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LENGTH – WEIGHT RELATIONSHIP, CONDITION FACTOR AND THE FOOD OF JUVENILE NILE TILAPIA (*Oreochromis niloticus* L.) IN LAKE HAWASSA AND LAKE ZWAI, ETHIOPIA

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June, 2017

Length – weight relationship, condition factor and the food of juvenile Nile tilapia (*Oreochromis niloticus* L.) in Lake Hawassa and Lake Zwai, Ethiopia

A Thesis Submitted to the School of Graduate Studies,

Addis Ababa University,

In Partial Fulfillment of the Requirements for the Degree of

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Lubaba Mohammed

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SCHOOL OF GRADUATE STUDIES

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By

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Dedication

This thesis work is dedicated to my family.

Especially my father Ato. Mohammed Ahmed and

My mother W/ro. Kassech Ahmed

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Acronyms

FCF	Fulton condition factor
FO	Frequency of occurrence
LFDP	Lake Fisheries Development Project
NA	Numerical Abundance
RCF	Relative condition factor

Abstract

Length - weight relationship, condition factor and the food of juveniles of O. niloticus in lakes Hawassa and Zwai were studied from monthly samples taken during March to August 2016. Total length (TL, cm) and total weight (TW, g) of both juvenile populations were curvilinearly related (ANOVA, P<0.005) with high coefficient of determination ($R^2 \geq 0.86$). The equation was $TW = 0.0322*TL^{2.72}$ for the Lake Hawassa population whereas $TW = 0.0558*TL^{2.54}$for the Lake Zwai population. The length – weight coefficient (b) value suggested isometric growth for the juveniles in Hawassa (b=2.72) whereas allometric growth for those in Zwai. Mean ± SE fulton condition factor (FCF) was 1.74 and 1.65 for juveniles in Lake Hawassa and Lake Zwai, respectively. Mean FCF did not vary significantly (t_s, p>0.05) between the two populations. Mean ± SE relative condition factor (RCF) was 1.02 and 1.01 respectively, for Hawassa and Zwai populations. Mean RCF value (>1) suggested that both juvenile populations are in good growth condition. Stomach content analysis (Hawassa n=185, Zwai n=200) revealed that both populations feed on a variety of organisms belonging to phytoplankton, zooplankton, insects, nematodes and unidentified animals. Both frequency of occurrence and numerical abundance method showed that zooplankton were the most important food of both juvenile population and the least nematodes, in that order were the most important food items categories frequency of occurrence and numerical abundance showed that the relative importance of animals decrease whereas that of phytoplankton increases as the size (TL) of the juveniles increases (TL: 4cm to14.5cm).

Key words/ phrases: Condition factor, food, juvenile *Oreochromis niloticus*, lakes Hawassa and Zwai.

1. Introduction

Ethiopia is rich in water resources including ponds, lakes, rivers, reservoirs and wetlands. These water bodies are home for more than 150 fish species that have a great ecological and economical importance (Abebe Getahun, 2007). *Oreochromis niloticus* is a popular species among bony fishes in Africa including Ethiopia which is one of the most important cichlids for commercial and subsistence fisheries and it contributes about 60% of total landing in Ethiopia (LFDP, 1997).

Oreochromis niloticus (Linnaeus) is a bony fish which belongs to the family Cichlidae and they are commonly referred to as tilapias. Tilapia can be broadly classified into three subgenera which are mainly the *Tilapia*, *Sarotherodon* and *Oreochromis* species, the latter two being mostly mouth brooders (Pauly, 1976). The family Cichlidae is highly diversified with a wide area of distribution spreading across Africa and most parts of India and Ceylon (Pauly, 1976). *Oreochromis niloticus* is one of the most preferred species for consumption, and important for income generation in commercial as well as traditional fishermen in the country (Alemayehu Negassa and Prabu, 2008). Because of its multiple advantages this species has been introduced in many parts of the world such as Asia, Europe, North America and South America (Mark *et al*., 2005; Alemayehu Negassa and Prabu, 2008). The species has great significance in commercial fisheries in many African water bodies, and in aquaculture worldwide. This happens due to its fast growth rate, ability to reproduce in artificial conditions, high salinity tolerance, ability to survive in low dissolved oxygen concentrations, and in poor water quality, and has a wide range of feeding habits favoring to produce large quantities in a small area within a short period of time (Alemayehu Negassa and Prabu, 2008).

Various investigators have studied some aspect of the biology of *O. niloticus* in Ethiopian water bodies (Zenebe Tadesse, 1988; 1997; Demeke Admassu, 1994; 1996). Length-weight relationships give information on the growth patterns of fish (Bagenal and Tesch, 1978). Length - weight relationship is important in studying fish biology. Length-weight relationships can be used to predict weight from length measurements made in the yield assessment (Pauly, 1993). Fish can attain either isometric growth, negative allometric growth or positive allometric growth. Isometric growth is associated with no change of body shape as an organism grows. Negative allometric growth implies the fish becomes more slender as it increase in weight while positive allometric growth implies the fish becomes relatively stouter or deeper-bodied as it increases in length (Riedel *et al*., 2007).

Condition factor gives some information about health status of the fish (Demeke Admassu, 1990). Condition factor refers to the well-being of the fish in question and by extension its health status (Blackwell et al., 2000). It is therefore an index reflecting interactions between biotic and abiotic factors to the physiological condition of fish (Edah *et al*., 2010 ,Mohammed *et al*., 2011). The condition factor which show the degree of well-being of the fish in their habitat is expressed by 'coefficient of condition' also known as length – weight factor. This factor is a measure of various ecological and biological factors such as degree of fitness, gonad development and the suitability of the environment with regard to the feeding condition (Mac Gregoer, 1959). When condition factor value is higher it means that the fish has attained a better condition. The condition factor of fish can be affected by a number of factors such as stress, sex, season, and availability of feeds (Khallaf *et al*., 2003). If relative condition factor is less than 1, it suggests a poor growth condition, were as if it is greater than or equal to 1 it suggests a good growth condition (Bagenal and Tesch,1978; Ayode,2011). Ebongi River (Mohammed *et al*., 2011). Relative condition factor value >1 also indicate good health status and desirable in fish farm (Ayode, 2011). This being due to favorable factor such as temperature and good quality and quantity of food (Bagenal and Tesch, 1978; Demeke Admassu, 1990) it also suggests a favorable water quality in habitats (Ighwela and Ahmed, 2011). The fish breeds intensively during the rainy seasons with some breeding activity occurring at other time of the year (Zenebe Tadesse, 1988). The condition of these juveniles is important as they are the ones used in stocking fish farms. The present study aims at providing information on the length-weight relationship and condition factor of *Oreochromis niloticus* in Lake Hawassa and Lake Zwai with a view to determining whether the fishes are in good condition.

The food of *O. niloticus* consists of a great variety of aquatic organisms depending upon availability (Canonico GC, *et al.,* 2005). A study of the primary diet of *Oreochromis niloticus* has been inconsistent in much of the research papers. Some studies classified *O. niloticus* as omnivorous and others as herbivorous (Canonico GC, *et.,al* 2005). There is a good deal of information on the food and feeding habits of *O. niloticus* in many water bodies (Tudoranceae *et al*, 1988; Zenebe Tadesse, 1988; Yirgaw Teferri *et al.,* 2000). Those authors describe the species feeds on a wide variety of food items such as Phytoplankton, Zooplankton, Insects, Detritus, Macrophytes and Nematodes. According to Tudoranceae *et al*. (1988), the feeding habits of *O. niloticus* showed differences based on its size and seasonal feeding activities. Adult *O. niloticus* feeds mainly on phytoplankton with some food of animal origin, especially zooplankton (Tudoranceae *et al*, 1988; Zenebe Tadesse, 1988; Getachew Tefera and Fernando, 1989; Yirgaw Teferri *et al.,* 2000; Alemayehu Negassa and Prabu, 2008). Juvenile *O. niloticus* feed mainly on zooplankton and insect larvae, but they shift to feed on mainly phytoplankton as they grow larger (Tudoranceae *et al*., 1988). As the fish changes it's feeding from primarily omnivorous diet to herbivorous diet may be due to energy demands, because of this large volumes of phytoplankton are filtered out from the water column as mentioned by earlier researchers (Alemayehu and Prabu, 2008). The ontogenetic dietary shift of *O.niloticus* in Lake Victoria highlights zooplankton were most important food items for fish less than 5 cm TL and little importance for larger than 10 cm TL (Njiru *et al*., 2004).

Seasonally, phytoplankton, especially blue green algae dominates the diet of the fish in dry season (Zenebe Tadesse, 1988, 1998; Yirgaw Teferri *et al*., 2000). During wet month fish moves to shallow parts of the lake for reproduction and stays for longer period of time by feeding macrophytes and vegetations. In addition, during wet month due to high flooding from the catchments area may cause fluctuations in water level and increasing turbidity of the lake. This decreases the penetration of light in the lake and there by affecting the growth and abundance of phytoplankton in the water (Getachew, 1989). During dry month fish may move to pelagic region of the lake and feeding mainly on suspended phytoplankton. During this period phytoplankton production may be high due to increased light penetration into the photic zone of Lake. The seasonal variation on the feeding habit of O. niloticus due to seasonal succession of phytoplankton in some rift valley lakes of Ethiopia was well explained (Yirgaw Teferi *et al* ., 2000). The biology of many *Tilapia* species in natural systems is well documented, but not much work has been done on the food, length-weight relationship and condition factor or well-being of juveniles. Such knowledge on juveniles would provide scientific bases to protect pre-recruited fishes in order to ensure recruitment.

Obviously, the growth and survival of juvenile fish's affects future recruitment success and fishery catch levels. Juvenile fishes, however, are exposed to high levels of natural mortality, for example. Due to predation (Neilson and Geen, 1986; Houde, 1989; DeAngelis *et al*., 1993). In addition, their growth and survival are negatively affected by unfavorable change in food quantity and quality resulting from natural and/or anthropogenic causes (Bowen, 1982). Juvenile *O. niloticus* in Ethiopia are heavily preyed upon by fishes such as *Lates niloticus* and *Clarias gariepinus* (Demeke Admassu *et al.,* 2015). In addition, the recent rapid growth of towns and other development activities near Ethiopian water bodes including Lakes Zwai and Hawassa, are sources of environmental and biodiversity concern. For instance, if such development activities are not well managed, they may result in fish habitat degradation and unfavorable changes in the quality and quantity of fish food (Bowen, 1982).

The age and growth of Juvenile *O. niloticus* in Lake Hawassa, Zwai, Langano and Chamo have been studied (Yosef Teklegorgis and Calselman, 1995; Demeke Admassu and Ahlgren, 2000). Probably the only other study dealing with juvenile *O. niloticus* is that of Tudoramceoe *et al.* (1988) who reported on their food habit in Lake Hawassa. However that study was conducted long before the lake is exposed to concerning level of development activities (urbanization, agriculture, industries, hotels) calling for a recent investigation. Therefore, this project is proposed to study the length weight relationship, condition factor and the food of *O. niloticus* juveniles in lakes Zwai and Hawassa.

2. Objectives of the study

General objective

- To study comparison between length- weight relationship, condition factor and food of juvenile *O. niloticus* L. Hawassa and Lake Zwai.

Specific objectives

- To determine the length- weight relationship and condition factor of juvenile *O. niloticus* from Lake Hawassa and Zwai.
- To identify food items of juvenile *O. niloticus* in Lake Hawassa and Lake Zwai.
- To study the diet shifts related to size of juvenile *O. niloticus* from Lakes Hawassa and Zwai
- To study the Lake based differences in the diet of juvenile *O. niloticus*.

3. Materials and Methods

3.1. Description of Lakes Zwai and Hawassa

Lakes Hawassa and Zwai are among a series of lakes found in the Ethiopian rift valley, the former 275 km and the later 160km south of Addis Ababa (Fig.1). The Zwai watershed falls in between 7°15'N to 8°30'N latitude and 38°E to 39°30'E longitude covering a total area of about 7300 km^2 (Girma Tilahun and Ahlgren 2010). Lake Zwai is shallower (mean depth=2.5m) but a wider (surface area = 432km^2) lake fed by two main rivers: Meki and Katar, and its main outflow is Bulbula river flowing to the near by Lake Abijata (Fig.1). Lake Hawassa has an area of 91 km^2 and an average depth of 11 m (LFDP, 1997). It is fed by one main river Tikur wuha river (Fig.1). The part of the rift valley in which the lakes are located is generally characterized by semi-arid to sub-humid climate (Girma Tilahun and Ahlgren 2010). The region of lakes Hawassa and Zwai is generally characterized by having two rainy seasons a year: the 'little rains' during March to May and the 'heavy rains' during June to September (Girma Tilahun and Ahlgren, 2010). Some features of the two lakes are presented in Table 1. Lakes Zwai and Hawassa are chemically similar to the other rift valley lakes in that Na+ and HCO3-+CO3- are their dominant ions (Talling & Talling, 1965). Fish fauna of Lake Zwai includes *O. niloticus*, *Tilapia zillii*, *Cyprinus carpio*, *Garra* species and *Clarias gariepinus* (Girma Tilahun and Ahlgren 2010). Fish species found in Lake Hawassa include *O. niloticus*, *C. gariepinus*, *Labeobarbus intermedius*, *Barbus amphigrama* and *Garra* species (LFDP, 1998). Both lakes support important fisheries with *O. niloticus* and *C. gariepinus* being among the most exploited species (LFDP, 1998). Annual potential fish yield is about

2000 tons for Lake Zwai whereas about 2200 tones, for Lake Hawassa the annual catch being 900 tons, and 420 tons, respectively (LFDP, 1998).

Table 1 Some physical, chemical and biological features of lakes Zwai and Hawassa.

Feature	Zwai	Hawassa
Altitude (M)	1636 [a]	1680 [a]
Surface area(Km^2)	432 [a]	88 [a]
Depth max	7 [a]	22 [a]
mean	2.5	10.7
Temperature (0c)	22.4±2.2 [a]	21.23 [a]
Conductivity(K_{25}, μS cm^{-1})	410 [b]	830 [b]
Salinity (g L^{-1})	0.4 [a]	0.8 [a]
Total nitrogen(mg L^{-1})	1.32±0.37 [a]	1.44±0.22 [a]
Total phosphorus (μg L^{-1})	68.5±14.6 [a]	34.1±13.2 [a]
Chlorophyl a (μg L^{-1})	39.2±9.4 [a]	18.7±5.2 [a]
Fish landing ($t.yr^{-1}$)	2500 [c]	1000 [c]

Source: a. Girma Tilahun (2010)

b. Zenebe Tadesse (1998)

c. LFDP (1997)

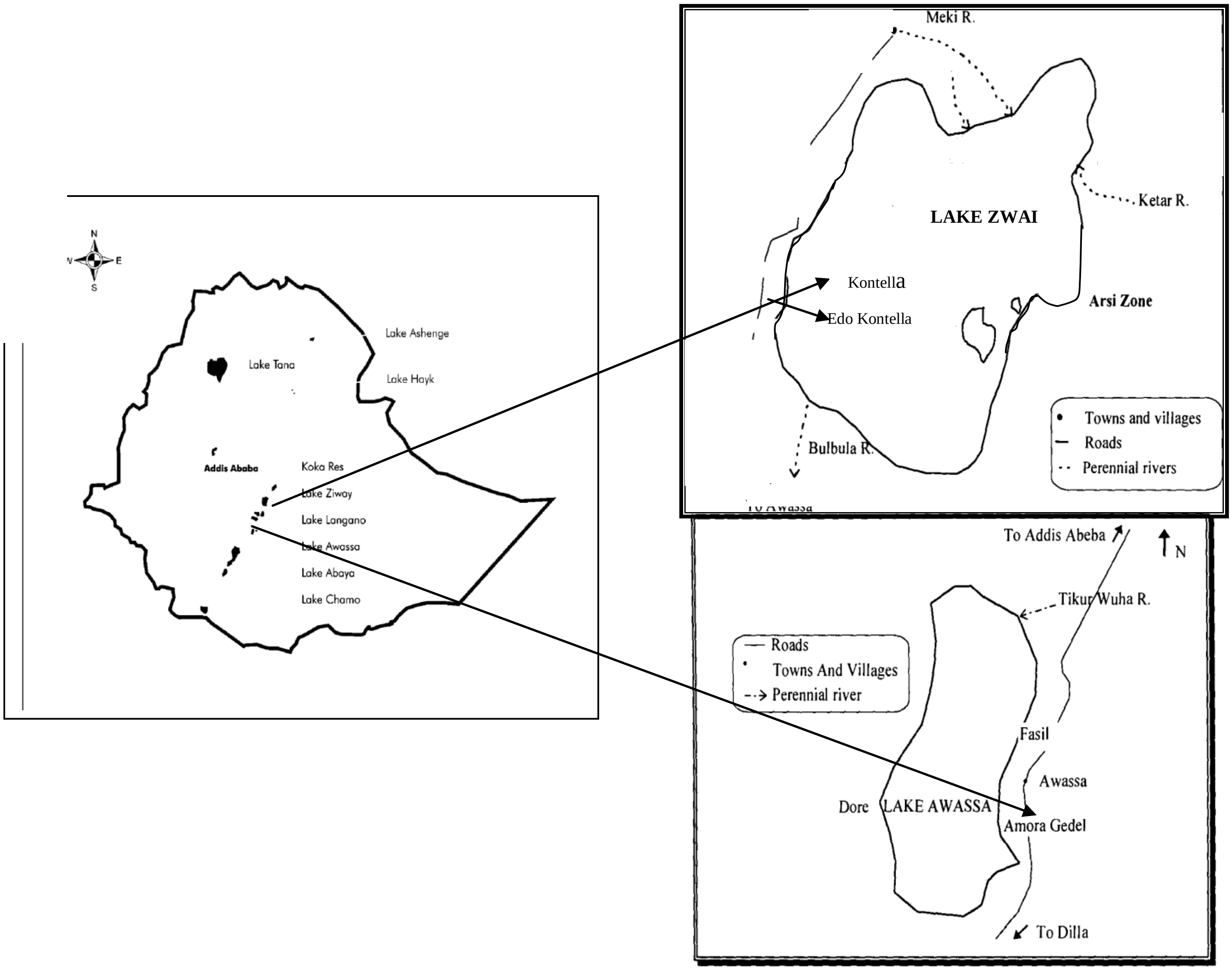


Figure 1 Map of Ethiopia showing L. Tana and the rift valley Lakes; Enlarged Maps of lakes Zwai and Hawassa are shown on the right (Modified from Alemayehu Negassa and Prabu, 2008; LFDP, 1997; Vijverber *et al*., 2012).

3.2. Sampling and measurement

Samples of *O. niloticus* juveniles were caught from inshore of the two lakes between March to August 2016. L. Zwai Sampling sites were grouped into the following areas: Edo Kontella (Site 1) and Kontella (Site 2), L. Hawassa Sampling sites were Amora Gedel. The fish were caught using beach seine net of 1.0cm stretched mesh size. Immediately after capture, total length (TL) and total weight (TW) of each specimen were measured to the nearest centimeter and gram. Each specimen was dissected and its sex and stage determined by inspecting the gonads (Babiker and Ibrahim, 1979). Stomach containing food was preserved in 5% formaldehyde (Demeke Admassu, *et al*., 2015) and transported to Addis Ababa for farther study in the laboratory.

Samples taken in March, April and May were considered as little rainy season samples, whereas those taken in June, July and August were considered as Heavy rains season samples.

3.3. Estimation of length-weight relationship

The length-weight relation was estimated using the following formula (Bagenal and Tesch, 1978):

$TW = aTL^b$

where,

W = total body weight in gram

TL= total length in centimeters

a= the intercept and

b = the slope of the regression line (also called length-weight coefficient).

Length - weight relationship was estimated separately for female and males, and for the total data.

3.4. Estimation of condition factor

The condition or well being of each fish was estimated by calculating Fulton condition factor as well as relative condition factor (Le Cren, 1951; Bagnal and Tesch, 1978).

3.4.1. Fulton condition factor

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

where FCF= Fulton condition factor

TW = Total weight in grams

TL= Total length in centimeter

3.4.2. Relative condition factor

$RCF = TW/\ aTL^{b}$

where

RCF = Relative condition factor

TW and TL = as described above.

a and b = the intercept and slope, respectively, of the length-weight relationship.

3.5 Stomach content analysis

Stomach content of each fish was microscopically examined to identify, and estimate relative importance of food items as described below.

3.5.1 Identification of food items

A drop of the stomach content was put on a microscope slide, and microscopically examined at 40x to 400x magnifications. At least three sub samples, each one drop, were microscopically examined for each fish. Items encountered were identified to the lowest taxa possible using descriptions in the literature (Mamaril and Fernando, 1978; Pennak, 1978; Edington and Hildrew, 1981; Defaye, 1988). A list of items encountered was then prepared for the fish from Lake Hawassa and from Lake Zwai.

3.5.2 Estimation of relative importance of food items

The relative importance of food items to the diet were analyzed using the frequency of occurrence and the numerical abundance methods (Windell and Bowen, 1978; Hyslop, 1980). Results from those methods will serve as bases to identify major and minor food items.

3.5.2.1 Frequency of occurrence

The number of stomach samples containing one or more of a given food item were expressed as a percentage of all non-empty stomachs examined. This shows the proportion of the population that feeds on a particular food item $Fi = ni/n * 100$

Where, F*i*: percent Frequency of occurrence of food items *i* .

n*i*: the Number of stomachs in which food item *i* is found.

n: Total number of stomachs containing food

This shows the proportion of the population that feed on a particular food item. (Hyslop, 1980; Bowen, 1983; Demeke Admassu, *et al*., 2015).

3.5.2.2 Numerical abundance

Simultaneously with identification, food items were counted along five transects of a microscope slide. This was done on three slides (sub - samples) per fish, and the average was calculated to represent the number of food item per fish. In the numerical abundance (contribution), of a food item was taken estimated as its number in percent of the total number of food items.

3.5.3. Estimation of size based, seasonal and Lake based difference in food habits.

The relative importance (Frequency of occurrence and numerical abundance) sized-based of food item categories (phytoplankton, zooplankton, etc) was plotted by total length of fish to investigate size based difference in food habits. The same plotted were done by season (Little rains and Heavy rains) and by Lake (Hawassa and Zwai) to investigate seasonal and lake based differences, respectively, in the food habit of the fish.

Data analysis

The data collected were entered into SPSS software program to analyze Length - weight relationship and condition factor.

4. Result

4.1. Size composition of fish samples

A total of 839 juvenile *O. niloticus* (420 from L. Hawassa and 419 from L. Zwai) were caught in this study. Total length (TL) in the sample from both lakes ranged from 4.0cm to 14.5 cm. Total weight (TW) ranged from 1.1g to 36g for the fish from Lake Hawassa whereas from 0.8g to 35.1g for those from Lake Zwai.

All the fish caught in this study had thread like (very thin) and flesh- colored gonads. Such features characterize immature (stage Ia) gonads (Babiker and Ibrahim, 1979). Therefore, all fish in this study were considered to be juveniles.

Length frequency distributions of *O. niloticus* juveniles caught from both lakes are shown in Fig 2. For those from Lake Hawassa, fish from 4.0cm to 5.9 cm TL were most frequent whereas fish from the intermediate TL group (8.0-9.9cm, TL) were least frequent (Fig 2a). Fish in the rest of the TL groups (6.0-7.9cm, 10.1-11.9cm and >11.9cm) were represented at comparable frequencies. In contrast, for the sample from L. Zwai, the intermediate length groups (8.0-9.9cm and 10.0-11.9cm) were well represented but those between 4.0cm and 5.9cm and >11.9cm in TL were least represented (Fig. 2b).

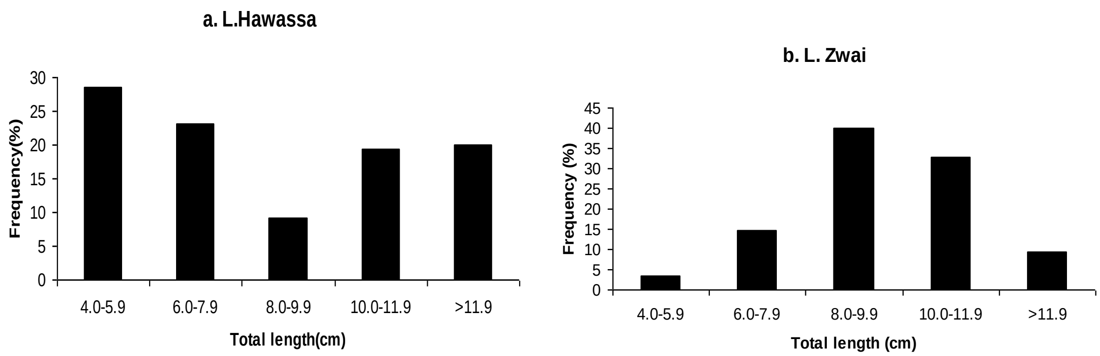


Figure 2. Length frequency distribution of juvenile *O. niloticus* in the sample from a) L. Hawassa and b) L. Zwai.

4.2. Length-weight relationship

The relationship between total length (TL, cm) and total weight (TW, g) of juvenile *O. niloticus* from L. Hawassa was best described by the following equations for the females, the males and for the combined data, respectively.

$$\text{Female:} \quad TW = 0.0292 * TL^{2.75} \quad R^2 = 0.9248 \quad n=185$$

$$\text{Male:} \quad TW = 0.0304 * TL^{2.68} \quad R^2 = 0.959 \quad n= 235$$

$$\text{Combined:} \quad TW = 0.0322 * TL^{2.72} \quad R^2 = 0.9476 \quad n=420$$

All the above equations were highly significant (ANOVA, P<0.005) with high values of coefficient of determination, and suggested a curvilinear relationship (Fig. 3).

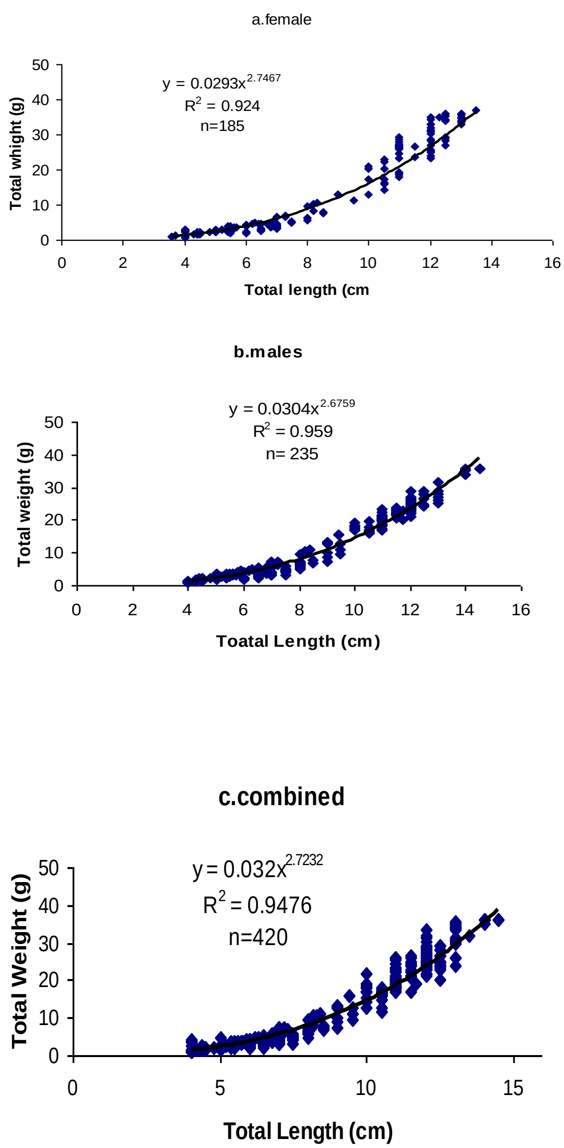


Figure 3 Length – weight relationship of females (a), males (b) and combined data(c) of juvenile *O. niloticus* in Lake Hawassa.

The relationship between total length (TL, cm) and total weight (TW, g) of juvenile *O. niloticus* from L. Zwai was best described by the following equations for the females, the males and for the combined data, respectively.

Female:	$TW= 0.0459*TL^{2.55}$	$R^2 = 0.9208$	n=149
Male:	$TW = 0.051*TL^{2.53}$	$R^2 = 0.8588$	n= 270
Combined:	$TW = 0.0558*TL^{2.54}$	$R^2 = 0.8809$	n= 419

All the above equations were highly significant (ANOVA, $P<0.005$) with high values of coefficient of determination, and suggested a curvilinear relationship (Fig. 4).

4.3 Condition factor

4.3.1 Fulton condition factor (FCF)

Fulton condition factor values of juvenile *O. niloticus* from Lake Hawassa ranged from 0.78 to 3.90 with mean ± SE of 1.74 ± 0.47 (Table 2). The value of the females ranged from 0.93 to 3.90 with mean ± SE of 1.75± 0.52 (Table 2). FCF value for the males ranged from 0.78 to 2.96, and the mean ± SE value was 1.74 ± 0.43 (Table 2). The data separated by season showed that FCF ranged from 0.80 to 3.90 and 0.78 to 2.73 during the little rains and heavy rains dry and the wet season, respectively (Table 2). Mean ± SE FCF was higher during the little rains (1.92± 0.39) than the heavy rains wet season (1.44± 0.45) (Table 2). FCF was not significantly different (ANOVA, $P>0.05$) between female and male juvenile *O. niloticus* in Lake Hawassa. However, it was significantly different (ANOVA, $P<0.05$) between the seasons being larger during the little rains than heavy rains season.

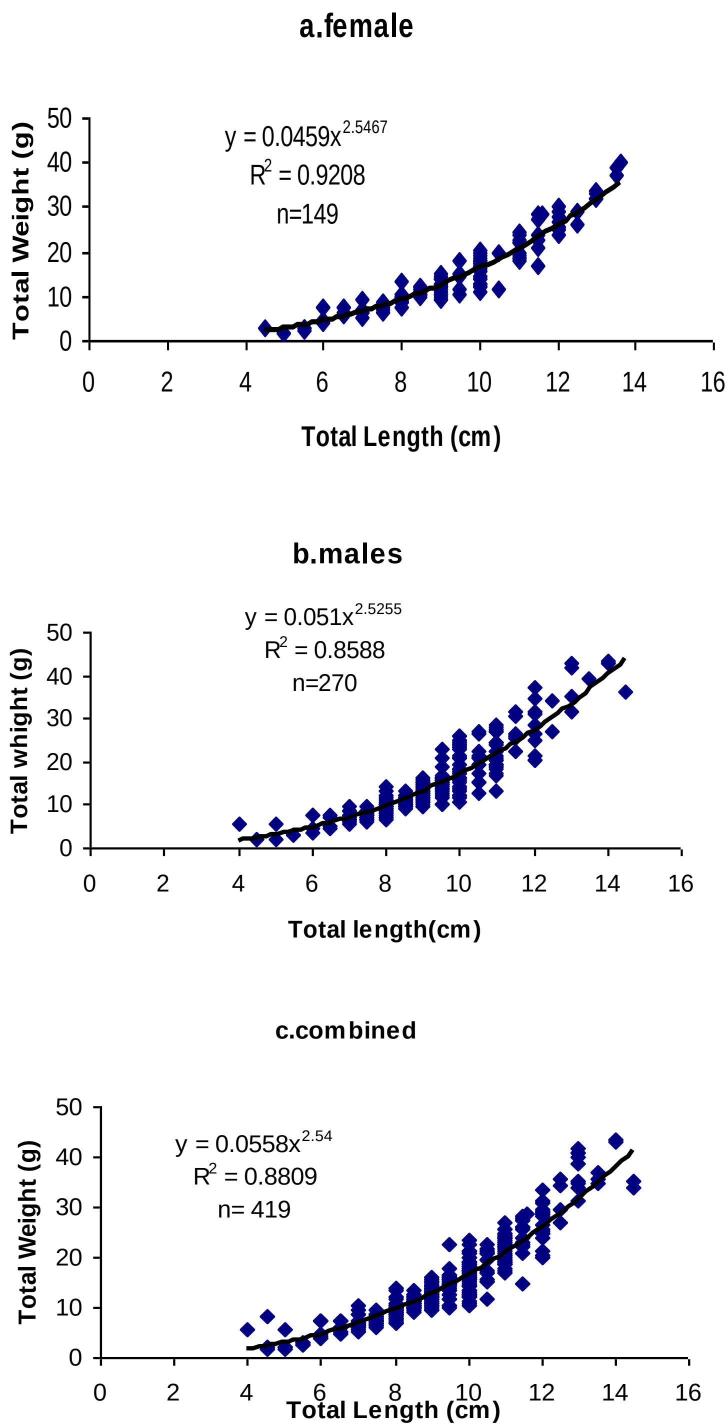


Figure 4 Length – weight relationship of females (a), males (b) and combined data(c) of juvenile *O. niloticus* in Lake Zwai.

Table 2 Range and mean ± SE Fulton condition factor of juvenile *O. niloticus* in Lake Hawassa separated by sex and season.

Sex/season	range	mean ± SE	n
Female	0.93-3.90	1.75±0.52	185
Male	0.78-2.96	1.74±0.43	235
Little rains season (March, April and may)	0.80-3.90	1.92±0.39	261
Heavy rains season (June, July and August)	0.78-2.73	1.44±0.45	159
Total sample	0.78-3.90	1.74±0.47	420

Fulton condition factor value of juvenile *O. niloticus* from Lake Zwai ranged from 0.99 to 3.76 with mean ± SE of 1.65 ± 0.68 (Table 3).The value of the female ranged from 1.02 to 3.47 with mean ± SE of 1.64± 0.81 (Table 3). FCF value for the male ranged from 0.99 to 3.76, and the mean ± SE value was 1.65 ± 0.68 (Table 3). The data separated by season showed that FCF ranged from 1.33 to 3.76 and 1.06 to 3.47 during the little rains and and the heavy rains season, respectively (Table 3). Mean ± SE FCF was equal during the little rains (1.81±0.23) and the heavy rains season (1.81±0.8) (Table 3). FCF was not significantly different (ANOVA, P>0.05) between female and male and between the seasons in Lake Zwai.

Table 3 Range and mean ± SE Fulton condition factor of juvenile *O. niloticus* in Lake Zwai separated by sex and season**.**

Sex/season	range	mean ± SE	n
Female	1.02-3.42	1.64±0.81	149
Male	0.99-3.76	1.65±0.68	270
Little rains season (March, April and May)	1.33-3.76	1.81±0.23	225
Heavy rains season (June, July and August)	1.06-3.47	1.81±0.87	194
Total sample	0.99-3.76	1.65±0.68	419

4.3.2 Relative condition factor (RCF)

Relative condition factor value of juvenile *O. niloticus* from Lake Hawassa ranged from 0.47 to 3.84 with mean ± SE of 1.02 ± 0.23(Table 4). The value of the females ranged from 0.53 to 2.30 with mean ± SE of 1.07± 0.29 (Table 4). RCF value for the males ranged from 0.47 to 3.84, and the mean ± SE value was 1.02 ± 0.23 (Table 4). The data separated by season showed that RCF ranged from 0.52 to 2.41 and 0.55 to 3.84 during the little rains and heavy rains season, respectively (Table 4). Mean ± SE RCF was slightly higher during the heavy rains (1.10± 0.36) than the little rains season (1.01± 0.17) (Table 4). FCF was not significantly different (ANOVA, P>0.05) between female and male juvenile *O. niloticus* and between seasons in Lake Hawassa.

Table 4. Range and mean ± SE Relative condition factor of juvenile *O. niloticus* in Lake Hawassa separated by sex and season.

Sex/season	range	mean ± SE	n
Female	0.53-2.30	1.07±0.29	185
Male	0.47-3.84	1.02±0.23	235
Little rains season (March, April and May)	0.52-2.41	1.01±0.17	267
Heavy rains season (June, July and August)	0.55-3.84	1.10±0.36	153
Total sample	0.47-3.84	1.02±0.23	420

Relative condition factor value of juvenile *O. niloticus* from Lake Zwai ranged from 0.57 to 2.89 with mean ± SE of 1.01 ± 0.22 (Table 5). The value of the females ranged from 0.61 to 1.71 with mean ± SE of 1.02± 0.22 (Table 5). RCF value for the males ranged from 0.61 to 2.89, and the mean ± SE value was 1.01 ± 0.18 (Table 5). The data separated by season showed that RCF ranged from 0.74 to 2.89 and 0.57 to 2.74 during the little rains and the heavy rains season, respectively (Table 5). Mean ± SE RCF was lower during the little rains (1.01± 0.13) than the heavy rains season (1.02± 0.26) (Table 5). RCF was not significantly different (ANOVA, $P>0.05$) between females and males and between the seasons for juvenile *O. niloticus* in Lake Zwai.

Table 4 Range and mean ± SE Relative condition factor of juvenile *O. niloticus* in Lake Zwai separated by sex and season.

Sex/season	range	mean ± SE	n
Female	0.61-1.71	1.02±0.22	149
Male	0.61-2.89	1.01±0.18	270
Little rains season (March, April and May)	0.74-2.89	1.01±0.13	225
Heavy rains season (June, July and August)	0.57-2.74	1.02±0.26	194
Total sample	0.57-2.89	1.01±0.22	419

4.4 Composition of stomach contents

Item identified from the stomach contents of juvenile *O. niloticus* are listed in Table 6 for fish from Lake Hawassa and in Table 7 for those from Lake Zwai. Juvenile *O. niloticus* from both lakes had ingested diverse groups of organisms of both plant and animal origins. In both populations, items of plant origin ingested by the fish were phytoplankton belonging to Cyanophytes, Bacillariophytes and Chlorophytes (Table 6 and 7). Item of animal origin ingested by both populations were zooplankton, insect, nematodes and some unidentified animals (Tables 6 and 7).

Phytoplankton ingested by juvenile *O. niloticus* from L. Hawassa was nine algal genera, two Cyanophytes, four Bacillariophytes and three Chlorophytes (Table 6). Zooplankton component of the diet of these juveniles was composed of one genus each of Rotifera and Cladocera, and two genera of Copepoda. The insects were chironomid larvae, Coleoptera, Hemiptera and Tricoptera larvae (Table 6). The phytoplankton diet of juvenile *O. niloticus* from Lake Zwai was composed of thirteen algal genera of which four were Cyanophyta, seven were Bacillariophyta and two were Chlorophytes (Table 7). The zooplankton diet of this fish is represented by two rotiferan genera, two cladoceran genera and one copepod genus, whereas chironomid larvae were the only insects identified from the stomach of the fish from Lake Zwai.

Table 5 Items encountered in the stomach contents of juvenile *O. niloticus* from L. Hawassa (n=185).

- Phytoplankton
  - Cyanophytes
    - *Microcystis*
    - *Arthrospira*
  - Bacillariophytes
    - *Aulacoseira*
    - *Tabellaria*
    - *Fragilaria*
    - *Navicula*
  - Chlorophytes
    - *Elakatothrix*
    - *Gloeotila*
    - *Botryococcus*
- Zooplankton
  - Rotifera
    - *Karatella*
  - Cladocera
    - *Diaphanosoma*
  - Copepoda
    - *Mesocyclops*
    - *Thermocyclops*
- Insecta
  - Chironomid larvae
  - Coleoptera larvae
  - Hemiptera larvae
  - Tricoptera larvae
- Nematoda
- Unidentified animals

Table 6 Items encountered in the stomach contents of juvenile *O. niloticus* from L. Zwai (n=200).

Phytoplankton
Cyanophytes
Planktolyngbya
Microcystis
Oscillatoria
Cylindrospermopsis
Bacillariophytes
Aulacoseira
Amphora
Navicula
Nitzschia
Monoraphidium
Diatoma vulgaris
Tabellaria focculosa
Chlorophytes
Pediastrum
Closterium
Zooplankton
Rotifera
Trichocerca
Brachionus
Cladocera
Moina micrura
Diaphanosoma
Copepoda
Thermocyclops
Insecta
Chironomid larvae
Nematoda
Unidentified animals

4.5. Relative importance of food items

The study showed that for juvenile tilapia from Lake Hawassa, zooplankton as a group had the highest frequency of occurrence (Table 8). The frequency of occurrence of zooplankton was followed, in descending order, by insects, phytoplankton and nematodes (Table 8). Among the zooplankton ingested by the fish in Lake Hawassa, Cladocera occurred at relatively higher frequency (36.2%) than Rotifera and Copepoda which occurred at comparable frequency (30-31%) (Table 8). Chironomid larvae had the highest frequency of occurrence (42.7%) than Insects as well as all other individual food items (Table 8). Frequency of occurrence of phytoplankton groups (Cyanophytes, Bacillariophytes and Chlorophytes) ranged from 11.3% to 17.3%, high frequencies being that of the Bacillariophyte genus *Aulacoseira* (12.4%) and the Cyanophyte genus *Microcystis* (11.4%) (Table 8).

In terms of numerical abundance, zooplankton as a group was the most important food of juvenile *O. niloticus* in Lake Hawassa (Table 8). The numerical abundance of zooplankton (37%) was followed by that of insect (26.2%), phytoplankton (22.5%) and nematodes (7.4%) (Table. 8). Cladocera had the highest numerical contribution (16.1%), and this was followed by that of Chironomid larvae (11.9%), and of Rotifers and Copepods (10.5% each) (Table 8). The highest numerical contribution among phytoplankton was that of Bacillariophytes as a group (10.5%) which is smaller to that of Rotifers or Copepods (Table 8). The numerical contribution of Bacillariophytes was followed by that of Cyanophytes (7.4%) and Chlorophytes (4.7%), the Cyanophyte

Microcystis being the most numerous algal genus ingested by juvenile *O. niloticus* in Lake Hawassa (Table 8).

For Lake Zwai, also Zooplankton as a group had the highest frequency of occurrence (Table 9). The frequency of occurrence of zooplankton was followed, in descending order, by phytoplankton, insects and nematodes (Table 9). Among the zooplankton ingested by the fish in Lake Zwai, Cladocera occurred at relatively higher frequency (33%) than Rotifers and Copepods which occurred at comparable frequency (31-31.5%) (Table 9). Frequency of occurrence of phytoplankton groups (Cyanophytes, Bacillariophytes and Chlorophytes) ranged from 10.0% to 20.0%, high frequency being that of the Cyanophyte genus *Microcystis* (20.0%) (Table 9). In terms of numerical abundance, zooplankton as a group was the most important food of juvenile *O. niloticus* in Lake Zwai (Table 9). The numerical abundance of zooplankton (44.6%) was followed by that of phytoplankton (24.42%) insects (13.04%), and nematodes (7.55%) (Table 9). Rotifers had the highest numerical contribution (21.42%), and this was followed by that of Chironomid larvae (13.04%), and of Cladocerans and Copepods (11.33% and 11. 86) (Table 9). The highest numerical contribution among phytoplankton was that of Bacillariophytes as a group (10.5%) which is similar to that of Rotifers or Copepods (Table 9). The numerical contribution of Bacillariophytes was followed by that of Cyanophytes (8.14%) Chlorophytes (5.84%), the Cyanophyte *Microcystis* being the most numerous algal genus ingested by juvenile *O. niloticus* in Lake Hawassa (Table 9).

Table 7 Relative importance of food items of 185 juvenile *O. niloticus* in Lake Hawassa based on frequency of occurrence (%) and numerical abundance (%).

Food item (taxon)	Frequency of occurrence %	Numerical abundance %
Phytoplankton	76.2	22.5
Cyanophytes	17.4	7.4
Microcystis	11.4	4.5
Arthrospira	4.9	2.8
Bacillariophytes	15.1	10.5
Aulacoseira	12.4	3.8
Tabellaria	10.8	2.8
Fragilaria	9.7	1.8
Navicula	9.7	1.9
Chlorophytes	11.4	4.7
Elakatothrix	4.9	1.7
Gloeotila	8.6	1.7
Botryococcus	5.4	1.3
Zooplankton	91.4	37
Rotifer	30.3	10.5
Cladocera	36.2	16.1
Copepods	31.4	10.5
Insect	86.5	26.2
Chironomidae larvae	42.7	11.8
Coleoptera larvae	16.8	2.9
Hemiptera larvae	12.4	5.5
Tricoptera larvae	20	5.8
Nematoda	24.3	7.4
Unidentified animals	14.6	6.9

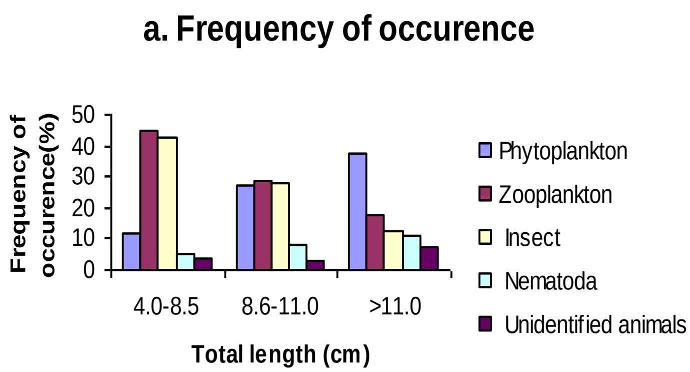
Table 8 Relative importance of food items of 200 juvenile *O. niloticus* in Lake Zwai based on frequency of occurrence (%) and numerical abundance (%).

Food item (taxon)	Frequency of occurrence %	Numerical abundance %
Phytoplankton	55	24.4
Cyanophytes	24	8.1
Planktolyngbya	11	0.2
Microcystis	20	6.3
Oscillatoria	14	0.9
Cylindrospermopsis	8.5	0.8
Bacillariophytes	18	10.4
Aulacoseira	10	2.7
Amphora	2	1.5
Navicula	7	1.5
Nitzschia	3	1.4
Monoraphidium	1	1.1
Diatoma	2	1.1
Tabellaria	3	1.2
Chlorophytes	11	5.8
Pediastrum	6	3.9
Closterium	10	1.9
Zooplankton	58	44.6
Rotifers	31	21.4
Cladocerans	33	11.3
Copepods	31.5	11.9
Insects	32	13.0
Nematoda	23.5	7.5
Unidentified animals	6	10.4

4.6. Size based difference in food habit

For juvenile *O. niloticus* in Lake Hawassa, frequency of occurrence (FO) of phytoplankton was lowest for the smallest fishes (4.0-8.5cm), and tended to increase with the size of the fish (Fig. 5a). In contrast, FO of zooplankton and of insects was highest for the smallest fishes, and tended to decrease with the size of the fish (Fig. 5a). In terms of numerical abundance, the contribution of phytoplankton tended to increase whereas that of zooplankton and insect tended to decrease with the size of the fish (Fig.5b).

For juvenile *O. niloticus* in Lake Zwai, frequency of occurrence (FO) of Phytoplankton was highest for smallest fishes, and it increased with fish size (Fig. 6a). In contrast, FO of zooplankton and of insects tended to decrease with fish size (Fig.6a). In NA fish size increase phytoplankton and insect abundance increase, size decrease zooplankton abundance increase and other remaining food items categories decreased in all size (Fig. 6b).



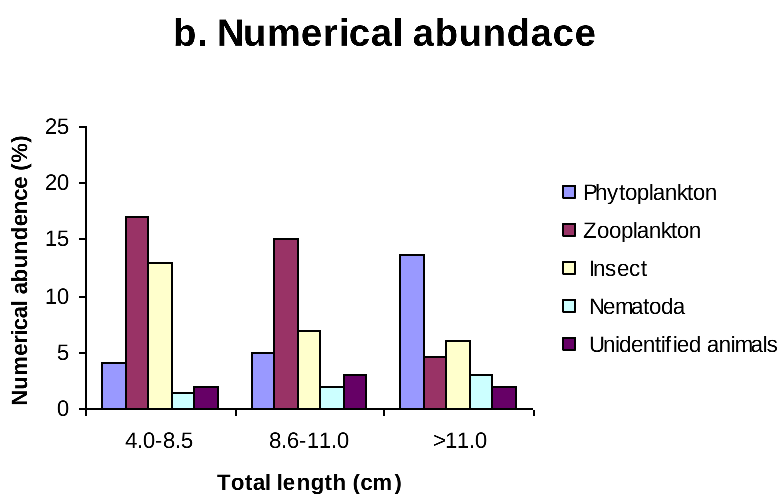
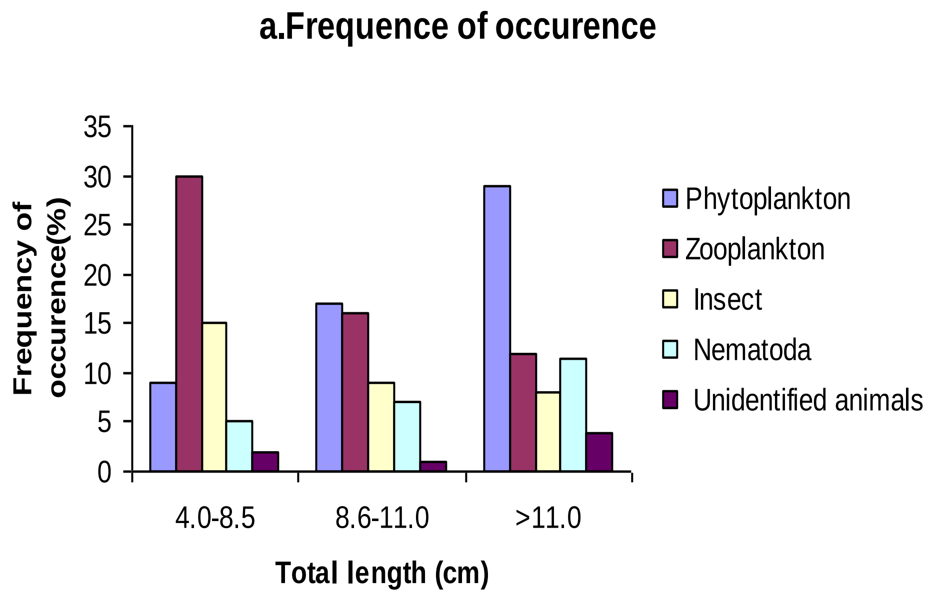


Figure 5 Size based difference in the food of juvenile *O. niloticus* in L. Hawassa based on frequency of occurrence (a) and numerical abundance (b)



b. Numerical abundance

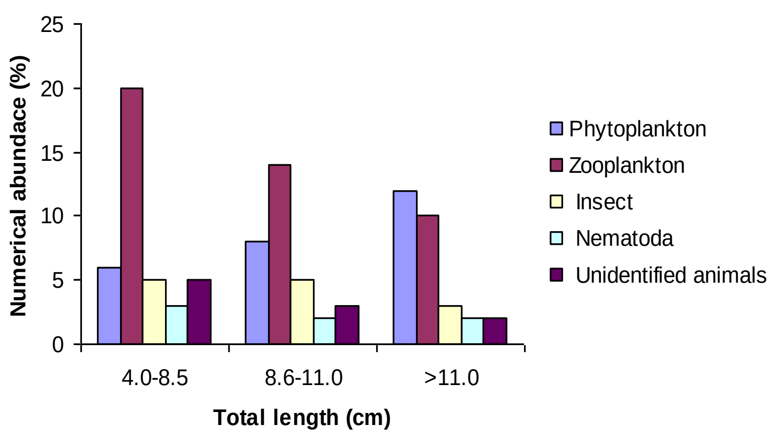
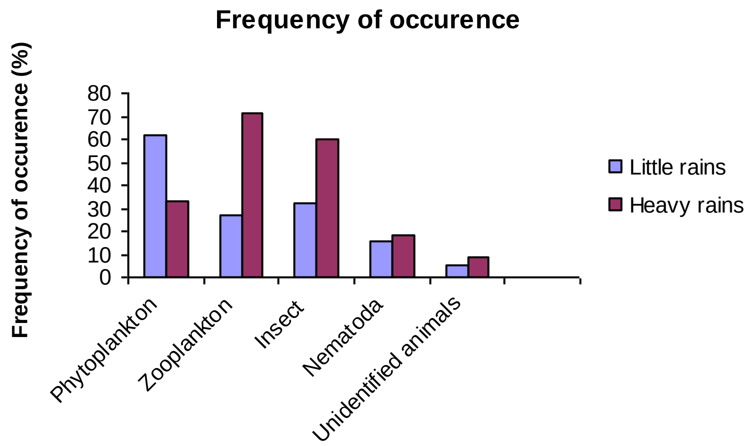


Figure 6 Size based difference in the food of juvenile *O. niloticus* in L. Zwai based on frequency of occurrence (a) and numerical abundance (b).

4.7. Seasonal difference in food habit

All the major food items categories, i.e., phytoplankton, zooplankton, insects, nematodes and unidentified animals, were ingested by juvenile *O. niloticus* in Lake Hawassa during both the little rains and the heavy rains seasons (Fig. 7a). However, their relative contribution was different between the seasons. Thus, for instance, phytoplanktons were more frequent (Fig. 7a) and more numerous (Fig.7 b) in the little rains season than in the heavy rains season in the diet of juvenile *O. niloticus* in Lake Hawassa. In contrast, the other food item categories were more frequent (Fig7a) and more numerous (Fig. 7b) in the Heavy rains than in the little rains season.

All the five food item categories were ingested also by juvenile *O. niloticus* in Lake Zwai in both the little rains and the heavy rains season (Fig. 8a). The relative contribution of the food items categories, however, differed between the seasons. Thus, the relative contribution of phytoplankton was higher in the little rains season than the Heavy rains season in terms of both frequency of occurrence (Fig. 8a) and numerical abundance (Fig 8b). However, zooplankton, insects and nematodes were more frequent in the heavy rains season (Fig 8a) but more numerous in the little rains season (Fig. 8b). Frequency of occurrence of unidentified animal was similar between the seasons (Fig 8a), but their numerical abundance was slightly larger in the little rains season (Fig. 8b).



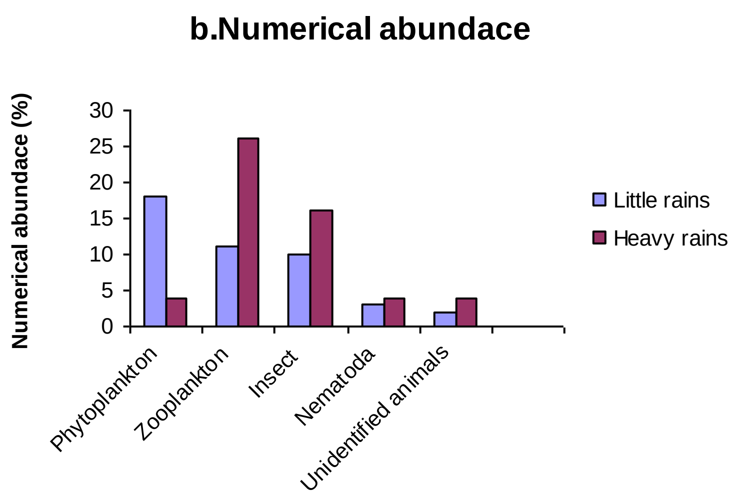
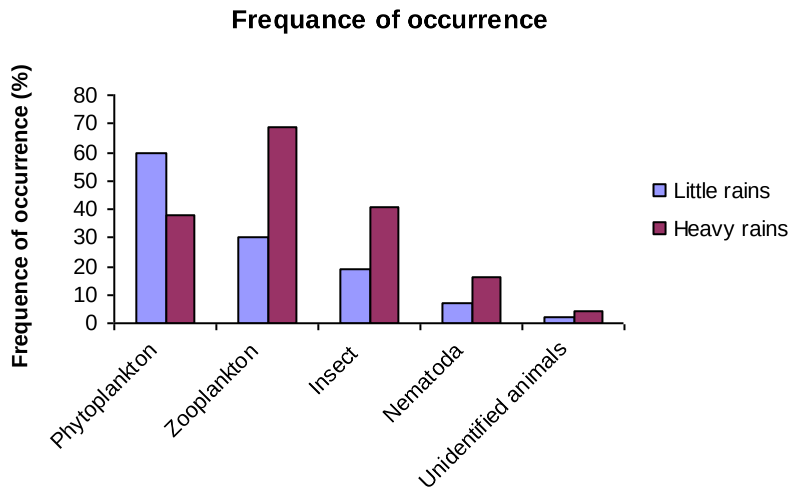


Figure 7 Difference between little rains and heavy rains season in the food habit of juvenile *O. niloticus* in L. Hawassa based on frequency of occurrence (a) and numerical abundance methods (b).



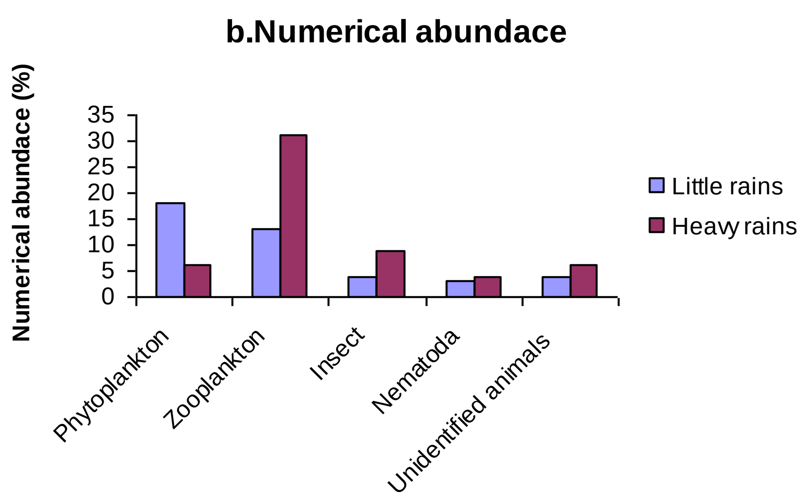
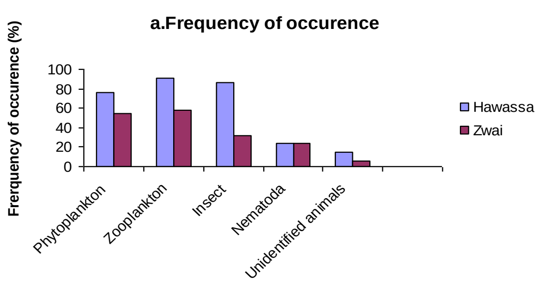


Figure 8 Difference between little rains and heavy rains seasons in the food habit of juvenile *O. niloticus* in L. Zwai based on frequency of occurrence (a) and numerical abundance methods (b).

4.8. Lake based difference in food habit

Both populations (Hawassa, Zwai) of juvenile *O. niloticus* had ingested all the five major food item categories. However, the relative contribution of most of the food item categories differed between the two populations. Thus phytoplankton, zooplankton, insect, nematodes and unidentified animals were more frequent in the diet of the Lake Hawassa population (Fig. 9a). On the other hand, phytoplankton, zooplankton, and unidentified animals were more numerous in the diet of the Lake Zwai population (Fig. 9b). Insects were more important for the Lake Hawassa population in terms of both frequency of occurrence and numerical abundance (Figs 9 a&b). Both methods showed that nematodes were equally important to the diet of both populations (Figs. 9a & b).



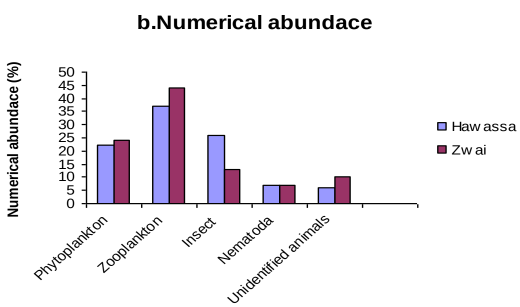


Figure 9 Lake based (Hawassa vs Zwai) differences in the food habit of juvenile *O. niloticus* based on frequency of occurrence (a) and numerical abundance (b).

5. Discussion

The study showed that the length – weight relationship of both populations (Hawassa, Zwai) of juvenile *O. niloticus* was highly significant and curvilinear with high values of coefficient of determination (Figs 3&4). A curvilinear length-weight relationship in fishes is a general natural fact (Allen, 1938; Bagenal and Tesch, 1978, Demeke Admassu, 1990). However, the value of the length – weight coefficient (b) is believed to range from 2 to 4 and vary within as well as between species (Bagenal and Tesch, 1978, Demeke Admassu, 1990). The b values estimated for the juvenile *O. niloticus* populations in this study (2.53 to 2.75) also fall within the range 2 to 4 being toward the lower end of the range. The coefficient was similar between the sexes in Lake Hawassa (females =2.75, males =2.68) as well as in lake Zwai (females =2.55, males =2.53). The coefficient was slightly larger for juvenile *O. niloticus* in Lake Hawassa (b=2.72) than those in Lake Zwai (b=2.54). Therefore, the coefficient for the lake Hawassa population is closer to the cube law (b=3) than that of the Lake Zwai population.

Other studies on length – weight relationship of *O. niloticus* in Ethiopia have found similar b values. According to Berhanu Lemma and Demeke Admassu (unpublished data), the coefficient is 2.79 for juvenile *O. niloticus* in Koka reservoir. Zenebe Tadesse (1997), who focused mainly on adults reported a b value of 2.74 for *O. niloticus* in lake Tana. This is similar to the b value of juvenile *O. niloticus* in Lake Hawassa calculated in this study (b=2.74). Other b values reported for adult *O. niloticus* included 2.9 for the population in Lake Hawassa (Demeke Admassu, 1990), 2.95 for that in Lake Chamo (Yirgaw Teferi and Demeke Admassu, 2000) and 3.03 for the population in Zwai

(Zenebe Tadesse 1988). Since these b values are close to the cube law (b=3), the growth pattern of those *O. niloticus* populations is said to be isometric (Bagenal and Tesch, 1978; Zenebe Tadesse 1988; Demeke Admassu, 1990; Yirgaw Teferi and Demeke Admassu, 2000). The same can be concluded for juvenile *O. niloticus* in Lake Hawassa in this study. In contrast, the growth pattern of juvenile *O. niloticus* in Lake Zwai (b=2.54) may be allometric. Allometric growth (b≠3) has been reported also for other Nile tilapia populations (e.g., Offem and Omoniyi, 2007).

Nevertheless, a smaller b value alone does not necessarily show poor growth or a lighter weight for a given length, because the y- intercept of the length weight equation should also be considered. In this study, the y- intercept is 0.032 and 0.056 for juveniles in Lake Hawassa and Lake Zwai, respectively. Accordingly, the respective length – weigh equations suggest that a 10 cm juvenile *O. niloticus* would weight about 17.0g in Lake Hawassa and 19.4g in Lake Zwai suggesting a more or less similar growth condition between the two juvenile populations. This is indicated also by condition factor values (see below).

The sexes of juvenile *O. niloticus* from both Lake Hawassa and Lake Zwai have similar mean Fulton condition factor (Tables 2 & 3). In addition, mean condition factor of the fish from Lake Zwai is found to be the same (1.81) between the little rains and heavy rains seasons (Table 3). However, the fish in Lake Hawassa had a larger mean Fulton condition factor in the little rains (1.92) than the heavy rains (1.44) season (Table 2). This may be due to better growth during the little rains season associated with warmer temperature and availability of better quantity and quality of food (Bagenal and Tesch, 1978). The mean FCF of juvenile *O. niloticus* was slightly larger for the Lake Hawassa (1.74) and the Lake Zwai (1.65) population (Tables 2 & 3). However, the difference between them was not significant (t-test, $p > 0.05$). As mentioned above, therefore, the growth condition as well as the health status of the two juvenile *O. niloticus* populations could be similar (Bagenal and Tesch, 1978; Demeke Admassu, 1998; Blackwell *et al.,* 2000; Demeke Admassu and Ahlgren, 2000). According to the unpublished data of Berhanu Lemma and Demeke Admassu, mean FCF of juvenile *O. niloticus* of Koka Reservoir is 1.08. This is similar to mean RCF of juvenile *O. niloticus* in this study. However, were smaller than those of adult *O. niloticus* populations in the Lake Hawassa (2.35: Demeke Admassu, 1990), Lake Zwai (1.89: Zenebe Tadesse, 1998) and in Lake Chamo (2.03: Yirgaw Teferi and Demeke Admassu, 2000). This could be due to differences in condition factor between juveniles and adult and/or difference between habitats in biotic and abiotic factors (Edah *et al*., 2010; Mohammed *et al*., 2011).

The study showed that mean relative condition factor of the studied juvenile *O. niloticus* was similar between the seasons as well as between the lakes (Tables 4 and 5). Thus, for instance, mean relative condition factor is 1.02 for juvenile in Lake Hawassa and 1.01 for those in Lake Zwai. Therefore, as it has been concluded from mean FCF (see above), mean relative condition factor also shows that the growth condition and the health status of the two juvenile populations could be similar (Bagenal and Tesch,1978; Demeke Admassu, 1990; Blackwell *et al.,* 2000). In addition, if relative condition factor is less than 1, it suggests a poor growth condition, whereas if it is greater than or equal to 1 it suggests a good growth condition (Bagenal and Tesch, 1978; Ayode, 2011). The mean relative condition factor of both populations of juvenile *O. niloticus* in this study is slightly greater than 1. Therefore, it can be concluded that both populations have a good growth condition. The same result has been reported for tilapia populations in Lake Naivasha (Ayode, 2011).

The study showed that juvenile *O. niloticus* in Lake Hawassa and Lake Zwai feed on variety of food items of either plant or animal origin. Items of plant origin were several genera of phytoplankton whereas those of animal origin were several genera of zooplankton, insect, nematodes and some unidentified animals (Table. 8 & 9). Composition of the food of the two juvenile *O. niloticus* populations is more or less similar to other *O. niloticus* populations in Ethiopia (Berhanu Lemma and Demeke Admassu, unpublished[*], Tudorance *et al*., 1988; Zenebe Tadesse 1988; Getachew Tefera and Fernando,1989; Yirgaw Teferi *et al*., 2000) and elsewhere (Moriarity *et al*.,1973; Bowen, 1980; Khallaf and Alne-na-ei,1987). Berhanu Lemma and Demeke Admassu (unpuplished), for instance, found that the species in Koka reservoir feeds on phytoplankton, zooplankton, insects and some other items. The spices in Lake Chamo as well feeds on a divers genera of phytoplankton (blue green, green, diatom, charophytes), zooplankton, chironomide larvae and detritus (Yirgaw Teferi *et al.,* 2000).

Although the juvenile populations of *O. niloticus* in this study feed on diverse food items, both frequency of occurrence (FO) and numerical abundance (NA) methods showed differences in relative importance of food item categories. Both methods showed that zooplankton as a group is the most important food of the fish in both Lake Hawassa and Lake Zawi. Insects or phytoplankton were the next whereas nematodes were the least

[*] Berhanu Lemma and Demeke Admassu (unpuplished). The food and feeding habits of Nile tilapia (*Oreochromis niloticus* L.) in Koka reservoir, Ethiopia.

important food of both populations. This finding agrees with other studies on juvenile *O. niloticus* (Berhanu Lemma and Demeke Admassu, unpublished; Tudorance *et al*., 1988; Yirgaw Teferi *et al.*, 2000). According to Berhanu Lemma and Demeke Admassu (unpublished), food items of animal origin, especially zooplankton and chironomids, are more important than items of plant origin (phytoplankton) to the diet of juvenile *O. niloticus* in Koka Reservoir. Yirgaw Teferi *et al.* (2000) have also reported that zooplankton and insects are most important to the diet of small (6.1-11.5cm TL) *O. niloticus* is Lake Chamo. Likewise, Tudorance *et al*. (1988) reported that zooplankton, phytoplankton and chironomid larvae are most important than phytoplankton to the diet of juvenile *O. niloticus* in Lake Hawassa.

The study showed size based difference in the food habit of juvenile of *O. niloticus* in both Lake Hawassa and Lake Zwai. Generally, the relative importance of zooplankton and insect decreases whereas that of phytoplankton increases as the size of the juveniles increases (Figs 5 and 6). Therefore, juvenile *O. niloticus* in both lakes feed on more food of animal origin than plant origin at smaller size (4.8-8.5) shifting to a more food of plant origin (phytoplankton) as they group larger. The same has been found for other *O. niloticus* populations (Berhanu Lemma and Demeke Admassu unpublished; Tudorance *et al*., 1988; Yirgaw Teferi *et al.*, 2000). Tudorance *et al*. (1988), for instance, reported that juvenile *O. niloticus* Lake Hawassa feed more animals (zooplankton, chironomids, nematodes) than plants and above 6.0cm TL shifts to a mainly phytoplanktivore diet. According to Yirgaw Teferi *et al*. (2000) as well zooplankton and chironomids are more important in the diet of small (6.1-11.5cmTL) than larger *O. niloticus* in Lake Chamo, and the latter are mainly phytoplanktivorous.

The study found seasonal (little rain vs heavy rains) difference in the food habit of juvenile *O. niloticus* in Lake Hawassa as well as Lake Zwai (Figs 7&8). Generally, phytoplankton is more important in the little rains season whereas animals (especially zooplankton, insects and nematodes) are more important in the heavy rains season to the diet of the two populations. Considering lake based difference in food habit, frequency of occurrence method showed all the major food item categories (phytoplankton, zooplankton and insects) are more important to the diet of the fish in Lake Hawassa than that in Lake Zwai (Fig. 9). Both seasonal and lake Based differences in the food habit of the fish could not be explained, but it may reflect differences in abundance of the food items between seasons and between the lakes (Philipart and Ruwet, 1982; Khallaf and Alen-na-ei, 1987).

6. Conclusion and Recommendation

The length – weight relationship of juvenile *O. niloticus* in Lake Hawassa and Lake Zwai is highly significant (ANOVA, $P<0.005$) and curvilinear. The value of length – weight coefficient (b) is 2.54 and 2.72 for fish from Lake Hawassa and Zwai, respectively. Those values suggested allometric growth for juvenile *O. niloticus* in Lake Zwai whereas isometric growth for those in Lake Hawassa. Mean Fulton condition factor was 1.65 for the fish in Lake Zwai and 1.74 for the fish in Lake Hawassa. Mean relative condition factor was greater than 1 (Hawassa =1.02, Zwai = 1.01) suggesting a good growth condition and health status of both juvenile *O. niloticus* populations. Both populations feed on phytoplankton, zooplankton, insects, nematodes and some unidentified animals. Thus, the juveniles were considered omnivores in their feeding habit. However, zooplankton were more important to the diet of small-sized (4-4.9cm TL) than larger juvenile *O. niloticus* in both lakes. In contrast, Phytoplankton were more important for larger (especially ≥11.0cm TL) than smaller juveniles.

The following recommendations are forwarded

- A more detailed similar study based on year round samples is recommended
- Other aspects of the biology of juvenile *O. niloticus* such as growth, mortality, distribution, showed be studied
- In light of the extensive development activities around lakes Hawassa and Zwai, appropriate management is recommended to maintain the good growth and health condition, and to protect the natural food of the juvenile *O. niloticus* population of the lakes.

7. References

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Declaration

I, the undersigned, hereby declare that this thesis is my original work and that all sources of material used for the thesis have been properly acknowledged.

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