*SINET: Ethiop. J. Sci.*, 43(2):77–87, 2020 ISSN: 0379–2897 (PRINT)

eISSN: 2520–7997

# Food and feeding habits of the juvenile and adult Common carp (*Cyprinus carpio*) in Lake Ziway, Ethiopia

**Abebe Tesfaye [1]*, Abebe Getahun[2] and Tadesse Fetahi[2]**

[1]Ethiopian Environment and Forest Research Institute, Bahir Dar Environment and Forest Research Center, PO. Box, 2128, Bahir Dar, Ethiopia. E-mail: abebetesfaye07@gmail.com
[2]Departments of Zoological Sciences, College of Natural and Computational Science, Addis Ababa University, PO. Box, 1176, Addis Ababa, Ethiopia

**ABSTRACT:** *Cyprinus carpio* (common carp) is one of the most commercially important fish species in Lake Ziway. Even though the species is economically important, there is no data on the feeding ecology of the fish for the lake. The present study aims to investigate the food and feeding habits of the juvenile and adult common carp collected for five sampling months from April to August 2017.The juveniles were collected using a beach seine net and the adult fishes were purchased from catches of the fisher men. A total of 315 common carp (75 juveniles and 240 adults) specimens ranging from 5.2 to 55 cm were examined that have a total weight (TW) from 4.6 to 1610.2 g, respectively. Among the total number of juvenile and adult common carp, 71 (94.5%) and 180 (75%) fish samples had food content in their guts, respectively, which were analyzed using the frequency of occurrence and volumetric analysis methods. Volumetrically, the major food items found in the juvenile guts were zooplankton (34.2%), insects (26.3%), and detritus (25.8%) while adults fed on detritus (31.4%), macrophytes (30%) and insects (20%). Juveniles fed largely on animal origin food items whereas plant origin was more important for adults. However, both juveniles and adults were omnivores feeding on plant and animal origins. Schoener's Overlap index revealed the absence of significant dietary overlap between juveniles and adults corroborating ontogenetic dietary shift of the common carp. The study provides an insight on the diet of common carp which is a vital input in developing sustainable management strategy options in the multispecies fishery and provides data for diet formulation for aquaculture.

**Key words/phrases: Diet composition, ecology, Ontogenetic dietary shift, tropical ecosystem**

## INTRODUCTION

Fishes are key elements in many natural food webs and 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 (Afrah, 2013; Rishikanta *et al*., 2015). Aiming at increasing the fish production of water bodies, introductions of exotic freshwater fishes like common carp have been made to several man-made and natural water bodies in Ethiopia (Kassahun Asaminew *et al*., 2011).

Common carp is native to Eastern Europe and Central Asia and has been widely introduced throughout the world (Froese, 2002). It is probably the first fish species whose distribution was widely extended by the human introduction (Balon, 1995) and accounts for the world's highest farm fish production (Abdelhamid *et al*., 2017). The fish was introduced to Ethiopia in 1936 for aquaculture purposes (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). It was introduced into Lake Ziway in the late 1980s by the Ministry of Agriculture to increase fish production (FAO, 1997). A recent study has shown the contribution of the fish to the total annual catch of the lake has increased dramatically from zero (0%) before 2012 to 25% in 2014 (Lemma Abera, 2016). At present common carp constitutes the second most important commercial fishery in the lake next to Nile tilapia.

Various investigators have studied the food and feeding habits of common carp in its area of native distribution (Magalhaes, 1993; Adamek and Sukop, 2003; Rahman et al., 2006; Saikia and Das, 2008; Ali *et al*., 2010; Mustafizur *et al*., 2010). According to Ali *et al*. (2010), its diet composition may vary within a wide range of seasonal and spatial conditions of the environment, and

*Author to whom correspondence should be addressed.

depending on the size of the fish. Adult common carp was reported to feed on a variety of food items including detritus, phytoplankton, macrophytes, ostracods, gastropods, 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 (Adamek *et al*., 2003; Rahman *et al*., 2009; Dulic *et al*., 2011; Elias Dadebo *et al.,* 2015).

Even though common carp has economic importance and it is an aquaculture candidate fish in Ethiopia, little information is available on its feeding ecology in Lake Koka (Kassahun Assaminew, 2005; Elias Dadebo *et al.,* 2015) and biology in Amerti Reservoir and Lake Ziway (Mathewos Hailu, 2013; Lemma Abera, 2016). However, no published information is available on the feeding habits of the fish for Lake Ziway. Furthermore, the study of the food and feeding habits of a 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) but also the diet of the fish might shift based on the available food (Tadesse Fetahi *et al*. 2016). 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).

Therefore, the present study aimed at studying the feeding habits of juvenile and adult common carp in the lake, and this information is vital to produce baseline data for proper management and utilization of the fish in the future.

## METHODOLOGIES

### *Description of the study area*

Lake Ziway (70 52′ to 80 8′ N latitude and 70 52′ to 380 56′ E longitude) is one of the shallowest 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 km$^2$ (Wood and Talling, 1988). It is located about 160 km south of Addis Ababa. The lake has a maximum depth of 8.9 m and an average depth of 2.5 m (Von Damm and Edmond, 1984). Two main rivers, Meki from the north-west and Katar from the east are flowing into the lake and it has an outflow through Bulbula River, draining into Lake Abijata (Fig.1).

The weather in the lake region is frequently windy to stormy (Schroder, 1984), and characterized by Semi-arid to Sub-humid with mean annual precipitation (650 mm) and temperature (25°C) (Lemma Abera *et al*., 2018). There are two distinct seasons in the Lake Ziway region: the main rainy season ranging from June to September, and the dry season from October to February. Peak rains are exhibited from July to September in which the precipitation curve goes above 1000 mm. Due to the large surface area relative to the shallow depth and highly exposed to wind, slight wind can cause complete mixing of the lake. The lake is highly turbid, with a Secchi depth of less than 19cm due to resuspended sediment particles and algae (Dessie Tibebe, 2017).

In the lake, 122 phytoplankton species were identified (Tsegaye Miheretab, 1988), of which 50 blue-green algae, 41 green algae and 31 were diatoms. The zooplankton community composed of 59 species, dominated by rotifers (49 species), 7 cladoceran and 3 copepod species (Adamneh Dagne, 2010). Fourteen macrophyte species were identified and the macrophyte composition was dominated by *Arundo donax* (Girum Tamire and Seyoum Mengistou, 2013). The invasive water hyacinth (*Eichhornia crassipes)* has also been reported in Lake Ziway (Fishpool and Evans, 2001). Fish communities of the lake comprise *Oreochromis niloticus, Cyprinus carpio, Barbus paludinosus, Carassius carassius, Clarias gariepinus, Garra dembecha, Garra makiensis, Labeobarbus ethiopicus, Labeobarbus intermedius,* and *Tilapia zilli* (Lemma Abera *et al*., 2018).

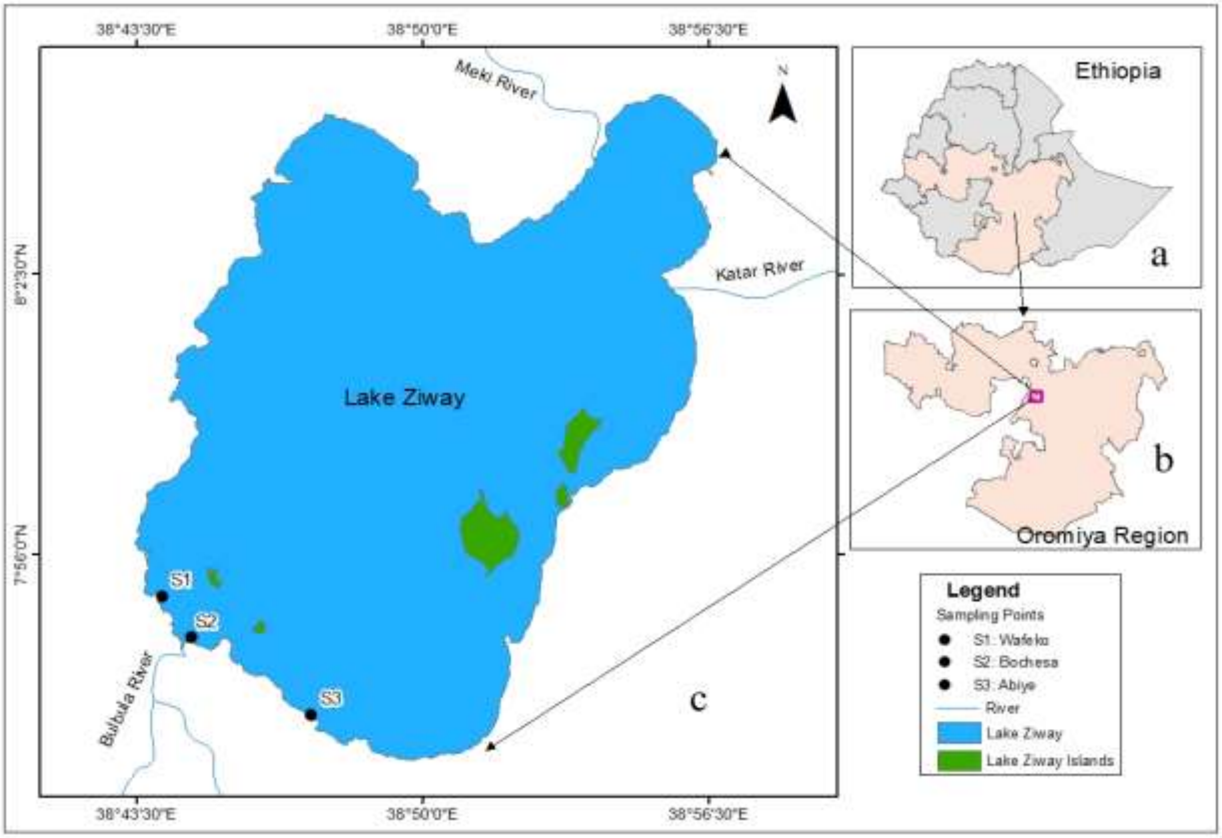


**Figure 1: Map of Ethiopia (a), Oromia region (b) and Lake Ziway with sampling sites (c).**

### *Fish sampling and measurement*

Sample of common carp was collected monthly between April and August using gillnets of different mesh sizes (6cm, 8cm, 10cm, and 12cm stretched mesh sizes) from the selected sites. The gear was set parallel to the shoreline in the afternoon (5:00 pm) and lifted in the following morning (7:00 am). Three sampling sites were selected for sample collection. Sites are located at shore station fringed with macrophyte vegetation and relatively open water station (Fig. 1).To obtain juveniles, a beach seine net (3 cm mesh size) was used. Fish caught by fishermen were also included to obtain a wide range of fish sizes to increase the sample size. Immediately after capture, the total length (TL) and total weight (TW) of each specimen were measured to the nearest value of 0.1 cm and 0.01g, respectively. Each specimen was then dissected and checked if it contained food. If it was empty, this was recorded whereas the gut with contents was preserved with 4% formaldehyde solution. Preserved samples were then transported to Addis Ababa University, Fisheries Laboratory at Department of Zoological Science for further laboratory analysis.

### *Gut content analysis*

The preserved content of each gut was transferred into Petri-dishes. Large food items were identified by eye, whereas smaller-sized food items examined microscopically using a WILD type stereoscope (5X to 50X) and each food item was identified to the lowest possible taxa using descriptions, illustrations, and keys in the literature (Edmondson, 1959; Whitford and Schumacher, 1973; Pennak, 1978; Komarek, 1989). In addition, smaller food items such as phytoplankton were examined at high magnification (100X to 400X) under a compound research microscope. After identification, a list of items found in the gut content was prepared and each item counted whenever appropriate. Counting was performed with the whole gut content for the majority of the sample. In some cases, however, counting was done from a subsample of 10 ml gut contents. All counts converted to number per total volume of gut contents.

***Frequency of Occurrence***

A frequency of occurrence was defined as gut samples contain one or more of a given food item was expressed as a percentage of all non-empty guts examined.

$$\%\mathbf{Fi} = \frac{The\ number of\ stomachs\ in\ which\ a\ given\ food\ item\ is\ found}{Number\ of\ stomachs\ containing\ food} * 100$$

Where %Fi is the frequency of occurrence of given food i

***Volumetric Analysis***

Food items that were found in the guts were grouped into different taxonomic categories and the water displaced by a large group of food items was measured in a partially filled graduated cylinder. The volume of the water displaced by each category of food items was expressed as a percentage of the total volume of the gut contents. In the case of microscopic food items, the estimated average volume of an individual organism was multiplied by the total number of organisms counted in the gut samples.

$$\%\mathbf{Vi} = \frac{Volume\ of\ one\ food\ item\ found\ in\ all\ specimens}{The\ volume\ of\ all\ food\ items\ in\ all\ specimens} * 100$$

Where %Vi is the percentage of food item i

***Estimation of fish size and food habit relationship***

To study whether an ontogenetic shift in the diet of common carp results from each method were plotted against the length of fish. Food items were grouped into major taxonomic groups for this purpose.

***Estimation of feeding periodicity***

The monthly difference in feeding habit of common carp was studied from the frequency of empty gut, and also results from the relative contribution of major items as determined from frequency occurrence and volumetric methods.

***Statistical analysis***

Chi-square test was used to compare the frequency of occurrences of the different food categories during five sampling months (Sokal and Rohlf, 1995). Similarly, the non-parametric Mann-Whitney's U-test was used to compare the volume of the different food categories consumed during five sampling months since the data did not satisfy the assumption of equal variance to employ a parametric test.

Dietary overlap between juveniles and adults was calculated using Schoener Diet Overlap Index (SDOI) (Schoener, 1970; Wallace, 1981):

$$\boldsymbol{a = 1 - 0.5 * (\sum_{i=1}^{n} |pxi - pyi|}$$

Where α is percentage overlap, SDOI, between juveniles and adults $x$ and $y$, $pxi$ and $pyi$ are proportions of food category (type) $i$ used by $x$ and $y$, and $n$ is the total number of food categories. Overlap in the index is generally considered to be biologically significant when α value exceeds 0.60 (Mathur, 1977).

## RESULTS

***Gut contents***

A total of 315 gut sample fish varying in length between 5.2 and 55 cm TL were examined for food composition study. Of these 4 (5.3%) and 60 (25%) fish samples had empty guts in juvenile and adult, respectively. The gut contents were found to be composed of diverse items of both plant and animal origins and detritus and others (Table 1). The plant food was made up of phytoplankton particularly blue-green algae, diatom and green algae. Items of animal origin were diverse and include insects, zooplankton, nematodes, ostracods, and gastropods (Table 1). Besides macrophytes, detritus, and fragments of animal origin were also encountered frequently in the gut content of the fish (Table 1).

***Fish size and the relative contribution of major food items***

The frequency and volumetric contribution of different food items in juvenile and adult common carp is given in Table 1.The size of juvenile and adult stage of common carp in the present study was determined depending on their gonad development. Fishes (≤10cm TL) had a 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 5.2-10cm TL, whereas the adult common carp include all fish whose size >10cm. Organisms that were found relatively more frequently were detritus, insect, macrophyte, and zooplankton (Table 1). In juveniles of ≤ 10 cm TL, the major food items in terms of frequency of occurrence were detritus occurred in 89% followed by zooplankton (83%) and insect (73. 8%). Volumetrically, zooplankton constituted 34.2% followed by insect (26.3%) and detritus (25.4%) (Table 1). Accordingly, zooplankton, insect, and detritus were the most important food items of juvenile common carp in Lake Ziway. Other food items including, macrophytes and phytoplankton make up a relatively lower portion of the diet of juvenile common carp (Table 1). In the adult fish (22-55 cm TL) detritus constituted the largest component of the diet occurring in 93.0% followed by macrophytes (87.8%) and insects (76.3%). In the same manner, detritus constitutes 31.18% of the diet volumetrically followed by macrophytes (30.1%) and insects (20%) (Table 1). Accordingly, detritus, macrophytes, and insects were the most important food items of adult common carp in Lake Ziway (Table 1). Even though the contribution of nematodes, ostracods, and unidentified animals was low in the diet of both juvenile and adult common carp; they are relatively higher in juveniles (Table 1). Adults consumed a relatively high amount of plant materials while juveniles preferred animal origin. Indeed, the Schoener Overlap Index showed no significant diet overlap between juvenile and adult common carp (α=0.5) indicating the presence of ontogenetic dietary shift.

**Table 1: Frequency of occurrence and volumetric contributions of different food items consumed by (n=315) common carp from Lake Ziway.**

| Food items | Juvenile | | Adult | |
|---|---|---|---|---|
| | Frequency of occurrence (%) | Volumetric contribution (%) | Frequency of occurrence (%) | Volumetric contribution (%) |
| **Phytoplankton** | **21** | **3.35** | **45.51** | **5.18** |
| Blue green algae | 11 | 0.52 | 35.26 | 2.04 |
| Green algae | 10 | 0.23 | 25.77 | 0.95 |
| Diatoms | 20 | 2.58 | 42.31 | 2.11 |
| Euglena | 3 | 0.02 | 3.85 | 0.08 |
| **Zooplankton** | **83** | **34.24** | **51.28** | **6.58** |
| Rotifers | 20 | 1.68 | 42.05 | 0.74 |
| Copepods | 81 | 27.41 | 47.44 | 3.41 |
| Cladocerans | 44 | 5.15 | 37.18 | 2. 43 |
| **Insect** | **73.78** | **26.34** | **76.33** | **20** |
| Diptera | 72 | 19.97 | 68.59 | 11.95 |
| Ephemeroptera | 14 | 1.90 | 17.95 | 1.67 |
| Trichoptera | - | - | 12.95 | 0.96 |
| Hemiptera | 16 | 1.79 | 16.67 | 1.69 |
| Plecoptera | - | - | 12.82 | 1.19 |
| Coleoptera | 22 | 2.68 | 21.15 | 2.54 |
| **Ostracods** | **23** | **3.49** | **25.79** | **3** |
| **Gastropods** | - | - | **19.87** | **2.41** |
| **Nematodes** | **27** | **3.88** | **5.77** | **0.57** |
| **unidentified animal fragments** | **13** | **1.16** | **14.1** | **1.31** |
| **Macrophytes** | **23** | **2.12** | **87.82** | **30.07** |
| **Detritus** | **89** | **25.42** | **93.03** | **31.18** |

***Feeding periodicity of the fish***

The frequency of occurrence of the different food items consumed by adult common carp varied significantly ($\chi 2$-test, $p<0.05$) with months (Table 2). In the same manner, the volumetric contributions of the different food items varied significantly (U-test, $p < 0.05$) with sampling months (Table 2). In terms of frequency of occurrence, the contribution of insects was higher in May and April occurring in 90.6% and 92.8% of the guts, respectively. In the same manner, the volumetric contribution of insects was higher in May (25.2%) and April (25.8%) (Table 2). However, the contribution of insects declined in July and August occurring in 61.8% and 60.8% of the guts and constituting 13.1% and 14.2% of the total volume of the food categories, respectively (Table 2).Similarly, the contribution of phytoplankton was relatively high in April and May and low from June to August (Table 2). Conversely, volumetrically the contribution of detritus was low in April and May and high from June to August in the diet of adult common carp (Table 2). The contribution of macrophytes was comparable among months with relatively high in June. On the other hand, there was no significant difference in the contribution of major food items in the diet of juvenile common carp (Table 2).

**Table 2: Monthly variation in the relative contributions of different food items in the diet of common carp (juveniles from July to August) and adults (from April to August) in Lake Ziway.**

| Food items | Adult common carp | | | | | | | | | | Juvenile common carp | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frequency of occurrence (%) | | | | | Volumetric contribution (%) | | | | | Frequency of occurrence (%) | | Volumetric contribution (%) | |
| | April | May | June | July | August | April | May | June | July | August | July | August | July | August |
| Phytoplankton | 45.5$^{a}$ | 53.6$^{a}$ | 42.3$^{ab}$ | 22.4$^{b}$ | 21.4$^{b}$ | 8.8$^{a}$ | 9.0$^{a}$ | 5.7$^{ab}$ | 2.6$^{ab}$ | 2.0$^{b}$ | 26.2$^{a}$ | 19.2$^{a}$ | 3.71$^{a}$ | 3.2$^{a}$ |
| Zooplankton | 57.1$^{a}$ | 60.6$^{a}$ | 55.2$^{a}$ | 45.5$^{a}$ | 39.4$^{a}$ | 10.1$^{a}$ | 11.6$^{a}$ | 7.5$^{ab}$ | 3.2$^{ab}$ | 2.1$^{b}$ | 86.9$^{a}$ | 81.1$^{a}$ | 35.8$^{a}$ | 33.5$^{a}$ |
| Insect | 90.6$^{a}$ | 92.8$^{a}$ | 68.1$^{ab}$ | 61.8$^{b}$ | 60.8$^{b}$ | 25.2$^{a}$ | 25.8$^{a}$ | 19.6$^{ab}$ | 14.1$^{ab}$ | 13.1$^{b}$ | 75.6$^{a}$ | 72.6$^{a}$ | 27.0$^{a}$ | 24.2$^{a}$ |
| Ostracods | 26.9$^{a}$ | 27.3$^{a}$ | 27.6$^{a}$ | 9.1$^{b}$ | 6.1$^{b}$ | 7.1$^{a}$ | 3.9$^{ab}$ | 4.0$^{ab}$ | 1.6$^{ab}$ | 1.0$^{b}$ | 29.2$^{a}$ | 21.1$^{a}$ | 3$^{a}$ | 3.8$^{a}$ |
| Gastropods | 17.9$^{a}$ | 15.2$^{a}$ | 20.7$^{a}$ | 24.2$^{a}$ | 21.2$^{a}$ | 2.3$^{a}$ | 4.8$^{a}$ | 3.9$^{a}$ | 2$^{a}$ | 2.2$^{a}$ | - | - | - | - |
| Nematodes | 3.6$^{a}$ | 6.1$^{a}$ | 3.4$^{a}$ | 6.0$^{a}$ | 9.0$^{a}$ | 0.6$^{a}$ | 0.7$^{a}$ | 0.5$^{a}$ | 0.8$^{a}$ | 0.6$^{a}$ | 22.5$^{a}$ | 29.5$^{a}$ | 3.2$^{a}$ | 4.4$^{a}$ |
| unidentified animals | 17.9$^{a}$ | 18.2$^{a}$ | 13.8$^{a}$ | 12.1$^{a}$ | 9.1$^{a}$ | 1.1$^{a}$ | 1.5$^{a}$ | 1.4$^{a}$ | 1.5$^{a}$ | 0.5$^{a}$ | 18.5$^{a}$ | 12.2$^{a}$ | 1.2$^{a}$ | 1.2$^{a}$ |
| Macrophytes | 82.1$^{a}$ | 75.8$^{a}$ | 89.7$^{a}$ | 93.9$^{a}$ | 97.0$^{a}$ | 25.1$^{a}$ | 23.6$^{a}$ | 31.9$^{a}$ | 30.2$^{a}$ | 29.1$^{a}$ | 25.5$^{a}$ | 22.2$^{a}$ | 2.2$^{a}$ | 2.1$^{a}$ |
| Detritus | 82$^{a}$ | 78.8$^{a}$ | 86.2$^{a}$ | 97.0$^{a}$ | 97.0$^{a}$ | 19.3$^{a}$ | 19.1$^{a}$ | 25.8$^{ab}$ | 44.1$^{b}$ | 48.9$^{b}$ | 86.7$^{a}$ | 92.4$^{a}$ | 23.9$^{a}$ | 27.5$^{a}$ |

***(Note: *Values of respective food categories under the same category given different superscript letters are significantly different (a <0.05).***

## DISCUSSION

Feeding habits of juvenile and adult common carp in Lake Ziway feeds on a variety of food items and it can be considered as polyphagous. It is typical for cyprinid fishes and perhaps the reason for their wide adaptability (Cambray, 1983). The food items identified from the gut of common carp in Lake Ziway were similar to what has been reported by previous studies for Lake Koka (Kassahun Asaminew, 2005; Elias Dadebo *et. al*., 2015). Adult common carp was reported to feed on a 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 on the other hand feed on zooplankton, insect larvae, and ostracods (Adamek *et al*., 2003; Rahman *et al*., 2009; Dulic *et al*., 2011). 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; Elias Dadebo *et al*., 2015). The presence of a high level of detritus in almost all guts of common carp in Lake Ziway might indicate wide adaptability to the habitat in which they live.

Because, a detritivorous feeding habit is a common form of omnivory since detritus originate 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 (Naeem *et al.,* 2016).

Macrophyte was the second abundant food item in the diet of adult common carp in Lake Ziway. A similar result was also reported by various authors (Rahman *et al*., 2006; Saikia and Das, 2008). The high contribution of macrophytes in the diet of adult common carp in the present study might be related to the high availability of macrophytes in the lake (Girum Tamire and Seyoum Mengistou, 2012). The other reason for the higher contribution of macrophytes and detritus in the diet might 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 that otherwise cannot be digested at younger ages (Flipos 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) for nearby Lake Koka. On the contrary, Karaca (1995) reported that the majority of the food found in the digestive tracts of common carp 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 in the present study might be due to the low biomass of phytoplankton in Lake Ziway (Girma Tilahun, 2006; Getachew Beneberu and Seyoum Mengistou, 2009). The other possible reason would be the benthic habitat of common carp that did not support the fish to feed on phytoplankton (Naeem *et al.,* 2016). Unlike plant-based items, the contribution of animal-based food items was low in the diet of adult common carp in Lake Ziway. A similar result was also reported for Lake Koka by Elias Dadebo *et al*. (2015).

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. The high contribution of zooplankton in the diet of juvenile common carp in the present study (<10cm TL) is in agreement with the one reported by Adamek *et al*. (2003); Dulic *et al*. (2011); Rahman *et al*. (2009) who stated that juveniles of common carp mainly feed on zooplankton. Furthermore, Mohammad (2015) has reported that the proportion of zooplankton ingestion decreases with the increasing size of common carp.

Among zooplankton, copepods contribute the largest portion of the diet of juvenile common carp in Lake Ziway. On the other hand, the contribution of cladoceran and rotifers was very low when compared with copepods. The low contribution of cladoceran in the diet of juvenile common carp in Lake Ziway might be due to the low abundance and biomass of the cladoceran in the lake especially in the rainy season (Adamneh Dagne, 2008). On the other hand, the low contribution of rotifers to the diet of juvenile 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 for the low biomass of rotifers from gut samples of common carp could be their rapid digestion (Sutela and Huusko, 1997). 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 the insect in the diet of juvenile common carp in the present study might be due to the differences in the fish size of juveniles. The small size of juvenile common carp in the present study than the size of the juvenile from Lake Koka might favor juveniles of Lake Ziway in the present study to feed on zooplankton than insects. Mohammad (2015) has also reported that the proportion of zooplankton ingestion decreases with the increasing size of common carp. The other possible reason for the differences in the volumetric contribution of zooplankton and insects might be due to the difference in the bio-volume of zooplankton and insects in the lakes.

Next to zooplankton, insects are the main diet of juvenile common carp. However, the contribution of macrophytes and other plant-based items was low to the diet of juvenile common carp. Because, juveniles have a higher mass protein demand due to their higher specific growth rate and greater mass-specific metabolism (Benavides *et al.,* 1994). The other most probable reason why smaller sized fishes consume more zooplankton and insects is due to the animal origin of the food items that are easily digested. A small volume of the gut of juveniles might also not support juveniles to feed on big macrophytes and detritus. Thus, younger fish tend to feed more on animal-based foods and change to more plant-based foods as they grow.

A significant ontogenetic dietary shift was observed during the present study. The most notable change observed was that smaller sized fish (<10cm TL) predominantly fed on foods of animal origin such as zooplankton and insects whereas adults mainly fed on detritus and macrophytes. Different factors may be responsible for the ontogenetic dietary shifts in fish. The different developmental stages of the digestive system and age-specific changes in the use of habitats are some of these factors (McCormick, 1997; Sivadas and Bhaskaran, 2009; Brett, 2002). The preferred habitat of adult common carp is pelagic whereas the preferred habitat for the juvenile common carp is lakeshore (Christopher, 2008). The high contribution of the insect in the diet of the juveniles than adults in the present study might be associated with the habitat uses of the juveniles in the shallow littoral areas where these invertebrates are plenty. Schoener Overlap Index value also indicates that there was a high variation in the diet of juvenile and adult common carp ($\alpha$=0.52). Because, only values of $\alpha$ greater than 0.6 are considered as biologically significant in dietary overlap (Zaret, 1971; Mathur, 1977). Indeed, the result indicates that there was an ontogenetic dietary shift in the diet of common carp. Ontogenetic diet shift has been shown to occur during the life history of many fish species, and prey size is generally positively correlated with fish size (Elias Dadebo *et al*. 2015).

***Feeding periodicity of the fish***

The results of the present study have confirmed that the diets of common carp show 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). The contribution of detritus in the diet of adult common carp was low from April to May (dry months) and high from June to August (rainy months). The highest volume of detritus from June to 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 Elias Dadebo *et al*. (2015) which stated that the 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 adult common carp was comparable among months. However, Elias Dadebo *et al*. (2015) reported that the contribution of macrophytes was high (22.6%) in rainy months and low (8.3%) in dry months in Lake Koka. This difference may be because macrophytes grow all-year-round in Lake Ziway but, only in wet months (June to August) in the case of Lake Koka.

The highest and lowest contributions of insects in the diet of adult common carp 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, constitutes the bulk of insects (58.2%) comparable among months. This difference might be due to the impact of fine sediment on insect taxa. EPT taxa are sensitive taxa that 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 which in turn affects EPT taxa. However, taxa, such as Chironomidae are tolerant and adapted to take advantage of fine sediment and flourish during sedimentation as they can burrow into the sediment for shelter (Harding *et al*., 2000). The high contribution of insects during May to the diet of adult common carp in the present study supports other studies (Adamek *et al*.2003; Saikia and Das 2008; Ali *et al*. 2010) who reported that the 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 months creates a favorable environmental condition for the reproductive cycle of insects in the tropics. This might be the reason for the high abundance of insects in the diet of adult common carp in May. The contribution of phytoplankton was relatively high during April and May and low in July and August in the diet of adult common carp. It is also in line with 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).

## CONCLUSIONS

The present finding showed that common carp is omnivorous fish with diverse food items including macrophytes, phytoplankton, zooplankton, nematodes, ostracods, fish scale, insects, and detritus. Of all items, detritus and macrophytes were the dominant food items consumed by the adult common carp while juveniles mainly fed on zooplankton and insect larvae demonstrating the ontogenetic dietary shift in the species. Diet temporal variation was also observed in the diet of adult common carp in Lake Ziway as the contribution of the insect was higher in April and May and lower in July and August. Conversely, the contribution of detritus was higher in July and August and lower in April and May. The present work was carried out by taking only five months of data due to time and budget constraints, therefore further research is recommended to examine the diet of juvenile and adult common carp with year-round data to show the seasonal variations. In addition to the conventional methods, the food and feeding habit of the fish can also be supplemented with a recent technique – stable isotope analysis.

## ACKNOWLEDGMENTS

The authors would like to thank the Department of Zoological Sciences of Addis Ababa University for assisting us in laboratory facilities, and the Battu Fish and Other Aquatic Life Research Center for providing a beach seine net for sample collection. This work was funded by the Austrian Development Cooperation (ADC).

## REFERENCES

1. Abdelhamid, M. A., Sweilum, A. M., Marwa, M., Zaher, H.M. (2017). Improving Nile tilapia production under different culture systems. *International journal of current research in bioscience and plant biology* **4:**41–56
2. Adamek, Z., Sukop, I., Rendon, P.M., Kouril, J. (2003). Food competition between 2+tench (Tincatinca L.), common carp and bigmouth buffalo in pond polyculture distribution of planktonic rotifers and crustaceans in Lake Ziway (Rift Valley, Ethiopia). *J. Appl. Ichthyol* **19**:165–169.
3. Adamneh Dagne, Alois, H., Christian, D.J., Zenebe Tadesse (2008). Abundance, species composition and spatial distribution of planktonic rotifers and crustaceans in Lake Ziway (Rift Valley, Ethiopia).Internat. Rev. *Hydrobiologia* **93**:210–226.
4. Adeyemi, S.O., Bankole, N.O., Adikwu, I.A, Akombu, P.M. (2009). Food and feeding habit of some commercially important fish species in Gbedikere Lake, Bassa, Nigeria. *Int. J. Lakes and Rivers*. **2**:31–36.
5. Ali, G., Mehmet, Y., Ayse, K., Semra, B. (2010). Feeding properties of common carp (*Cyprinus carpio* L. 1758) living in Hirfanli Dam Lake, Ankara, Turkey. *Aquatic Ecology*.**18**:545–556.
6. Babiker, M.M. and Ibrahim, H. (1979). Studies on the biology of reproduction in the cichlids Tilapia nilotica (L): Gonadal maturation and fecundity. *J. Fish Biol*., **14**:431–448.
7. Balon, E.K. (1995). Origin and domestication of the wild carp from Roman gourmets to the swimming flowers. *Aquaculture*.**129**: 3–48.
8. Benavides, A.G., Cancino, J.M., Ojeda, F.P. (1994).Ontogenetic change in gut dimensions and microalgal digestibility in the marine herbivorous fish, *Aplodactylus punctatus*, *Functional Ecology*.**8**:46–51.
9. Bhuiyan, A.S., Nessa, Q., Hossain, M.D. (1999). Seasonal pattern of feeding of grey mullet, *Mugil cephalous* (L.).Pakistan. *J. Zool*.**31**:295–297.
10. Chapman, G., Fernando, C.H. (1994).The diets and related aspects of feeding of Nile tilapia and

common carp in lowland rice fields in northeast Thailand. *Aquaculture.***123**:281–307.

11. Dessie Tibebe (2017). External and internal agrochemical load, dynamic and impacts on freshwater ecosystem of Lake Ziway, Ethiopia, Ph.D. Thesis, School of graduate studies, Addis Ababa University, Addis Ababa.

12. Dulic, Z., Stankovic, M., Raskovic, B., Spasic, M. (2011). Role and significance of Zooplankton in semi-intensive carp production. In: V International conference "aquaculture and fishery". Z. Markovic (Ed.). University of Belgrade, Faculty of Agriculture, Belgrade, Serbia, 6 pp.

13. Edmondson, W.T. (1959). Fresh-water biology.2nd ed. John Wiley & Sons Inc., NY, 1248p.

14. Elias Dadebo, Alamrew Eyayu, Solomon Sorsa, Girma Tilahun (2015). Food and Feeding Habits of the common carp (*Cyprinus carpio* L. 1758) (Pisces: Cyprinidae) in Lake Koka, Ethiopia, *Momona Ethiopian Journal of Science.***7**:16–31.

15. FAO (Food and Agriculture Organization) (1997). Aquaculture production statistics, 1986-1996. FAO fish.Circ, 815, Rev.9.195pp.

16. Flipos Engdaw, Elias Dadebo, Raja, N. (2013). Morphometric Relationships and Feeding Habits of Nile tilapia, *Oreochromis niloticus* (L.) (Pisces: Cichlidae) From Lake Koka, Ethiopia, *International Journal of Fisheries and Aquatic Sciences.***4**:65–71.

17. Froese, R. (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *J. Appl. Ichthyol.***22**:241–253.

18. Getachew Beneberu and Seyoum Mengistou (2009). Oligotrophication trend in Lake Ziway, Ethiopia. *Ethiop. J. Sci.***32**:141–148.

19. Getachew Tefera (1993). The composition and nutritional status of the diet of *Oreochromis niloticus* in Lake Chamo, Ethiopia. *J. Fish Biol.**42***:865–874.

20. Girma Tilahun (2006). Temporal Dynamics of the Species Composition Abundance and Size-fractionated Biomass and Primary Production of Phytoplankton in lakes Ziway, Hawassa and Chamo, Ethiopia. PhD. Dissertation, Addis Ababa University, Ethiopia.

21. Girum Tamire and Seyoum Mengistou (2012). Macrophyte species composition, distribution and diversity in relation to some physicochemical factors in the littoral zone of Lake Ziway, Ethiopia. *African Journal of Ecology.* **51**: 66–77.

22. Golubtsov, A.S., Darkov, D.A., Dgebuadze, Y.U., Mina, M.U. (1995). An artificial key to fish species of Gambella Region: the White Nile basin in the limits of Ethiopia. Addis Ababa. 84 pp.

23. Harding, J.S., Quinn, J.M., Hickey, W.C. (2000). Effect of mining and production forestry. In: New Zealand stream invertebrates: ecology and implications for management, edited by. Collier J K and Winterbourn J.M. New Zealand Limnological Society Christchurch. 30 pp.

24. Henning, W., Wely, O., Booth, J., Ellender, B. (2008).Understanding the role of carp in South Africa largest impoundment, Rhodes. *Ichthyologia.***24**:117-128.

25. Hyslop, E.J. (1980). Stomach contents analysis: A review of methods and their application. *J. Fish. Biol.***17**: 411–429.

26. Karaca. I. (1995). Hirfanlı Baraj Golii (Kırşehir) "ndeyaşayan Sazanın Büyümeve Beslenme Özellikleri, Gazi Üniv. Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Ankara.

27. Kassahun Asaminew (2005). Distribution, abundance and feeding biology of fish species in Koka reservoir and the associated Awash River floodplain, Ethiopia. MSc thesis, Institute for Water Education, Delft, the Netherlands.

28. Komarek, J. (1989). Modern approach to the classification system of Cyanophytes Nostocales. Arch. *Hydrobiol*. Suppl. 82: 247–345.

29. Lemma Abera (2016). Current status and trends of fishes and fishery of a shallow rift valley Lake, Lake Ziway, Ethiopia. Ph.D. dissertation, Addis Ababa University, Ethiopia.

30. Lemma Abera, Abebe Getahun, and Brook Lemma (2018). Changes in fish diversity and fisheries in Ziway-Shala basin: The case of Lake Ziway, Ethiopia. *International Journal of Advanced Research in Biological Sciences* **5**(2)**:**165–177. 2pp.

31. Magalhaes, M.F. (1993). Feeding of an Iberian stream *Cyprinid* assemblage: seasonality of resources in a highly variable environment.*Oecologia*.**96**:253–260.

32. Maitland, H. (1992). A comparative study of the feeding mechanisms of some African Cyprinidae, Bjdragen *J. Ecol.***33**:12–35.

33. Makin, M., Kingham, A.E., Wadams, C., Birchal, J., Tenalem Teferra (1975). Development Prospects in the Southern Rift Valley, Ethiopia, Land resources study 21, Land Resources Division, Ministry of Overseas Development Survey, England, 270 pp.

34. Mathewos Hailu. (2013). Reproductive aspects of common carp (*Cyprinus carpio* L. 1758) in a tropical reservoir (Amerti: Ethiopia). *Journal of Ecology and the Natural Environment*, **5**: 260–264.

35. Mathur, D. (1977). Food habits and competitive relationships of Bandfin shiner in Halawakee

Creek Alabama. *American Midland Naturalist.* **97**:89–100.

*36.* Michel, P., Oberdorff, T. (1995). Feeding habits of fourteen European freshwater fish species, *Cybium International Journal of Ichthyology.***19**:5–46.

*37.* Mohammad, M.R. **(**2015). Role of common carp (*Cyprinus carpio*) in aquaculture production systems, *Frontiers in Life Science.* **8**:399–410.

*38.* Mustafizur, R., Shusaku, K., Balcombe, S., Abdul, W. (2010). Common carp alters its feeding niche in response to changing food resources: direct observations in simulated ponds. *Journal of Biological Sciences.***22**:405–431.

*39.* Otieno, O., Kitaka, N., Njiru, M. (2014). Some aspects of the feeding ecology of Nile tilapia, *Oreochromis niloticus* in Lake Naivasha, Kenya, *International Journal of Fisheries and Aquatic Studies.***2**:01–08.

*40.* Naeem, M. K., Shahzad, K., Ansar, C., Sohail, M., Piria, M., Treer, T. (2016). A review of introduction of common carp, *Cyprinus carpio* in Pakistan: origin, purpose, impact and management, *Croatian Journal of Fisheries*.74: 71 – 80.

*41.* Pennak, R.W. (1978). Fresh-water invertebrates of the United States.2nd ed. John Wiley & Sons, New York, 803p.

*42.* Polis, G.A. and Strong, D.R. (1996). Food Web Complexity and Community Dynamics, *the American Naturalist.***147**: 813–846.

*43.* Rahman, M.M., Nagelkerke, L.A., Wahab, M.A., Milstein, A., Verreth, J. (2006). Growth, production and food preference of rohu Labeorohita (H.) in monoculture and polyculture with common carp, *Cyprinus carpio* (L. 1758) under fed and non-fed ponds. *Aquaculture.***257**:359–372.

*44.* Rahman, M.M. and Meyer, C.G. (2009). Effects of food type on diel behaviour of common carp, *Cyprinus carpio* L. in simulated aquaculture pond conditions. *J Fish Biol.***74**:2269–2278.

*45.* Redeat Habtesilassie (2012). Fishes of Ethiopia. Annotated Checklist with Pictorial Identification Guide. Addis Ababa, Ethiopia.

*46.* Rishikanta, N., Singh, S., Das, K., Kumar, S., Behera, S., Nagesh, T.S. (2015). Length-weight relationship and condition factor of *Cyprinus carpio* reared in bheries of South 24 Parganas district in West Bengal, *International Journal of Fisheries and Aquatic Studies*. **6**: 239–242.

*47.* Saikia, S.K. and Das, D.N. (2008). Feeding ecology of common carp (*Cyprinus carpio* L. 1758) in a rice–fish culture system of the Apatani Plateau (Arunachal Pradesh, India*). Aquatic. Ecol.***23**:513–524.*48.* Schoener, T.W. (1970). Non-synchronous spatial overlap of lizards in patchy habitats. *Ecology*.**51**:408–418.

*49.* Shalloof, K. and Khalifa, N. (2009). Stomach Contents and Feeding Habits of *Oreochromis niloticus* (L.) From Abu-Zabal Lakes, Egypt. *World Applied Sciences Journal.***6**:01–05.

*50.* Shibru Tedla and Fisha Haile-Meskel (1981). Introduction and transplantation of freshwater fish species in Ethiopia. *Ethiop. J. Sci.***4**:69–72.

*51.* Sokal, R.R and Rohlf, F.J. (1995). Biometry: The principles and practices of statistics in biological research. 3rd edition, Freeman and Company, New York, 859p.

*52.* Sutela, T. and Huusko, A. (1997). Food consumption of vendace Coregonus albula larvae in Lak Lentua, Finland. *J. Fish Biol*.**51**:939–951.

*53.* Tadesse Fetahi, Karl-Otto Rothhaupt, Frank Peteers (2017). Dietary map of Nile tilapia using stable isotopes in three tropical lakes, Ethiopia. Ecology of Freshwater Fish.00:1-11. DOI:10.1111/ eff.12361.

*54.* Troca, A., Lemos, V. M., Junior, V., Vieira, P. (2012). Evidence of reproductive activity of the invasive common carp in a subtropical coastal system in southern Brazil. *BioInvasions Records*. **4**: 289–293.

*55.* Tsegaye Miheretab (1988). A seasonal study on the species composition and phytoplankton biomass in Lake Ziway, Ethiopia. M.Sc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

*56.* Von Damm, K.L. and Edmond, I.M. (1984). Reverse weathering in the closed basin lakes of Ethiopian Rift. SINET: Ethiopian Journal of Sciences. **284**:835–862.

*57.* Wallace, R. K. (1981). An assessment of diet-overlap indexes. *Transactions of American Fisheries Society*, **110**: 72–76.

*58.* Welcome, R. (1988). International introductions of inland aquatic species. *FAO Fish.Tech.Pap.* *285*:237–278.

*59.* Whitford, L.A. and Schumacher, G.J. (1973). A Manual of Freshwater Algae. Sparks Press. Raleigh, N.C. 324 pages.

*60.* Wood, R.B. andTalling, J.F. (1988). Chemical and algal relationships in a salinity series of Ethiopian inland waters. *Hydrobiologia.* **158**:29–67.

*61.* Zaganini, R.L., Vidotto-Magnoni, A.P., Carvalho, E.D. (2012). Ontogenetic diet shifts of *Oreochromis niloticus* and *Tilapia rendalli* of the Barra Bonita reservoir, Brazil. *Biological Sciences.***34**:255–262.

*62.* Zaret, T.M. (1971). Competition in tropical stream fishes: a support for the competitive exclusion principle. *Ecology*.**52**: 336–342.