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The food and feeding ecology of Nile tilapia, *Oreochromis niloticus*, in Lake Hayq, Ethiopia

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Abstract

A study was conducted to investigate the food and feeding habits of Nile tilapia, *Oreochromis niloticus,* in Lake Hayq, Ethiopia from August 2008 to March 2009. A total 931 fish were collected by gill nets of various stretched mesh sizes, of which 326 individuals of *Oreochromis niloticus* stomachs contained food. The stomach contents were analyzed using frequency of occurrence, numerical methods and the Geometric Index of Importance (GII). The food items in the stomach covered a wide variety, ranging from various types of phytoplankton to zooplankton and to macrophytes. The major food items in terms of frequency of occurrence were *Microcystis* (87.7%)*, Cosmarium* (65.13%), *Navicula* (64.2%) and *Daphnia* (71%) genera. Numerically, *Cosmarium* (38.5%) and *Microcystis* (31%) dominated the food of *O. niloticus*. However, Geometric Importance Index GII suggested that the most consumed group were *Microcystis* (83.93%). A monthly variation was also noted in the stomach contents of *O. niloticus* over the period of investigation. The food composition of *O. niloticus* showed slight variation among fish size. The contribution of zooplankton (*Daphnia* and *Keratella*) tended to increase with decreasing size of the fish, but Copepoda (*Thermocyclops*) tended to increase in size. Size based difference is also supported by one-way analyses of similarities (ANOSIMs) and the difference is mainly due to the differences in the importance of green algae (*Cosmarium*) and blue greens (*Microcystis*). This investigation is an important measure towards the data needed to create a food web in Lake Hayq, and eventually a trophic model that can be used in fisheries management.

Keywords: Diet composition, feeding habits, food items, size groups, planktivorous.

1. Introduction

Ethiopia is endowed with enormous freshwater resources. It owns over 20 natural lakes, including pond, rivers, man-made lakes and wetlands covering an estimated surface area of 18587 km². These water bodies have been estimated to give a refuge for more than 150 fish species [1]. Nile tilapia, *Oreochromis niloticus,* is one of the popular species among commercial fishes of Ethiopia. The species is distributed in almost all inland waters of Ethiopia [2], and accounted 60 % of the capture fishery in the country [1].

The feeding habits of Nile tilapia consist of a great variety of aquatic organisms depending upon availability [3]. A study of the primary diet of *O. niloticus* has been inconsistent in much of the research papers. Some studies classified *O. niloticus* as omnivorous and others as herbivorous [3]. For example, the species were essentially planktivorous, showing preference for phytoplankton species such as blue greens, green algae and diatoms in Lake Chamo [4] and in crater lakes of Uganda [5]. On the other hand, *O. niloticus* was found to be omnivorous in Lake Abu-Zabal, Egypt [6] and in Ero Reservoir, Nigeria [7]. Their feeding habits also vary with age and size [9]. As the sizes of the fish increases, the consumption of large quantities of various phytoplankton evidently increased [8, 9]. Juvenile *O. niloticus* with less than 6 cm total length consumes Chironomid larvae, copepods, and rotifers in Lake Ziway [9] and nematodes and zooplankton in Lake Awassa [10]. *O. niloticus* is able to modify their feeding habits depending on the availability of natural foods as well [11]. For instance, in Lake Victoria, Nile tilapia exhibited a traffic shift from predominantly herbivorous to a more diversified diet where the importance of algae decreases while fish, plants and invertebrates increases [12].

Lake Hayq, which is one of a freshwater highland lake in Ethiopia, situated about 450 kilometers far from the capital, Addis Ababa. *O. niloticus* was introduced in the study area in 1978 [13].

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Some 20 years ago, the lake had changed its trophic status from oligotrophic to eutrophic. Probably, this was caused by the introduction of Nile Tilapia [13]. Since then the fish has quickly established successfully and become commercially important species in the region. In the 1990s an annual harvest of 200 tons *O. niloticus* was recorded and a sustainable maximum yield (biomass) of 298 tons was estimated in the year 2009 [14]. However, the food and feeding habits of this species in Lake Hayq had not been studied so far. Therefore, the present study is designed to generate baseline information on the food and feeding habits of *O. niloticus* in Lake Hayq. The information would be useful to create a food web in Lake Hayq, and eventually a trophic model that can be used in fisheries management and designing conservation strategies for sustainable utilization the fish as the biotic integrity of the lake is being affected by human activity such as deforestation, agriculture, use of chemicals in the catchment and grazing of lake shore.

2. Materials and methods
2.1 Description of the study area
Lake Hayq is located (Lat. $11^0 15$'N, Long. 39^0 57' E) in northern Ethiopia at an altitude of 2,030 m (Fig 1). The surface area, mean and maximum depth of the lake is 23 km^2, 37 m and 88.2 m, respectively, and the lake has a volume of 0.87 km^3 [15]. The water level of the lake fluctuates in relation to seasonal variations in rainfall. The volume of water increases during rainy season and vice versa for the dry season. Water temperature also varies from season to season. It becomes low in January, February, July and November where as it gets higher during April, May, August and September. The dominant cations in Lake Hayq water are magnesium and calcium [16]. The lake is alkaline, having a pH of 9.06 on average and the alkalinity, salinity and conductivity of the lake water are 50 meqL^{-1}, 0.828 gL^{-1} and 923 μscm^{-1}, respectively [16].
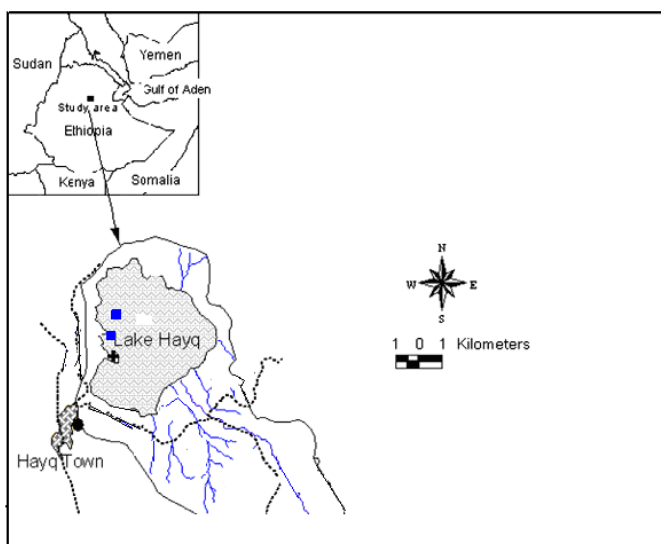

Fig 1: The map of Lake Hayq together with sampling stations (square dots) and drainage basin (Modified from Demlie *et al*. 2007).

2.2 Data collection and laboratory analysis
Fish samples were collected monthly, from August 2008 to March 2009 at the shore station fringed with macrophyte vegetation and relatively open water station (Fig 1). Fish were captured by gill nets (stretched mesh sizes of 3, 5, 6, and 8

cm). Gill nets were set always overnight and picked up on the following day morning. Soon after collection individual fish was measured to the nearest centimeter total length (TL) and gram total weight (TW), respectively. Then each fish was dissected and the gut contents were transferred to a labeled plastic bag containing 5% formaldehyde solution. Those fish without gut content were recorded as empty stomachs. The preserved stomach contents were taken to Addis Ababa University, for investigation. In the laboratory, the stomach contents were spread into flat and transparent materials such as petri-dishes. The food composition was identified both by visual inspection and microscope [17]. For the purpose of microscopic analysis, the samples were diluted to a manageable level. For zooplankton and other invertebrates, a 10 ml subsample was taken and placed in a counting chamber. The food items were then identified under a WILD type stereoscope (magnification 6X to 50X). In the same way, for phytoplankton enumeration a subsample was taken using a teat pipette. This was placed in a Sedgewick rafter cell which carries a volume of 1 ml. The food items were then enumerated under a compound inverted microscope (magnification 10X to 400X). The phytoplankton in the stomach contents was counted by the transect method using the procedures outlined in Lind [18]. The food items were identified to the lowest possible taxonomic group using descriptions, illustrations and keys in the literature [19, 20].

2.3 Data analysis
The contribution of each prey item to the diet was analyzed with two Relative Measures of Prey Quantity (RMPQ): frequency of occurrence % FO (percentage of the stomach with a prey item in relation to the number of stomach with food) and numerical abundance % NA (percentage of specimens of a prey item in relation to the total number of specimens) [21]. The frequency of occurrence (FO) and numerical abundance (NA) were also used to depict the monthly feeding periodicity of *O. niloticus.* In order to evaluate the relative importance of the food items the Geometric Index of Importance GII [22] were computed. It provides a mathematical representation based on the geometric distribution of RMPQ's treated as vectors that leads to a graphical comparison and hierarchical ranking of prey in classes of importance, using the larger discontinuities in the sequence of points that represent the decreasing index values. It is expressed as: $GII_j = (\Sigma V_i)_j / \sqrt{n}$; where, GII_j = Index value for the jth prey category, V_i = the ith RMPQ of the jth prey category, and n = number of RMPQ's used for the analysis. Similarity in the makeup of the diet (% NA of each food item) between size groups was also measured by using the multivariate statistical software PAST [23]. For this purpose, the analyzed fish were divided into four size groups using cluster analysis [23]. These categories were analyzed by the % NA of each major food item group. One-way analyses of similarities (ANOSIMs) were performed to identify any paired relationships. Similarity percentages (SIMPER) were used to identify which taxonomic food item characterized the dietary composition of each sample, and which taxonomic food items made the greatest contributions to any dissimilarity [24].

3. Results
3.1 Diet composition
Out of a total 931 fish examined, 605 (65%) had empty stomachs and 326 (35%) contained food. The size of the fish analyzed ranged between 4 and 30 cm in total length (Table 1).

These stomachs contained a total of 43 different taxonomic groups, and unidentified items, detritus, fish scales and eggs both plant and animal origins (Table 2). The plant food items were composed of macrophyte shoots and phytoplankton. Phytoplankton were represented by blue-green algae, diatoms, green algae and Euglenophyta. The first three taxonomic groups consisted of 9, 11 and 8 genera, respectively, while Euglenophyta was represented by a single genus, *Phacus* species (Table 2). On the other hand, the animal food item's composition of *O. niloticus* were Rotifera (6 genera), Cladocera (4 genera), Copepods (2 genera), fish eggs, scales and insect remains.

Table 1: The distribution of the 326 analyzed stomachs over size classes and months.

Class size in cm	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total
4-9.9	5	6	7	14	8	6	9	6	61
10-15.9	10	12	11	16	22	9	5	8	93
16-19.9	9	11	9	13	20	14	10	16	102
20-30	6	10	7	7	10	7	14	9	70

Based on numerical abundance method, the dominant food items of *O. niloticus* in Lake Hayq were green algae (42.2%) and blue green algae (41.8%). The significant quantities of these contributions were due to mainly *Cosmarium* (38.5%) and *Microcystis* (31.00%), respectively. Diatoms could be the second important food choice for the species constituting 11.6 % of the total food counted. Among diatoms high numerical abundance were due to *Nitzschia* (5.0%), *Melosira* (3.3%) and *Navicula* species (2.9%). Among zooplankton Cladocera (*Daphnia*) contributed 3.60% of the entire diet consumed by *O. niloticus*. The contribution of the remaining food items was negligible (See Table 2).

Blue-greens had the highest values of frequency of occurrence (95.6%). *Microcystis,* which were found in 87.7% of the examined guts, was the most important blue greens. Green algae were the second in occurrence (88.1%). This is mainly due to *Cosmarium* (65.13%). Diatoms were found to be the next most important dietary factors in the frequency of occurrence (86.5%), which appreciably represented by *Navicula* (64.3%), *Nitzschia* (56.54%) and *Melosira* (52.6%) of the examined guts (Table 2). Food items of animal origin cladocera, rotifera and copepoda contributed 76.2%, 58.5% and 50.2%, respectively. Fish eggs (13.3%) and scales (4.4%) were also consumed by the species. Moreover, macrophpyte shoots, detritus and insect remains were ingested by *O. niloticus* with frequency of occurrence of 6.5%, 5.5% and 2.0%, respectively. The remaining food items occurred rarely and made much less contributions to the diet of *O. niloticus* (Table 2). Therefore, blue greens, green algae, diatoms and Rotifera were found to be the most frequent food items.

Table 2: Qualitative and quantitative composition of the diet of Nile tilapia, *Oreochromis niloticus*, in Lake Hayq. %NA= percentage of numerical abundance, %NF= frequency of occurrence, GII= Geometric Index of Importance.

Food items	%NA	%FO	GII
Blue greens (Cyanophyta)	41.76	95.6	97.13
Anabaena	0.01	19.5	13.80
Microcystis	31	87.7	83.93
Oscillatoria	0.4	24.4	17.53
Lyngbya	0.03	26	18.41
Merismopedia	4.6	30.3	24.68
Aphanizomenon	0.001	8.5	6.01
Anabaenopsis	0.2	12.6	9.05
Chroococcus	5.3	46.9	36.91
Peridinium	0.3	24.4	17.47
Green Algae (Chlorophyta)	42.2	88.1	92.12
Oocystis	1.8	35.7	26.52
Tetraedron	1.6	38.2	28.14
Cosmarium	38.5	65.13	73.28
Pediastrum	0.002	17	12.02
Staurastrum	0.2	22.9	16.33
Spirogyra	0.01	18.5	13.08
Chlamydomonas	0.0031	17.5	12.38
Chlorococum	0.05	8.5	6.05
Planktonema	0.2	23.9	17.04
Diatoms (Bacillariophyta)	11.6	86.5	69.37
Navicula	2.9	64.2	47.45
Nitzschia	5	56.54	43.52
Fragilaria	0.1	20.4	14.5
Cyclotella	0.02	14.5	10.27
Gyrosigma	0.1	22.4	15.91
Melosira	3.3	52.6	39.53
Amphora	0.03	10	7.09

Cymbella	0.1	21.9	15.56
Hantzschia	0.01	1	0.71
Tabellaria	0.002	0.5	0.35
Surirella	0.03	1.5	1.08
Euglenophyta	0.2	13.8	9.9
Phacus	0.1	13.8	9.83
Rotifera	0.5	58.5	41.72
Keratella	0.4	52.3	37.26
Lecane	0.001	6.4	4.53
Trichocerca	0.02	9.4	6.66
Brachionus	0.01	2.5	1.77
Filinia	0.009	0.5	0.36
Cephalodella	0.001	2.5	1.77
Cladocera	3.6	76.2	56.43
Daphnia	3.6	71	52.75
Diaphanosoma	0.002	7.9	5.59
Moina	0.0002	4.9	3.46
Ceriodaphnia	0.01	11.8	8.35
Copepoda	0.1	50.2	35.57
Thermocyclops	0.1	43.8	31.04
Mesocyclops	0.001	4	2.83
Pisces	0.01	14.3	10.12
Fish scale	0.01	13.3	9.41
Fish eggs	0.004	4.4	3.11
Macrophyte shoots	0.024	6.6	4.68
Detritus	0.071	5.5	3.94
Insect	0.0004	2	1.42

3.2 Prey importance

The geometric importance index (Table 2) indicated that *Microcystis* (83.93) was the most consumed group (Fig 2). *Cosmarium* (73.28*)* and *Daphnia* (52.77) also appeared as the first level of prey importance (Fig 2). On the other hand, the plankton such as *Navicula* (47.45), *Nitzschia* (43.53), *Melosira* (39.53), *Keratella* (37.26), *Thermocyclops* (31.04), *Tetraedron* (28.14), *Oocystis* (26.52) and *Merismopedia* (24.68) were consumed secondarily by *O. niloticus* in the lake. The remaining prey categories as indicated in Fig 2 (below the *Lyngbya*) considered as the third order of importance or rare/occasional sources of food. Moreover, Food items (30 organisms, unidentified items and detritus) with GII values ranging from 18.41 to 0.35 did not appear to play an important role in the diet of *O. niloticus*. Therefore, these 30 organisms and others (*Lyngbya, Oscillatoria, Peridinium, Planktonema, Staurastrum, Gyrosigma, Cymbella, Fragillaria, Anabaena, Spirogyra, Chlamydomonas, Pediastrum, Cyclotella, Phacus, Anabaenopsis, Ceriodaphnia, Amphora, Trichocerca, Chlorococum, Aphanizomenon, Diaphanosoma, Lecane,* *Moina, Mesocyclops, Brachionus, Cephalodella, Surirella, Hantzschia, Filinia, Tabellaria*, macrophyte shoots, animal remains and detritus) were removed from subsequent evaluations both in monthly and size based variations in food consumption (Fig 2).

3.3 Seasonal variation in diet composition

The main food items from primarily and secondarily consumed 12 organisms (Fig 3, Fig 4, Fig 5 and Fig 6) were used to examine the seasonal variations of the diet of *O.* *niloticus* in Lake Hayq. As shown in Fig 3, *Microcystis* and *Cosmarium* were consumed throughout the study period with a mean GII over 70. During August-October, *Microcystis* were more preferred food items to *Cosmarium.* Yet, for the three consecutive months (November-January), Microcystis showed a decrease trend and substituted by Cosmarium (Fig 3). Fig 4 indicates an alternating consumption of three organisms: *Navicula, Nitzschia* and *Daphnia* over the period of investigation. As one understands from the figure, *O. niloticus* preferred *Daphnia* to *Navicula and Nitzschia* during August-October. *Daphnia* and *Nitzschia* tended to decrease in January (Fig 4). However, mean GII values for these organisms were under 30 (Fig 4). *Keratella, Chroococcus and Thermocyclops* preferred by *O. niloticus* almost in equal proportions in August and *Melosira* were consumed by the fish from October onwards (Fig 5). *Chroococcus* were dominated the food composition of the fish in September while *Thermocyclops* in February (Fig 5). The importance of *Merismopedia* in the early months was low, but progressively increased and reached maximum in March (Fig 6). The GII values of these organisms were lower than 26. If Figures 4, 5 and 6 are compared, it is observed that *Merismopedia*, *Melosira* and *Keratella* were highly consumed during dry season (January-February) but were consumed less in wet season (August-October), and *Oocyst* and *Chroococcus* were more heavily consumed in the wet season while *Daphnia* were indiscriminatingly consumed during dry and in the wet season. Generally, phytoplankton were the dominant food items in the study period, and the importance of diatoms as a group had increased during the dry season.
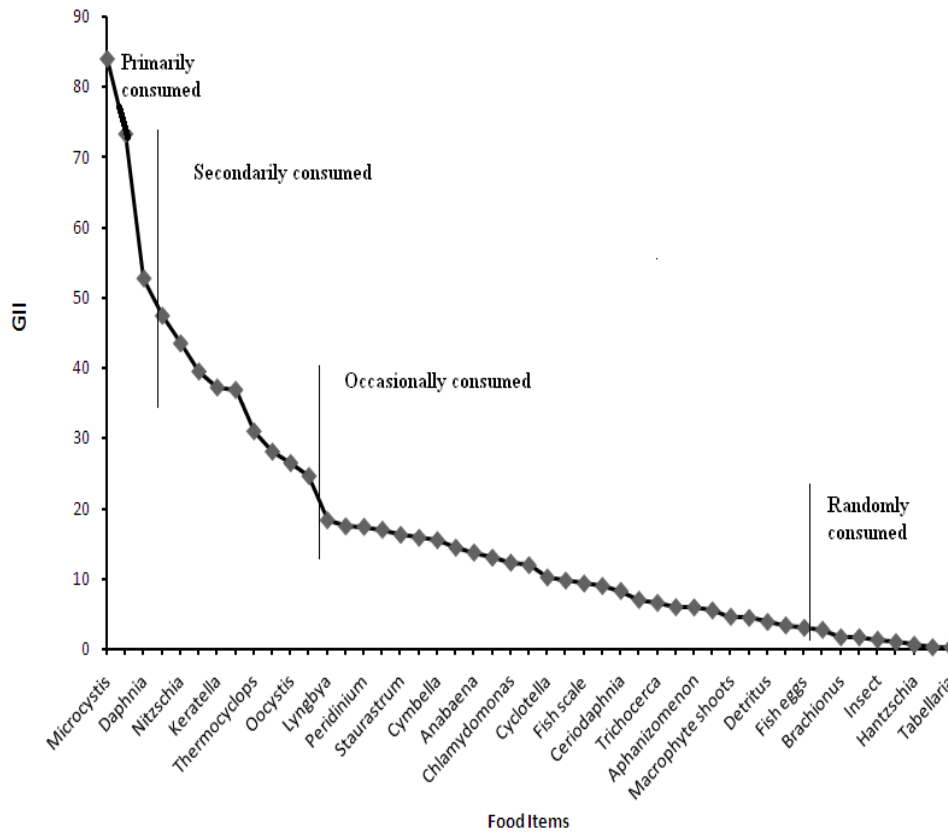
Fig 2: The values of the geometric importance index, GII, for all fish analyzed. Vertical lines separate first food items preferred from the secondary or the third food items.

3.4 Food in relation to fish size

The relationship between *O. niloticus* size (TL) and its food based on the GII values of 12 organisms are presented in Fig 7. All the size groups ingested almost all the major food items. In addition, all phytoplankton food items except *Oocyst* were equally important for fish in all length groups with mean GII values of 325. However, there were also some size-based differences in food habit. For instance, the fish belonging to size groups of 10-15.9 and 16-19.9 cm were relatively consumed higher proportions of *Cosmarium* to that of the rest of the group. In addition, the GII values of *Tetraedron* and *Oocyst* increased with fish size, but *Oocyst* did not occur in the smallest length classes (4-9.9 cm). Furthermore, the importance of *Thermocyclops* tended to increase with fish size whereas *Daphnia* and *Keratella* were preferred by the fish found in the size middle classes of 10-15.9 and 16-19.9 cm.

Some size-based difference in food habit of *O. niloticus* in Lake Hayq was also noted by one-way analyses of similarities (ANOSIMs), expressed by similarity percentage (SIMPER). The analysis showed that there was variation in diet between size groups (R= 0.989, P= 0.01). The pairwise tests result depicted that there were in significant differences between group I and group III (R = 0.975, p = 0.01) and group III and group IV (R = 0.664, p = 0.01). Among the food items, the ones that were principally responsible for the variation were Microcystis and Cosmarium (Table 3).

Table 3: The contribution of food items to observed dietary differences among *O. niloticus* size classes determined by SIMPER analysis. Abund. = abundance, CI= class interval, I= 4-9.9 cm, II= 10-15.9 cm, III= 16-19.9 cm, IV= >20 cm.

Taxon	Mean abund. 1	Mean abund. 2	Contribution	Cumulative%
Average dissimilarity I vs III =56.5				
Cosmarium	36.2	90.2	29.18	51.62
Microcystis	25.7	1.09	13.28	75.11
Navicula	11.1	0.73	5.62	85.05
Nitzschia	6.87	0.49	3.45	91.14
Melosira	5.87	1.28	2.48	95.53
Merismopedia	0.03	2.61	1.40	98
Average dissimilarity III vs IV=43.9				
Cosmarium	90.2	48.2	21.51	49.18
Microcystis	1.09	25.8	12.64	78.08
Nitzschia	0.49	12.5	6.13	92.11
Merismopedia	2.61	5.79	1.63	95.83

For instance, size group I (4-9.9 cm TL) and size group III (16-19.9 cm TL) had an average total dissimilarity of 56.53%.

The contribution to the total dissimilarity of *Cosmarium* was 29.2 %, whereas that of *Microcystis* and *Navicula* were 13.3%

and 5.6%, respectively. Similarly, size group III (16-19.9 cm TL) and size group IV ((>20 cm TL) had an average total dissimilarity of 43.9%. The contribution to the total dissimilarity of *Cosmarium* was 21.5 %, whereas that of *Microcystis* and *Nietzsche* were 12.6% and 6.1%, respectively. In general, the size groups pooled had an average dissimilarity of 34.8 %. The contribution to the total overall dissimilarity

Cosmarium was 16.6%, whereas that of *Microcystis, Nitzschia* and *Navicula* were 7.3%, 3.6% and 2.8%, respectively (Table 4). The rest groups combined contributed less than 4.4% to the dissimilarity of the diets for all between size groups' comparisons (Table 4). All between size group comparisons show a relatively low percentage of difference.

Table 4: The overall contribution of food items to observed dietary differences among *O. niloticus* size classes determined by SIMPER analysis. Abund. = abundance, CI= class interval, I= 4-9.9 cm, II= 10-15.9 cm, III= 16-19.9 cm, IV= >20 cm.

Taxon	Mean abund. I	Mean abund. II	Mean abund. III	Mean abund. IV	Contribution	Cumulative %
			Overall average dissimilarity = 34.77			
Cosmarium	36.2	74.9	90.2	48.2	16.6	47.8
Microcystis	25.7	15.8	1.09	25.8	7.32	68.86
Nitzschia	6.87	1.86	0.49	12.5	3.58	79.15
Navicula	11.1	0.99	0.73	0.91	2.82	87.26
Merismopedia	0.03	1.1	2.61	5.79	1.65	92.01
Melosira	5.87	0.72	1.28	0.44	1.51	96.36

4. Discussion
Nile tilapia, *O. niloticus*, has a versatile feeding behavior and characterized as a generalist and opportunistic omnivore [3]. This is in concord with the diet composition found in this work, which also demonstrated a high diversity of food points. This suggests that the species take advantage of the food items that are most available. Notable differences have been found in the diet composition of this species between different regions, which suggests a close relationship with the local fauna and flora. For example, it has been reported that detritus was an important food item for the same species in Lake Langeno [25], insects in Lake Victoria [11] and macrophytes in the Nile canal [26], which were insignificant contribution in the present study. However, the dominant food items eaten by the species in Lake Hayq based on mathematical methods were blue greens (41.76%), green algae (42.2%) and diatoms (11.6). The frequency of occurrence method also revealed that these three food items were the most important food menus in the diet of *O. niloticus*. In addition, cladocerans (56.43%), rotifers (41.72 %) and copepods (35.57%) had contributed an appreciable amount of diet for the species in terms of frequency of occurrence. Other studies conducted for the same species in Lakes Chamo [4, 27], Awassa [10], and Ziway [9] and elsewhere [5, 6, 28] showed similar results. Furthermore, the frequency of occurrence and numerical methods could not explain the relative importance of these food items adequately and it is, therefore, very important the need to estimate by a more objective method, Geometric Index of Importance (GII). The values obtained using GII further substantiated strong evidence to the fact that the blue greens, green algae and diatoms are the most preferred food source of *O. niloticus* in the study area. In improver to these food items, Cladocera, Rotifera and Copepoda were consumed secondarily while Pisces, Euglenophyta, macrophyte shoots, detritus and insect remain occasional sources of nutrient. The study conducted on the same lake by [14] 40 phytoplankton taxa identified belonging to Chlorophyta (47%), Bacillariophyta (30%), Cyanoprokaryota (11%), and Cryptophyta, Dinopyhyta and Euglenophyta together contributed 11% abundance. The study also included the presence of 11 zooplankton species belonging to Copepoda

(2 species), Cladocera (2 species) and Rotifera (6 species), but dominated by *Thermocyclops ethiopiensis*. Accordingly, analysis of stomach contents of *O. niloticus* in this study showed a good relation with the plankton recorded in the research studied by [14]. However, the abundance of Chlorophyta in the stomachs of *O. niloticus* is much exceeded to that of the actual environment obtained by [14]. Though we didn't calculate the selectivity index, the fish was preferentially consumed blue green algae. This could be because blue-green algae were efficiently assimilated off by the fish in tropical lakes [8]. Interestingly, before the introduction of this fish, Lake Hayq was oligotrophic water body [15]. Currently, however, it is turned into a eutrophic lake [14]. As confirmed from this study, the food spectrum of the fish comprised diverse plankton taxa. The intense grazing on zooplankton, which had been playing a role in structuring phytoplankton biomass formerly, by this fish may be facilitated for the aging of the lake via a cascading effect through the food web interactions [14]. Hence, the fish has been played a lot in shaping the ecology of Lake Hayq.
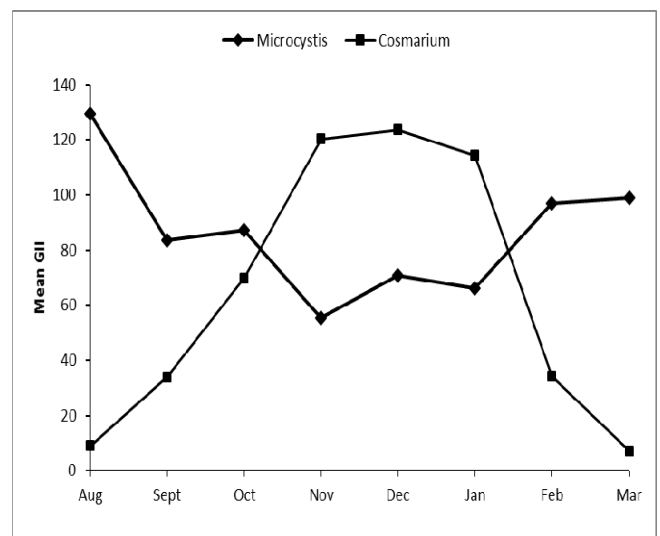

Fig 3: Monthly variations of *Microcystis* and *Cosmarium* ingested by *O. niloticus* in Lake Hayq based on its mean GII values.
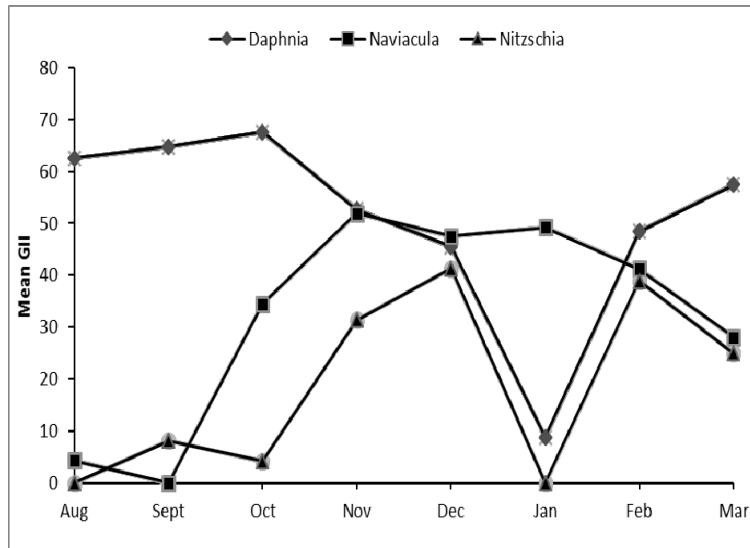
Fig 4: Monthly variations of *Daphnia, Navicula* and *Nitzschia* ingested by *O. niloticus* in Lake Hayq based on its mean GII values.
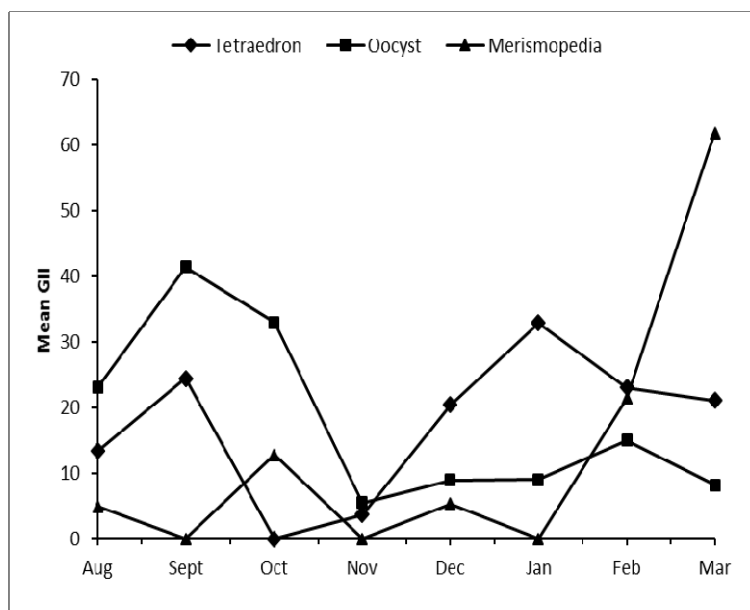

Fig 5: Monthly variations of *Melosira, Kerratella, Chroococcus* and *Thermocyclops* ingested by *O. niloticus* in Lake Hayq based on its mean GII values.
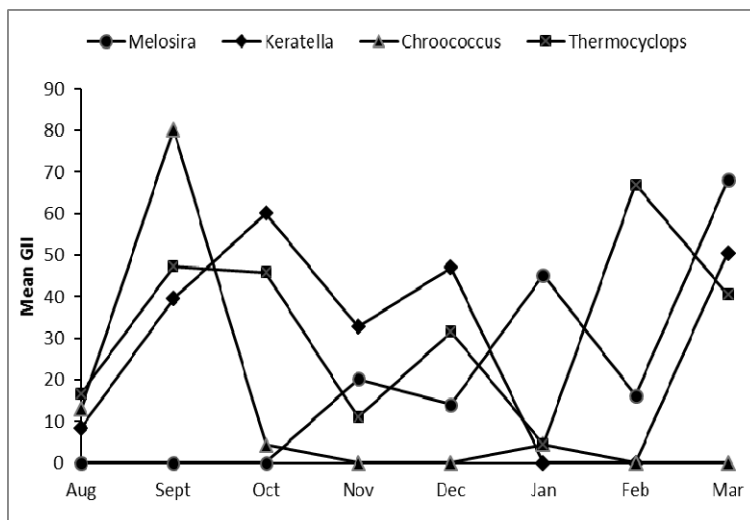

Fig 6: Monthly variations of *Tetraedron, Oocyst,* and *Merismopedia* ingested by *O. niloticus* in Lake Hayq based on its mean GII values.

The most dominant genera of food items for *O. niloticus* have been different for different populations. In this study, the dominant genera among phytoplankton were *Microsystis and Cosmarium* while *Daphnia* was among zooplankton. However,

the dominant genus/genera ingested by the species were *Botryococcus* (green algae) and *Oscillatoria* (blue green algae) in Lake Awassa [8, 10], and it was *Lyngbya* (blue green algae) in Lake Ziway [9] (and *Melosira* (diatoms) in Lake Chamo [27]. The dominance of one food item over the other could be the result of selective feeding to increase nutritional benefit [29]. Furthermore, it is related to the dominance and seasonal dynamics of plankton population in a given water body since *O. niloticus* is opportunistic feeders [3].

All the size groups of *O. niloticus* ingested the major food items, but the food composition of the fish varies with its size. The size based difference is also strongly supported by one way analysis of similarities (ANOSIMs) in this study. It has been theorized that because juvenile fish have higher mass specific protein demand as a result of higher specific growth rate and greater mass specific metabolism, they may not fulfill their needs by consuming an herbivorous diet [30]. Small fish

may be driven to consume animal prey, which have more outstanding substance of protein and energy per unit weight [30]. This suggests a reason why there is a change in diet as fish size increases. Such strategy could also help the fish to reduce competition for food within various size groups. Moreover, a general pattern of the feeding habits of *O. niloticus* was suggested by [31], in which small individuals feed mainly on zooplankton while larger individuals feed on diverse food items, but more on phytoplankton which is in partial agreement with the present study. However, in contrast to [9], copepods tended to increase with fish size in this study, probably the food items could be large in size as the zooplankton community Cyclopoid copepods dominated by *Thermocyclops ethiopiensis* in Lake Hayq [14]. Consequently, juvenile *O. niloticus* may not filter efficiently, which is waiting for further investigation.
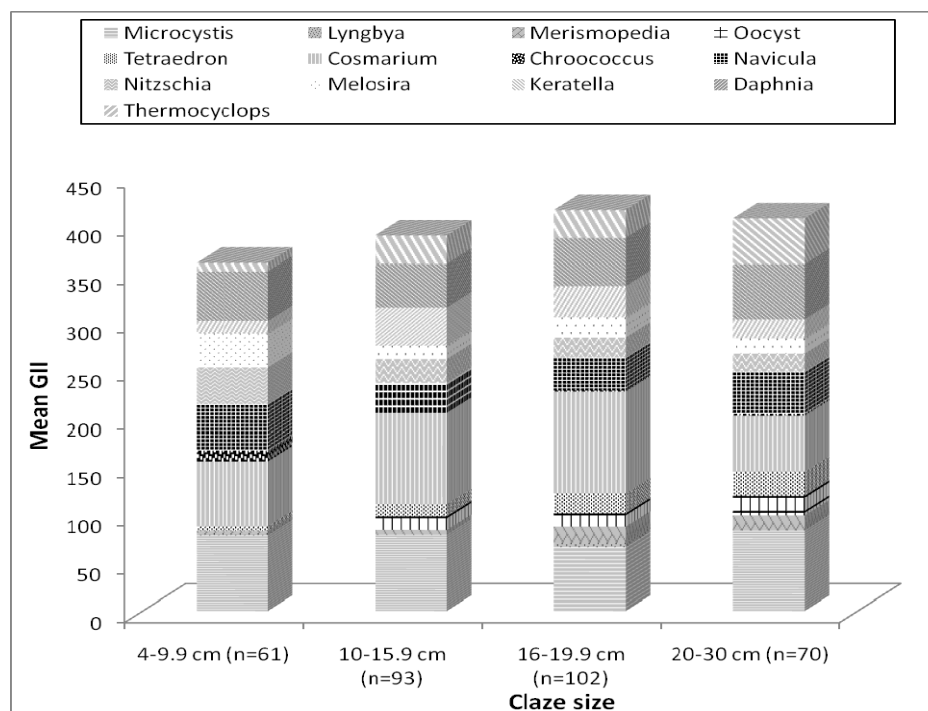

Fig 7: GII values of primarily and secondarily consumed food items of *O. niloticus* of different length groups from Lake Hayq.

The monthly variation in the composition of the food consumed by *O. niloticus* showed a slight fluctuation. For example, the contribution of zooplankton to the diet of *O. niloticus* was very low in January, while the importance of diatoms increases during dry season. In the same lake, [14] indicates that the lowest total biomass of zooplankton were recorded during the dry season and the biomass of diatoms was mainly dominated from December 2007 through June 2008 which is coinciding with the present study. The seasonal variability observed in the diets may be referred to local changes in the accessibility of food items that are determined by climatic changes [32]. The monthly diet observed may also be related to relative abundance and convenient size of food items in the lake. The seasonal variation in food habit could be due to the opportunistic nature of the fish, which is capable of shifting from one diet to another, depending on temporal and/or spatial variations in availability of the diet, which could be the case for *O. niloticus* in the present study [33].

The result obtained in this study showed that about 65% of the guts of *O. niloticus* examined had empty stomachs. The food

items in their stomach may have been regurgitated or digested as the fish try to scramble to escape from gill nets as it was gathered up after overnight. Moreover, during breeding activity, the fish spend more time on spawning than on feeding [8], which could be another element leading to the high incidence of empty stomachs.

In conclusion, the most important food items for *O. niloticus* in Lake Hayq were found to be blue greens, green algae, and diatoms. The diet of all size groups of *O. niloticus* consists mainly of phytoplankton and zooplankton and the species can be considered as a generalist and a planktivorous fish that can feed on a wide range of food resources. Presently, the global trend fisheries management is changing from a single species based towards a multispecies or ecosystem based management strategy [34]. Therefore, ecosystem function, organization and species interactions, such as food and feeding patterns of animals and understanding the factors that shape their behavior or competition must be understood [34]. Hence, the investigation of *O. niloticus* feeding habit is an important step towards the data needed to create a food web in Lake Hayq,

and eventually a trophic model that can be used in fisheries management.

6. References
1. Getahun A. An overview of the diversity and conservation status of the Ethiopian freshwater fish fauna. Journal of Afrotropical Zoology 2007; 87-96.
2. Shibru T. Freshwater Fishes of Ethiopia. Haile Selassie I University. Department of Biology, Addis Ababa, Ethiopia, 1973, 101.
3. Canonico GC, Arthington A, Mccrary JK, Thieme ML. The effects of introduced tilapias on native biodiversity. Aquatic Conservation: Marine & Freshwater Ecosystem, 2005; 15:463–483.
4. Bwanika GN, Makanga B, Kizito Y, Chapman LJ, Balirwa J. Observations on the biology of Nile tilapia, *Oreochromis niloticus* L., in two Ugandan crater lakes. African Journal of Ecology 2004; 42(Supplement 1):93-101.
5. Teferi Y, Admassu D, Mengistou S. The food and feeding habits of *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Chamo, Ethiopia. SINET. Ethiopian Journal of Science 2000; 23(1):1-12.
6. Shalloof KASH, Khalifa N. Stomach contents and feeding habits of *Oreochromis niloticus* (L.) From Abu-Zabal Lakes, Egypt. World Applied Science Journal 2009; 6(1): 01-05.
7. Oso JA, Ayodele IA, Fagbuaro O. Food and feeding habits of *Oreochromis niloticus* (L.) and *Sarotherodon galilaeus* (L.) in a Tropical Reservoir. World Journal of Zoology 2006; 1:118-121.
8. Tefera G. A study on an herbivorous fish, *Oreochromis niloticus* L., diet and its quality in two Ethiopian Rift Valley lakes, Awasa and Zwai. Journal of Fish Biology 1987; 30:439-449.
9. Tadesse Z. Food and Feeding Ecology of Tilapia, *Oreochromis niloticus* L. and effects of diet on the lipid quality of fish in some Lakes in Ethiopia. Ph.D. dissertation, School of Graduate studies, Addis Ababa University, Addis Ababa, 1998; 139.
10. Tudorancea C, Fernando CH, Paggi JC. Food and feeding ecology of Oreochromis niloticus (Linnaeus, 1758) juveniles in Lake Awassa (Ethiopia). Achieve Hydrobiologia, 1988; 79(Supplement):267-289.
11. Njiru M, Okeyo-Owuor B, Muchiri M, Cowx IG. Shifts in the food of Nile tilapia, *Oreochromis niloticus* (L.) in Lake Victoria, Kenya. African Journal of Ecology 2004; 42(3):163-170.
12. Njiru M, Ojuok J, Getabu A, Jembe T, Owili M, Ngugi C. Increasing dominance of Nile tilapia, *Oreochromis niloticus* (L) in Lake Victoria, Kenya: Consequences for the Nile perch *Lates niloticus* (L) fishery. Aquatic Ecosystem Health and Management 2008; 11(1):42–49.
13. Kebede E, Teferra G, Taylor WD, G/Mariam Z. Eutrophication of Lake Hayq in the Ethiopian Highlands. Journal of Plankton Research 1992; 14(10):1473-1482.
14. Fetahi T. Plankton Communities and Ecology of Tropical Lakes Hayq and Awasa, Ethiopia. Ph.D. dissertation, School of Graduate Studies, Addis Ababa University, Addis Ababa, 2010, 98.
15. Baxter RM, Golobitsh DL. A note on the limnology of Lake Hayq. Limnology & Oceanography 1970; 15(1):144-149.
16. Gebre-Mariam Z, Chapman LJ, Chapman CA. Conductivity as a predictor of a total cations and salinity in Ethiopian lakes and rivers: revisiting earlier models. Limnologica 2002; 32:21-26.
17. Windell JT, Bown SH. Methods for the study of fish diets based on analysis of stomach contents. In: Bagenal TB, ed. Methods for Assessment of Fish Production on Freshwaters. IBP. Handbook, Black well, Oxford, 1978; 3:219-226.
18. Lind OT. Hand Book of Common Methods in Limnology. The C.V. Mosby Company, Saint Louis, 1974, 199.
19. Whitford LA, Schuamacher GJ. A Manual of Freshwater Algae. Sparks Press. Raleigh, N.C., 1973, 324.
20. Defaye D. Contribution a la connaissance des crustaces copepodes d'Ethiopie. Hydrobiologia 1988; 164:103-147.
21. Hyslop EJ. Stomach content analyses- A review of methods and their application. Journal of Fish Biology 1980; 17:411-429.
22. Assis CA. A generalised index for stomach contents analysis in fish. Scientia Marina 1996; 60:385–389.
23. Hammer Ø, Harper DAT, Ryan PD. PAST: Palaeontological Statistics, software Package for education and data analysis, ver. 1.90. Palaeonotologia Electronica, 2001.
24. Clarke KR. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 1993; 18:117-143.
25. Tadesse Z. The nutritional status and digestibility of *Oreochromis niloticus* L. diet in Lake Langeno, Ethiopia. Hydrobiologia 1999; 416:976-106.
26. El-Sayed AK, Alme-na-ei A. Feeding ecology of *Oreochromis niloticus* and *Tilapia zillii* in a Nile canal. Hydrobiologia 1987; 146:57–62.
27. Tefera G. The composition and nutritional status of the diet of *Oreochromis niloticus* in Lake Chamo, Ethiopia. Journal of Fish Biology, 1993; 42:864-874.
28. Getabu A. A comparative study on the feeding habits of *Oreochromis niloticus* in Nyanza Gulf, Lake Victoria and Sewage ponds. In: Okemwa E, Wakwabi E, Getabu A, eds. Proceedings of the Second EEC Regional Seminar on Recent Trends of Research on Lake Victoria Fisheries, Kisumu, Kenya. ICIPE Press, Nairobi, Kenya, 1994, 93-103.
29. Bown SH. Detrital non-protein amino acids are the key to the rapid growth of Tilapia in Lake Valencia, Venezuela. Science 1980; 207:216-1218.
30. Benavides AG, Cancino JM, Ojeda FP. Ontogenetic change in gut dimensions and microalgal digestibility in the marine herbivorous fish, *Aplodactylus punctatus*. Functional Ecology 1994; 8:46–5.
31. Moriarty CM, Moriarty DJW. The assimilation of carbon from phytoplankton by two herbivorous fishes: *Tilapia nilotica* and *Haplochromis nigripinnis*. Journal of Zoology 1973; 171:41–55.
32. Sierra LM, Claro R, Popova OA. Alimentación y relaciones tróficas. In: Claro C, ed. Ecología de los peces marinos de Cuba, Centro de Investigaciones de Quintana Roo (CIQRO), México, 1994, 263-320.
33. Philipart JC, Ruwet TM. Ecology and distribution of

Tilapias. In: Pullin RSV, Lowe-McConnell RH, eds. The Biology and Culture of Tilapias. Manila, Philippines, 1982, 25-59.

34. Marasco RJ, Goodman D, Grimes CB, Lawson PW, Punt AE, Quinn TJ. Ecosystem-based fisheries management: some practical suggestions. Canadian Journal of Fisheries & Aquatic Science 2007; 64(6):912-928.