameters

Physico-chemical parameters such as water temperature, dissolved oxygen (DO), pH, total dissolved solids (TDS), conductivity, Nitrate-nitrogen, Soluble reactive phosphate (SRP), Total phosphorus (TP) and Ammonia are given in Table 2. The mean (±SD) value of dissolved oxygen (mgL\(^{-1}\)) ranged from 6.89 ±0.11mgL\(^{-1}\) at Abiye to 8.16 ±0.6mgL\(^{-1}\) at Wafeko and there is no significant variation in the value of dissolved oxygen among sampling sites (p>0.05) (Table 7). Similarly, the variation in pH and temperature among sites was not significant (P>0.05) (Table 2). The mean (±SD) value of specific conductivity at the sampling sites ranged from 133.4±5.5μS cm\(^{-1}\) at Bochessa to 178±9.15μS cm\(^{-1}\) at Abiye. Abiye and Wafeko sites showed significantly higher value of specific conductivity than Bochessa site (p<0.05). The concentration of nutrients like nitrate and total phosphorus indicated significant variation among sampling sites (Table 2). However there is no significant variation in concentration of ammonia and soluble reactive phosphate among sampling sites (Table 2).

Table 2: Physico-chemical parameters of selected sites from Lake Ziway

<table>
<thead>
<tr>
<th>Physico-chemical parameters</th>
<th>Units</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wafeko</td>
</tr>
<tr>
<td>DO</td>
<td>(mgL(^{-1}))</td>
<td>8.16±0.6(^a)</td>
</tr>
<tr>
<td>Temperature</td>
<td>(°C)</td>
<td>29.17±0.37(^a)</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>8.1±0.12(^a)</td>
</tr>
<tr>
<td>EC</td>
<td>(μScm(^{-1}))</td>
<td>173±6.124(^a)</td>
</tr>
<tr>
<td>TDS</td>
<td>(mgL(^{-1}))</td>
<td>203±1.91(^a)</td>
</tr>
<tr>
<td>Turbidity</td>
<td>(NTU)</td>
<td>169±5.67(^a)</td>
</tr>
<tr>
<td>NH(_3)</td>
<td>(mgL(^{-1}))</td>
<td>0.123±0.018(^a)</td>
</tr>
<tr>
<td>NO(_3)</td>
<td>(mgL(^{-1}))</td>
<td>0.06±0.01(^a)</td>
</tr>
<tr>
<td>SRP</td>
<td>(mgL(^{-1}))</td>
<td>0.052±(^a)</td>
</tr>
<tr>
<td>TP</td>
<td>(mgL(^{-1}))</td>
<td>0.11±0.04(^a)</td>
</tr>
</tbody>
</table>

Mean in the same row with different superscript are significantly different (p<0.05).
4.2. Size composition of the fish sample

Table 3: Size composition of juvenile and adults of common carp and Nile tilapia

<table>
<thead>
<tr>
<th>Fish samples</th>
<th>Fish stages</th>
<th>Sampling sites</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common carp</td>
<td>Juvenile</td>
<td>Wafeko</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bochessa</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Abiye</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>29</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td></td>
<td>38</td>
<td>39</td>
<td>45</td>
<td>56</td>
<td>62</td>
</tr>
<tr>
<td>Nile tilapia</td>
<td>Juvenile</td>
<td>Wafeko</td>
<td>10</td>
<td>10</td>
<td>12</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bochessa</td>
<td>11</td>
<td>10</td>
<td>17</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Abiye</td>
<td>10</td>
<td>10</td>
<td>13</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>31</td>
<td>30</td>
<td>42</td>
<td>47</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td></td>
<td>30</td>
<td>31</td>
<td>33</td>
<td>36</td>
<td>40</td>
</tr>
</tbody>
</table>

4.3. Food and feeding habits

4.3.1. Diet composition of juvenile and adults of common carp

Among the 240 adults and 75 juveniles of common carp examined for gut content analysis, 60 (25%) and 4 (5.3%) were found to be completely empty, respectively. On the other hand, the majority, 180 (75%) adults and 71 (94.6%) juveniles gut contained one or more food items (Table 4).
Table 4: List of food items identified from the gut of adult common carp from Lake Ziway

<table>
<thead>
<tr>
<th>Phytoplankton</th>
<th>Chlorophyta</th>
<th>Bacillariophyta</th>
<th>Euglenophyta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanophyta</td>
<td>Botryococcus sp. *</td>
<td>Navicula sp.</td>
<td>Phacus sp.</td>
</tr>
<tr>
<td>Lyngbya sp.</td>
<td>Pediastrum sp.</td>
<td>Fragillaria sp.</td>
<td></td>
</tr>
<tr>
<td>Myrcocystis sp.</td>
<td>Scenedesmus sp.</td>
<td>Cymbella sp.</td>
<td></td>
</tr>
<tr>
<td>Oscillatoria sp. *</td>
<td>Staurastrum sp. *</td>
<td>Synedra sp.</td>
<td></td>
</tr>
<tr>
<td>Chroococcus sp. *</td>
<td>Coelastrum sp. *</td>
<td>Aulacoseira sp.</td>
<td></td>
</tr>
<tr>
<td>Planktoya nya sp.</td>
<td></td>
<td>Nitzschia sp. *</td>
<td></td>
</tr>
<tr>
<td>Cylindrospermopsis sp. *</td>
<td></td>
<td>Diatomasp.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zooplankton</th>
<th>Copepodes</th>
<th>Cladoceran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotifers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filinia sp.</td>
<td>Thermocyclops decipiens</td>
<td>Moina micrura</td>
</tr>
<tr>
<td>Brachionus sp.</td>
<td>Mesocyclops aequatorialis</td>
<td>Ceriodaphnia cornuta</td>
</tr>
<tr>
<td>Trichocerca sp. *</td>
<td></td>
<td>Diaphanosaexcisum</td>
</tr>
<tr>
<td>Anuraeopsis fissa</td>
<td></td>
<td>Alona sp.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Insects</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diptera</td>
<td>Plecoptera*</td>
<td>Trichoptera*</td>
</tr>
<tr>
<td>Ephemeroptera</td>
<td>Coleoptera</td>
<td>Hemiptera</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Macrophytes | Gastropods* | Nematodes |
| Detritus    | Ostracods   | Unidentified animals |
| Fish scale  | Fish egg *  | Plastics * |

* Food items only found in the gut of adult common carp
4.3. 2. Diet Composition of juvenile and adults of Nile tilapia

Among 170 adult and 195 juvenile Nile tilapia examined for stomach content analysis, 55 (26.5%) and 30 (15%) were found to be completely empty, respectively. On the other hand, the majority, 115 (73.5%) adults and 165 (85%) juveniles stomach contained one or more food items (Table 5).

Table 5: List of food items identified from the stomach of juvenile and adult Nile tilapia from Lake Ziway

<table>
<thead>
<tr>
<th>Phytoplankton</th>
<th>Chlorophyta</th>
<th>Bacillariophyta.</th>
<th>Euglenophyta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cyanophyta</strong></td>
<td><strong>Chlorophyta</strong></td>
<td><strong>Bacillariophyta.</strong></td>
<td><strong>Euglenophyta</strong></td>
</tr>
<tr>
<td>Anabaena sp.</td>
<td>Botryococcus sp.</td>
<td>Navicula sp.</td>
<td>Phacus sp.</td>
</tr>
<tr>
<td>Myrcocystis sp.</td>
<td>Oocystis sp.</td>
<td>Fragillaria sp.</td>
<td></td>
</tr>
<tr>
<td>Oscillatoria sp.</td>
<td>Pediastrum sp.</td>
<td>Cymbella sp.</td>
<td></td>
</tr>
<tr>
<td>Chroococcus sp.</td>
<td>Scenedesmus sp.</td>
<td>Synedra sp.</td>
<td></td>
</tr>
<tr>
<td>Planktolyngbya sp.</td>
<td>Staurastrum sp.</td>
<td>Aulacoseira sp.</td>
<td></td>
</tr>
<tr>
<td>Cylindropermopsis sp.</td>
<td>Coelastrum sp.**</td>
<td>Pinnularia sp.</td>
<td></td>
</tr>
<tr>
<td>Merismopedia sp.</td>
<td>Closterium sp.</td>
<td>Nitzschia sp. **</td>
<td></td>
</tr>
<tr>
<td>Anabaenopsis sp.**</td>
<td></td>
<td>Diatoma sp.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zooplankton</th>
<th>Copepodes</th>
<th>Cladoceran</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rotifers</strong></td>
<td><strong>Copepodes</strong></td>
<td>Moina micrura</td>
</tr>
<tr>
<td>Filinia sp.</td>
<td>Thermocyclops decipiens</td>
<td>Ceriodaphnia cornuta*</td>
</tr>
<tr>
<td>Brachionus sp.</td>
<td>Mesocyclopsaequatorialis</td>
<td>Diaphanosomaexcisum</td>
</tr>
<tr>
<td>Keratella sp. *</td>
<td></td>
<td>Alona sp. *</td>
</tr>
<tr>
<td>Trichocerca sp.</td>
<td></td>
<td>Daphnia barbata</td>
</tr>
<tr>
<td>Anuraeopsis fissa</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Insects**                        |                                    |                 |
| Diptera                            | Plecoptera*                        |                 |
| Ephemeroptera                      | Coleoptera                         | Hemiptera*      |
| Others                             |                                    |                 |

| Macrophytes                        | Nematodes                          | Fish scale      |
| Detritus                           | Ostracods*                         | Unidentified animals |

* Food items only found in the stomach of juvenile Nile tilapia from Lake Ziway

** Food items only found in the stomach of adult Nile tilapia
4.4. The relative importance of food items

4.4.1. The relative contribution of food items in the diet of juvenile and adult common carp

Frequency and volumetric contribution of different food items in juveniles and adults of common carp in Lake Ziway is given in Table 6. In juveniles ≤ 10 cm TL, detritus constituted the major portion of the diet and occurred in 89% followed by zooplankton, occurred in 83% and insect, occurred in 73.78%. Volumetrically, constituted by the major maximum part by zooplankton (34.24%) followed by insect (26.34%) and detritus (25.42%) (Table 6). Accordingly, zooplankton, insect and detritus were the most important food items of juvenile common carp in Lake Ziway. Other food items including, macrophytes, phytoplanktons, nematodes, ostracods and unidentified animals made up a relatively lower portion of the diet of juvenile common carp. The former contributed 13.98% of the total volume of food items in the diet of juvenile common carp (Table 6).

In adult (22-55 cm TL) of fishes detritus constituted the largest component of the diet occurring in 93.03% followed by macrophytes, occurring in 87.82% and insect occurred in 76.33%. Volumetrically, detritus made up (31.18%) followed by macrophytes (30.07%) and insects (20%). Accordingly, detritus, macrophytes and insect were the most important food items of adult common carp in Lake Ziway (Table 6). Zooplankton occurred in 51.28% of the stomach and constitutes 6.58% of the total volume of food items in the diet of adult common carp. On the other hand, the contribution of phytoplankton, nematode, ostracods, and unidentified animals was low in the diet of adult common carp (like juvenile common carp) with phytoplankton relatively higher in adult common carp and nematodes, ostracods and unidentified animal fragment relatively higher in juvenile common carp (Table 6).

Even though, only two size classes were considered, there is ontogenetic dietary shift in common carp in which the importance of detritus and macrophytes was higher in adult common carp than juvenile common carp whereas the importance of zooplankton, insects and other animal origin food was higher in juvenile common carp than adult common carp. Schoener Index value also indicates that there was a high variation in the diet of juvenile and adult of common carp (a=0.52) (Table 8) in Lake Ziway.
Table 6: Frequency of occurrence and volumetric contributions of different food items consumed by juvenile and adult common carp (n=315) from Lake Ziway. Note that the volume of the major food categories in bold adds up to 100%.

<table>
<thead>
<tr>
<th>Food items</th>
<th>Juvenile</th>
<th></th>
<th>Adult</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency of occurrence (%)</td>
<td>Volumetric contribution (%)</td>
<td>Frequency of occurrence (%)</td>
<td>Volumetric contribution (%)</td>
</tr>
<tr>
<td>Phytoplankton</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue green algae</td>
<td>11</td>
<td>0.52</td>
<td>35.26</td>
<td>2.04</td>
</tr>
<tr>
<td>Green algae</td>
<td>10</td>
<td>0.23</td>
<td>25.77</td>
<td>0.95</td>
</tr>
<tr>
<td>Diatoms</td>
<td>20</td>
<td>2.58</td>
<td>42.31</td>
<td>2.11</td>
</tr>
<tr>
<td>Euglena</td>
<td>3</td>
<td>0.02</td>
<td>3.85</td>
<td>0.08</td>
</tr>
<tr>
<td>Zooplankton</td>
<td>83</td>
<td>34.24</td>
<td>51.28</td>
<td>6.58</td>
</tr>
<tr>
<td>Rotifers</td>
<td>20</td>
<td>1.68</td>
<td>42.05</td>
<td>0.74</td>
</tr>
<tr>
<td>Copepodes</td>
<td>81</td>
<td>27.41</td>
<td>47.44</td>
<td>3.41</td>
</tr>
<tr>
<td>Cladocerans</td>
<td>44</td>
<td>5.15</td>
<td>37.18</td>
<td>2.43</td>
</tr>
<tr>
<td>Insect</td>
<td>73.78</td>
<td>26.34</td>
<td>76.33</td>
<td>20</td>
</tr>
<tr>
<td>Diptera</td>
<td>72</td>
<td>19.97</td>
<td>68.59</td>
<td>11.95</td>
</tr>
<tr>
<td>Ephemeroptera</td>
<td>14</td>
<td>1.9</td>
<td>17.95</td>
<td>1.67</td>
</tr>
<tr>
<td>Trichoptera</td>
<td>-</td>
<td>-</td>
<td>12.95</td>
<td>0.96</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>16</td>
<td>1.79</td>
<td>16.67</td>
<td>1.69</td>
</tr>
<tr>
<td>Plecoptera</td>
<td>-</td>
<td>-</td>
<td>12.82</td>
<td>1.19</td>
</tr>
<tr>
<td>Coleoptera</td>
<td>22</td>
<td>2.68</td>
<td>21.15</td>
<td>2.54</td>
</tr>
<tr>
<td>Ostracods</td>
<td>23</td>
<td>3.49</td>
<td>25.79</td>
<td>3</td>
</tr>
<tr>
<td>Gastropods</td>
<td>-</td>
<td>-</td>
<td>29.87</td>
<td>2.41</td>
</tr>
<tr>
<td>Nematodes</td>
<td>17</td>
<td>3.88</td>
<td>5.77</td>
<td>0.57</td>
</tr>
<tr>
<td>unidentified animal fragments</td>
<td>13</td>
<td>1.16</td>
<td>14.1</td>
<td>1.01</td>
</tr>
<tr>
<td>Macrophytes</td>
<td>23</td>
<td>2.12</td>
<td>87.82</td>
<td>30.07</td>
</tr>
<tr>
<td>Detritus</td>
<td>89</td>
<td>25.42</td>
<td>93.03</td>
<td>31.18</td>
</tr>
</tbody>
</table>
4.4.2. The relative contribution of food items in the diet of juvenile and adult Nile tilapia

Frequency and volumetric contribution of different food items in juveniles and adults of Nile tilapia in Lake Ziway is given in Table 7. In juveniles < 10 cm TL, phytoplankton constituted the largest component of the diet occurring in 85.29% followed by zooplankton, occurring in 83.53% and, detritus occurring in 72.65%. Insects contributed moderately and they occurred in 66.80% of the stomach content. Volumetrically, the major portion food items constituted by zooplankton 33.79% followed by phytoplankton (25.44%), insect (18.69%) and detritus (14.02%) (Table 7). Accordingly, zooplankton, phytoplankton, insect and detritus were the most important food items of juvenile Nile tilapia in Lake Ziway. Other than the four major food items, macrophytes, nematodes, ostracods and unidentified animals made up a relatively lower portion of the diet of juvenile Nile tilapia. The former contributed 8% of the total volume of food items (Table 7).

In adults (11-30 cm TL), phytoplankton constituted the largest component of the diet occurring in 89% followed by detritus, occurring in 82% and, macrophytes occurred in 79%. Volumetrically, macrophytes were dominant making up 36.2% followed by phytoplankton (34.36%) and detritus (18.55%) (Table 7). Accordingly, macrophytes, phytoplankton and detritus were the most important food items of adult Nile tilapia in Lake Ziway. Insects occurred in 24% of the stomach and constituted 2.28% of the total volume of food items in the diet of adult Nile tilapia. In addition food items such as nematodes, ostracods and unidentified animals made up a minor portion of the diet of adult Nile tilapia like that of juvenile Nile tilapia with relatively higher in juvenile Nile tilapia (Table 7).

Ontogenetic dietary shift was observed in the diet of Nile tilapia. The importance of phytoplankton, macrophytes and detritus was higher in adult Nile tilapia than in juvenile Nile tilapia whereas the importance of zooplankton, insects, and other animal origin food was higher in juvenile Nile tilapia than in adult Nile tilapia. Schoener Index value also indicate that there was a high variation in the diet of juvenile and adult Nile tilapia ($\alpha=0.52$) (Table 8) in Lake Ziway.
Table 7: Frequency of occurrence and volumetric contributions of different food items consumed by juvenile and adult Nile tilapia (n=365) from Lake Ziway. Note that the volume of the major food categories in bold adds up to 100%.

<table>
<thead>
<tr>
<th>Food items</th>
<th>Juvenile</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency of occurrence (%)</td>
<td>Volumetric contribution (%)</td>
</tr>
<tr>
<td>Phyttoplankton</td>
<td>85.29</td>
<td>25.44</td>
</tr>
<tr>
<td>Blue green algae</td>
<td>55.1</td>
<td>5.79</td>
</tr>
<tr>
<td>Green algae</td>
<td>48.35</td>
<td>3.45</td>
</tr>
<tr>
<td>Diatoms</td>
<td>72.75</td>
<td>15.39</td>
</tr>
<tr>
<td>Euglena</td>
<td>4.8</td>
<td>0.81</td>
</tr>
<tr>
<td>Zooplankton</td>
<td>83.53</td>
<td>33.79</td>
</tr>
<tr>
<td>Rotifers</td>
<td>60.78</td>
<td>3.28</td>
</tr>
<tr>
<td>Copepodes</td>
<td>79.41</td>
<td>22.29</td>
</tr>
<tr>
<td>Cladocerans</td>
<td>54.9</td>
<td>8.22</td>
</tr>
<tr>
<td>Insect</td>
<td>66.8</td>
<td>18.69</td>
</tr>
<tr>
<td>Diptera</td>
<td>61.67</td>
<td>12.68</td>
</tr>
<tr>
<td>Ephemeroptera</td>
<td>34.9</td>
<td>1.68</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>20.59</td>
<td>1.08</td>
</tr>
<tr>
<td>Plecoptera</td>
<td>16.67</td>
<td>1.09</td>
</tr>
<tr>
<td>Coleoptera</td>
<td>38.63</td>
<td>2.24</td>
</tr>
<tr>
<td>Ostracods</td>
<td>9.8</td>
<td>1.79</td>
</tr>
<tr>
<td>Nematodes</td>
<td>19.61</td>
<td>3.64</td>
</tr>
<tr>
<td>unidentified animal fragments</td>
<td>11.76</td>
<td>1.57</td>
</tr>
<tr>
<td>Macrophytes</td>
<td>32.35</td>
<td>1.06</td>
</tr>
<tr>
<td>Detritus</td>
<td>72.65</td>
<td>14.02</td>
</tr>
</tbody>
</table>
4.5. Temporal variation in feeding habit of the fish

4.5.1. Temporal variation in the diet of juvenile and adult common carp

There was notable variation in the proportions of food items consumed by common carp in Lake Ziway between months as shown in both frequency of occurrence and volumetric methods. The volumetric contribution of detritus was high in August (48.86%) and low in May (19.12%) (Fig. 2). However, variation in frequency of occurrence was very low among months which ranged from 90.9% in August to 96.2% in June. Conversely, the contribution of insects was high in May occurring in 83.8% and constituting 25.21% of the total volume of food items and low in August occurring in 74.57% and constituting 13.1% of the total volume of the food bulk.

The contribution of macrophytes was also comparable among months and their volumetric contribution ranged from 26.62% in May to 32.15% in June (Fig. 4). The contributions of phytoplankton was relatively high from April to May occurring in 45.45%-53.57% and comprising 8.81%-12.68% total volume of food items and low from July to August occurring in 32.42% to 29.39% and comprising 2.13% to 2% of total volume of food items, respectively (Fig. 2).

The contribution of zooplankton was also relatively high in May occurring in 57.6% and constituting 11.56% of total volume of food items and low in August occurring in 39.39% of the stomach and constituting 2.1% of the total volume of food items (Fig. 2). The highest percentage (4.08%) of ostracods were observed in June and the lowest percentage (2.04%) in August. The highest percentage (4.07%) of gastropods were observed in May and the lowest percentage (2.2%) in August. The highest percentage (2.12%) of unidentified animals were observed in April and the lowest percentage (1.01%) in August.

In case of juvenile common carp, the contribution of zooplankton was high in the two months (July and August) with relatively higher in July than in August. The contribution of phytoplankton, insects and ostracods decreased from July to August. While, the contribution of nematodes, detritus and macrophytes increased from July to August (Fig. 2).
Figure 2: Monthly variation in the diet of juvenile and adult common carp in Lake Ziway from April-August 2017 (a) Juvenile common carp and (b) adult common carp (Where: PHY=phytoplankton, ZPK=zooplankton, INS=insects, OST=stracoda, GAS=gastropods, NEM=nematode, UNIA= unidentified animal, MAC=macrophytes and DET=detritus).
4.5.2. Temporal variation in the diet of juvenile and adults of Nile tilapia

The result clearly shows temporal variation in the diet of adult Nile tilapia. The contribution of phytoplankton was high from April to May occurring in 91.67% to 92.86% of the total stomach and constituted 49% to 51% of the total volume of food items and low from June to August occurring from 85.71% to 54.28% and constituting 32.51% to 12.22% of the total volume of food items (Fig. 3). Conversely, the volumetric contribution of detritus was high in August (30%) and low in May (13%) (Fig. 3). The contribution of macrophytes was low in May occurring in 61.16% of the total stomach and constituting 23.4% of total volume of the stomach and high in August occurring in 89% of the total stomachs and constituting 52.81% of the total volume of the stomachs (Fig. 3). The contribution of zooplankton was comparable among months. However, their volumetric contribution was relatively high in May (9.13%) and low in August (2.69%). The volumetric contribution of insects were also relatively high in July (3.17%) and very low in May (0.95%) (Fig. 3). The relatively highest percentage (2.12%) of nematodes was observed in August and the lowest percentage in April (1.01%).

Similar to adult Nile tilapia, juvenile Nile tilapia mainly feed on phytoplankton from April to May occurring in 84.57% to 88% of the stomach and comprising 35.72% to 37.04% of the total volume of food items, while decreased from June to August occurring in 63.16% to 41% and comprising 23.94% to 11.97% of the total volume of food items, respectively (Fig. 3). The contribution of zooplankton was comparable among months and their volumetric contribution ranged from 33% in May to 38.43% in July (Fig.3). Among zooplankton groups, copepods were the most important food items in all months and their contribution was relatively high in July (26.49%) and August (27.84%) and low in April (19.46%) and May (18.41%). The contribution of insect was comparable among months and its contribution was high in June (20.27%) and relatively low in August (16.96%). In contrast, the contribution of nematode was low (2.6%) in May and high (5.4%) in August (Fig. 3). The contribution of detritus was relatively high in August and low in May (Fig. 3). The highest percentage (3.6%) of ostracods was observed in April and the lowest percentage (0.7%) in August. The highest (1.8%) of unidentified animals was observed in April and the lowest (1.2%) in August (Fig. 3).
Figure 3: Monthly variation in the diet of juvenile and adult Nile tilapia from Lake Ziway from April-August 2017 (a) Juvenile Nile tilapia and (b) adult Nile tilapia (The abbreviation of food items are described in figure 2)

4.7. Dietary overlap between common carp and Nile tilapia in both juvenile and adult stages

The food items utilized by both species varied in their contribution to the diet. However, Schoener Overlap Index values shows the presence of significant dietary overlap between adults ($\alpha=0.63$) and juveniles ($\alpha=0.84$) of common carp and Nile tilapia in Lake Ziway (Table 8).
Dietary overlap between common carp and Nile tilapia from Lake Ziway also shows some temporal variations as indicated by Schoener Index values (Table 8). Diets of adult common carp overlapped significantly with a diet of adult Nile tilapia in four of five sampling months (April (α=0.6), June (α=0.61), July (α =0.64) and August (α=0.66)). While there was no significant dietary overlap between the two species in May (α =0.58) (Table 8). In case of juveniles, high dietary overlap occurred in both months with relatively higher in August (α =0.85) than July (α=0.82).

Table 8: Summary of Schoener Index values between common carp and Nile tilapia from Lake Ziway

<table>
<thead>
<tr>
<th>Sample months</th>
<th>Schoener Overlap Index values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JON &amp; ACC</td>
</tr>
<tr>
<td>April</td>
<td>0.51</td>
</tr>
<tr>
<td>May</td>
<td>0.5</td>
</tr>
<tr>
<td>June</td>
<td>0.48</td>
</tr>
<tr>
<td>July</td>
<td>0.52</td>
</tr>
<tr>
<td>August</td>
<td>0.51</td>
</tr>
<tr>
<td>Overall</td>
<td>0.51</td>
</tr>
</tbody>
</table>

(Where: JCC=Juvenile common carp, ACC=adult common carp, JON= Juvenile Nile tilapia and AON= Adult Nile tilapia). Bolds indicates significant dietary overlap)

4.3. Length-Weight relationship

The total length of the fish ranged from 5.2 to 55 cm for common carp and 2.5 to 30 cm for Nile tilapia. The corresponding total weight ranged from 4.6 to 1610.2 grams for common carp, and from 0.5 to 459.7 gram for Nile tilapia.

Length-weight relationship of common carp was expressed by the following equations:

\[ W = aL^b \]

**Juveniles**  \( TW=0.025TL^{2.707}, R^2=0.910, n=75 \) (Fig.4a)

**Adults**  \( TW=0.0179TL^{2.909}, R^2=0.962, n=240 \) (Fig. 4b)

The relationship between total length and total weight of common carp was curvilinear with a strong relationship for both juveniles and adults. The adult common carp had an isometric growth whereas; the growth of juvenile common carp was nearly allometric.
Length-Weight relationship of Nile tilapia was curvilinear and the relationships were expressed by the following equations: $W = aL^b$

- **Juveniles**
  $$TW=0.043TL^{2.523}, \ R^2=0.948, \ n=195 \ (\text{Fig. 5a})$$

- **Adults**
  $$TW=0.0238TL^{2.908}, \ R^2=0.979, \ n=170 \ (\text{Fig. 5b})$$

The adult Nile tilapia had an isometric growth whereas; the growth of juvenile Nile tilapia was nearly allometric (Fig. 5).

**Figure 4:** Length-weight relationship of common carp from Lake Ziway (a, juveniles and b, adults)

**Figure 5:** Length-weight relationship of juvenile and adult Nile tilapia from Lake Ziway (a, juveniles and b, adults)
5. Discussions

5.1. Physico-chemical parameters

The physico-chemical parameters of the lake’s water were markedly differing between the three sampling stations (Table 2). Site 1 (Wafeko) was characterized by having higher DO, temperature and TP. Site 2 (Bochessa) was characterized by having low level of nitrate, SRP and TP (Table 2). Site 3 (Abiye) was again characterized by having lower dissolved oxygen, and higher turbidity, nitrate, SRP, TDS and conductivity. The high level of nutrients (nitrate, SRP and TP) at Abiye site might be associated with the farm lands located near the shore of the lake where use of fertilizers which are rich in nutrients, especially phosphates and nitrates (Personal observation) are common. Conversely, the low concentration of nutrients at Bochessa site might be related with the location of the site. Bochessa site is located at the outlet of the lake. The concentration of nutrients was low at this site as nutrients could have been used by phytoplankton and large aquatic plants in the system, and some were also retained in sediments similar interpretation was also made by other investigator (Dessie Tibebe, 2017).

The value of DO in the present study is higher than previously reported for the same lake, which was 3.4-5 and 5 mgL$^{-1}$ by Lemma Abera (2016) and Dessie Tibebe (2017), respectively. Similarly, the value of temperature in present study is higher than the value ($23^\circ$C) reported by Lemma Abera (2016). The high value of oxygen and temperature in the present study might be associated with sampling time of the study in the study period. During the study period, physico-chemical parameters were taken in the afternoon by considering higher temperature in afternoon could make the juvenile fish active that can increase the chance of collecting enough sample size of juvenile fishes. This sampling time might also be the reason for high DO value as the production of oxygen is higher when photosynthetic activity is high in the presence of enough sunlight.

On the other hand, the result obtained for pH in this study was comparable with the values (8.1 and 8-8.4) reported by Dessie Tibebe (2017) and Lemma Abera (2016), respectively, and the pH values of the lake water in the sampling sites is suitable for normal biological activity as it was found within the range of 6.5-8.5 that is set by the European Economic Community (1980). Conductivity is generally a very good predictor of both total cat ions and salinity in Ethiopian
water bodies (Zinabu Gebre Mariam et al., 2002). The result obtained for conductivity in this study was lower than the values (410 μScm⁻¹ and 361.5 to 484.5 μScm⁻¹, respectively) reported by Girum Tamire and Seyoum Mengistou (2012), and Lemma Abera (2016). The low value of conductivity in the present study might be associated with sampling time of the study period. Most of the sampling months in the present study are wet months, and conductivity measurements of the lakes were also expected to be lower during the wet months due to dilution from precipitation and less evaporation during the mostly cooler days (Zinabu Gebre Mariam et al., 2002).

The overall mean value of nitrate and soluble reactive phosphate in the present study were 0.045 mgL⁻¹ and 0.05 mgL⁻¹, respectively. The concentration of SRP in the present study was higher than the value (0.029 mgL⁻¹) reported by Girum Tamire and Seyoum Mengistou (2012) and slightly less than the value (0.06 mgL⁻¹) reported by Dessie Tibebe (2017). Likewise, the concentration of nitrate in the present study was less than the value (0.06 mgL⁻¹ and 0.21mgL⁻¹, respectively) reported by Girum Tamire and Seyoum Mengistou (2012) and Dessie Tibebe (2016). Low concentration of SRP and nitrate in the present study might be due to differences in sampling sites. Inlet Rivers of the lake (Meki and Katar) and floriculture farm where higher nitrate and SRP concentration were expected was not included in the present sampling sites. This may be one of the reasons for low concentration of nitrate and SRP in the present study than the recent studies reported by Dessie Tibebe (2017) and Lemma Abera (2016).

5.2. Abundance of juveniles of common carp and Nile tilapia

During the present study, juveniles of Nile tilapia were found distributed in all the three sampling sites while common carp was found in one of the three sites (Abiye) and almost absent in the other two sites (Wafeko and Bochessa). Differences in bottom substrate and macrophyte coverage, and the significant difference in physico-chemical parameters among the sites might have an impact on the distribution and abundance of fish species especially on the juvenile one. The low occurrence of common carp juvenile in the latter two sites might be associated with differences in macrophyte coverage and the type of bottom substrate. The high macrophyte coverage and muddy substrate (Personal observation) at Abiye site might contribute to the presence of common carp at Abiye site. McCrimmon (1968) also reported that carps prefer well-vegetated waters with a muddy or silt substrate. This may be one of the reasons for low catches.
of juvenile common carp at selected sites in Lake Ziway. Because, substrate of all sampling sites were not muddy, and even the muddy substrate with macrophyte belt is difficult for dragging nets. Sampling months might also be one of the reasons for the differences in catch of juvenile common carp as the catches of juvenile common carp was relatively higher in July and August months than other three sampling months. Because, flooding during July and August may accumulate mud which is suitable for dwelling of juvenile common carp in shallow habitat of the lake. The other reason might be the significantly different physicochemical parameters of the lake at different sites. For example, the high concentration of nutrients (nitrate and TP) and turbidity at Abiye site than other two sites might have contributed to the presence of common carp at Abiye site. Lemma Abera (2016) have reported that high concentration of nutrients create conducive environment for the common carp in Lake Ziway.

5.4. Food and feeding habit

5.4.1. Feeding habits of juvenile and adult common carp

The food item identified in the present study period from the gut of common carp in Lake Ziway was similar with what has been reported by previous studies in Lake Koka (Kassahun Asaminew, 2005; Elias Dadebo et al. 2015). The present study showed that common carp in Lake Ziway feeds on a variety of food items (macrophytes, detritus, insects, Phytoplankton, zooplankton, nematodes, ostracods, gastropods and unidentified animals) and it can thus be considered as polyphagous. Polyphagy is typical for cyprinid fishes (Cambray, 1983), this have contributed to the highly adaptable nature of common carp in Lake Ziway. Adult common carp was reported to feed on variety of food items including detritus, phytoplankton, macrophytes, ostracods, gastropods, nematodes and benthic aquatic invertebrates (Maitland, 1992; Magalhaes, 1993; Rahman et al., 2006; Saikia and Das, 2008; Elias Dadebo et al., 2015) whereas juveniles are feeding on zooplankton, insect larvae and ostracods (Chakrabarti and Jana, 1991; Adamek et al., 2003; Rahman et al., 2009; Dulic et al., 2011; Manon, 2012). In the present study, eggs of other fishes were identified in the diet of adult common carp from Lake Ziway. This is consistent with the report by Hana and Manal (1988) who reported that eggs of other fish and small fish were found in the gut of common carp. However, unlike the report of Hana and Manal (1988) small fish were not identified in this study. This might be due to the presence of a piscivorous
fish (*C. garpienus*) that largely feeds on Nile tilapia in the lake as reported by Lemma Abera (2016).

The present work confirmed that adult common carp in Lake Ziway consumed large quantities of detritus. Detritus was found to be the most important food item in lakes for which data are available (Chapman and Fernando, 1994; Michel and Oberdorff, 1995; Manon, 2012; Elias Dadebo *et al*., 2015). The presence of high level of detritus in almost all stomachs of common carp in Lake Ziway might indicate a wide adaptability to the habitat in which they live. Because, detritivory feeding habit is a common form of omnivory, since detritus originates differently through the trophic spectrum and does not form one homogeneous food source (Polis and Strong, 1996). The abundance of detritus in the diet of adult common carp might also be associated with its habitat as they are bottom dwellers.

Macrophyte was the second abundant food item in the diet of adult common carp in Lake Ziway. A similar result was also reported by different authors (Rahman *et al*., 2006; Saikia and Das, 2008; Elias Dadebo *et al*., 2015). The high contribution of macrophytes in the diet of adult common carp in the present study might be related with high availability of macrophytes in the lake (Girum Tamire and Seyoum Mengistou, 2012). Studies have also shown that common carp are attracted by more abundant food items in the environment where they live (Mustafizur *et al*., 2010). Common carp might alter its food preference and behavior in response to changing food resources (Adamek *et al*. 2003; Rahman *et al*. 2006). The other reason for higher contribution of detritus and macrophytes in the diet of adult common carp might also be related to their wider mouth gapes and their developed digestive system in terms of having more developed digestive enzymes, coupled with the longer and larger gut length. This makes it possible for the fish to digest more complex food items which cannot be digested at younger ages (Filpos Engdaw *et al*., 2013).

However, the contribution of phytoplankton was found to be low in the diet of adult common carp in the present study. A similar result was also reported by Elias Dadebo *et al*. (2015) in Lake Koka, Ethiopia. However, Karaca (1995) in Ankara reported that the majority of the food found in the digestive tracts was constituted by Chrysophyta with 55.46% followed by benthic organisms with 16.17 % and copepod from zooplankton with 8.49 %. The low contribution of
phytoplankton to the diet of common carp might be due to the low biomass of phytoplankton per square meter in Lake Ziway (Girma Tilahun, 2006; Getachew Beneberu and Seyoum Mengistou, 2009). The other possible reason might be benthic habitat of common carp that might not support the fish to feed on phytoplankton.

The contribution of animal based food items was low when compared with plant based food items like macrophytes in the diet of adult common carp in Lake Ziway. Out of this low contribution of animal based food items (34.48%), 58% was constituted by benthic organisms and 19% was by zooplankton. However, Ali et al. (2010) have reported that out of the animal based organisms that constituted 33.8% of the total food consumed, 56.7% were zooplankton and 43.3 % were benthic organisms. The differences in the volumetric contribution of zooplankton and benthic organisms might be due to the difference in bio volume of zooplankton and benthic organisms in the lakes.

Even though, the contribution of zooplankton to the diet of adult common carp was low in Lake Ziway, major volume of zooplankton was contributed by copepods. On the other hand, the contribution of cladocera and rotifers was very low when compared with copepods. However, Magalhaes (1993) reported that the most important zooplanktonic organisms in the gut contents of common carp were cladocerans (35.7%), copepods (23.8%), rotifers (4.3%) and ostracods (3.8%). The low contribution of cladocera in the diet of adult common carp in Lake Ziway might be due to low abundance and biomass of the cladocera in the lake especially in rainy season (Adamneh Dagne, 2008). On the other hand, the low contribution of rotifers to the diet of adult common carp in Lake Ziway might be due to the relatively smaller size of rotifer as compared to copepods and cladocerans. The law of optimal foraging could explain why the bigger zooplanktons were selected by the fish over the smaller ones based on the net energy gain from the two choices (Zaganini et al., 2012). The other most probable reason to low biomass of rotifers from gut samples of common carp could be rapid digestion of rotifers in the fish gut (Sutela and Huusko, 1997).

On the other hand, foods of animal origin, mainly zooplankton and insect larvae were the most important food items for juvenile common carp in Lake Ziway. Zooplankton contributed the largest proportion of the food items in the diet of juvenile common carp (<10cm TL). This is also comparable with the report by Chakrabarti and Jana (1991); Adamek et al. (2003); Rahman et al.
(2009); Dulic et al. (2011); Manon (2012) who stated that juveniles of common carp mainly feed on zooplankton. Furthermore, Mohammad (2015) has reported that the proportion of zooplankton ingestion decreases with increasing size of common carp. In Lake Koka common carp <20 cm TL mainly fed on insects (49.9%) and declined sharply as the size of the fish increased above 20 cm TL (Elias Dadebo et al., 2015).

The relatively low contribution of insect in the diet of juvenile common carp in the present study than the values reported by Elias Dadebo et al. (2015) might be due to the differences in the fish size of juveniles and habitat of the lake that produce conducive environment for production of insects. The small size of juvenile common carp in the present study than the size of juvenile from Lake Koka might favor juveniles of Lake Ziway in the present study to feed on zooplankton than insects.

The possible reason for juveniles feeding on zooplankton and larval stages of insects is that juvenile fish have higher mass protein demand due to their higher specific growth rate and greater mass specific metabolism, they may not satisfy this demand by consuming a plant-based diet (Benavides et al., 1994). Thus, younger fish tend to feed more on animal based foods and change to more plant based foods as they grow. Small volume of the gut of juveniles might also not support juveniles to feed on big macrophyte and detritus. The other most probable reason why smaller sized fishes consume more zooplankton and insects is due to the animal origin of the food items are easily digested so that zooplankton and insects are most preferable by smaller sized fish. The habitat uses of the juveniles in the shallow littoral areas where these invertebrates are plenty could also be a reason for the high contribution of insects to the diet of juveniles of common carp, because insects use macrophytes as shelter from their predators.

In the present study in Lake Ziway, the contribution of ostracods, nematodes and unidentified animals in the diet of common carp is comparable in the juveniles and adults; yet still, it was a better source for juveniles than the adults. Generally, the contribution of animal sources (zooplankton, insects, nematodes and ostracods) was relatively higher in juveniles while the plant source (macrophytes and phytoplankton) and detritus was higher in the adults. Therefore, slight ontogenetic diet shift was observed in the present study and it demonstrates that at earlier stage, common carp diet depends on zooplankton and insects in a high proportion and nematode

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and ostracods in low proportion. At the adult stage, its diet depended mostly on macrophytes and detritus, which are of plant origin. However, detritus and insects are the intermediate food item for juvenile and adult common carp, respectively.

5.4.2. Feeding habit of juvenile and adults of Nile tilapia

Food items of both plant and animal origin food items were found in the diet of Nile tilapia in Lake Ziway. The food from gut analyses consisted of phytoplankton, zooplankton, macrophytes, detritus, insects, nematodes, ostracods and unidentified animals. The types of food items found in the stomachs of Nile tilapia were quite similar to what has been reported by several authors in different rift valley lakes of Ethiopia. Adult Nile tilapia was reported to feed on variety of food items including phytoplankton, macrophytes, benthic aquatic invertebrates and detritus (Getachew Tefera, 1987; Todurancea et al., 1988; Getachew and Fernando, 1989; Zenebe Tadesse, 1988, 1998, 1999; Yirgaw Teferi et al., 2000; Oso et al., 2006; Alemayehu Negassa and Prabu, 2008; Filipos Engdaw et al., 2013; Yirga Enawgaw and Brook Lemma, 2018) whereas juveniles are generally omnivorous feeding on zooplankton, insect larvae (Zenebe Tadesse, 1988; Filipos Engdaw et al., 2013; Lubaba Mohamed, 2017) and phytoplankton (Witte and Winter, 1995; Alemayehu Negassa and Prabu, 2008).

The present work confirmed that adult Nile tilapia in Lake Ziway consumed large quantities of macrophytes. However, different authors have reported that phytoplankton was found to be the most important food item than macrophytes in lakes for which data are available (Getachew Tefera, 1987; 1993; Zenebe Tadesse, 1988, 1998, 1999; Yirgaw Teferi et al., 2000; Alemayehu Negassa and Prabu, 2008; Mulugeta Wakijira, 2013; Filipos Engdaw et al., 2013; Workye Worie and Abebe Getahun, 2015; Yirga Enawgaw and Brook Lemma, 2018).

The dominance of macrophytes in the diet of adult Nile tilapia over phytoplankton in the present study could be due to declining phytoplankton biomass in Lake Ziway (Girma Tilahun, 2006; Lemma Abera, 2016) and the presence of high load of suspended sediments that is difficult for filter feeding behavior of tilapia (Tadesse Fetahi et al., 2018). Furthermore, most sampling months of the present study were wet months which might provide the chance for high production of macrophytes than phytoplankton. The predominance of macrophytes to a diet of adult Nile tilapia in the present study is also in agreement with the report by Tadesse Fetahi et al. 38
(2018) who reported the high contribution of macrophytes (64%) in the diet of Nile tilapia in the same lake. Furthermore, Rao et al. (2015) have reported the high contribution of macrophytes (54%) in the diet of Nile tilapia in South Lake, China. The occurrences of macrophytes were also found slightly high in the diet of Nile tilapia in other rift valley lakes (Zenebe Tadesse, 1999; Filipos Engedaw et al., 2013; Yirgaw Teferi et al., 2000).

In addition to phytoplankton and macrophytes, detritus were also consumed in large quantities. Zenebe (1999) and Yirgaw Teferi et al. (2000) have reported the importance of detritus in the diet of Nile tilapia in Lake Langeno and Lake Chamo (Ethiopia), respectively. Bowen (1980) has also reported the presence of large quantities of detritus in the diet of Nile tilapia in Lake Valencia (Venezuela). Several authors have also provided similar interpretations about the importance of detritus in different parts of Africa (Getabu, 1993; Shipton et al., 2008; Oso et al., 2006; Flipos Engdaw et al., 2013; Mulugeta Wakijira, 2013). However, the contribution of animal origin (zooplankton and insect) was low to the diet of adult Nile tilapia of Lake Ziway. This is also in line with the study by other authors (Yirgaw Teferi et al., 2000; Alemayehu and Prabu, 2008, Flipos Engdaw et al., 2013).

The reason for taking less zooplankton during adult life might be that the fish changes its mode of feeding by gulping the water within its area. The zooplankton may detect feeding current and swim away to avoid being swallowed by the fish (Flipos Engdaw et al., 2013). The low abundance and biomass of zooplankton, in particular cladocera in the lake (Adamneh Dagne, 2010) might also be the reason for low contribution of zooplankton to the diet of adult Nile tilapia in the present study. Even though, the nutritive quality of foods of animal origin consumed by early stages of the fish was high, the energy demands of growing fish cannot be met by particulate feeding on zooplankton and benthic invertebrates (Flipos Engdaw et al., 2013). That is why adult Nile tilapia mainly feeds on macrophytes and phytoplankton. The other reason for dominance of food items of plant origin (macrophytes and phytoplankton) and detritus in the diet of adult Nile tilapia could be that adult fish have wider mouth gapes and their developed digestive system in terms of having more developed digestive enzymes, coupled with longer and larger gut length. This makes it possible for the fish to digest more complex food items like plant materials which cannot be digested at young ages. Because, their enzymes can break the cell walls of plant materials like macrophytes.
On the other hand, foods items of animal origin, mainly zooplankton, were most important food items of the juvenile Nile tilapia in Lake Ziway. Zooplankton in particular copepods, contributed the largest proportion of the food items in juveniles (<10 cm TL). In Lake Koka Nile tilapia<10 cm TL mainly fed on zooplankton (25%) and insects (30%) and declined sharply as the size of fish increased above 10 cm TL (Flipos Engdaw et al., 2013). Zooplankton were the most important food items for fish less than 5 cm TL and little importance for larger than 10 cm TL of Nile tilapia in Lake Victoria (Njir et al., 2004). Similarly, zooplankton (46%) were the most important food items for fish less than 10 cm TL and little importance for larger than 10 cm TL of Nile tilapia in Lake Tinishu Abaya (Ethiopia) (Yirga Enawgaw and Brook Lemma, 2018). The result of the present study is also in agreement well with Todurancea et al., (1988); Zenebe Tadesse (1988); Abdel-Tewwab and El-Marakby (2000) and Yirgaw Teferi et al. (2000) where the contribution of zooplankton in the smaller size of Nile tilapia is significant.

In addition to zooplankton and insect larvae, juvenile Nile tilapia mainly feeds on phytoplankton particularly diatoms. This is also in agreement with the study by Zenebe Tadesse (1988). The high contribution of diatom in the diet of juvenile Nile tilapia might be associated with small size of diatom when compared with filamentous algae. The type and size of food items consumed changes with age and size of the fish. This is mainly because fish can only feed on food items that can fit into their mouth and what their gut can digest (Otieno et al., 2014).

The possible reason for juveniles feeding on zooplanktons and larval stages of insects over plant materials (macrophytes) and detritus in the present study might be due to the small volume of the stomach that may not support big macrophyte and detritus (Flipos et al., 2013). Benavides et al. (1994) have also hypothesized that since juvenile fish have higher mass protein demand due to their higher specific growth rate and greater mass specific metabolism, they may not satisfy this demand by consuming a plant-based diet. Thus, younger fish tend to feed more on zooplankton and insect larvae (animal based foods) and change to more plant based foods as they grow. Tengjaroenkul et al. (2002) also reported that an ontogenic change in the development of intestinal enzymes in cultured Nile tilapia providing evidence that ontogenetic shift is not just a behavioral phenomenon but is controlled by enzymes in the fish gut. Younger fish may, therefore, be forced to consume animal prey, which has greater content of protein and energy per unit weight compared to a plant-based diet (Outa et al., 2014).
In the present investigation, the contribution of nematodes and unidentified animals in the diet of Nile tilapia is comparable in the juveniles and adults; yet still, it was a better source for juveniles than for the adults. Generally, the contribution of animal sources (zooplankton, insects, nematodes, and ostracods) is relatively high in juveniles while the plant source (phytoplankton and macrophytes) and detritus are high in the adults. Therefore, slight ontogenetic diet shifts was observed in the present study and it demonstrates that at the earlier stage, Nile tilapia is most probably omnivorous; its diet depends on zooplankton, insect and phytoplankton in a high proportion and nematode and ostracods in low proportion. It shifts to herbivores as its size increases. At the adult stage, the diet is dependent mostly on macrophytes, detritus, and phytoplankton, which are food items of plant origin.

**5.4.3. Temporal variations in the diet of common carp**

The results of the present study have confirmed that the diets of common carp show some monthly variations. These monthly variations may be attributed to the fact that the fish changes its location in certain periods (Ali et al., 2010) and the changes in the composition of food organisms occurring at different seasons of the year (Bhuiyan et al., 1999).

Based on frequency of occurrence detritus was comparable among months being relatively higher in June. However, its volumetric contribution increased from June to August and low in April and May. The highest volume of detritus in July and August during the present study could be due to the fact that large quantities of plant materials and debris may be carried into the lake by runoff during the rainy months and create a larger load of sediments. The high contribution of detritus in July and August in the present study is also in agreement with the report by Shukla et al. (2013) who stated that the organisms which could not be defined (detritus) were most frequently observed in August in Lake Rewa, India. Similarly, Elias Dadebo et al. (2015) reported that volumetric contribution of detritus was high (48%) in wet months (July and August) and low (36%) in dry months (April and May) in Lake Koka, Ethiopia.

During the present study, the contribution of macrophytes to the diet of common carp was comparable among months. However, Elias Dadebo et al. (2015) reported that the contribution of macrophytes was high (22.6%) during July and August and low (8.3%) during April and May.
in Lake Koka. This difference may be due to the fact that macrophytes grow all year around in Lake Ziway but, only in wet months (June to August) in the case of Lake Koka.

The highest and lowest contributions of insects were recorded during May and August, respectively. Among insect groups, the contribution of EPT taxa (Ephemeroptera, Trichoptera and Plecoptera) and Hemiptera was relatively high in April and May and very low in July and August. However, the contribution of Diptera which is represented by Chironomids which constitutes the bulk of insects (58.2%) was comparable among months. This difference may be due to the impact of fine sediment on insect taxa. EPT taxa are sensitive taxa which may be negatively affected by fine sediment that resulted from the content of runoff during rainy months (July and August). Furthermore, the allochthonous organic matter might have increased the oxygen demand as organic compounds consume high oxygen for oxidation processes and results in low oxygen concentration. However, taxa, such as Chironomidae are tolerant and adapted to take advantage of fine sediment and flourish during sedimentation as they are able to burrow into the sediment for shelter (Harding et al., 2000). The high contribution of insects during May to the diet of common carp in the present study supports the study by (Adamek et al., 2003; Saikia and Das, 2008; Ali et al., 2010) who reported that contribution of insects to the diet of common carp is high in May and low in July. Elias Dadebo et al. (2015) also stated that increased temperature in dry month crate favorable environmental condition for reproductive cycle of insects in tropics. This might be the reason for the high abundance of insect in the diet of common carp in May.

The low contribution of zooplankton to the diet of common carp in July and August might be due to the low abundance and biomass of the zooplankton in the lake in the rainy season (Adamneh Dagne, 2008). Similar results were also reported by different authors in other tropical countries (Ali et al., 2010; Shukla and Patel 2013; Naik et al., 2015). These authors reported that contribution of zooplankton was high in April and May and low in July and August to the diet of common carp.

The contribution of phytoplankton was relatively high during April and May and low in July and August. It is also in line with the report by Elias Dadebo et al. (2015) who reported that the contribution of phytoplankton was relatively higher during dry months than wet months. The
probable reason might be that during July and August, the high flooding from the catchment area may cause fluctuations in water level and increased turbidity of the lake. This decreases the penetration of light in the lake and thereby affecting the growth and abundance of phytoplankton in the water (Getachew Tefera, 1993).

5.4.4. Temporal variations in the feeding habit of juvenile and adults of Nile tilapia

The temporal changes of biotic and abiotic factors alter the structure of the food web along the year and as a consequence, the fish often shows temporal and seasonal diet variation. In the present study, the proportion of phytoplankton was higher from April to May and low from July to August (Fig.5). Among the phytoplankton, blue green algae were dominant in May and April, and diatoms were also dominant from June to August. This is quite similar with the findings of other investigators in the Ethiopian rift valley lakes (Zenebe Tadesse, 1988, 1998; Yirgaw Teferi et al., 2000; Filipos Engdaw et al, 2013) who reported that blue green algae are dominant in dry months and diatoms are dominant in wet months. According to Filipos Engdaw et al. (2015) the contribution of phytoplankton to the diet of Nile tilapia was high (66.1%) in dry month (May) and low (3.51%) in wet month (August). On the contrary, the contribution of macrophyte was high from July to August and low from April to May.

The differences in composition and the varying relative contribution of food items may be due to the difference in micro habitat occupied by the fish. During dry months fish may move to the pelagic region of the lake and feed mainly on suspended phytoplankton because, phytoplankton production may be high due to increased light penetration into the photic zone of the lake (Filipos Engdaw et al., 2013). That is why the contribution of phytoplankton was higher in dry months than in wet months as primary production of Lake Ziway is light limited rather than nutrient (Girma Tilahun, 2006; Tadesse Fetahi, 2018).

On the other hand, during the wet months high flooding from the catchment area may cause fluctuations in water level and increase the turbidity of the lake. This decreases light penetration in the lake, thereby affecting the growth and abundance of phytoplankton in the water (Getachew Tefera, 1993). Since the biomass of phytoplankton in the lake is low in wet months, Nile tilapia
has to rely on any plant material available in the lake that is why macrophytes and detritus constitute the bulk of its diet during July and August. In addition, during wet months fish moves to shallow parts of the lake for reproduction and stays for longer period of time by feeding macrophytes.

In addition to macrophytes, the contribution of detritus to the diet of Nile tilapia was high in July and August. The high contribution of detritus in these wet months could be associated with plant materials coming with flooding during the wet months (Zenebe Tadesse, 1999; Workye Worie and Abebe Getahun, 2015). The contribution of zooplankton to the diet of adult Nile tilapia was low in July and August, and relatively high in April and May and moderate in June (Fig. 7). This is in line with the report by Flipos Engdaw et al (2013) who reported that contribution of zooplankton was higher in a dry month (May) (9.7%) than a wet month (August) (1.2%) in Lake Koka.

In case of juveniles of Nile tilapia, the contribution of zooplankton was high in all months with peak in July and low in May (Fig. 6). The highest proportion of zooplankton during July and August months might be also associated with the low availability of phytoplankton which is the second important food item for juvenile Nile tilapia. In contrast, the contribution of phytoplankton was high in May and low in August (Fig. 6). The reverse is true for the contribution of detritus to the diet of juvenile Nile tilapia in Lake Ziway (Fig. 7). A similar result also reported by Lubaba Mohamed (2017) in the same lake and by Filipos Engdaw (2015) from Lake Koka. However, the contribution of insects to the diet of juvenile Nile tilapia was comparable among months with relatively higher in June.

5.4.5. Feeding overlap between common carp and Nile tilapia

In the present study significant dietary overlap was noted between common carp and Nile tilapia in Lake Ziway with high Schoener Index values of 0.63 and 0.84 for adults and juveniles of the two species, respectively. Maceina and Murphy (1988) considered an index of 0.80 to indicate a high degree of similarity in diet while, Pedersen (1999) interpreted values above 0.74 as indicative of high overlapping. Other considered values above 0.60 biologically significant and indicative of inter-species competition (Zaret and Rand, 1971; Horstkotte and Strecker, 2005).
The result of the present study indicates that the juvenile stages of the two species have no significant differences in feeding ecology over the study period. Indeed, there was a high degree of dietary overlap (0.84), indicating a high level of food similarity. However, the diet overlap between adult common carp and Nile tilapia (α=0.63) was moderate relative to the juveniles though it still demonstrates significant overlap for food. The high fecundity of common carp compared to Nile tilapia in Lake Ziway (Lemma Abera, 2016) might have created intense competition favors juvenile common carp and have pushed the adults to different food preference. Adult common carp mainly fed on detritus and macrophytes followed by insects, while adult Nile tilapia mainly fed on phytoplankton and macrophytes and followed by detritus. Juvenile of the two species, on the other hand have the same food preference and mainly fed on animal origin items such as zooplankton, insects, ostracods and nematodes. This is the reason for higher Schoener Index values that were recorded between juveniles of the two species. However, the preference of juvenile Nile tilapia on phytoplankton than juvenile common carp deviate the value of Schoener Index from complete overlap (α=1).

Dietary overlap between common carp and Nile tilapia from Lake Ziway also shows some temporal variations as indicated by Schoener Index values (Table 7). Diets of common carp overlapped significantly with Nile tilapia diets in four of the five sampling months (April, June, July and August). However, there was no significant overlap between the two species during May. This suggests that the degree of overlap among adults is related to similar temporal shifts in the diet by both species. Nile tilapia mainly feeds on phytoplankton during May while common carp mainly feeds on insects and macrophytes in similar month. But, in the other four months, the contribution of phytoplankton to the diet of adult Nile tilapia has decreased and both species consumed macrophytes and detritus that is why significant overlap was observed during April, June, July and August, but not in May.

The significant dietary overlap that has been observed between common carp and Nile tilapia in the present study might have contributed for the declining of Nile tilapia particularly due to intense competition among the juveniles. The preferred food item of Nile tilapia (phytoplankton) has declined (Girma Tilahun, 2006; Getachew Beneberu and Seyoum Mengistou, 2009) and Nile tilapia shifted to macrophyte which is a major food items of common carp. Diet overlap might
reflect competition under conditions of limited resource availability (Odum, 1971). Indeed the decline of Nile tilapia in Lake Ziway might indicate a great competitive disadvantage for food and space with common carp. Kassahun Asaminew (2005) has also reported that there was a clear food competition between common carp and Nile tilapia in Lake Koka.

When common carp forage with other fish on the same food resources, interspecific competition for food will be intense, and common carp follows the classical optimal foraging theory, whereby it broadens its feeding niche to maximize its food intake (Rahman and Meyer, 2009). Common carp is a very active fish, which grazes during both day and night (Rahman et al., 2008; Rahman and Meyer, 2009) while, Nile tilapia is a diurnal feeder, spending the majority of its grazing and swimming time in the water column during daytime (Yirgaw Teferi et al., 2000). The feeding ability of common carp on day and night time might have given a competitive advantage over Nile tilapia to feed more on the available resource.

According to Rahman et al. (2006) common carp affect diel feeding rhythms of diurnal feeder fish. For example, the presence and density of common carp affect the diel rhythms of roho labeo in polyculture ponds. Oyugi et al. (2011) also reported that food intake of Nile tilapia was reduced (and potentially its growth rates also decreased) at high common carp density. The survival of Nile tilapia in Lake Naivasha face challenges with high populations of the invasive common carp which is a bottom feeder, thus interfering with the breeding grounds of Nile tilapia (a gravel spawner) (Otieno, 2014). Furthermore, Hickley et al. (2008) reported that highly abundant common carp with anthropogenic disturbance of the littoral vegetation, particularly through clearance and burning could have reduced spawning areas of Nile tilapia and resulting to its disappearance in Lake Naivasha, Kenya.

The major reasons put forth by different ecologists for the predominance of common carp over the more prized endemic fish fauna in lakes were food competition due to more or less identical food spectra, higher fecundity, spawning facilities prevailing in the lake, shorter incubation period, better fertilization and better growth rate (Naik et al., 2015). Among these, the diet similarity observed in Lake Ziway could be one of the causes for the decline of Nile tilapia.
5.3. Length-weight relationship

5.3.1. Length-weight relationship of common carp

The length-weight relationship of common carp in the study lake was found to be curvilinear and highly significant. The estimated length weight coefficient (b) value of common carp in the study area is within the range of b values (2-4) in fishes in general (Bagenal and Tesch, 1978) and in tropical fishes (b=2.5-3.5) in particular (Gayannilo and Pauly, 1997). The slope of the regression line (b) was indicating isometric growth pattern of the fish; where its shape and specific gravity do not change as the fish grows in size (Elias Dadebo et al., 2014). It means that growth occurs at the same rate for all parts of the organisms (Flipos Engdaw et al., 2013).

The value of b for adults in the present study is slightly lower than the previous studies. Elias Dadebo et al. (2015) reported that the slope of the line to be 3.018 in Lake Koka (Ethiopia); James et al. (2000) reported length-weight relationship of common carp and found the ‘b’ value to be 3.010 and Daniela et al. (2009) reported the slope of the line to be 3.002 in Brazil. The other study which was different from the present work was done by Moata et al. (2005) in Morocco and reported that the growth pattern of common carp was found to be 3.412, which is considerably positive allometry. However, the value of b in the present study is higher than the value of b (2.3) that was reported by Otieno et al. (2014) from Lake Naivasha, Kenya. Such differences in length-weight relationship coefficient are not unexpected and may result from differences in sampling size, sampling time, food availability and habitats (Froes, 2006). The study by King and Udo (1998) also showed that the functional regression value of ‘b’ represents the body form and is directly related to the weight affected by ecological factors such as temperature, habitat selection as well as sampling vessels.

5.3.2. Length-Weight relationship of juvenile and adult of Nile tilapia

The length-weight relationship of Nile tilapia in the study lake was found to be curvilinear and highly significant (Fig. 4). The "b" value of both adult and juveniles Nile tilapia is found within the range of b values (2-4) in fishes in general (Bagenal and Tesch, 1978) and in tropical fishes (b=2.5-3.5) in particular (Gayannilo and Pauly, 1997).
The value of b for adult Nile tilapia in this study is comparable to the value of b calculated for the same species in Lake Hawassa (b=2.91) (Demeke Admassu, 1990) and Lake Hayq (b=2.95) (Workye Worie and Abebe Getahun, 2014). However, this value is slightly higher than for the same species in Lake Tana (b=2.74) (Zenebe Tadesse, 1997) and lower than in Lake Victoria (b=3.20) (Njiru et al, 2006) and in Lake Turkana (b=3.17) (Stewart, 1988). The value of “b” for juveniles of Nile tilapia in present study was also comparable with the value of b calculated for the same species in the same lake (b=2.53) (Lubaba Mohamed, 2017). However, this value is lower than for the same species and at the same stage in Nigeria (b=3.10) (Olurin, 2006). Froese (2006) and Abari et al. (2015) the variation in the value of ‘b’ happens due to season, habitat, gonad maturity, sex, diet, stomach fullness, health, gear selectivity and differences in environmental conditions. The regression co-efficient value of the present study was also within the expected range of 2-4 appropriate for fresh water fishes (Anani and Nunoo, 2016).
6. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

The length-weight relationship of common carp and Nile tilapia in Lake Ziway was found to be curvilinear. The slope of the regression line for adult common carp and adult Nile tilapia indicated isometric growth pattern of the fish, while allometric growth for juvenile of both species.

Foods of both plant and animal origins were identified in the diets of the two species. Adult common carp mainly fed on detritus and macrophytes followed by insects while juvenile common carp mainly fed on zooplankton, insects and detritus. On the other hand, the contribution of other items like ostracods, nematodes and unidentified animals was low for both juvenile and adult common carp with relatively high in juveniles. Juvenile Nile tilapia mainly feed on zooplankton, phytoplankton, insect and detritus whereas adult Nile tilapia feeds mainly on macrophytes, phytoplankton and detritus. However, the contribution of animal origin items was low in the diet of adult Nile tilapia. Conversely, the contribution of macrophytes was very low in the diet of juvenile Nile tilapia. Slight ontogenetic diet shift was observed in the present study in both species and it demonstrates that juveniles mainly focused on animal based items whereas adults depend on plant items.

The two fish species also show monthly variation in their feeding habits as they mainly feed on detritus and macrophytes in July and August months while the contributions of phytoplankton, zooplankton and insects were high in April and May months in the diet of adults of the two species. However, volumetric contribution of macrophytes was comparable among months in the diet of adult common carp. The contribution of zooplankton and insect was comparable among months in which zooplankton was higher from June to August and insect was higher in April and May in the diet of juvenile Nile tilapia, while the contribution of phytoplankton was higher in April and May and lower from June to August.

Schoener's index value indicates that there was significant dietary overlap between the two species. This might contribute for the reduction in harvest of Nile tilapia in Lake Ziway.
6.2. RECOMMENDATIONS

The following recommendations are forwarded based on the study conducted on feeding habit of common carp and Nile tilapia in Lake Ziway

- The present work was carried out by taking only five months data due to time and budget constraints, therefore further research is recommended to examine the dietary overlap by taking year round data so as to show seasonal variations.

- Spatial variation in feeding habit of common carp and Nile tilapia should be studied.

- In this study it was attempted to generate crucial data on some aspects of feeding biology of common carp and Nile tilapia. Other aspects like fertilization and growth rate should be studied to give us full information on the ecology of both species.

- In this study it was attempted to show that dietary overlap between the two species is one of the factors that possibly contribute to the reduction of Nile tilapia biomass in Lake Ziway. Other aspects like fishing gear selectivity to both species, anthropogenic impact on spawning and nursery ground of the two species and the impact of piscivorous fish (C. garpienus) on Nile tilapia should be studied to give adequate evidence for reduction of Nile tilapia while increasing the abundance of common carp in Lake Ziway.

- Ecological indices should be developed to evaluate the ecological damage caused by exotic fishes in Lake Ziway.

- Economic gain versus ecological damage from the introduction of exotic freshwater fishes of Lake Ziway should be studied.
7. REFERENCES


Tenalem Ayenew (2002). Recent changes in the level of Lake Abijata, central main Ethiopian Rift valley. *Journal of Hydrological Sciences*, **47**: 493-503


