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The Food and Feeding Ecology of Nile Tilapia, *Oreochromis niloticus*, in Lake Hayq, Ethiopia

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ABSTRACT

We investigated 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 gillnets 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 *Microsystis* (31%) dominated the food of *O. niloticus*. However, Geometric Importance Index GII suggested that the most consumed group was *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 with 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 study is an important step towards understanding the food web in Lake Hayq, and eventually developing a trophic model for use in fisheries management.

Key Words**:** Diet Composition; Feeding Habits; Food Items; Size Groups; Planktivorous; Geometric Importance Index

INTRODUCTION

Ethiopia is endowed with enormous freshwater resources. It has over 20 natural lakes including ponds, rivers, reservoirs and wetlands covering an estimated surface area of 18587 km^2 (Ethiopian Environmental Protection Authority, 2010). These water bodies have been estimated to give a refuge for more than 150 fish species (Getahun 2007). 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 (Shibru Tedla 1973), and accounted 60 % of the capture fishery in the country (Getahun 2007).

The feeding habits of Nile tilapia consist of a great variety of aquatic organisms depending upon availability (Canonico et al. 2005). A study on 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 (Canonico et al. 2005). For example, the species was essentially planktivorous, showing preference for phytoplankton species such as blue greens, green algae and diatoms in Lake Chamo (Teferi et al. 2000) and in crater lakes of Uganda

(Bwanika et al. 2004). On the other hand, *O. niloticus* was found to be omnivorous in Lake Abu-Zabal, Egypt (Shalloof and Kahlif 2009) and in Ero Reservoir, Nigeria (Oso et al., 2006). Their feeding habits also vary with age and size (Philipart and Ruwet 1982). As the sizes of the fish increases, the consumption of large quantity of various phytoplankton evidently increased (Teferra 1987, Tadesse 1998). Juvenile *O. niloticus* with less than 6 cm total length consumes chironomid larvae, copepods, and rotifers in Lake Ziway (Tadesse 1988) and nematodes and zooplankton in Lake Awassa (Tudorancea et al. 1988). *O. niloticus* is able to modify their feeding habits depending on the availability of natural feeds as well (Njiru et al. 2004). For instance, in Lake Victoria, Nile tilapia exhibited a trophic shift from predominantly herbivorous to a more diversified diet where the importance of algae decreases while fish, plants and invertebrates increases (Njiru et al. 2008).

Lake Hayq, which is one of the freshwater highland lakes in Ethiopia, is located some 450 km far from the capital, Addis Ababa. *O. niloticus* was introduced in the study area in 1978 (Kebede et al. 1992). 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 (Kebede et al. 1992). Since then the fish has quickly established successfully and become commercially important species in the region. In the 1990s an annual harvest of 200 Mg (=ton) *O. niloticus* was recorded and a sustainable maximum yield (biomass) of 298 Mg was estimated in 2009 (Fetahi 2010). 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 habit 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 lakeshore.

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 (Figure 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 (Baxter and Golobitsh 1970).

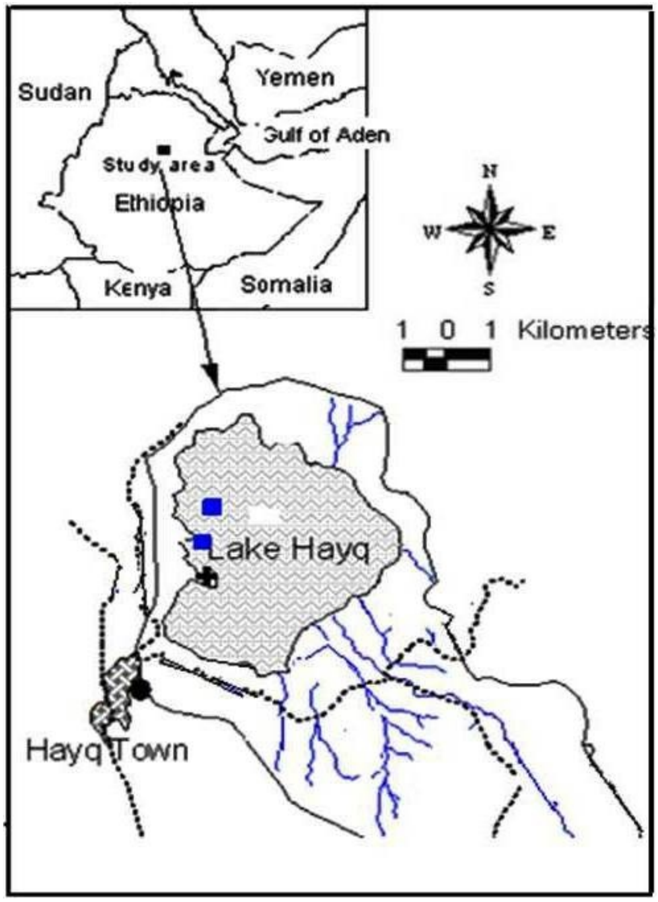

Figure 1. Map of Lake Hayq showing sampling stations (square dots) and drainage basin (Modified from Demlie et al. 2007)

The water level of the lake fluctuates in relation to seasonal variability 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 high during April, May, August and September. The dominant cations in Lake Hayq water are magnesium and calcium (Gebre-Mariam et al. 2002). The lake is alkaline having an average pH of 9.06. The alkalinity, salinity and conductivity of the lake water are 50 meq L^{-1}, 0.828 g L^{-1} and 923 μS cm^{-1}, respectively (Gebre-Mariam et al. 2002).

Sample Collection and Laboratory Analysis

Fish samples were collected monthly from August 2008 to March 2009 at shore station fringed with macrophyte vegetation and relatively open water station (Figure 1). Fish were captured by gill nets (stretched mesh sizes of 3, 5, 6, and 8 cm). Gill nets were set always overnight and collected 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 under microscope (Windell and Bown 1978). For the purpose of microscopic analysis, the samples were diluted to 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 were counted by transects method using the procedures outlined in Lind (1974). The food items were identified to the lowest possible taxonomic group using descriptions, illustrations and keys in the literature (Whitford and Schumacher 1973, Defaye 1988).

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 stomachs with a prey item in relation to the number of stomachs with food), and numerical abundance - % NA (percentage of specimens of a prey item in relation to the total number of specimens) (Hyslop 1980). 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 (Assis 1996) 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:

$$GIIj = (\Sigma Vi)j/\sqrt{n};$$

where, GIIj = Index value for the j^{th} prey category, Vi = the i^{th} RMPQ of the j^{th} prey category, and n = number of RMPQ's used for the analysis.

Similarity in the composition of the diet (% NA of each food item) between size groups was also assessed by using the multivariate statistical software PAST (Hammer et al. 2001). For this purpose, the analyzed fish were divided into four size groups using cluster analysis (Hammer et al. 2001). These categories were analyzed by % 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 (Clarke 1993).

RESULTS

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* spp. (Table 2). On the other hand, the animal food items composition of *O. niloticus* were Rotifera (6 genera), Cladocera (4 genera), Copepoda (2 genera), fish eggs, scales and insect remains.

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

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

Class size in cm	August	September	October	November	December	January	February	March	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

Cladocera (*Daphnia*) contributed 3.60 % of the entire diet consumed by *O. niloticus*. The contribution of the remaining food items were 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 components in 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. Qualitative and quantitative composition of the diet of Nile tilapia in Lake Hayq.
NA= Numerical Abundance, FO= 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
Fragillaria	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

(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. Further, macrophyte 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 little contributions to the diet of *O. niloticus* (Table 2). Thus, blue greens, green algae, diatoms and rotifers were the most frequent food items.

Prey Importance

The geometric importance index (Table 2) indicated that *Microcystis* (83.93) was the most consumed group (Figure 2). *Cosmarium* (73.28*) and Daphnia* (52.77) also appeared as first level of prey importance (Figure 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 Figure 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 (Figure 2).

Seasonal Variation in Diet Composition

The main food items from primarily and secondarily consumed 12 organisms (Figure 3, Figure 4, Figure 5 and Figure 6) were used to examine the seasonal variations of the diet of *O. niloticus* in Lake Hayq. As shown in Figure 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.* However, for the three consecutive months (November to January), *Microcystis* showed a decrease trend and substituted by *Cosmarium* (Figure 3). Figure 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 (Figure 4). However, mean GII values for these organisms were below 30 (Figure 4). *Keratella, Chroococcus* and *Thermocyclops* preferred by *O. niloticus* almost in equal proportions in August and *Melosira* were consumed by the fish from October on wards (Figure 5). *Chroococcus* were dominated the food composition of the fish in September while *Thermocyclops* in February (Figure 5). The importance of *Merismopedia* in early months was low but progressively increased and reached maximum in March (Figure 6). The GII values of these organisms were lower than 26. A comparison of Figures 4, 5 and 6 shows that *Merismopedia*, *Melosira* and *Keratella* were highly consumed during dry season (January-February) but were consumed less in wet season (August-October), and *Oocystis* and *Chroococcus* were more heavily consumed in the wet season while *Daphnia* were indiscriminatingly consumed during dry and 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.

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 Figure 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 cm and 16-19.9 cm consumed relatively higher proportions of *Cosmarium* than that of the rest of the groups. In addition, the GII values of *Tetraedron* and *Oocystis* 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 where as *Daphnia* and *Keratella* were preferred by the fish found in the size middle classes of 10-15.9 cm 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

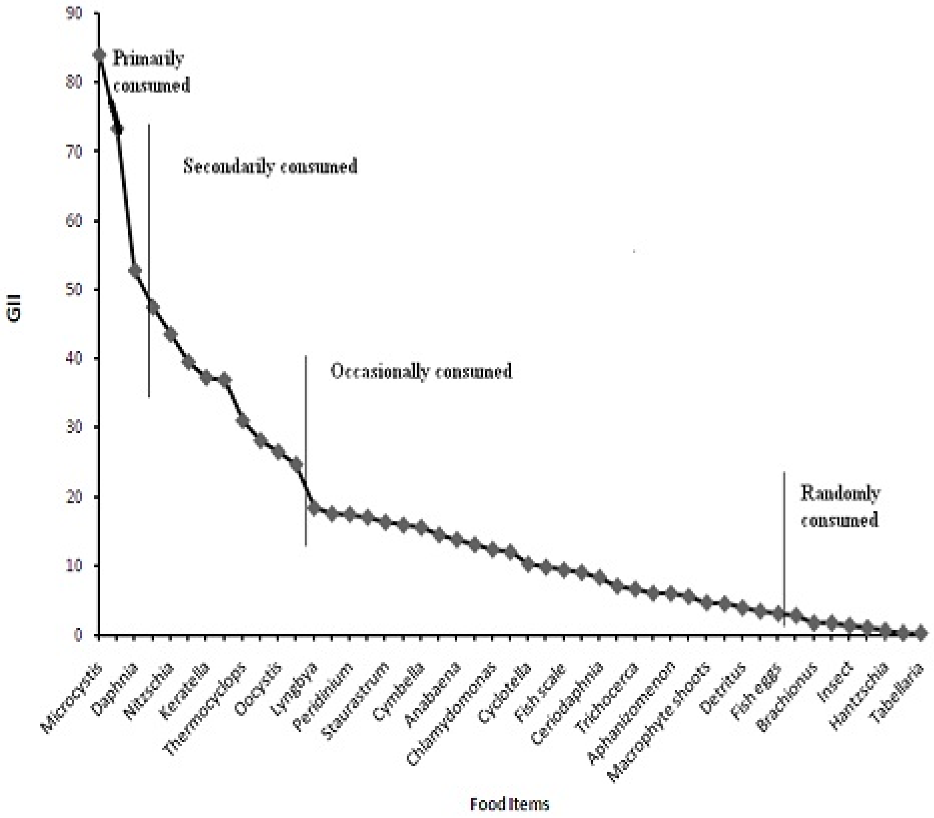

Figure 2. Values of the geometric importance index, GII, for all fish analyzed. Vertical lines separate first food items preferred from the secondary or the third food items.

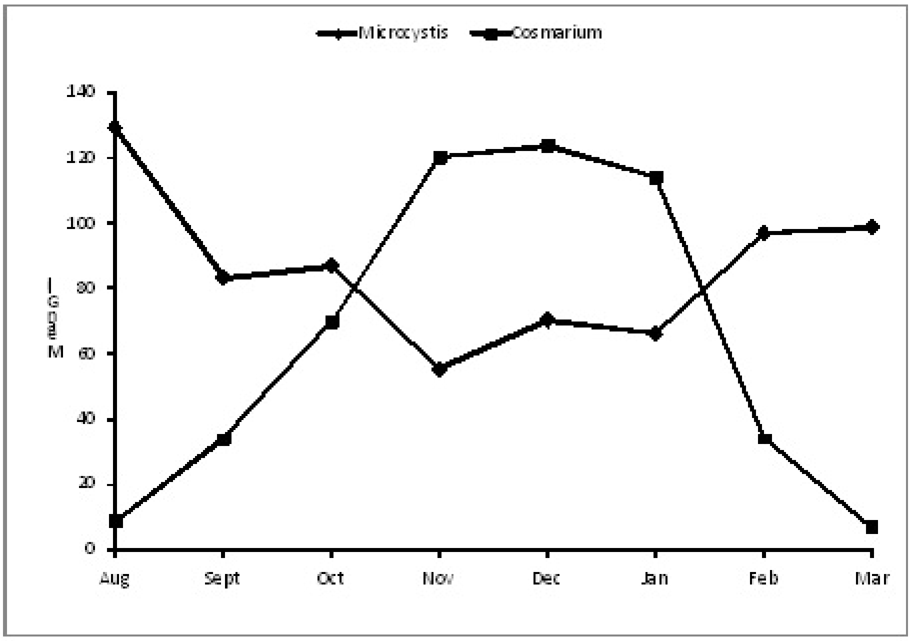

Figure 3. Monthly variations of *Microcystis and Cosmarium* ingested by *O. niloticus* in Lake Hayq based on its mean GII values.

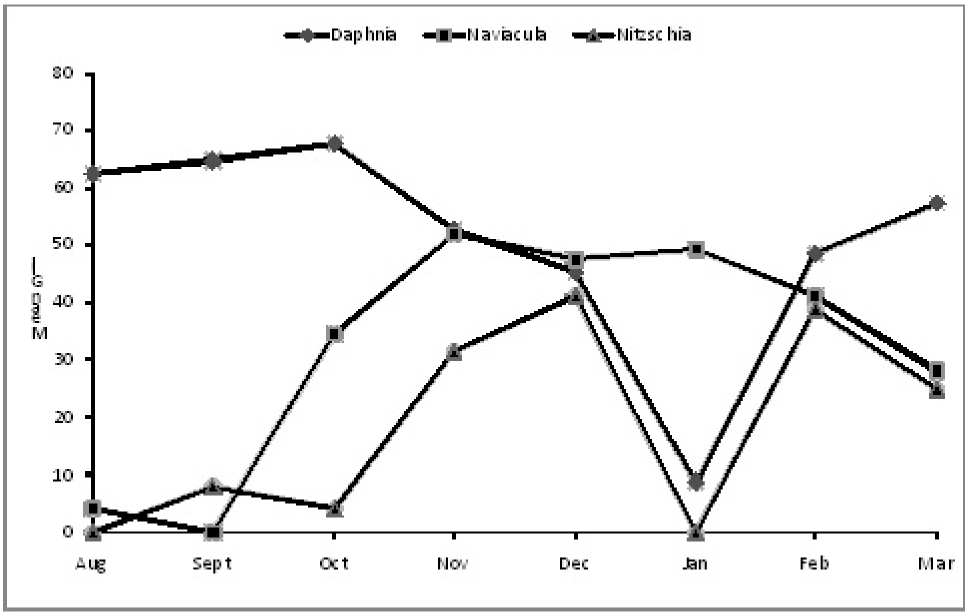

Figure 4. Monthly variations of *Daphnia, Navicula and Nitzschia* ingested by *O. niloticus* in Lake Hayq based on its mean GII values.

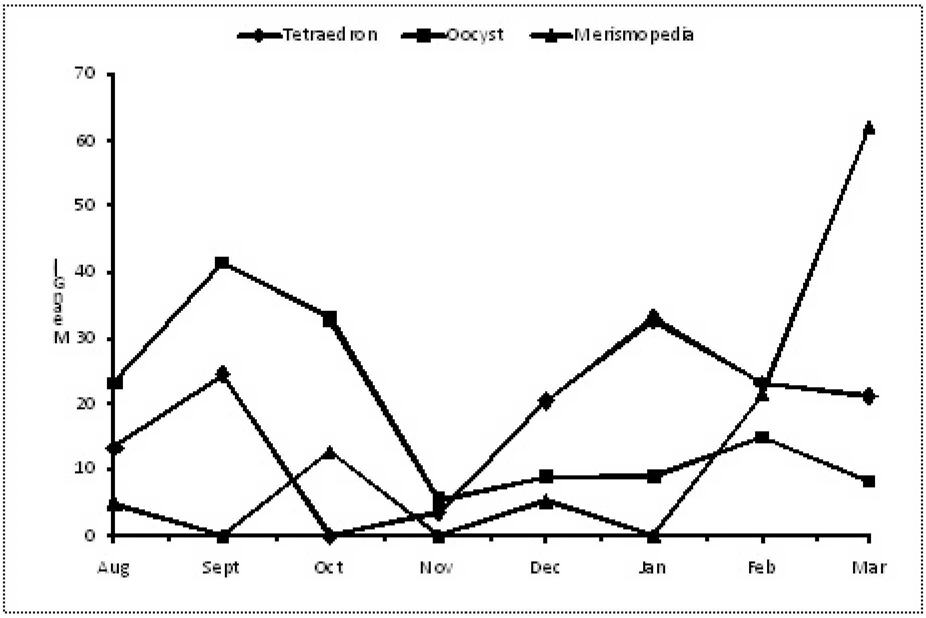

Figure 5. Monthly variations of *Melosira, Kerratella, Chroococcus and Thermocyclops* ingested by *O. niloticus* in Lake Hayq based on its mean GII values.

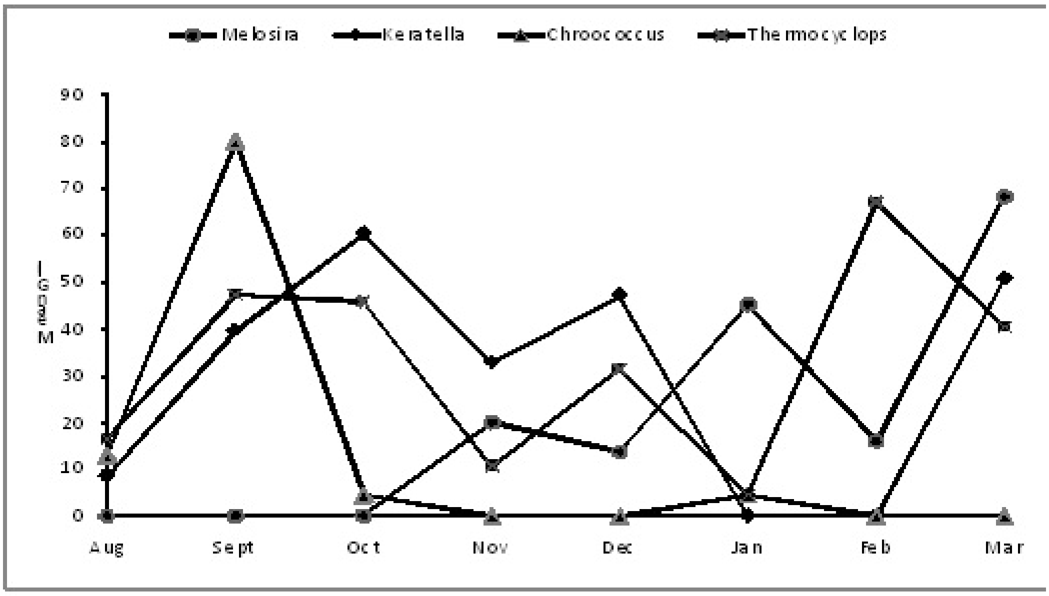

Figure 6. Monthly variations of *Tetraedron, Oocyst, and Merismopedia* ingested by *O. niloticus* in Lake Hayq based on its mean GII values.

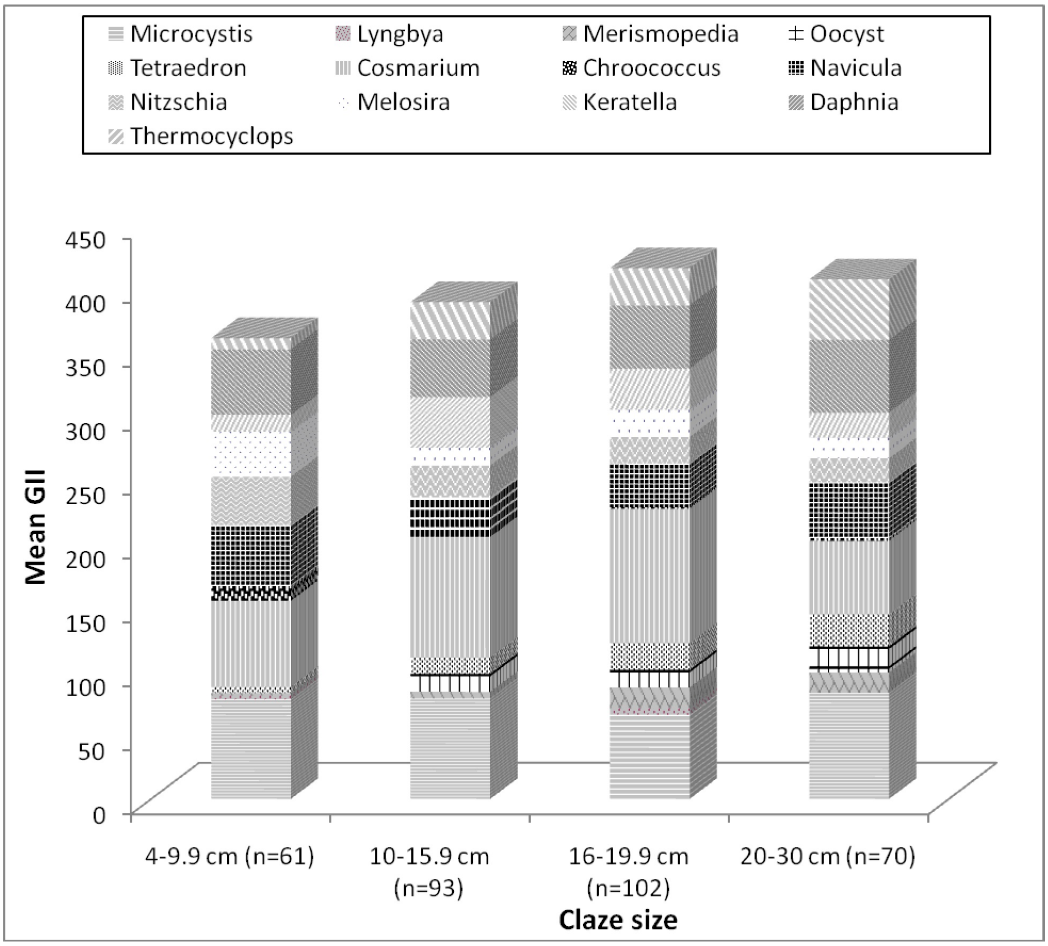

Figure 7. GII values of primarily and secondarily consumed food items of *O. niloticus* of different length groups from Lake Hayq.

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 primarily responsible for the variation were *Microcystis* and *Cosmarium* (Table 3). 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 %, where as 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 %, where as that of *Microcystis* and *Nitzschia* 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%, where as 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) with a relatively low difference.

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

Taxon	Mean Ab. 1	Mean Ab. 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	98.00
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

DISCUSSION

Nile tilapia, *O. niloticus*, has a versatile feeding behavior and characterized as a generalist and opportunistic omnivore (Canonico et al. 2005). This is in agreement with the diet composition found in this study, which also showed a high diversity of food items. This suggests that the species takes 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 items for the same species in Lake Langeno (Tadesse 1999), insects in Lake Victoria (Njiru et al. 2004) and macrophytes in the Nile canal (El-Sayed and Alne-na-ei 1987), which were insignificant contribution in the present study. Nevertheless, the dominant food items consumed by the species in Lake Hayq based on numerical 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 %) contributed appreciable amount of diet for the species in terms of frequency of occurrence. Other studies conducted for the same species in Lakes Chamo (Teferra 1993; Teferi et al. 2000), Awassa (Tudorancea et al. 1988), and Ziway (Taddesse 1998) and elsewhere (Getabu 1994; Bwanika et al. 2004; Shalloof and Khalifa 2009) 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 addition to these food items, Cladocera, Rotifera and Copepoda were consumed secondarily while Pisces, Euglenophyta, macrophyte shoots, detritus and insect remains occasional sources of food. The study conducted on the same lake by Fetahi (2010) 40 phytoplankton taxa identified belonging to Chlorophyta (47%), Bacillariophyta (30%), Cyanoprokaryota (11%), and Cryptophyta, Dinopyhyta and Eugelenophyta together contributed 11% abundance. The study also included the presence of 11 zooplankton species belonging to Copepoda (two species), Cladocera (two species) and Rotifera (six species), but dominated

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 (see Table 3).
Overall average dissimilarity = 34.77

Taxon	Mean abund. I	Mean abund. II	Mean abund. III	Mean abund. IV	Contribution	Cumulative %
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

by *Thermocyclops ethiopiensis*. Accordingly*,* analysis of stomach contents of *O. niloticus* in this study showed good relation with the plankton recorded in the research studied by Fetahi (2010). However, the abundance of Chlorophyta in the stomachs of *O. niloticus* is much exceeded to that of the actual environment obtained by Fetahi (2010). 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 of by the fish in tropical lakes (Teferra 1987). Interestingly, before the introduction of this fish, Lake Hayq was oligotrophic water body (Baxter & Golobitsch 1970). Currently, however, it is turned into a eutrophic lake (Fetahi 2010). As confirmed from this study, the food spectrum of the fish comprised diverse plankton taxa. The intense grazing on zooplankton, which had been played 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 (Fetahi 2010). Hence, the fish has been played a lot in shaping the ecology of Lake Hayq.

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 genera ingested by the species were *Botryococcus* (green algae) and *Oscillatoria* (blue green algae) in Lake Awassa (Teferra 1987; *Tudorancea* et al. *1988*), and it was *Lyngbya* (blue green algae) in Lake Ziway (Taddesse 1998) and *Melosira* (diatoms) in Lake Chamo (Teferra 1993). The dominance of one food item over the other could be the result of selective feeding to increase nutritional benefit (Bown 1980). Furthermore, it is related to the dominance and seasonal dynamics of plankton population in a given water body since *O. niloticus* is opportunistic feeders (Canonico et al. 2005).

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 hypothesized that because juvenile fish have higher mass specific protein demand as a consequence of higher specific growth rate and greater mass specific metabolism, they may not satisfy their demand by consuming an herbivorous diet (Benavides et al. 1994). Small fish may be forced to consume animal prey, which have greater content of protein and energy per unit weight (Benavides et al. 1994). 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 for the feeding habits of *O. niloticus* was suggested by Moriarty and Moriarty (1973), 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 Tadesse (1998), 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 (Fetahi 2010). Consequently, juvenile *O. niloticus* may not filter efficiently which is waiting for further investigation.

The monthly variation in the composition of the food consumed by *O. niloticus* showed 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, Fetahi (2010) indicates that the lowest total biomass of zooplankton was recorded during dry season and the biomass of diatoms was mainly dominated from December 2007 through June 2008 which is coincided with the present study. The seasonal variability observed in the diets may be related to local changes in the availability of food items that are regulated by climatic changes (Sierra et al. 1994). 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 (Philipart and Ruwet, 1982).

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 struggle to escape from gillnets as it was collected after over night. Moreover, during breeding activity, the fish spend more time on spawning than on feeding (Teferra 1987), which could be another factor contributing 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. Currently, the global trend fisheries management is shifting from a single species based towards a multispecies or ecosystem based management strategy (Marasco et al. 2007). Therefore, ecosystem function, organization and species interactions, such as food and feeding patterns of animals and understanding the factors that shape their behaviour or competition must be understood (Marasco et al. 2007). 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.

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