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RESEARCH ARTICLE

FOOD AND FEEDING HABITS OF NILE TILAPIA, *OREOCHROMIS NILOTICUS* (L.) (PISCES: CICHLIDAE), IN LAKE LANGENO, ETHIOPIA

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ABSTRACT: The study aimed to determine the diet composition, dietary change and diel feeding pattern of *Oreochromis niloticus*, in Lake Langeno. Fish specimens were collected monthly from July 2017 to June 2018 using a beach seine with 40 mm mesh size and scoop-net with small mesh size (1.0 mm). A total of 264 non-empty fish stomachs were examined for dietary analysis. The relative importance of different food items was analyzed using frequency of occurrence (%FO) and numerical abundance (%N). The most frequently encountered food items in the stomach of *O. niloticus* were phytoplankton, zooplankton, macrophytes and detritus. Among the phytoplankton groups, the genera *Microcysts* (%FO = 85.25), *Cyclotella* (65.51), *Anabaena* (%FO = 50.0), *Cymbella* (%FO = 65.15), and *Chlorella* (%FO = 54.17) contributed the most. Numerically, Cyanophyta, Chlorophyta, Bacillariophyta, and Zooplankton contributed 5.2%, 3.4%, 53.03% and 42.28%, respectively, to the total food items. Insect and fish remains occurred in rare occasions in the stomach content of all length groups of fishes. The dominance of animal-based food items progressively decreased as the fish grew to larger size while the importance of macrophytes and detritus increased. *O. niloticus* feeds mainly during the day time and stomach fullness peaked at 16:00 hr. The daily food consumption rate and gastric evacuation rate were 9.0% body weight and 48% per hr, respectively. Crude protein dominated nutrient composition of the fish and this could be attributed to the high percentage in frequency of nutritious diets like Rotifers (64.0%), Cladoceras (63.6%) and *Microcystis* (85.6%). It can be concluded that juvenile *Oreochromis niloticus* feeds mainly on animal food sources whereas adults feed primarily on macrophyte food items.

Key words/phrases: Diel feeding rhythm, Evacuation rate, Numerical abundance, Ontogenetic diet shift, Stomach content.

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INTRODUCTION

Nile tilapia (*Oreochromis niloticus* L.) is widely distributed in African freshwater systems along the Nile basin (Trewavas, 1983). It is also widely distributed in Ethiopian lakes, rivers and reservoirs (Abebe Getahun, 2017). *O. niloticus* is one of the most important fish that contribute more than 50% of the total fish supply in Ethiopia (Gashaw Tesfaye, 2016). Zenebe Tadesse (1999) reported its contribution to be about 85% of landings in Lake Langeno, while a recent report raised the value to about 90% (Mathewos Temesgen, 2018).

Biological assessment like food and feeding habits of fish is significant in increasing our understanding and knowledge of ecosystem interactions. It provides valuable information on the trophic relationships (Abdel-Aziz and Gharib, 2007) and diet composition, structure and stability of food webs in ecosystems (Otieno *et al*., 2014). Tilapia plays an important role in transferring energy from the bottom of the food chain to the highest consumers in tropical freshwater systems (Afrah and Al-Awady, 2013). Thus, knowledge of the stomach content of fish is necessary not only for ichthyologists, but also for other freshwater ecologists, and for fish farmers who want to culture this species in different culture systems.

Many researchers have studied the feeding habit of *O. niloticus* in some African water bodies (e.g. Getachew Tefera, 1993; Zenebe Tadesse, 1999; Tengjaroenkul *et al*., 2002; Njiru *et al*., 2004; Abidemi-Iromini, 2019). The available information indicates that *O. niloticus* feeds on a wide variety of food items including, phytoplankton, zooplankton, macrophytes, insects, worms and detritus in different ecosystems. However, they show preference for particular food items within their environment. Therefore, area-specific information is needed for the proper management and utilization of this important fishery target species.

Investigations on the diet composition and nutrient status of *O. niloticus* have been documented only from a few lakes of Ethiopia (Getachew Tefera, 1993; Zenebe Tadesse *et al*., 1998). However, data on fatty acid content of the diet of the fish was well studied for the species in many water bodies in the country (Zenebe Tadesse, 2010). According to Getachew Tefera (1993) and Zenebe Tadesse *et al*. (1998), protein, carbohydrates and lipids are the major chemical constituents of the food of the species. However, the proportion of these nutrients varied based on the composition of the diet, season and lake system. For instance, in Lake Ziway (Ethiopia), the tilapia diet was mainly dominated by lipids, whereas in Lake Hawassa and Chamo

(Ethiopia) carbohydrate was the most dominant constituent in the diet of *O. niloticus* (Getachew Tefera, 1987; 1993).

Previous studies on age and growth have shown that *O. niloticus* in Lake Langeno grew more slowly than the same species in some other lakes (e.g., Lake Ziway) in Ethiopia (Demeke Admassu, 1998). The largest size of *O. niloticus* in the lake had a total length not exceeding 35 cm (LFDP, 1997; Zenebe Tadesse, 1999; Gashaw Tesfaye, 2006; Mathewos Temesgen, 2018). It is suspected that the quality and quantity of the fish diets in the lake could explain this poor growth.

Furthermore, most fish species change their diet composition during the different life stages. The changes in diet utilization occurring over the life span of an individual consumer, commonly referred to as ontogenetic dietary shift, is widespread in the animal kingdom (Sanchez-Hernandez *et al*., 2018). Thus, understanding this dietary shift is very essential to deepen our understanding of the biological and ecological processes that function at the individual, population and community levels, and is critical in studying key concepts in trophic theory and modeling. Njiru *et al*. (2004) reported that the food ingested by Lake Victoria *O. niloticus* differed depending on the size/ age of the fish, habitat occupied and time of the year. A similar study in Lake Chamo showed an ontogenetic dietary shift in *O. niloticus* (Yirgaw Teferi *et al*., 2000). But this has not been studied in Lake Langeno yet.

Moreover, fish like most animals show daily feeding rhythms consuming food at certain times during the 24 hrs of a day (López-Olmeda *et al*., 2012). Many species of fish feed during the daytime while others are active during the night time (Getachew Tefera, 1993). *O. niloticus* in Lakes Hawassa and Ziway appears to feed continuously during the day times and stops feeding at night (Getachew Tefera, 1987; Zenebe Tadesse and Getachew Tefera, 1998). Knowledge of fish daily feeding rhythm is very crucial for proper fishery management. However, such information is not available for Lake Langeno.

Generally, many research works have been published on the food and feeding habits of *O. niloticus* in different inland waters of Ethiopia (e.g., Yirgaw Teferi *et al*., 2000; Alemayehu Negassa and Prabu, 2008; Workiye Worie and Abebe Getahun, 2015; Yirga Enawgaw and Brook Lemma, 2018; Abebe Tesfaye *et al*., 2020). However, most of these research works only listed food items that the fish ingested. Thus, our understanding on different feeding behavior of *O. niloticus* in Ethiopia in general and in Langeno in particular is insufficient. Therefore, the aim of this study was to describe different feeding behaviour such as diel feeding rhythm, feeding habit of the different size groups, gastric evacuation and daily food consumption rates, and nutrient composition in the food of *O. niloticus* in Lake Langeno.

MATERIALS AND METHODS

Study area

Lake Langeno, also reported in some literature as Lake Langano, is located in the Central Main Ethiopian Rift Valley (07°35′N and 38°45′E) nearly 200 km south of the capital Addis Ababa. Its 1600 km^2 catchment area is drained by six perennial rivers (Gedemso, Hulka, Lepsi, Tufa, Metti and Garabula), runoff and hot springs, while River Hora Kello is the only outlet which empties into Lake Abijata (Fig. 1). The estimated annual inflow and outflow of the lake water is 533.4 million m^3 and 527.9 million m^3, respectively (Tenalem Ayenew, 2004). The main geographical and climatological characteristics of the lake can be found from Daniel Gemechu (1977). Physico-chemical characteristics of the lake were published by Wood *et al*. (1978) and also recently reported by Mathewos Temesgen (2018). The water temperature is fairly warm with a mean of 24.1°C all year round. The phytoplankton community of the lake is dominated by *Microcystis* spp., *Oocystis* sp. and *Cyclotella* sp. (Elizabeth Kebede and Willén, 1998). Phytoplankton biomass of Lake Langeno is 1.6 mgl^{-1} (Elizabeth Kebede and Willén, 1998). The dominant zooplanktons include *Mesocyclops* sp., *Daphnia* spp., *Ceriodaphnia* sp. and *Brachionus* sp. (Kassahun Wodajo and Amha Belay, 1984). The macrophyte vegetation of the lake is dominated by *Scirpus* sp. and *Juncellus* sp. The natural vegetation around the lake is composed of *Acacia* spp. and scrub grassland (Kassahun Wodajo and Amha Belay, 1984).

The fish species of the lake includes tilapia (*O. niloticus* and *Coptodon zilli*), African catfish (*Clarias gariepinus*), common carp (*Cyprinus carpio*), *Labeobarbus intermedius*, *Enteromius paludinosis*, and *Micropanchax antnori*. Other than common carp, the exotic fish species, *Carassius auratus*, has been reported in the lake (Golubtsov and Mina, 2003). Fishing is an important practice in Lake Langeno and *O. niloticus* and African catfish are the most important commercially exploited fish species (LFDP, 1997; Mathewos Temsgen, 2018). During the current study, however, we observed that African catfish contributed little to the commercial fishery in the lake. The remaining five species have also little or no commercial importance.

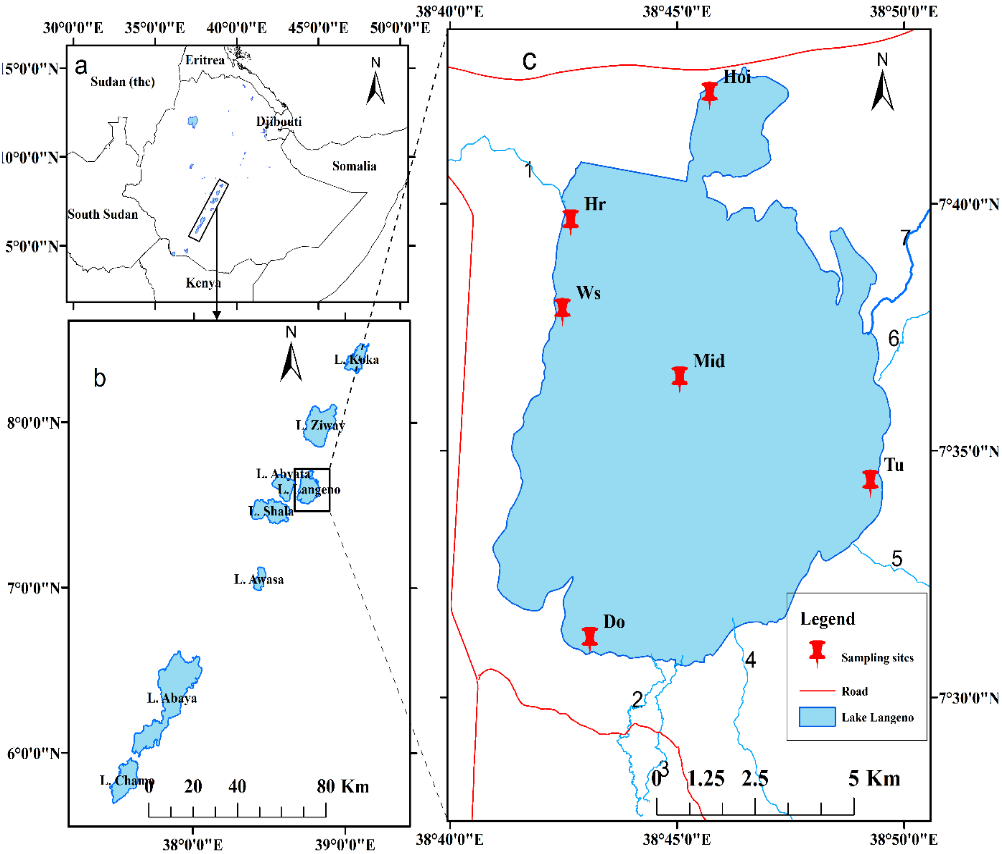

Fig. 1. Maps showing (a) East African countries and Ethiopian lakes, (b) major Ethiopian Rift Valley lakes, (c) Lake Langeno. Sampling sites: Hr is Horakelo, Ws is Wabi-Shebelle, Do is Dole, Tu is Tufa, Hoi is Hoitu; Rivers: - 1 = Horakelo, 2 = Huluka, 3 = Lepsi, 4 = Gedemso, 5 = Garabula, 6 = Meti, 7 = Tufa.

Other wildlife in and around the lake include hippos, and high diversity of water birds. Flamingos seasonally use the lake as refuge site during migratory season in the winter time. The areas around the lake, particularly the northern and western parts, are highly deforested, and a large number of livestock also graze all around the lake area.

Fish sampling and measurements

Fish specimens were collected on monthly basis between July 2017 and June 2018. A beach seine net (200 m long with 8 m cod-end length and a mesh size of 4 cm at the cod-end) was used to collect fish samples. In shallow littoral and macrophyte zones, a hand (scoop net with 1 mm mesh size) net was also used to collect small sized (juvenile) fish. The samples were collected late in the afternoon, between 2:00 PM and 6:00 PM. Fish samples from the middle of the lake were collected using gillnet with stretched mesh size of 6–12 cm. The nets were set late in the afternoon and collected in the following morning. Sampling sites are indicated in Fig. 1. Immediately after capture, total length was measured to the nearest 0.1 cm and weight to the nearest 0.1 g. Then fish specimens were dissected ventrally to collect stomach specimens. The fish stomachs were isolated, fullness index determined following Hyslop (1980), weighted and preserved in vials with 4% formaldehyde solution for a later examination.

Laboratory and data analysis

The stomach specimens were dissected and the contents were scrapped with spatula into a glass petri-dish. The contents of each stomach were examined under a WILD type stereoscope (magnification 6X to 50X). In addition, smaller food items such as phytoplankton taxa were examined at high magnifications (100X - 400X) under a compound inverted research microscope. Each prey item was identified to a genera level using descriptions and keys in the literature (Harding and Smith, 1974; Edington and Hildrew, 1981; Defaye, 1988).

Data analysis

The relative importance of the different food items found in the stomach contents was determined using:

Frequency of occurrence: which is the number of stomach samples in which one or more of a given food item is found was expressed as a percentage of all non-empty stomachs examined as:

$$\text{Frequency of occurence} = \frac{\text{total number of stomach with particular food item}}{\text{total number of stomach with food in the sample}} \text{ X } 100$$

This gives an estimate of the proportion of the population that feeds on a particular food item (Hyslop, 1980).

Percent composition by number (%N): The number of food items of a given food type that was found in all stomachs was recorded. The total number of individuals of each food item was then expressed as a percentage of the total number of all food items (Bagenal and Tesch, 1978). This estimates the relative abundance of that food item in the diet.

$$\%N = \frac{\text{total number of food item i}}{\text{total number of indentified food items}} \text{ X } 100$$

Ontogenetic dietary shift: Length group-wise percentage composition of stomach contents was analyzed by the Point (numerical) method described in Swynnerton and Worthington (1940). For this analysis, the importance of different food categories was determined by classifying the TL of the fish into 7 length groups (I: 1 to 5 cm, II: 5 to 9 cm, III: 9 to 13 cm, IV: 13 to 17 cm, V: 17 to 21cm, VI: 21 to 25 cm, and VI: above 25 cm. The contents of all stomachs were analyzed for each length group and their abundance was categorized in seven indices as "very common", "common", "abundant", "less abundant", "rare", "very rare" and little when their counts were 12 and above, 10–11, 8–9, 6–7, 4–5, 2–3 and less than 2, respectively, in each stomach specimen. The integers in each section of the table were then added together and scaled to the percentage, for presentation in the table.

Diel feeding rhythm: A total of 360 specimens of *O. niloticus* were collected at intervals of two hours during 24 hours using beach seine of 4cm stretched mesh size. The number of fish specimens caught was 30 every 2 hour intervals in February 2018. After each capture, fish were immediately taken to the temporary laboratory near the shore, and total length and total weight of each specimen were measured to the nearest 0.1 cm and total length and 0.1 g using a measuring board and a balance, respectively. The stomach of each fish specimen was isolated and weighed to the nearest 0.1 g using a sensitive balance, respectively. Wet weight of stomach contents in percent of body weight was considered as stomach fullness (Alemayehu Negassa and Abebe Getahun, 2004). The number of empty stomachs was also recorded for each time interval. Percent stomach fullness was determined according to Getachew Tefera (1987) and Yirgaw Teferi *et al*. (2000) as follows:

$$\%SF = \frac{Wt}{TW} * 100$$

Where, %SF = percent stomach fullness, Wt = weight of stomach content, and TW = total weight of the fish. Then, %SF was plotted against the time of capture. A regression relationship was estimated between stomach fullness and time of the day, starting with the time when the highest percent stomach fullness was observed (Zenebe Tadesse, 1998). The slope of this regression relationship was then used to express the rate of gastric evacuation (Getachew Tefera, 1987; Zenebe Tadesse and Getachew Tefera, 1998; Yirgaw Teferi *et al*., 2000). Then, the amount of food consumed per day was estimated according to Getachew Tefera (1987) and Zenebe Tadesse and Getachew Tefera (1998).

Nutrient composition: Fish samples were dissected and the stomach contents were transferred into separate glass vials and kept overnight in an oven at 60°C to dry. After drying, the contents were grounded using a mortar and pestle. Since the stomach contents of *O. niloticus* in Lake Langeno are too small to do all chemical analysis on a single sample, 10 stomach contents were pooled and used in the analysis. The analysis included total organic matter (ash-free dry weight), crude protein, and crude fat. All the analyses were done in four replicates for each nutrient and the results were presented in a table as mean ± standard deviation.

Determination of ash: Ash was determined as described in Zenebe Tadesse (1999) as follows: 10 g of the oven-dried sample was weighed into an empty pre-weighed crucible and placed in a muffle furnace. The content was ignited in a furnace at 550°C for 4 hrs and turned off to cool to 250°C before sample removal. Then, the sample was desiccated prior to weighting. The ash content was calculated as follows:

$$\%\text{Ash} = \frac{\text{wt2} - \text{wt1}}{\text{wt3}} * 100$$

Where, wt2 is weight of crucible plus sample after ashing, wt1 is empty weight of crucible and wt3 is weight of sample before ashing.

Total fat: Total fat in the diet of *O. niloticus* of Lake Langeno was determined by the Soxhlet lipid extraction method as follows: 10 g of oven-dried stomach content sample was placed in a thimble and the thimble was placed in Soxhlet extractor. Then a 150 ml round bottom flask filled with 90 ml petroleum ether was assembled into the thimble and the whole extraction setting was placed on the heating mantle to boil. After 6 hrs of the extraction process, the condensing unit was removed from the extraction unit and allowed to cool down. All the solvents were collected after distillation and the sample was placed in an oven, and then in the desiccator. Finally, the weight of the thimble with the extract was recorded. The following calculation was applied to determine the total lipid in the sample: -

$$\%TF = \frac{(W2 - W1)}{P} * 100$$

Where, %TF is the percentage of crude fat, W1 is the empty thimble weight, W2 is the thimble weight and extracted fat, and P is the weight of dried sample used.

Crude protein (total): This was determined following the micro-Kjeldahl procedure as follow. 1 g of the oven-dried sample was placed in Kjeldahl digestion flask and digested with concentrated sulfuric acid in the presence of catalyst (digestion tablets) which is copper salts by boiling at about 420°C until the mixture turned clear. The digest was then steam-distilled using 40% NaOH to release ammonia which was trapped in 250 ml receiving flask in a solution of boric acid. 150 ml of this distillate was collected in a conical flask containing 100 ml of 0.1N HCl and methyl red indicator. The ammonia that distilled into the receiving conical flask reacted with the acid, and the excess acid in the flask was estimated by back titration against 2.0M NaOH with colour change from red to yellow (end point). The volume of acid used for titration was recorded, where, percentage of H^+ is equivalent to percentage of N (% crude protein = % N). Total protein was estimated by multiplying total nitrogen content in the diet by the factor of "6.25" as follows:

$$\%\text{protein} = \frac{(\text{titre vol sample} - \text{titre vol blank}) \times 0.014 \times 0.1 \times 6.25)}{\text{Weight of samle used}} * 100$$

RESULTS

Diet composition: Of the total of 360 fish specimens collected for stomach content analysis, 264 non-empty *O. niloticus* stomachs (73.3%) were examined. The fish specimens examined for stomach content analysis ranged from 1 to 32 cm TL. The major food items ingested by *O. niloticus* were composed of phytoplankton (40 genera), zooplankton, macrophyte debris, and detritus. Some groups of aquatic insects (zoobenthos) and fish scales were also ingested (Table 1). Among the Cyanophyta groups, the genera *Microcystis* dominated the diet composition of the fish in terms of frequency of occurrence (%FO = 85.60). *Cyclotella*, *Surirella*, and *Anabaena* were also common food items in the stomachs of fish. Bacillariophyta and Chlorophyta groups were also found to be the preferred food items and occurred in 75% and 55.86%, respectively, of the stomachs, examined. Numerically, the genera *Cyclotella* (%N = 22.23) and *Surirella* (%N = 10.15) contributed most to the diet of *O. niloticus* in Lake Langeno. Among the zooplankton groups, Cladocera (%N = 13.86) and Rotifer (%N = 23.12) prey were dominant in terms of numerical abundance. Of all the food items, *Microcystis* (%FO = 85.60), detritus (%FO = 82.57) and macrophyte debris (%FO = 77.65) were the most frequently encountered food items in the stomach of *O. niloticus* in Lake Langeno (Table 1).

Table 1. Frequency of occurrence (%FO) and numerical abundance (%N) of food items in the diet of *O. niloticus* in Lake Langeno (n = 264).

Food items	%N	%FO	Food items	%N	%FO
Phytoplankton	**57.49**	**87.88**			
Cyanophyta (blue-green algae)	**5.74**	**50.38**	**Green algae (Chlorophyta)**	**3.40**	**55.68**
Anabaena	0.80	29.17	*Chlamydomonas*	0.98	26.89
Aphanothec	1.03	16.67	*Oocystis*	0.81	27.27
Cylindrospermopsis	0.16	7.58	*Botryococcus*	0.58	26.14
Arthrospira	0.21	13.26	*Chlorella*	0.25	13.26
Oscillatoria	0.23	17.80	*Spirogyra*	0.14	11.74
Gloeotrichia	0.01	1.89	*Microspora*	0.31	11.36
Trichodesmium	0.03	5.30	*Crucigena*	0.00	0.38
Merismopedia	0.15	7.58	*Ankistrodesmus*	0.21	10.61
Chroococcus	3.12	3.79	*Pleurococcus*	0.02	2.65
Microcysts		85.60	*Stigeoclonium*	0.06	3.03
Diatoms (Bacillariophyta)	**48.16**	**75.00**	*Closterium*	0.05	4.92
Cyclotella	22.32	65.15	**Zooplankton**	42.28	82.56
Surirella	10.15	45.83	Cladocera	13.86	63.64
Navicula	2.29	27.27	Copepoda	5.21	56.06
Cymbella	5.46	28.79	Nauplii stages	2.06	23.86
Fragilaria	3.81	15.53	Rotifers	23.12	64.02
Diatoma	0.28	7.58	Ostracods	0.02	15.91
Gomphonema	0.38	5.68	**Zoobenthos**	0.18	
Nitzshia	0.95	15.91	Mosquito larvae	0.05	6.06
Pinnularia	0.84	9.85	Trichoptera)	0.00	0.38
Amphora	0.31	4.55	Water beetle	0.00	1.52
Cocconeis	0.88	10.61	Beetle larvae	0.00	0.76
Synedra	0.14	3.41	Naucoridae)	0.01	1.52
Tabellaria	0.35	3.79	Ant (Formicidae)	0.06	12.88
Thalassionem	0.00	0.38	Centipedes	0.06	14.02
Chrysophyta	**0.08**	**7.65**	**Fish scales**	0.05	19.32
Dinobyron	0.05	2.65	**Macrophytes**		77.65
Uroglena	0.03	1.14	**Detritus**		82.57
Cryptophyta	0.03	1.14			
Cryptomonas	0.03	1.14			
Dinophyta	**0.08**	**3.41**			
Peridinium	0.08	3.41			
Ceratium	0.00	0.38			

Ontogenetic dietary shift: The importance of food items estimated using Swynnerton and Worthington (1940) method was indicated in Fig. 2. The results showed an ontogenetic dietary shift in the feeding habits of the *O. niloticus*. Juvenile fish (whose sizes are 1.0 to 17.0 cm TL) size class (class I to IV) had a diet dominated by zooplankton primarily Rotifers, Cladocera, Nauplii stages and Copepods. The occurrence of other food items such as macrophytes and detritus were low in the stomach of juveniles (Fig. 2). The percentage numerical abundance of animal source diets was higher in small size groups (I to IV). On the other hand, plant origin food items (phytoplankton, macrophytes and detritus) dominated the diet composition of larger size classes (>IV). In terms of point (numerical) abundance, phytoplankton food items did not show substantial ontogenetic change as the fish grew to a larger size. The contribution of insects and fish scales was low and also did not show an ontogenetic shift (Fig. 2). But fish scale was absent in size groups I and II. Similarly, insects were absent in the gut of size group I. The composition of detritus, macrophytes and *Microcystis* progressively increased as the fish grew to a larger size.

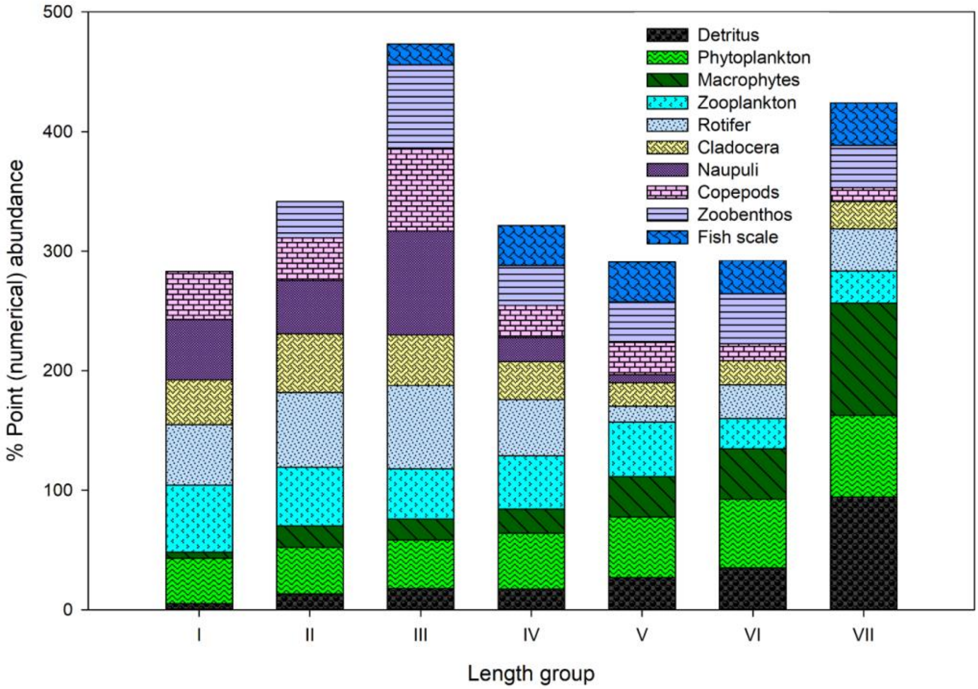

Fig. 2. Point (numerical) percentage occurrence of major food items consumed by different size classes of the *O. niloticus* in Lake Langeno. Zooplankton includes: Rotifers, Cladocera, copepods, Nauplii and Ostracods; whereas Phytoplankton includes: Cyanophyta, Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Dinophyta, and Euglenophyta.

Diel feeding rhythm: The feeding pattern of *O. niloticus* in Lake Langeno showed diel rhythm. The proportion of stomach fullness increased continuously beginning early morning (6:00 hr) until the peak time at 16:00 hr (Fig. 3). Conversely, the proportion of empty stomachs increased progressively from peak 16 h to 4 h. This indicated that *O. niloticus* in Lake Langeno feeds during the daytime and ceases feeding at the night.

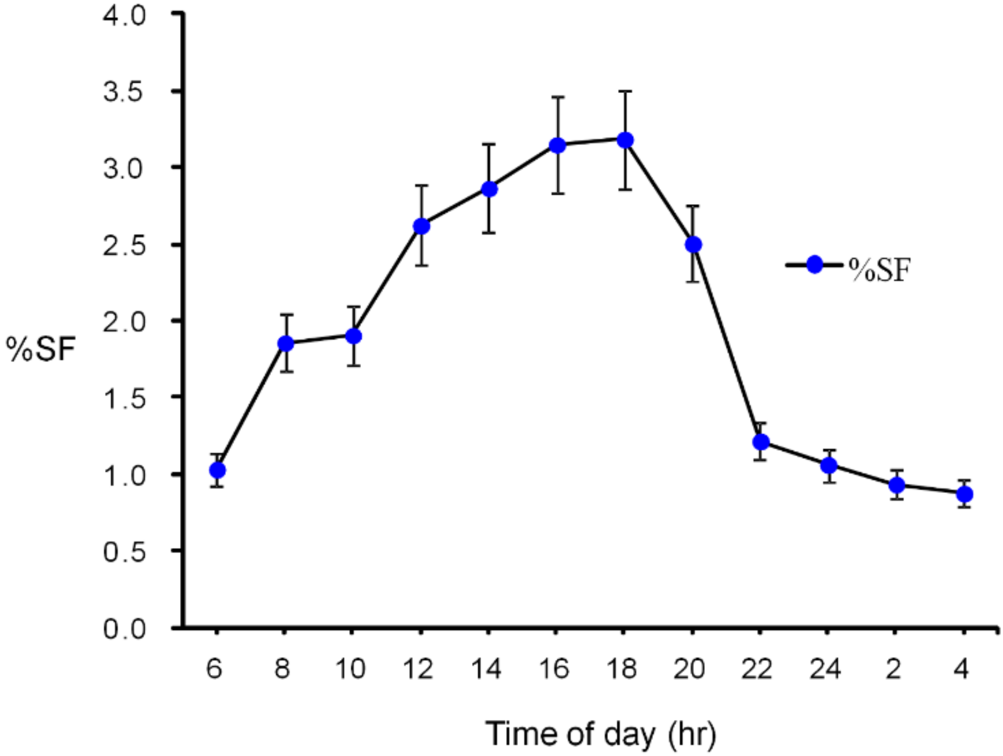

Fig. 3. Diel feeding regime of *O. niloticus* in Lake Langeno. Vertical bars = sd

The rate of gastric evacuation at an average water temperature of 24.1°C (average water temperature of Lake Langeno during the study period) was predicted from 3.29% at 16 hr to 0.82% at 4 hr or 0.477% per hour (Fig. 4) as shown by the following equation:

%SF = -0.477hr + 3.798; R^2 = 0.912

Where %SF = percentage of stomach fullness, hr = hour of the day

The amount of food consumed per day was estimated from the time when the fish was eating (6 hr to 16 hr =10 hr). Assuming the same evacuation rate (0.477% per hr) (Fig. 4), the amount of food evacuated to the intestine was estimated to be 4.77% (0.477* 10 hr). As a whole, 8.06% (3.29% ± 4.77%) of wet body weight is ingested by the fish per day.

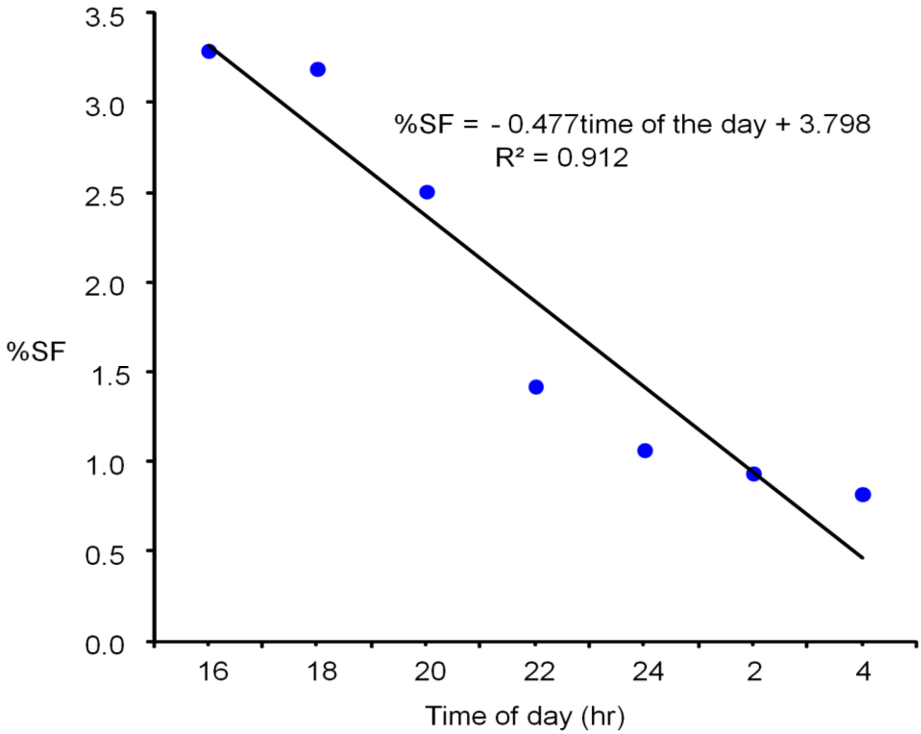

Fig. 4. Gastric evacuation rate of *O. niloticus* in Lake Langeno.

Nutrient composition: The level of different nutrient components expressed as a percentage (%) of DW was mainly dominated by protein: 49.13% in the dry and 49.37% in the wet seasons, respectively (Table 2). The remaining percentage was accounted for other nutrients such as carbohydrates, nucleic acids, etc.

Table 2. Percentage of crude protein, crude fat, ash and total organic matter content (mean ± SD) in the diet of *O. niloticus* in Lake Langeno.

Season	Lipid	Protein	Ash	DW	Percentage in dry weight		
					Lipid	Protein	Ash
Dry	6.52±0.68	40.89±2.98	17.95±1.06	82.47±0.82	7.93	49.82	21.86
Wet	7.3±0.50	42.41±1.47	20.84±0.97	85.84±1.02	8.28	49.37	23.74

DISCUSSION

Diet composition: The results on the diet composition of *O. niloticus* in Lake Langeno (Table 1) indicated that the fish have wider food item choices available to the fish and hence when one food item is in short supply, others were in abundance for the fish to feed on (Yirgaw Teferi *et al*., 2000). The presence of such varied food items in the stomach of the fish also provides evidence for a generalist/omnivore feeding strategy of the fish in Lake Langeno. Some food items such as insects, fish scales, and some algal genera identified in the stomach of *O. niloticus* in the current study were not reported by previous research for *O. niloticus* in the same lake (Zenebe Tadesse, 1999). Moreover, food items such as Heterokontophyta (*Mallomonas*), Euglenophyta (*Trachelomonas* spp and *Euglena* spp), reported on the same lake by Mathewos Temesgen (2018) were not recorded in the current study. The presence of these prey items in the present study is probably related to variations of sampling sites, hence prevalence of food prey items in the water body at different sites. Bozza and Hahn (2010) stated that the variation in the diet composition of fish could be attributed to the spatial and temporal variations and ontogenetic dietary shifts. Meurer and Zaniboni-Filho (2012) also stated that the availability, composition and abundance of prey items determine the dietary composition of fishes.

Food items of plant origin such as phytoplankton and macrophytes were the most consumed items by *O. niloticus* in many Ethiopian water bodies (e.g., Mulugeta Wakjira, 2013; Workiye Worie and Abebe Getahun, 2015; Mathewos Temesgen, 2018; Yirga Enawgaw and Brook Lemma, 2018; Abebe Tesfaye *et al*., 2020). Similar findings were also reported for the same species in Lake Chamo, Ethiopia (Yirgaw Teferi *et al*., 2000) and from other several water bodies in Africa. Otieno *et al*. (2014), for instance, reported that the major diets ingested by *O. niloticus* were algae, plant materials, and detritus in Lake Naivasha, Kenya. The current finding was also similar to the work of Abidemi-Iromini (2019) who reported that phytoplankton, dinoflagellates, sand grains, insect parts, plants parts, fish parts and unidentified constituents in *O. niloticus* stomach contents in Lagos Lagoon, Nigeria. Moore and Sander (1976) discussed that the dominance of particular food items in the gut of fish might have been due to the availability of a particular food item or due to size selection of diets by the species during the time of sampling.

Among phytoplankton, Cyanobacteria (blue-green algae) in *O. niloticus* diet was dominated by *Microcystis* and *Anabaena* species (Table1). According to Turker *et al*. (2003), *Microcystis* sp. tend to form large colonies that are more efficiently ingested by filter-feeding fishes such as *O. niloticus*. This is likely why *Microcystis* and *Anabaena* are the most dominant phytoplankton ingested by *O. niloticus* in the current study and in other studied Ethiopian lakes (Mulugeta Wakjira, 2013; Workiye Worie and Abebe Getahun, 2015; Mathewos Temesgen, 2018; Yirga Enawgaw and Brook Lemma, 2018; Abebe Tesfaye *et al*., 2020). In addition, the genera in the Bacillariophyta (diatoms) group were also the most frequently encountered food items in the diet of the fish in the current study. Zenebe Tadesse (1999) reported the dominance of diatoms in Lake Langeno.

The food items found in the stomach of *O. niloticus* in the current study are similar to what have been reported for other tilapine species. Elias Dadebo *et al*. (2014) discussed that macrophytes, detritus and phytoplankton were the dominant food categories occurring in 94.9%, 94.2% and 82.5% of the total stomachs examined, respectively in the gut of *C. zilli* in Lake Ziway, Ethiopia. Oso *et al*. (2006) also reported macrophytes, phytoplankton, detritus, sand grain, insects and zooplankton to be the main diet of *Seratherodon galilaeus* and *O. niloticus* in Ero Reservoir in Nigeria. According to him, both species are omnivorous and occupy the same ecological niche in the reservoir. Zagnanini *et al*. (2012) compared the feeding habits of *O. niloticus* and *Coptodon rendalli* in Barra Bonita reservoir, São Paulo State, Brazil and concluded that these two species consume similar food items like phytoplankton, micro-crustaceans, insects and fish remains.

Ontogenetic dietary shift: The present study showed that the composition and proportions of food items consumed by *O. niloticus* in Lake Langeno varied between size classes (Fig. 2). Animal origin food items (mainly rotifers, cladocerans and nauplii) were observed to be the most frequently encountered in the stomachs of juvenile fishes less than 17 cm TL. Similarly, Njiru *et al*. (2004) reported that zooplankton were the most important food items for juvenile *O. niloticus* in Lake Victoria. The results of this study also agreed with previous studies carried out in various water bodies in Ethiopia (Yirgaw Teferi *et al*., 2000; Alemayehu Negassa and Prabu, 2008; Flipos Endalew *et al*., 2013; Workiye Worie and Abebe Getahun, 2015; Yirga Enawgaw and Brook Lemma, 2018; Abebe Tesfaye *et al*., 2020). All these authors reported that the contribution of zooplankton in small-sized *O. niloticus* is significantly high. Similar findings were also published by Otieno *et al*. (2014) for *O. niloticus* in Lake Naivasha, Kenya. The reason could be juveniles need high protein intake to support high growth rate and metabolism (Benavides *et al*., 1994). Having a small stomach volume that cannot support big macrophytes and detritus loads can be another reason for juveniles/smaller fishes to feed on zooplankton (Flipos Endalew *et al*., 2013). Tengjaroenkul *et al*. (2002) discussed that ontogenetic dietary shift is controlled by enzymes in the fish stomach than the behaviour of the fishes. It has been also reported that fish switch from soft-bodied prey to harder-bodied prey when their jaws reach a cursing strength, despite the difference in the size of fish or gape size (Wainwright, 1988).

In this study, some phytoplankton groups (e.g. *Microcystis* and diatoms) and small zooplankton groups (mainly rotifers) occurred in the diet composition of the fish in all size groups (Fig. 2). It was hypothesized that slow swimming rotifers such as *Keratella* and *Filinia* can be ingested by the fish together with macrophytes (Zenebe Tadesse, 1999). The diet composition was dominated by macrophytes and detritus food products, as the fish grew bigger in size. This may be due to their wider mouths and well developed digestive systems, which have more digestive enzymes and longer and broader gut lengths (Chakrabarti *et al*., 1999). This allows the fish to digest more complex foods, such as plant materials which they failed to digest at a younger age. Previous studies that supported this hypothesis include Tudorancea *et al*. (1988) in Lake Hawassa, Zenebe Tadesse (1988) in Lake Ziway, and Flipos Endalew *et al*. (2013) in Lake Koka, and Yirga Enawgaw and Brook Lemma (2018) in Lake Tinishu Abaya, Ethiopia.

Diel feeding rhythm: *O. niloticus* in Lake Langeno feeds mainly during the daytime (Fig. 3). The result of this study agreed with the findings of Zenebe Tadesse and Getachew Tefera (1998) who reported that the proportion of empty stomachs of *O. niloticus* in Lake Ziway decreased progressively from high point at 6:00 hrs to 14:00 hrs and stayed low from 14:00 hrs to 18:00 hrs and then increased during the night. The current finding was also in accordance with the studies conducted on the feeding behaviour of *O. niloticus* in other African lakes (Otieno *et al*., 2014; Oso *et al*., 2006; Njiru *et al*., 2004). Njiru *et al*. (2004) discussed that the empty stomachs recorded from around midnight is mainly due to the completion of digestion of the food consumed before dusk. The rise in stomach content at 08.00 hrs could be a response of intensive feeding by the fish at dawn since they had exhausted the food eaten at dusk the previous day. On the other hand, factors that may favour daytime feeding include temperature and oxygen. When temperature is high, light penetration is also at its maximum, with high photosynthetic activity and high production of oxygen. This would allow high respiratory activity and high swimming and feeding activity of the fish (Zenebe Tadesse, 1998). In the current study, it was observed that the water of Lake Langeno is turbid (mean Secchi depth = 14.5 cm) compared to Lakes Chamo, Hawassa and Ziway (Adane Fenta and Almaz Kidanemariam, 2016; Abnet Woldesenbet, 2015; Lemma Abera, 2016). This indicates that temperature is more important than sight in promoting day feeding behaviour of the fish in the lake.

The current finding was different from what has been reported for *C. zilli* in Lake Ziway, Ethiopia. Alemayehu Negassa and Abebe Getahun (2004) found that the feeding pattern of *C. zilli* in the lake showed both diel and nocturnal rhythm; with more intense during daytime. In terms of feeding rate, the current computed level of feeding rate is high compared with the feeding rate of *O. niloticus* in Lake Chamo, Ethiopia (Getachew Tefera, 1987), but lower than the estimate for the fish in Lake Hawassa (Getachew Tefera, 1987), and similar to *O. niloticus* in Lake Ziway (Zenebe Tadesse and Getachew Tefera, 1998) (Table 3). Getachew Tefera (1987) discussed that *O. niloticus* in Lake Chamo spend substantial amount of time under vegetated areas rather than open water to avoid predators. The author hypothesized that fishes existing in such precarious situations ingest less than their maximum ration. In contrast, it has been observed that fishes were caught both from open water and shore areas of Lake Langeno in the present study. This indicates that fishes do not spend a considerable amount of time at a particular location in the lake. This situation coupled with the absence of high abundance of predator organisms in the lake (the only predator in the lake was *Clarias gariepinus*) might have favoured the fish in the lake to ingest a relatively large percentage (8.06%) of its body wet weight.

Table 3. Food consumed per day per body weight by *O. niloticus* in different water bodies in Ethiopia.

Lake	**Evacuation rate (% per hr)**	**r^2**	**Food consumption per day (% body weight)**	**Reference**
Ziway	0.330	0.941	7.6	Zenebe Tadesse and Getachew Tefera (1998)
Langeno	0.477	0.9124	8.0	Present study
Hawassa			11.4	Getachew Tefera (1987)
Chamo	0.168	0.9801	4.4	Getachew Tefera (1987)
Chamo	0.132	0.8775	3.7	Yirgaw Teferi *et al*. (2000)

Nutrient composition: The high level of protein in the food of *O. niloticus* in Lake Langeno could be related to different factors. In the current study, Rotifers and cladocerans occurred in high frequency in the diet of the fish, and this might have contributed for the high protein content in the diet of this fish. According to Odum *et al*. (1979), detritus and associated bacteria also contain non-protein amino acids and contribute to the high protein level in the diet. Moreover, *Microcystis* which have been considered as one of the most nutritious algae, with very high protein content (De la Fuente *et al*., 1977), occurred more frequently in the stomach of the fish studied (Table 1). The results of this study agreed well with the previous study report of Zenebe Tadesse *et al*. (1998) who stated that protein was the major portion of the diet in *O. niloticus*.

CONCLUSION

O. niloticus in Lake Langeno principally feeds on phytoplankton, zooplankton, macrophytes and detritus. The contribution of these food items in the diet of the fish slightly varied with the size of the fish. Zooplankton and phytoplankton food items dominated the diet of small fish groups, while macrophytes and detritus were the major components of food items in large-sized fishes. Thus, *O. niloticus* in Lake Langeno clearly showed an ontogenetic dietary shift. The nutrient chemical composition of the diet of fish is dominated by protein. The feeding pattern of *O. niloticus* in the lake showed a diel pattern but the fish fed more intensely during the daytime.

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