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Seasonality in the diet composition and ontogenetic dietary shifts of (*Oreochromis Niloticus* L.) (Pisces: Cichlidae) In Lake Tinishu Abaya, Ethiopia

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Abstract
The aim of this work was to investigate seasonal variation in diet composition and, the ontogenetic dietary shift of *O. niloticus* for Lake Tinishu Abaya, Ethiopia. Into the bargain, some of the morpholgical parameters of the study fish was also measured. Fish samples were collected using gill nets of 6 cm, 8 cm, 10 cm, and 12 cm stretched mesh sizes. Beach seine was used to obtain fingerlings in the shallower part of the lake. Samples were collected from March to May (dry season) and July to September (wet season) in 2017. The relative importance of the different food items found in the stomach contents was determined using frequency of occurrence and volumetric method. In the study, a total of 428 fish samples from 2.5 to 30.9 cm in TL and 1.1 to 475 g in TW were used to determine length-weight relationships. The relationship between total length and the total weight of *O. niloticus* was curvilinear with a strong relationship (R^2= 0.9848). The slope of the regression (b) was 2.9876 which was closer to the isometric growth value (b=3) of fish. Among the 428 stomach content used to analyze the diet composition, 55 (12.85%) were completely empty and 373 (87.15%) observed with one or more food items. phytoplankton, detritus, zooplankton, and macrophytes were the most important food items of *O. niloticus* in Lake Tinishu Abaya. Insects, nematodes, ostracods and fish scales made up a minor portion of the diet of *O. niloticus*. There was notable variation in the type of diet and the proportions consumed by *O. niloticus* in Lake Tinishu Abaya during the dry and wet seasons. Phytoplankton was extensively dominated the fish gut during the dry season, while zooplankton, macrophytes, and detritus was high from the total food bulk of the fish in the wet season. Comparing the two seasons, the contribution of Nematodes and Ostracods to the diet of *O. niloticus* was relatively higher during wet season than dry season. The reverse was true for insects and fish scale composition by which its occurrence was higher during the dry season than wet season. Ontogenetic diet shift was evident during the present study by means of the importance of phytoplankton, macrophytes and detritus increased with size whereas the importance of zooplankton, insects and other animal origin food declined with fish size. Ontogenetic diet shifts in the present study demonstrated that at the earlier stage, *O. niloticus* was omnivorous; its diet depends on zooplankton and phytoplankton in a high proportion. It shifts to herbivores as its size increase. At the adult stage, the diet is depended mostly on macrophytes, detritus, and phytoplankton, which are a plant origin of food. Thus, we concluded that the dietary habits of *O. niloticus* in Lake Tinishu Abaya is generally, the omnivorous type.

Keywords: diet compostion, isometric growth, *O. niloticus*, ontogenetic dietary shift, seasonal varation

Introduction

Fish are key elements in many natural food webs and important sources of food for humans and as feeds to other domesticated animals (Afrah, 2013) [4]. They have impacts on the physicochemical properties of the system in which they occur and affect plankton, macrophytes and other aquatic organisms (Wootton, 1990) [61]. They also can serve as environmental indicators (Shibru and Fisseha, 1981; Tesfaye Wudneh, 1998) [53, 58]. Exploitation of the aquatic resource, in particular, the fishery is a well-developed activity in several parts of the world (Kassahun *et al.*, 2011) [37]. In countries like Ethiopia, where there is a shortage of protein, the country should utilize its fishery resources. To fill the gap in food limitations, the aquatic ecosystem can serve as an inexpensive source of fish protein and needs to be fully exploited (Tesfaye, 1998) [58]. Aiming at increasing the productivity of water bodies, the introduction of both exotic and indigenous freshwater fishes have been made to several man-made and natural water bodies in Ethiopia since the 1970's (Kassahun *et al.*, 2011) [37].

In most cases, the Nile tilapia (*Oreochromis niloticus*) has been stocked to several small water bodies because of its adaptability to wide environmental conditions as well as the high demand of the fish by the local consumers (Fryer and Iles, 1972). *O. niloticus* is one of the most known members of the tropical and subtropical freshwater fishes (Demeke, 1998; Yirgaw *et al*., 2000; Elias *et al.*, 2013; Job *et al.*, 2015) [65, 17, 21, 34]. It is widely distributed in tropical and subtropical Africa in the Volta, Gambia, Senegal, Niger Rivers and the Nile River basin and is native to Lakes Chad, Tanganyika, Albert, Edward, and Kivu (Njir *et al.*, 2004; Shipton *et al.*, 2008) [42, 54]. *O. niloticus* is recommended by the FAO (1999) [22] as a culture fish species because of its importance in aquaculture and its capability in contributing to the increased production of animal protein in the world. Therefore, it is now globally distributed and has become very popular through the advances in the cultivation techniques (Teame *et al.*, 2016) [57]. In Ethiopia, it is widely distributed in the lakes, rivers, reservoirs, and swamps which contribute about 60% of total landings of fish (LFDP, 1997; Demeke, 1998, Tesfaye, 1998; Akinuwmi, 2003) [38, 58]. Adult *O. niloticus* have a high degree of plasticity and opportunism in their feeding behavior and are hence classified as omnivorous (Demeke, 1998; Zenebe *et al.*, 1998; Jauncey, 2000; Zenebe, 2010) [33]. They are capable of consuming a wide variety of food items including phytoplankton, zooplankton detritus and macrophytes (Spataru, 1978) [56]. It is reported that *O. niloticus* from Lakes of Hawassa, Ziway and Chamo, Ethiopia, mainly feeds on phytoplankton, macrophytes, and detritus (Getachew, 1993; Yirgaw *et al*., 2000; Alemayhu and Prabu, 2008) [65]. However, food composition differs depending on the season and also lake type (Getachew, 1987b; Getachew and Fernando, 1989; Olurin and Aderibigbe, 2006; Kamal *et al*., 2010) [27].

The study of the food and feeding habits of freshwater fish species is a subject of continuous research because it constitutes the basis for the development of successful fisheries management program on fish capture and culture (Oronsaye and Nakpodia, 2005). Feeding behavior of fish is the major important factor affecting their nutrition and growth (Afrah, 2013) [4]. Food availability determined the well being of fishes, as well as their reproductive potentialities in any aquatic ecological system and the weight and size of fish, is a reflection of food availability in the aquatic ecosystem (Elias *et al*. 2014) [18, 19]. Quantitative determination of the components 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 influences growth can be essential for understanding the ecological role and the productive capacity of fish populations (Bowen, 1982). Studying feeding can be also considered as an important step to make growing fish more successful (Luther, 1962). *Oreochromis niloticus* fry were stocked into Lake Tinishu Abaya in 1997 from the nearby rift valley Lake Ziway, with the aim of developing fishery and availing inexpensive fish protein to the local community (Kassahun *et al.*, 2011) [37]. Following the stock Kassahun *et al.,* (2011) [37] conducted to a study to examined the adaptability and reproductive status of the fish. However, there was no any information about the feeding ecology of *O. niloticus* in the lake and thus detailed study is required to guide the management of the stock in the study lake. The aim of this work was, therefore, to explore seasonal variation in diet composition and ontogenetic dietary shift of *O. niloticus* for Lake Tinishu Abaya, Ethiopia.

Materials and Methods

Study area description

Lake Tinshu Abaya, or interchangeably called, Small Abaya, is a small freshwater lake located in the Rift Valley nearly 160 km southwest of Addis Ababa, which is a capital city of Ethiopia. It locate at 7^{0}29´03.65´´N, 38^{0}03`17.79´´E, and 1835 m above sea level (GPS measurment during the study).the lake has nearly oval shape(Fig. 1). The lake, situated in a remote area 15 km from a small village in the township of Silttie. It is a mall-sized lake and shallow lake, having a surface area of 1253 ha. (Kassahun *et al.*, 2011) [37], with a maximum and a mean depth of 3.7 m and 2.9 m respectively (survey on this study). During this study, two major perennial rivers (Rivers Dacha and Boboda) and a single outlet (River Badober) were always active. The former two rivers are relatively big. The lake has some commercially important fish species including the native *Tilapia Zilli* and *Barbus* species, while Nile tilapia (*Oreochromis niloticus)*, was stocked from the nearby Lake Ziway in 1997 (Kassahun *et al*., 2011) [37].

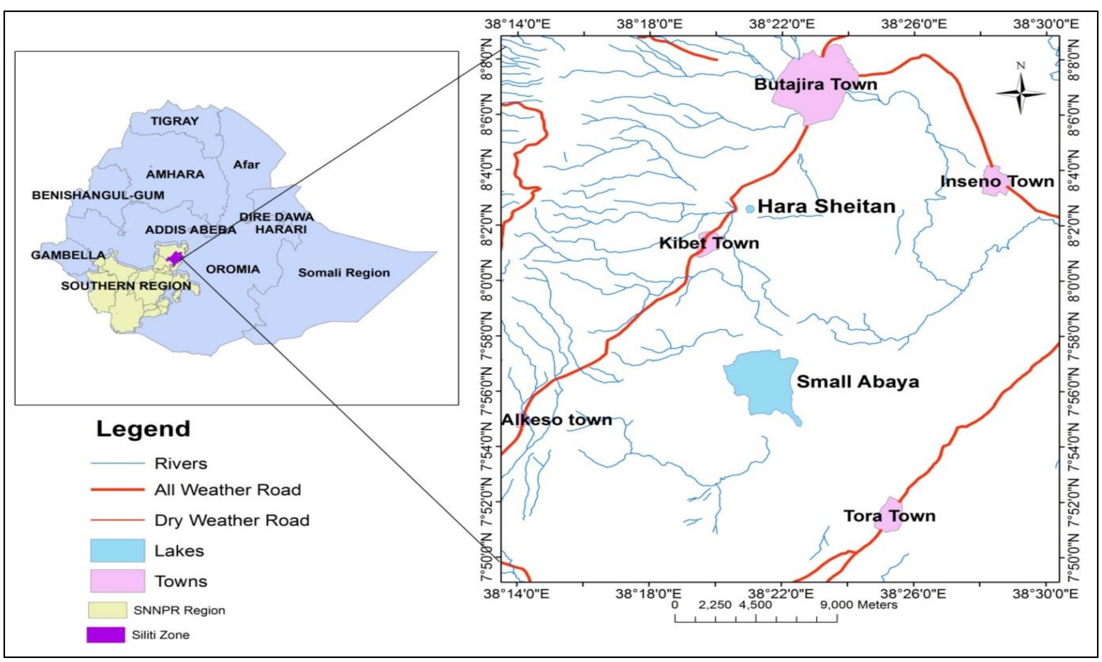

Fig 1: Location of Lake Tinishu Abaya/Small Abaya (source: www.earth.google.com)

Fish Sampling and Measurement

Fish samples were collected using gill nets of 6 cm, 8 cm, 10 cm and 12 cm stretched mesh sizes. In order to obtain fingerlings, beach seine was used in the shallower part of the lake. Samples were collected from March to May (dry season) and July to September (wet season) in 2017. Total length (TL) and total weight (TW) of all specimens were measured using a measuring board and a sensitive balance to the nearest value of 0.01 cm and 0.01g, respectively. The sex of each fish sample was determined by visual observation of genital organs.

Length-weight relationship and Condition factor

Length-weight relationship of fish was estimated according to Pauly (1984) as the following equation: $W = aTL^b$

The relationship was transformed into a linear form using the following logarithm equation $\log TW = \log a + b \log TL$

Fulton´s condition factor (FCF) (%) was calculated using the formula of Pauly (1984) in equation below

$$FCF(k) = \frac{100TW}{TL^3}$$

Where TW is total weight of fish (g), TL is total length of fish (cm), a is the regression constant, b is TLTW coefficient

Estimation of sex ratio

Both female and male fishes were recorded for each sampling occasion. Sex-ratio (female: male) was calculated for the total fish which already identified sex. Sex ratio was determined using the formula:

$$\text{Sex ratio} = \frac{\text{Total number of female fishes}}{\text{Total number of male fishes}}$$

Stomach content analysis

In the field, the stomach content of each fish was kept in labeled sampling bottles containing 5% formalin solution and kept in icebox. Then it transferred to the limnology laboratory of Addis Ababa university for further analysis. In the laboratory, the stomach contents were examined using a compound microscope (Leica, DME, with magnification of 100 x). The relative importance of the different food items found in the stomach contents was determined using frequency of occurrence and volumetric methods (Hyslop, 1980). In frequency of occurrence method, the number of stomach samples in which a given food item found was expressed as a percentage of all non-empty stomachs examined. This method gave an estimate of the proportion of the population that feeds on a particular food item. In the volumetric analysis, food items were sorted into different taxonomic categories, and the water displaced by a group of items in each category was measured in a partially filled graduated cylinder (Hyslop, 1980). The volume of water displaced by each category of food items was expressed as a percentage of the total volume of the stomach contents. 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 (1981).

Frequency of Occurrence

The number of stomach samples contains one or more of a given food item was expressed as a percentage of all non-empty stomachs examined. The proportion of the population that feeds on particular food item was estimated and the frequency of occurrence was calculated (Hyslop, 1980; Bowen, 1983) as:

$$\text{Frequency of Occurrence(FO)} = \frac{\text{Total number of stomach with particular food item}}{\text{Total number of stomach with food}} \times 100$$

Volumetric Analysis

Food items that were found in the stomachs were sorted out into different taxonomic categories. The water displaced by a group of items in each category was measured in the partially filled graduate cylinder and expressed as a percentage of total volume of the stomach contents (Bowen, 1983). The importance of different food items for different size classes was determined by dividing the fish into four size classes (I, < 10 cm TL, II, 10-19.9 cm TL, III, 20-29.9 cm TL and IV, > 30 cm TL) and determining percentage mean volume of food in each size class.

Statistical Analysis

Chi-square test was used to compare the frequency of occurrences of the different food categories during the different seasons (Sokal and Rohlf, 1995). The non-parametric Mann Whitney's U-test was used to compare the volume of the different food categories consumed during the seasons. Analysis of various (ANOVA) was used to see the significant variation in the condition factor between sexes. Dietary overlap between different length-classes was calculated using Schoener Diet Overlap Index (SDOI) (Schoener, 1970) using the following formula:

$$\alpha = 1 - 0.5\left(\sum_{i=1} n\,|pxi - pyi|\right)$$

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

Results

Length-weight relationships, condition factor, and sex ratio

A total of 428 fish samples from 2.5 to 30.9 cm in TL and 1.1 to 475 g in TW were used to determine length-weight relationships. The relationship between total length and the total weight of *O. niloticus* was curvilinear with a strong relationship (R^2= 0.9848, TW =0.0194 $TL^{2.9876}$ (Fig. 2). The slope of the regression (b) was 2.9876 which was closer to the isometric growth value (b=3) of fish. The intercept (a) is 0.0194 g/cm and it signifies the average condition factor index of Tilapia in Lake Tinishu Abaya. There was a significant variation in the number of fishes caught in the sampling season ($\chi^2 = 6.14$; p< 0.05) with the high number was collected during the rainy season. There was no a significant difference between sexes in the total catch($\chi^2 = 3.65$, p >0.05) even the number of males were more than females. The study found out that the mean Fulton´s condition factor (FCF) of *O. niloticus* in Lake Tinishu Abaya was 1.88. It ranged from 0.96 to 3.51. There was a significant variation (ANOVA, P <0.05) in FCF between the two sexes with the higher value reported for males than females. The sex ratio (Female: Male) of the total fish catch was 1:1.4 which were a little deviate the theoretical or expected 1:1 ratio.

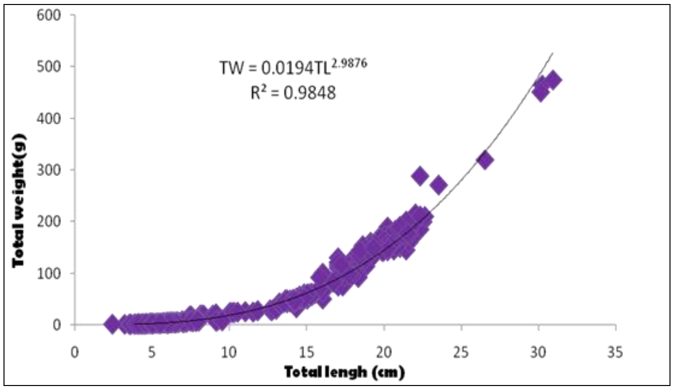

Fig 2: Total length (cm) and total weight (g) relationship of *O. niloticus* in Lake Tinishu Abaya (n=428)

Diet composition

Among the 428 stomach content used to analyze the diet composition, 55 (12.85%) were completely empty and 373 (87.15%) observed with one or more food items (Table 1). Phytoplankton, detritus, and zooplankton were dominant in the majority of the samples; macrophytes were intermediate; insects, nematodes, fish scale, and ostracods were low. Phytoplankton constituted the largest component of the diet occurred in 351 (94.11%) followed by detritus, occurred in 277 (74.26%) and zooplankton, occurred in 267 (71.58%). Macrophytes moderately contributed the frequency of occurrence of the food items and they occurred in 251 (53.9%) of the stomach content. Volumetrically, the maximum amount of the total food items constituted by phytoplankton (39.49%) followed by macrophytes (25.81%), detritus (14.39%) and zooplankton (12. 96%) (Table 1). Accordingly, phytoplankton, detritus, zooplankton, and macrophytes were the most important food items of *O. niloticus* in Lake Tinishu Abaya. Other than the four major food items, insects, nematodes, ostracods and fish scales made up a minor portion of the diet of *O. niloticus*. The former contributed 20.9% and 4.74% of the total stomach content and the total volume of food items, respectively. The diet composition of Nematodes, Ostracods, and Fish scale found in the stomach of *O. nloticus* was accounted 5.1%, 13.7%, and 2.9%, respectively. Volumetrically, they accounted only 0.12 %, 2.32% and 0.17 % of the total food items, respectively (Table 1).

Table 1: The frequency of occurrence and volumetric contribution of food items consumed by *O. niloticus* in Lake Tinishu Abaya (n=373). Note '**a**' represents the food items significantly contributed to the diet of the fish.

Food items	Frequency of occurrence		Volumetric contribution	
	Occurrence	Percent	Volume (ml)	Percent
Phytoplankton	351	94.1[a]	387	39.49 [a]
Blue green algae	317	85	178.5	18.21
Green algae	296	79.4	121	12.35
Diatom	277	74.3	52	5.31
Euglenoids	22	5.9	5.5	0.56
Zooplankton	267	71.6 [a]	127	12.96 [a]
Copepods	181	48.5	40.4	4.12
Cladoceran	119	31.9	25.3	2.58
Rotifers	251	67.3	61.3	6.25
Macrophytes	201	53.9 [a]	253	25.81 [a]
Detritus	277	74.3 [a]	141	14.39 [a]
Insects	78	20.9	46.5	4.74
Diptera	57	15.3	16.2	1.65
Ephemeroptera	40	10.7	9.1	0.93
Coleoptera	13	3.5	7.5	0.77
Hemiptera	47	12.6	8.1	0.83
Plecoptera	8	2.2	5.6	0.57
Nematods	19	5.1	1.2	0.12
Ostracods	51	13.7	22.7	2.32
Fish scale	11	2.9	1.7	0.17

Among the phytoplankton, blue-green algae (*Microcystis*, *Cylindrospermopsis*, *Anabaena*, *Oscillatoria)*, green-algae (*Pediastrum*, *Cosmarium*, *Ankistrodesmus*, *Botryococcus*, *Coelastrum)* and diatoms (*Fragilaria*, *Pinnularia*, *Navicula*, *Nitzschia*, *Synedra*, *Cyclotella)* species comprise most of the algae consumed by *O. niloticus* in the study Lake. Of them, blue-green algae were significantly dominated both the total volume of food items and the frequency of occurrence in a given stomach content. The frequency of occurrence of blue-green algae, green alga, and diatom was 85%, 79.4%, and 74.3%, respectively. Blue-green algae constituted the maximum value by volume (18.21%) followed by green algae (12.35%) and diatoms (5.31%) (Table 1).

The small-sized rotifer zooplankton (*Branchionus*, *Keratella*, and *Filinia*) were the most important groups of animal origin in the diet of *O. niloticus*. The frequency of rotifers occurrence was 67.3%. However, volumetrically they accounted relatively low (6.25%) of the total volume of food items. The two larger crustaceans (copepods and cladocerans) contributed a moderate amount of the food content of the fish stomach next to rotifers. Copepods (*Mesocyclpos aequatorialis* and *Thermocyclops decipins)* and Cladoceran (*Bosmina*, *Ceriodaphnia*, *Diaphnosoma*, *Daphnia*, *Moina*) relatively occurred in most of the stomach sample. The frequency of occurrence of copepods and cladocerans was 48.5% and 31.9%, respectively. Volumetrically, copepods comprised 4.12% while cladocerans accounted for 2.58% of the total volume of the food items (Table 1).

Seasonality in the diet of *O. niloticus*

There was notable variation in the type of diet and the proportions consumed by *O. niloticus* in Lake Tinishu Abaya during the dry (March-May) and wet seasons (June-August). The frequency of occurrence of macrophytes significantly varied during the dry (n= 134) and wet (n= 239) seasons ($\chi2$ test, P<0.05). Similarly, the volumetric contributions of macrophytes, phytoplankton, and detritus significantly differed during the two seasons (U test, P<0.01). The result clearly shows a seasonal effect in the diet of the fish. During the dry season, phytoplankton was extensively dominated the fish gut. They occurred in 98.5% of the stomach and comprising 56.5% of the total volume of food items. However, during the wet months, their contribution significantly declined and constituting 32.9% of the total volume of the food bulk. Conversely, the contribution of zooplankton was higher in the wet season than dry season. They occurred in 52.2% and 82.4% of the stomach during dry and wet seasons, respectively. Volumetrically, zooplankton constitutes 2.9% in dry season and 17% in a wet season (Table 2).

The contribution of macrophytes was lower during the dry season than wet season. During the dry season, they were found in 20.2% of the stomach contents and constituted 13.8% of the total volume of food items. However, during wet season one of the most important food items in the diet of *O. niloticus* were macrophytes. They occurred in 72.8% of the stomach contents and constituting 30.62% of the total volume of food items (Table 2). Next to macrophytes, detritus were the second most important food items in the diet of *O. niloticus* in the wet season. They were observed in 56.7% and 84.1% of the stomach content during the dry and wet seasons, respectively. Volumetrically, detritus comprised 11.6% in the dry season and 15.5% in the wet season from the total food bulk. Comparing the two seasons, the contribution of insects was relatively low during the dry month, occurring in 8.2% of the stomach contents examined. However, it accounted relatively high (17%) for the total volume of the food bulk. During the wet months, the contribution of insects was comparatively high which showed an occurrence of 28% of the stomach examined. Volumetrically, the contribution was insignificant (0.8%) in the wet season. The contribution of Nematodes and Ostracods to the diet of *O. niloticus* was relatively higher during wet season than dry season. The reverse was true for fish scale composition by which its occurrence was higher during the dry season than wet season. Ostracods contributed 6.7% and 17.6% of the stomach content of the fish diet in the dry and wet months, respectively. Volumetrically, they constituted only 0.9% and 3% of the total volume of food items in wet and dry months, respectively. The contributions of nematodes and fish scales were generally negligible (Table 2).

Table 2: Relative contribution (%) of different food items in the diet of *O. niloticus* during dry (n= 134) and wet (n= 239) season from Lake Tinishu Abaya. Note that the sum of the major categories of food items in bold add up to 100% in volumetric analysis and **'a'** represents the food items which significantly contributed in the diet of the fish in the season.

Food items	Frequency of occurrence (%)		Volumetric contribution (%)	
	Dry season	Wet season	Dry season	Wet season
Phytoplankton	98.51[a]	91.63[a]	56.5[a]	32.97[a]
Blue green algae	97.76	77.82	28.0	14.43
Green algae	96.27	69.87	9.01	13.7
Diatom	69.40	76.99	4.43	5.67
Euglenoids	5.97	5.86	0.69	0.51
Zooplankton	52.24[a]	82.43[a]	2.90	16.95[a]
Copepods	29.853	58.99	3.34	4.44
Cladoceran	8.21	45.19	0.65	3.35
Rotifers	82.84	58.58	18.23	1.58
Macrophytes	20.15	72.80[a]	13.80	30.62[a]
Detritus	56.72[a]	84.10[a]	11.62	15.52
Insects	8.21	28.03	16.89[a]	0.77
Diptera	30.6	6.69	4.10	0.77
Ephemeroptera	24.63	2.93	2.72	0.7
Coeoptera	9.70	0	2.72	0
Hemiptera	33.58	0.84	2.03	0.36
Plecoptera	5.97	0	2.03	0
Nematods	2.24	6.69	0.11	0.13
Ostracods	6.72	17.57	0.88	2.89
Fish scale	4.48	2.09	0.22	0.16

Ontogenetic Dietary Shift

Percent mean volume contribution of different food items with size class of *O. niloticus* in Lake Tinishu Abaya is given in (Fig. 3). There was a high variation in the diet of individuals in the size class I and III (α=0.556), I and IV (α=0.491), and II and IV (α=0.559). Overlap of food items was also seen as the size class closer each other and it was shown in the size class I and II (α =0. 692), II and III(α =0.783), and III and IV (α =0.661). Generally, ontogenetic diet shift was evident during the present study by means of the importance of phytoplankton, macrophytes and detritus increased with size whereas the importance of zooplankton, insects, and other animal origin food declined with fish size. Phytoplankton, zooplankton, Detritus, and macrophytes were the dominant food items in all size classes, whereas the contribution of insects, nematodes, ostracods and fish scales was low (Fig. 3).

In size class < 10 cm TL, the dominant food items were zooplankton (45.7%) followed by phytoplankton (21.3%) and detritus (11.2%) (Fig. 3). In this particular size class, the contribution of insects, macrophytes, and nematodes was relatively low. They constituted 7.7 %, 4.5 % and 5.2% of the total volume of the food items, respectively. The contributions of ostracods and fish scales were only 3.3% and 1.1% of the total volume of the diet of *O. nilticus*, respectively (Fig. 3). Of the zooplankton community, rotifers contributed the highest percentage (40.7%) volume of the food bulk. Phytoplankton and detritus were an essential food source of plant origin in the diet of *O. niloticus* in the study lake in that particular fish size. They contributed a fairly high proportion of the total food items. Generally, in this size class, the most important food items were zooplankton (particularly rotifers), phytoplankton and detritus. These three food items constituted 78.2% of the total volume of food consumed. The remaining food items constituted 22% of the total volume of food items (Fig. 3).
In size class 10.0-19.9 cm TL of fishes, foods of plant origin was most important than animal origin. Phytoplankton, macrophytes, and detritus comprised 33.7%, 11.5% and 22.6% of the total volume of the food items consumed, respectively (Fig. 3). On the other hand, the contributions of animal origin foods declined. However, zooplankton accounted relatively high (23%) for the total volume of the diet. Insects comprised low (5.5%) volume of the food items. The less important food items namely, nematodes (1.2%), ostracods (2%), and fish scales (0.5%) collectively constituted less than 5% of the volume of food consumed within the size class.
Foods of plant origin also accounted the highest proportion of the food items in the 20-29.9 cm TL of fishes. The dominant food items in size class 20-29.9 TL were phytoplankton (47.6%), macrophytes (18.3%), and detritus (15.5%). These three food items constituted 81.4% of the total food bulk within the size class. The contribution of foods of animal origin was low in this size class. Zooplankton and insects comprised 10.5% and 6% of the total volume of food items, respectively. The contributions of nematodes (0.65%), ostracods (0.5%) and fish scales (1%) were negligible and collectively constituted only 2% of the total volume of food consumed in that particular size class (Fig. 3).
In the largest size class (>30 cm TL), the order of the importance of dominant food items was in the direction of Macrophytes (40.5%) >detritus (25.9%) > phytoplankton (20.4%). The three dominant food items collectively contributed about 87% of the total food items. The less important food items in this large size class were foods of animal origin. The contribution of zooplankton and insects were 4.8% and 5.2% of the total volume of food items consumed, respectively. Another food source of animal origin in the diet of *O. niloticus* which contributed an insignificant amount in the largest size class (>30 cm TL) was included nematodes (0.4%), ostracods (1.5%), and fish scales (1.3%) (Fig). Compared to the lower size classes, the contribution of phytoplankton was considerably decreased while macrophytes and detritus contribution was increased (Fig. 3).

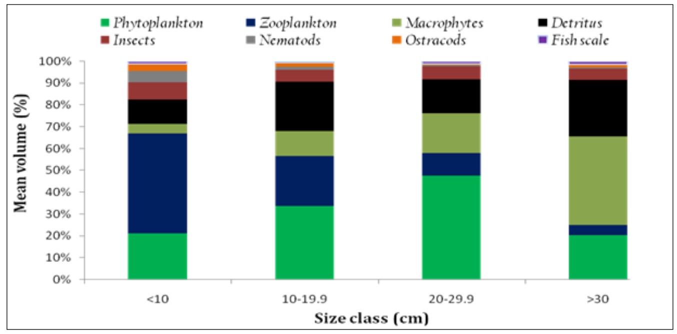

Fig 3: The relative proportion (%) of different prey items in the diet of *O.niloticus* at different size classes from Lake Tinishu Abaya

Discussion

Length-Weight Relationships, Condition Factor, and Sex-Ratio

The length-weight relationship of *O. niloticus* in the study lake was found to be curvilinear and highly significant. The estimated length weight coefficient (b) value of *O. niloticus* 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 *et al.*, 2014) [18, 19]. It may be due to the growth that occurs at the same rate for all parts of the organisms (Flipos *et al.*, 2013).
Several authors have reported isometric and allometric growth pattern of *O. niloticus* from different water bodies. The isometric growth pattern observed in the present study (b=2.9867) was in agreement with the earlier findings of Kassahun *et al*, (2011) [37] in the same lake where the b value was reported to be 2.99. The isometric growth pattern of *O. niloticus* was reported in other nearby rift valley lakes of Ethiopia such as in Lake Ziway (b=3.11; Zenebe, 1998), Lake Chamo (b=2.98; Yirga and Demeke, 2002), Lake Hawassa (b=3.01; Demeke (1998), Lake Koka (b= 3.0541; Flipos *et al.*, 2013). The coefficient for *O. nilticus* in this study was relatively higher than the coefficient for the same species in Lake Abaya (b=2.6; Berhanu 2016), Lake Hawasaa (b=2.91; Demeke, 1990), and Lake Tana (b=2.74; Zenebe, 1997). Such differences in length-weight relationship coefficient are not unexpected and may result from differences in habitats (Froes, 2006). According to Bagenal and Tesch (1978) and Froese (2006), the variation in the value of ‘b’ happens due to season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental conditions. The isometric growth of *O. niloticus* in the study lake may also be due to the high productivity of the lake. The growth of phytoplankton and zooplankton, which were the most important food in the fish diet, was reasonably high (Yirga and Brook, 2016; unpublished study). This may result in the proper growth of *O.* niltoticus fish in the present study lake.
The study of condition assumes that heavier fish of a given length is in a better condition. The indices have been used by fishery biologists as indicators of the general “well being” or

"fitness" of the population under consideration (Jones *et al.*, 1999). The well being of the fish in the study area was determined using Fulton's condition factor (FCF) Pauly (1984). The FCF of *O. niloticus* in Lake Tinishu Abaya is higher than the nearby rift valley Lake Abaya where FCF is 1.43 (Berhanu, 2016) and the Ethiopian highland Lake Hayq where FCF value is 1.81 (Workie and Abebe, 2014). However, FCF is lower in the study lake than that of the same species in some other Ethiopian lakes. FCF of *O. niloticus* is 2.29 in Lake Tana (Zenebe, 1997), and 2.23 in the nearby Lake Chamo (Yirga and Demeke, 2002).Therefore, the fish in the study lake appears to be in a better condition when compared to those in Lakes Abaya and Hayq but lower than those in Lakes Tana and Chamo. Yet, the data in this study further shows that 89.7% of the samples examined had condition factors above 1.5 and 43.5% had their condition factors above the mean (1.88) indicating that the majority of the population in Lake Tinishu Abaya are in a good condition. This could be attributed to various factors such as quality and quantity of food, the rate of feeding, reproductive potential, high phytoplankton and zooplankton, and polymictic nature of the lake water which induce the dynamics of nutrient enrichment.

Comparisons of length-weight equations fitted in the present study with that of Demeke (1990), Zenebe (1997) and Workie and Abebe (2014) could provide more additional evidence. For example, at 20 and 30 cm total length, *O. niloticus* have weights of 156 and 474 grams in Lake Tana, 124 and 383 grams in Lake Awassa and 138 and 461 grams in Lake Hayq, respectively. In Lake Tinishu Abaya, we have obtained 145 and 451.5 grams at 20 and 30.1 cm, respectively. This comparison shows that the species would be heavier in Lake Tinishu Abaya than of a similar sized fish in Lake Hawassa but lighter than those in Lake Tana. Hence, it can be concluded that *O. niloticus* population has a rapid growth rate in Lake Tinishu Abaya than in Lake Hawassa but slower than that in Lake Tana and comparative with Lake Hayq. This difference may be attributed to the difference in the availability and quality of food in the different lakes, Lake Tinishu Abaya may have better productivity with quality food than Lake Hawassa. However, further study is needed to verify the plausible reason for this hypothesis.

The condition factor of both sexes in Lake Tinishu Abaya was significantly different by means of the high value observed for males than females. Thus in Lake Tinisshu Abaya, male fishes are in a better condition than females. Similar results were reported in the same lake (Kassahun, 2011) [37], Lake Hawassa (Demeke, 1994), in Lake Abaya (Berhanu, 2016) where male *O. niloticus* is in a better condition than females. In this study, the overall sex-ratio (Female: Male) for *O. niloticus* in Lake Tinishu Abaya is deviated from the expected 1:1 in favor of males. This agrees with the results obtained for the same species in Lake Tana (Zenebe, 1997), Lake Victoria (Njiru *et al*, 2006) and Small/Tinishu Abay (Kassahun, 2011) [37]. On the contrary, sex ratios of the same species where females population dominate over males were reported in Lake Hawassa (Demeke, 1994), in Abu-Zabal Lake, Egypt (Shaloof and Salama, 2008), in Lake Coatetelco, Mexico (Gómez-Márquez *et al*, 2003). Although concrete evidence couldn't be drawn for biased sex ratio for the present study, it may be caused by sexual segregation during spawning, behavioral differences between the sexes, gear type and fishing site (Demeke, 1994). Moreover, sex ratio may be affected by several factors such as sex-based difference in maturity, mortality, migratory and other behaviors (Sandovy and Shapiro, 1987; Matsuyama *et al.*, 1988).

In addition to sex basis, during the measurement of the length of the fish, the size of males was larger than males in most of the samples. Male Nile tilapia typically grow larger than females in small water bodies and riverine habitats (Lowe-McConnell, 1958). Demeke (1989) also found that after 2 years of age female *O. niloticus* grows more slowly than males in Lake Hawassa (Ethiopia) and this may be related to the small size of the lake. This owing to be true in Lake Tinishu Abaya since the size of the lake is too small (seven times smaller than L. Hawassa). De Graaf *et al*. (1999) also reported that mean growth rates for males were greater than for females. The onset of sexual maturity could be another factor responsible for differences in sizes. Since females invest more energy in reproduction than males, they grow slower than males (Demeke, 1994). The occurrence of larger males may also be related to high water temperature; as higher temperatures induce sex reversal and higher proportions of males (Peterson *et al.*, 2004).

Feeding habits of *O. niloticus*

The diet of *O. niloticus* in Lake Tinishu Abaya, both plant and animal origin food items were found. The food from gut analyses consisted of eight groups of food items: Phytoplankton, zooplankton, macrophytes, detritus, insects, nematodes, ostracods, and fish scales. The types of food items found in the stomachs of *O. niloticus* were quite similar to what has been reported by several authors in different rift valley lakes of Ethiopia. Adult *O. niloticus* was reported to feed on variety of food items including phytoplankton, macrophytes, benthic aquatic invertebrates, insects and detritus (Getachew, 1987a, b; Todurancea *et al*., 1988; Getachew and Fernando, 1989; Yirgaw *et al*., 2000; Oso *et al*., 2006; Alemayehu and Prabu, 2008) [65] whereas juveniles are generally omnivorous feeding on zooplankton, insect larvae (Flipos *et al.*, 2013) and phytoplankton (Witte and Winter, 1995).

The present work confirmed that *O. niloticus* in Lake Tinishu Abaya consumed large quantities of phytoplankton. Phytoplankton was found to be the most important food item in lakes for which data are available (Getachew, 1987a, b; 1993; Zenebe, 1988, 1998; Yirgaw *et al*., 2000; Elias *et al.*, 2014; Flipos *et al.*, 2013) [65, 18, 19]. In addition to phytoplankton other foods of plant origin (macrophytes and detritus) were also consumed in large quantities. Zenebe (1988, 1998) and Yirgaw *et al*., (2000) [65] have reported the importance of macrophytes and detritus in the diet of *O. niloticus* in Lake Ziway and Lake Chamo (Ethiopia). Bowen (1980) has also reported the presence of large quantities of detritus in the diet of O. *niloticus* in Lake Valencia (Venezuela). Several authors have also provided similar interpretations about the importance of detritus and macrophyte in different parts of Africa (Zenebe, 1988; Getabu, 1993; Shipton *et al*., 2008; Oso *et al*., 2006; Kamal *et al*., 2010) [54]. The contribution of foods of animal origin represented by zooplankton in the diet composition of *O. niloticus* in Lake Tinishu Abaya was relatively low in adult but high in juveniles. Generally, phytoplankton, detritus, and zooplankton were dominant in the majority of the samples; macrophytes were intermediate; insects, nematodes, fish scale, and ostracods were low.

The present study showed that the proportions of different food items in the fish diet of *O. niloticus* varied considerably between the dry and wet seasons. The proportion of macrophytes, zooplankton, and detritus were higher during the wet season than the dry season. The reverse was true for the proportion of phytoplankton where the high proportion was seen during the dry season. This is fairly similar to the findings of other investigators in the Ethiopian rift valley lakes (Zenebe, 1988, 1998; Yirgaw *et al*., 2000) [65]. A pronounced seasonal succession of phytoplankton has been found in some Ethiopian rift valley lakes, Hawassa, Ziway, and Chamo (Zenebe, 1988, 1998; Elizabeth and Amha, 1994; Yirgaw, *et al*., 2000) [65] and Abaya (Elias *et al.*, 2014) [18, 19]. In most of the Ethiopian rift valley lakes for which data are available, phytoplankton predominantly constituted the diet of *O. niloticus* during the dry season whereas macrophytes were important in the wet season.

The composition differences and the relative contribution of food items may partly explain the difference in microhabitat occupied by the fish. During wet month fish moves to shallow parts of the lake for reproduction and stays for longer period of time by feeding macrophytes and vegetations (Flipos *et al.*, 2013). In addition, during the wet month due to high flooding from the catchment area may cause fluctuations in water level and increasing 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, 1987a, b, 1993). During the dry months, fish may move to the pelagic region of the lake and feeding mainly on suspended phytoplankton. In this period phytoplankton production may be high due to increased light penetration into the photic zone of Lake. During the dry seasons, when the water recedes away from the vegetation, the fish moves offshore and feeds mainly on suspended phytoplankton available in the open water (Zenebe, 1998). During the wet seasons, fish spend most of the time feeding in the littoral zones, where macrophyte vegetation is abundant. It is highly probable that changes in the habitat choice of the fish due to water level fluctuations may bring variations in the composition of the fish diet in Lake Tinishu Abaya.

The ontogenetic dietary shift of *O. niloticus* in Lake Tinishu Abaya highlights significant variations of food items as the fish grows older. In the first and third size class (< 10 cm and 10-19.9 cm TL), in the first and fourth size class (< 10 cm and > 30 cm TL) and in the second and fourth size classes (10-19.9 cm and > 30 cm TL), there is dietary shifts with overlap index values (α) of 0.556, 0.491, and 0.559, respectively. Overlap of food items was also observed as the fish size closer. In the first and second size classes (<10 cm and 19.9 cm), in the second and third size class (10-19.9 cm and 20-29.9 cm TL) and in the third and fourth size classes (20-29.9 cm and >30 cm TL), which are relatively closer each other in size, there is an overlap in their diet with α values of 0.692, 0.783, and 0.661, respectively. Generally, ontogenetic diet shift was apparent during the present study with the importance of phytoplankton, macrophytes and detritus increased with size whereas zooplankton, insects and other animal origin food declined with fish size.

Foods of animal origin, mainly zooplankton, were most important food items of the fish below 10 cm of TL. Zooplankton in particular rotifers, contributed the largest proportion (46%, by volume) of the food items in the first smaller size classes (<10cm TL). In the Ethiopian rift valley Lake Koka a fish (*O. niloticus*) <10 cm TL mainly fed on zooplankton and insects and declined sharply as the size of fish increased above 10 cm TL (Flipos *et al.*, 2013). The ontogenetic dietary shift of *O. niloticus* in Lake Victoria also shows zooplankton were most important food items for fish less than 5 cm TL and little importance for larger than 10 cm TL (Njir *et al*., 2004) [42]. The findings of the study area are also in corroborating well with Todurancea *et al*., (1988), Abdel-Tewwab and El-Marakby (2000), Yirgaw (*et al*., 2000) [65] and Alemayehu and Prabu (2008) where the contribution of zooplankton in the smaller size of *O. niolticus* is significant. The possible reason for juveniles feeding zooplanktons may be due to the small volume of the stomach that may not support big macrophyte and detritus, and again the volumes of the stomach are not large enough to make filter feeding energetically (Flipos *et al.*, 2013). The reason for taking less zooplankton during adult life may be the fish change 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.

In the case of larger size classes (10-19.9 and 20-29.9 cm TL) phytoplankton was dominated the diet of fish by volume. In the final size class (>30 cm TL) the contribution of phytoplankton declined while the contribution of macrophytes and detritus increased. The most plausible explanation for this variation in the proportion of different plant materials during the life cycle of the fish could be that adult fish have the wider mouth gapes and the ability to digest macrophytes and detritus in their stomach (Tudorancea *et al.*, 1988). Examination of the diet of *O. niloticus* in the study lake, shows that there is a high percentage of detritus in their stomach especially in the large size (adult). This is an indication that the fish is also a bottom browser. It is a well-established fact that the composition of different food items utilized by *O. niloticus* changes as the fish grows older. 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. As the fish changes it's feeding on a primarily omnivorous diet to herbivorous diet may be due to energy demands, because of this large volume of phytoplankton are filtered out from the water column (Shipton *et al*., 2008; Alemayehu and Prabu, 2008) [54].

In Lake Tinishu Abaya of the present investigation, the contribution of insects in the diet of *O. niloticus* is comparable in the different size classes; yet still, it was a better source for the fish <10 cm than the other size classes. The other animal food source including nematodes, ostracods, and fish scales which found in the stomach of *O. niloticus* during the study, are increasingly declined as the fish size older. Generally, the contribution of animal sources (zooplankton, insects, nematodes, and ostracods) are relatively high in the smaller size fish while the plant source (phytoplankton, macrophytes, and detritus) are high in the large size fish. Therefore, ontogenetic diet shifts in the present study demonstrate that at the earlier stage, *O. niloticus* is most probably omnivorous; its diet depends on zooplankton and phytoplankton in a high proportion and insect, nematode and ostracods in low proportion. It shifts to herbivores as its size increase. At the adult stage, the diet is depended mostly on macrophytes, detritus, and phytoplankton, which are a plant origin of food. Thus, we conclude that the dietary habits of *O. niloticus* in Lake Tinishu Abaya is the omnivorous type.

Conclusion

The length-weight relationship of *O. niloticus* in the study lake was found to be curvilinear. The slope of the regression line is indicating isometric growth pattern of the fish. The well being of the fish in the study area shows the that the majority of the population in Lake Tinishu Abaya are in a good condition. In Lake Tinisshu Abaya, male fishes are in a better condition than females. Generally *O. niloticus* in Lake Koka was found to be an omnivorous fish mainly feeding on phytoplankton, detritus and macrophytes. In addition, zooplankton and insects constituted minor portion of the diet of *O. niloticus* in Lake Koka.

Ethical concern

No any ethical issues in the study area

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