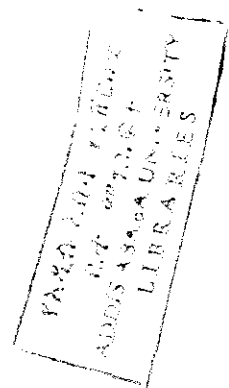


ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

SEX RATIO, LENGTH-WEIGHT RELATIONSHIP,
CONDITION FACTOR AND THE FOOD HABIT OF
CATFISH, *Clarias gariepinus* (BURCHELL) IN LAKE
LANGENO, ETHIOPIA

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JUNE 2001



Sex ratio, length-weight relationship, condition factor
and the food habit of Catfish, *Clarias gariepinus*
(Burchell) in Lake Langeno, Ethiopia

A thesis presented to the School of Graduate Studies,
Addis Ababa University,
In partial fulfillment of the requirements for the degree of
Master of Science in Biology

Leul Teka

June 2001

Dedication

This work is dedicated to my family:

My wife Akalat Mamo and my children,

Surafiel, Eyuael and Nahom

ACKNOWLEDGEMENTS

In presenting this thesis, I am profoundly indebted to my advisor, Dr. Demeke Admassu for suggesting the research area, unreserved advice and invaluable help at all times. Without his generous help and support it would have been impossible to complete my studies. Indeed, mere acknowledgement of indebtedness to him seems wholly inadequate.

I would like to express my deep gratitude to Yirgaw Teferi for his provoking discussion on matters related to my study. Subsequently help and encouragement was also received from him.

I would like to express my sincere appreciation to Dr. Abebe Getahun, Dr. Seyoum Mengistu, Elias Dadebo and Yosef Tekle Giorgis for providing me with relevant literature.

I wish to thank Medhane Asmalash who offered invaluable help in statistical evaluation of the data and for his constructive advice. I also acknowledge Meshesha Balkew for helping me in identification of some insect groups.

My deepest appreciation goes to my closest friends Getahun Molla and Gezahegn Getachew for their encouragement and support during the course of my study. They also made my stay here in Addis Ababa lively and comfortable.

To Getachew Tesfaye, Abebe Hailemariam, Berihun G/Medhin, Yemane G/Egziabher, Daniel Alemayehu and Yosef Assefa, I give my thanks for their encouragement and help in the tedious work of stomach examination. Thanks are also due to Kebede Molla, Mulugeta G/Mariam, Belay Ayalew, Mekonen Becha, Zenebech G/Kidan, Emebet Semre, Nigusie Semre and Tigist Getachew for providing their unreserved support in all my enquiries.

A special thanks is to Mulugeta Jovani, Arsi-Negele Woreda Agricultural Department, for assisting me during the early stages of the fieldwork. I am also grateful to the staff of the Zwai Fisheries Center, in particular, Daba Tuge, Meseret Taye, Yared Tigabu, Eskedar Tariku and Dawit Emiru who were very helpful and cooperative in providing me with some field equipment.

Ato Tulula Sete (a fisherman at Lake Langeno) and his assistants deserve many thanks for allowing me to sample their catch.

I am very grateful to W/ro Selam Assefa for her unforgettable assistance in typing the manuscript.

I must thank the Swedish Agency for Research Cooperation in Developing countries (SIDA-SAREC) for financial support through the School of Graduate Studies, AAU.

The Department of Biology, AAU, is gratefully appreciated for giving me the opportunity to study my M. Sc. at the department and also assisting me with material and resource during my thesis work. I am extremely grateful to Dr. Kifle Dagne who was very cooperative to me in so many ways. My thanks also extend to Dr. Gurga Belay for his encouragement and material support. The Department secretaries, particularly, Muluaem and Banchu, deserve special thanks for their consistent support.

I am thankful to the Amhara Regional State and the Bureau of Education for sponsoring my study. The staff of St. Lalibella Junior and Senior Secondary School are highly appreciated for helping me in many ways. In particular, my friend Mesfin Sileshi deserve special thanks in resolving my private cases and also for his constant encouragement and support through out the study.

Finally and most importantly, my wife, Akalat, and my children, Surafiel, Eyuael, and Nahom who are the sole source of motivation and encouragement, are highly appreciated for their patience in my absence for so long a time.

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ABSTRACT

Sex-ratio, length-weight relationship, condition factor ($n = 859$) and the food habit ($n = 764$) of *C. gariiepinus* were studied in Lake Langeno from monthly samples collected using hook and lines between April 2000 and October 2000.

Female to male sex-ratio was in favour of females in the total sample (1.41:1) and in both seasons of low water-level (1.29:1) and high water-level (1.53:1). Sex-ratio was not significantly different from 1:1 in five of the eight length classes used for the study. In three of the length classes (between 25 cm and 54 cm, TL), females were at least 1.53 times more numerous than males.

The relationship between total length (range: 28 to 104 cm) and total weight (range: 150 to 8000 g) was found to be curvilinear and statistically significant ($R^2=0.955$, $P<0.05$) with a slope ($b = 2.91$) very close to the cube.

Monthly mean Fulton condition factor (FCF) ranged from 0.55 to 0.65 for male and from 0.61 to 0.66 for female *C. gariiepinus*. Monthly mean relative condition factor (RCF) ranged from 0.91 to 1.09 for males and from 0.99 to 1.10 for females. Generally, females had seasonally higher FCF and RCF than males. On the average, large values of FCF and RCF were recorded in May, and low values in June for both sexes. There was no significant difference (ANOVA, $P=0.1334$) in FCF and RCF between the low water and high water seasons. Mean FCF and mean RCF of females were larger than those of males in all length-classes except in the smallest class (25 to 34 cm TL) in which case males had larger values.

Stomach contents of *C. gariiepinus* were composed of organisms belonging to six taxa or groups, detritus, sand grains and unidentified plant and animal remains. The identified taxa/groups were algae (*Microcystis* sp. and unidentified filamentous species), Macrophytes (shoots, roots, fruits and seeds), Crustacea, Insecta, Hydracarina and Pisces. Crustaceans were represented by *Ceriodaphnia* sp., *Diaphanosoma* sp. and *Mesocyclops* sp., and by unidentified Ostracod species. Insects were represented by various developmental stages of Trichoptera, Hemiptera, Diptera, Ephemeroptera, Odonota, Coleoptera, Plecoptera and Hymenoptera. *O. niloticus* was the only fish species ingested by *C. gariiepinus*. The presence of sand and benthic organisms (insect larvae and pupae) was considered as indicative of a bottom feeding habit.

The frequency of occurrence, the numerical abundance and gravimetric methods each suggested that crustaceans, insects and fish were the most important food of *C. gariiepinus* in Lake Langeno. Numerically, crustaceans were most important (93%) but in terms of frequency of occurrence (75%) and weight (93%) insects were most important items in the diet of *C. gariiepinus*. Fish were the least important (below 10% by each method) food as compared to crustaceans and insects.

Cladocera and Copepoda were found to be the dominant Crustacean members in the diet of *C. gariiepinus*. Diptera, Hemiptera and to some extent Odonata were the most important whereas Plecoptera and Hymenoptera were least important insects in the diet of *C. gariiepinus*.

The relative contribution of each food item varied with the size of *C. gariepinus*. Thus, frequency of occurrence was relatively high for Crustacea (about 60%) in *C. gariepinus* between 45 and 64 cm TL, for insects (>80%) in those below 54 cm TL, and for fish (20-60%) above 65 cm TL. Numerically, crustaceans contributed more than 90% for each length group but their contribution was below 90% for *C. gariepinus* above 84 cm TL. The numerical contribution of insects and fish increased for *C. gariepinus* above 84 cm. Gravimetric contribution of crustaceans was relatively high (10-15%) for *C. gariepinus* between 45 and 74 cm TL, and that of fish (about 10%) for large (>84 cm TL) *C. gariepinus*. The weight contribution of insects was about similar for all size groups of *C. gariepinus* caught in the study. The results suggested that as *C. gariepinus* grows larger it consumes progressively more fish.

The ratio between prey (*O. niloticus*) length and predator (*C. gariepinus*) length varied greatly. About 50% of the *C. gariepinus* had ingested tilapia whose length was between $1/10^{\text{th}}$ and $1/30^{\text{th}}$ of their own length. A few individuals had ingested tilapia whose length was either above $1/5^{\text{th}}$ or below $1/30^{\text{th}}$ of their length.

Frequency of *C. gariepinus* with empty stomach was quite low (0 to 2.2 %) in samples taken between April and June, which was coincident with period of low water level. In contrast, the frequency was high (9.5 to 20%) in July, August and October. In general, about 95% of the total number of empty stomachs were recorded during the season of high water level. This coincided with the period when *C. gariepinus* ingested more fish as compared to the other period.

The relative importance of fish to the diet of *C. gariepinus* was more pronounced during the season of high water level. Crustaceans and insects, however, were equally important throughout the study period.

1. INTRODUCTION

Providing adequate food for a rapidly increasing human population is one of the greatest challenges in the world. The problem is acute in countries like Ethiopia where, besides population explosion, natural and man-made calamities have aggravated the problem. In addition to increasing food production from land agriculture, therefore, it is necessary to sustainably exploit the fish resources. Ethiopia's fish resources could undoubtedly offer one of the solutions to the problem of food shortage in the country.

The inland water body of Ethiopia is estimated at about 7400km² of lake area and about 7000 km total length of rivers (Shibru Tedla, 1973). These water bodies contain large population of edible fish species such as *Oreochromis niloticus* (Tilapia), *Clarias gariepinus* (Catfish), *Barbus* species, and *Lates niloticus* (Nile perch) that are economically and ecologically important. Crude estimates based on commercial fisheries and other parameters indicated that sustainable fish yield in the country is about 30 to 40 thousand metric tones per year (Mebrat Alem, 1993). However, the current landing is quite low, and is about 20 percent of the potential. The yield that can be obtained from the resources will be sustained if the exploitation is well managed. However, proper management of the resources requires detailed knowledge on the fisheries as well as on the biology of the fish (Lackey and Nielson, 1980).

C. gariepinus, the African Walking Catfish, (Family Clariidae) is a widespread freshwater species which is found in the region from Turkey, the Middle East, through Central and South Africa (Spataru *et al.*, 1987). It inhabits natural lakes, impoundments, fishponds, streams and natural ponds, and can thrive in both deep and shallow waters. *C. gariepinus* is reportedly an

indiscriminate carnivore able to utilize a wide variety of food items including small crustaceans, insects, mollusks, Oligochaetes and other fish (Fryer, 1959; Groenwald, 1964; Thomas, 1966; Van der Waal, 1972; Bruton, 1978; 1979; Elias Dadebo, 1988; 2000; Tesfaye Wudneh, 1998). Some workers have also argued that *C. gariepinus* can utilize detritus, humus and macrophytes (Jubb, 1967; Willoughby and Tweddle, 1978), but others believe that these items were ingested by the fish accidentally (Groenwald, 1964; Kirk, 1967; Elias Dadebo, 1988; Sparatu *et al.*, 1987). Fish, particularly cichlids, have been found to be important prey of *C. gariepinus* in some waters (Thomas, 1966; Elias Dadebo, 1988; 2000), but *C. gariepinus* has also been considered as inefficient piscivore as compared to other species such as the Nile Perch, *Lates niloticus* (Elias Dadebo, Unpublished).

C. gariepinus is both a nocturnal and a day-time feeder, and vision is not considered to be a major factor in the search and capture of food (Hecht and Appelbaum, 1987). Most feeding takes place at night on active benthic organisms, but they may also feed during the day and at the water surface (Bruton, 1979). Seasonality in feeding activity or intensity is also likely to occur in *C. gariepinus*, as feeding is dependant on variation in availability of food and spawning activity (Fryer and Iles, 1972; Wootton, 1990).

Although knowledge on the biology of Ethiopian fish, particularly Tilapia (*O. niloticus*), is accumulating (e.g. Tudorancea *et al.*, 1988; Getachew Tefera, 1987; 1993; Demeke Admassu, 1998), very little is known about *C. gariepinus*. The only studies of reasonable detail are that of Elias Dadebo (1988), which was partly published only recently (Elias Dadebo, 2000), and that of Tesfaye Wudneh (1998). Elias Dadebo (1988; 2000) investigated some aspects of feeding, reproduction and commercial catch of the Lake Awassa population. Tesfaye Wudneh (1998)

investigated reproduction patterns and growth and mortality estimates of *C. gariepinus* in Lake Tana. Another study (Zenebe Tadesse *et al.*, 1998) dealt with fatty acid and lipid content of *C. gariepinus* sampled from Lake Langeno. A study on the food and the reproductive aspects of the Lake Chamo *C. gariepinus* is near completion (Elias Dadebo, Unpublished).

C. gariepinus is believed to occur almost in all freshwaters of Ethiopia containing fish (Shibru Tedla, 1973). It is also becoming among the most important species in the fishery. Since it is a fast growing fish (Clay, 1979) and an indiscriminate feeder (Bruton, 1978; 1979; Sparatu *et al.*, 1987; Elias Dadebo, 1988) it can be cultured to produce large quantity of inexpensive animal protein. It is, therefore, obvious that detailed knowledge on *C. gariepinus* in Ethiopia is urgently needed. The present study was, therefore, conducted to contribute to this urgently needed knowledge on *C. gariepinus* Lake Langeno.

Knowledge on the feeding ecology of fishes is important to protect the natural food of fish, and also for aquaculture development. The major objective of the present study was to generate basic biological information that could help to make proper exploitation and management strategies on the Ethiopian fishery in general and on *C. gariepinus* in Lake Langeno in particular.

The specific objectives were to:

- assess sex-ratio, length-weight relationship and condition factor of *C. gariepinus* in Lake Langeno,
- examine the diet composition of *C. gariepinus* in Lake Langeno,
- estimate the relative importance of various food items to the diet of the fish, and to study if food habit changes with fish length,
- study the feeding periodicity of *C. gariepinus*.

2. DESCRIPTION OF THE STUDY AREA

Lake Langeno ($7^{\circ} 36'N$, $38^{\circ} 45'E$) is one of the four northern natural lakes found in the Ethiopian Rift Valley (Fig. 1). It is about 190km south of Addis Ababa, and situated at an altitude of 1582m and occupies an area of 241km^2 with a mean depth of 17m. Some additional physical characteristics of the lake are listed in Table 1. The lake is fed by a number of small streams running from the highland to the east and south of it, and discharges in to Lake Abijata through the Horakello River. A portion of its inflow may also be derived from hot spring waters (Kassahun Wodajo and Amaha Belay, 1984). The color of the water is a light reddish brown mainly due to the presence of high colloidal suspension of inorganic silt, which is responsible for about 94-98% of the total light attenuation (Wood *et al.*, 1978).

The lake lies within the sub-humid region of Ethiopia (Daniel Gamachu, 1977). The major rainy period in the area is between June and September, with a monthly total of more than 160mm (Kassahun Wodajo and Amaha Belay, 1984). The driest period of the year is November to February, when a monthly total rainfall of less than 5-25mm is recorded (Fig. 3). During the year of the present study, January, February and March were dry, and the little rains occurred between April and June (Fig. 3). Short rain occurs in the region usually during March to May (Daniel Gamachu, 1977; Kassahun Wodajo, 1982) when the highest daily maximum temperatures ($27-29^{\circ}\text{c}$) are reached. During the study, level of the lake water begun to rise following the beginning of the heavy rains, and it was high between July and October, but low between April and June (Personal observation). Data on mean monthly minimum and maximum temperatures of the

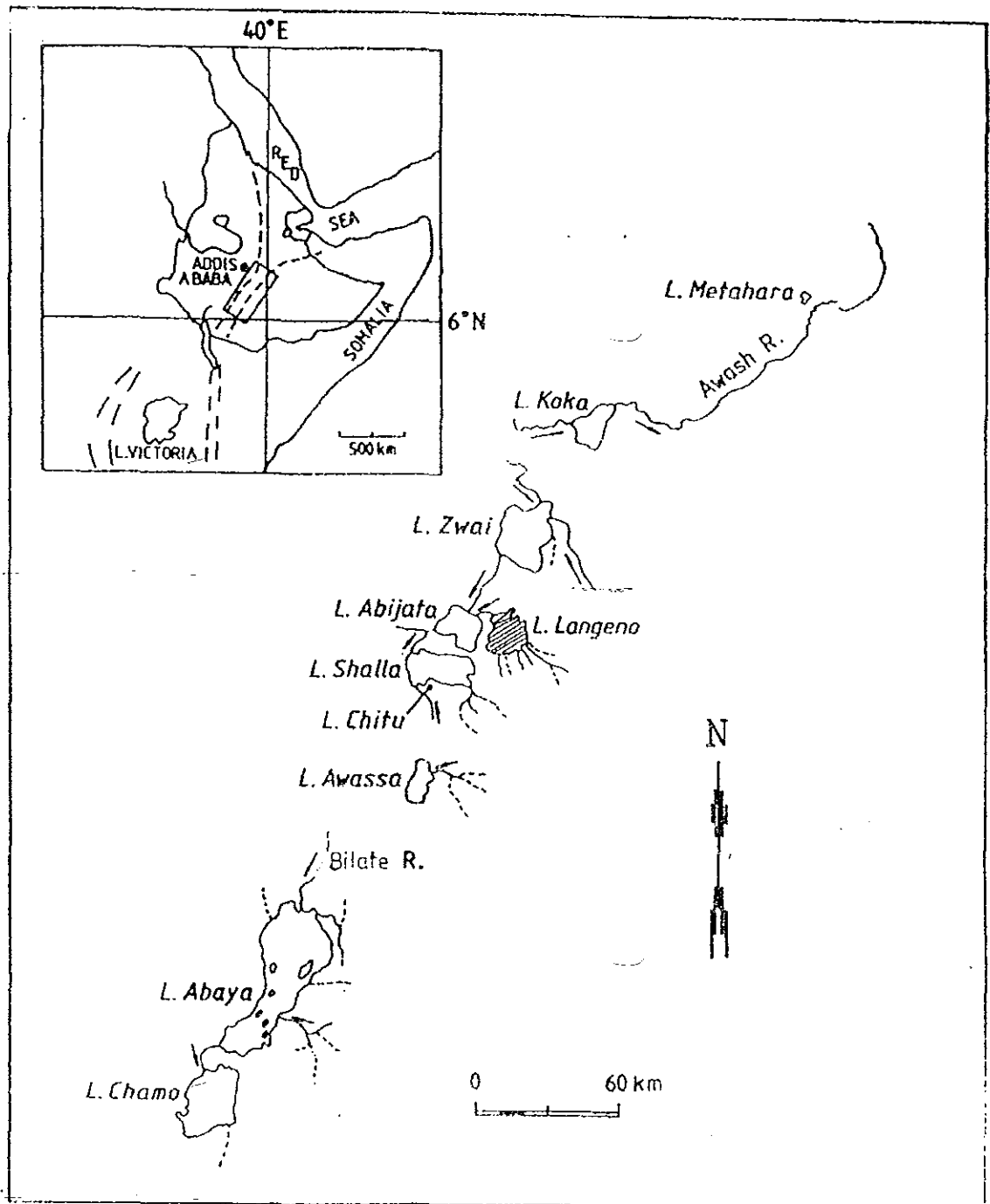


Figure 1. Map of Ethiopia (inset) and the Rift Valley lakes with their drainage pattern. Lake Langeno is highlighted (Modified after Elizabeth Kebede *et al.*, 1994).

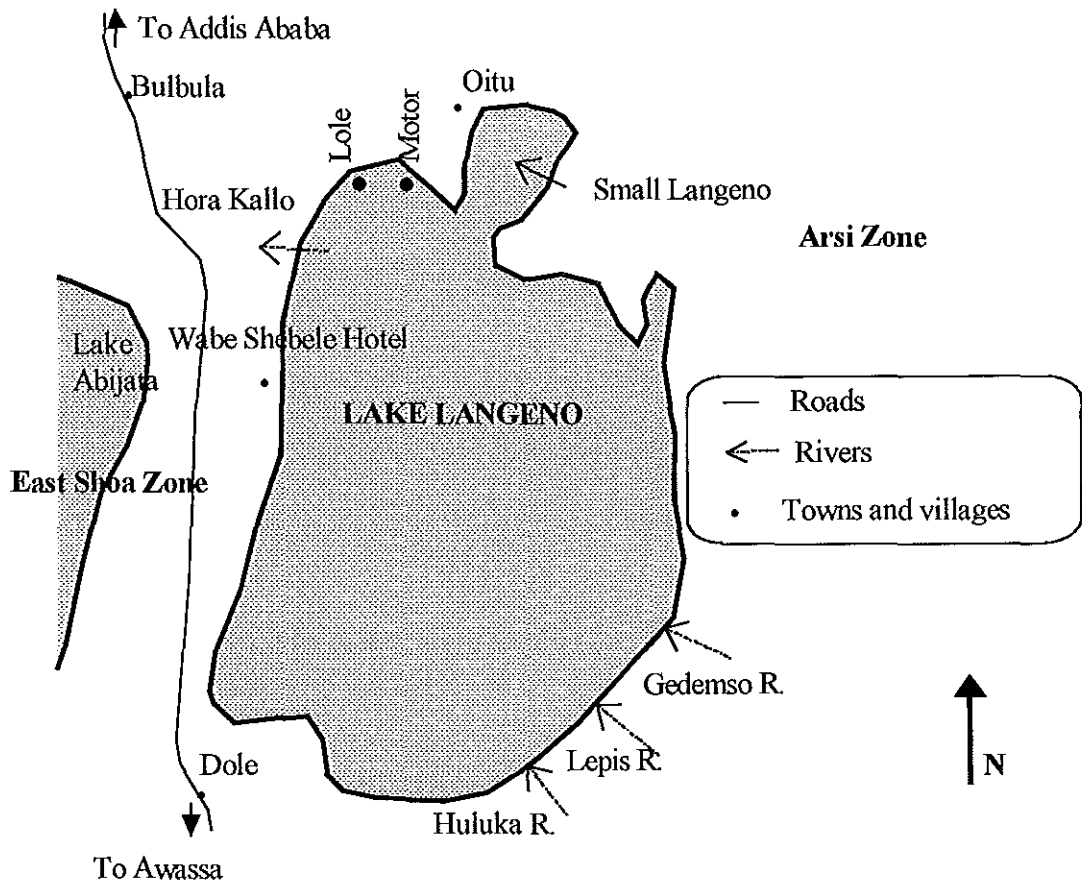


Figure 2. Map of Lake Langeno showing the sampling sites (•).

Table 1. Some morphological and physical characteristics of Lake Langeno.

Characteristics	Values
Location	7 ⁰ 36'N, 38 ⁰ 45'E
Altitude (m)	1582 ^a
Surface area (km ²)	241 ^b
Maximum depth (m)	48 ^b
Mean depth (m)	17 ^a
Secchi depth (m)	18-28.5 ^d
Maximum length (km)	25.4 ^e
Maximum width (km)	16 ^e
Catchment area (km ²)	1600 ^e
Perimeter (km)	77.5 ^e

Source: ^a Wood and Talling (1987), ^b Tudorancea *et al.* (1989), ^c Elizabeth Kebede *et al.*, (1994), ^d Zenebe Tadesse (1999), ^e Cannicci and Almagia (1947).

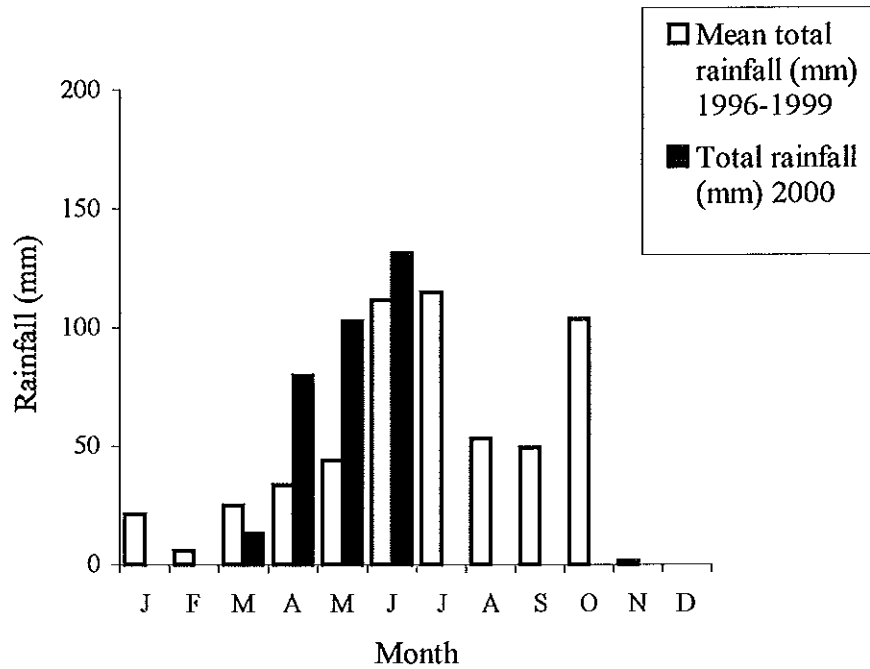


Figure 3. Mean monthly rainfall from 1996-1999 and total rainfall for 2000 (From Ethiopian Meteorological Agency) for the Lake Langeno region. Data not available for the period July to December 2000.

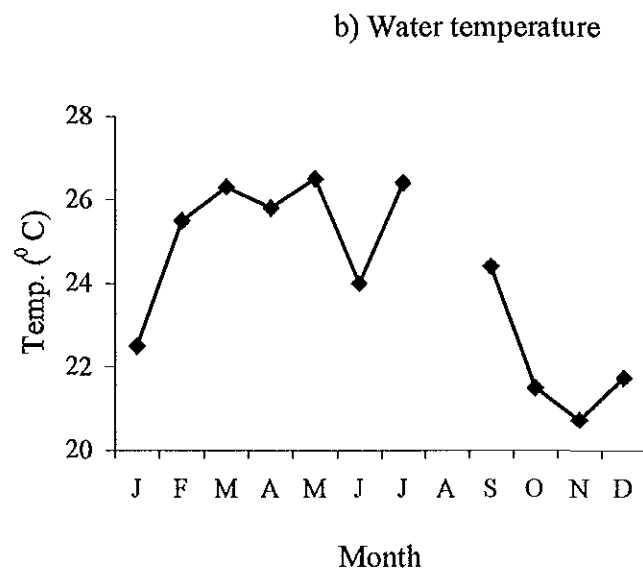
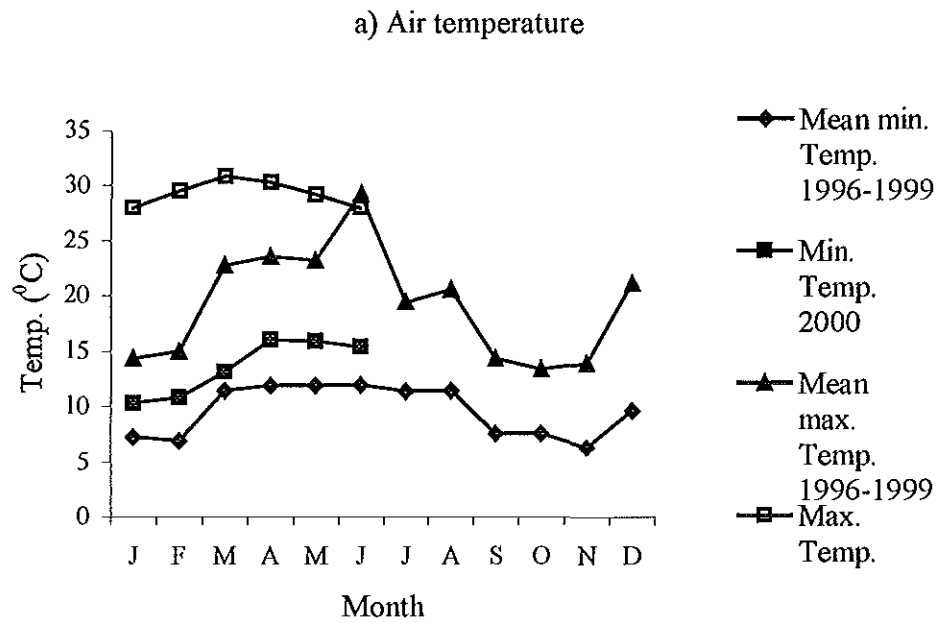


Figure 4. a) Seasonal variation in the maximum and minimum air temperature ($^{\circ}$ C) of the Lake Langeno region (from Ethiopian Meteorological Agency), and b) water temperature of the lake in 1996 (from Demeke Admassu & Zenebe Tadesse, unpublished data). Air temperature data for the period between July and December 2000 and water temperature for July 1996 not available.

region for the period 1996-2000 suggested that the period between March and June are warm (Fig. 4a). The water temperature (1996 data) is moderately warm with a mean of above 20⁰ C all year round, but warmer months are February to May and July (Fig. 4b).

Investigations on the limnology and phytoplankton of the lake have been made by several authors (e.g. Talling, 1965; Kassahun Wodajo, 1982; Kassahun Wodajo and Amaha Belay, 1984; Elizabeth Kebede *et al.*, 1994). The water chemistry (Table 2) is very similar to other lakes in the Ethiopian Rift valley where Na⁺ and HCO₃⁻ + CO₃²⁻ are dominant cation and anions, respectively (Talling, 1965; Kassahun Wodajo, 1982; Von Damm and Edmond, 1984).

Phytoplankton biomass (Chl *a* = 2µg l⁻¹) of lake Langeno is low (Elizabeth Kebede *et al.*, 1994). The major phytoplankton genera of the lake include *Microcystis* sp., *Oocystis* sp. and *Cyclotella* sp. (Elizabeth Kebede *et al.*, 1994). The natural vegetation around the lake is composed of *Acacia* sp. and Scrub grassland (Kassahun Wodajo and Amaha Belay, 1984). The macrophyte vegetation of the lake is dominated by *Scirpus* sp. and *Juncellus* sp., which provide feeding and spawning grounds for both adult and juvenile fish (Zenebe Tadesse, 1998). Zooplankton community of the lake is composed of *Lovenula* sp., *Mesocyclops* sp., *Daphnia* sp., *Ceriodaphnia* sp. and *Brachious* sp. (Kassahun Wodajo and Amaha Belay, 1984).

The fish population in the lake consists of *O. niloticus*, *Tilapia zilli*, common Carp, *C. gariepinus*, and *Barbus* sp. The potential fish yield of Lake Langeno is estimated to be 1,000 to 1,500 tons per year, but landings are about 500 tons per year of which *C. gariepinus* accounts for about 22% (LFDP, 1998).

Table 2. Some chemical features of Lake Langeno (from Zenebe Tadesse, 1999 and references therein).

Characteristics	Values
pH	8.95
Chlorophyll a ($\mu\text{g l}^{-1}$)	2
Salinity (g l^{-1})	2.4
Conductivity K_{25} (μScm^{-1})	1550-1770
Na^+ (meq l^{-1})	14.35-15.78
K^+ (meq l^{-1})	0.54
Ca^{2+} (meq l^{-1})	0.24
Mg^{2+} (meq l^{-1})	0.2
Cl^- (meq l^{-1})	3.66
SO_4^{2-} (meq l^{-1})	1.16
$\text{HCO}_3^- + \text{CO}_3^{2-}$ (meq l^{-1})	1.25
Total anions (meq l^{-1})	16.8
Total cations (meq l^{-1})	17.32

3. MATERIALS AND METHODS

3.1 Sampling and measurements

Samples of *C. gariepinus* were collected in each month (except September) during the period April 2000 to October 2000. Hooks and line fishing gear with hook numbers 5, 6, and 7 baited with tilapia pieces was used. In addition, the catch by local fishermen was also sampled. Tilapia was used as bait based on observation on the practice of local fishermen.

Immediately after retrieval from the hook, total length and total weight of each specimen were measured. Total length was measured to the nearest 0.1cm. Total weight was measured to the nearest 0.1 g for fish under 1000 gram, 1 g for fish between 1000 g and 2000g, and to the nearest 5g for larger specimens.

After length and weight measurement, each specimen was dissected and its sex determined by inspecting the gonads. The stomach was then examined if it contained any food. If it was empty, this was recorded. Otherwise, the stomach with its contents was preserved in approximately 15-30 ml (depending on size of stomach content) of 5% formaldehyde solution. Preserved samples were then transported to Addis Ababa University, Department of Biology, for laboratory analysis.

3.2 Estimation of sex-ratio

The number of female and male *C.gariepinus* that were caught was recorded for each sampling occasion. In addition, the same record was made by length group after data were classified into various length classes. Sex-ratio (female: male) was then calculated for the total sample, by sampling month and by fish total length. Chi-square test was employed to test if sex-ratio varied from one-to-one in the total sample, by sampling month and by fish length group.

3.3 Length-weight relationship

The relationship between total length and total weight was calculated using least squares regression analysis (Le Cren, 1951) as follows:

$$TW = a * TL^b,$$

Where, TW = total weight in grams

TL = total length in centimeters

a and b = Intercept and slope of the equation, respectively.

Significance of the relationship was statistically tested using ANOVA. In addition, significance of differences in length-weight equations between males and females was statistically tested using ANCOVA (Sokal and Rohlf, 1981).

3.4 Condition factor

The well-being or plumpness of each *C. gariepinus* sample was studied by calculating Fulton and Relative condition factors (Le Cren, 1951; Bagenal and Tesch, 1978). Fulton condition factor (%) was calculated as:

$$FCF = \frac{TW}{TL^3} \times 100$$

Where, FCF = Fulton condition factor,

TW = total weight in grams,

TL = total length in cms.

Relative condition factor was calculated as follows:

$$RCF = \frac{TW}{a TL^b}$$

Where, RCF = Relative condition factor

TW and TL = as described in FCF,

a and b = intercept and slope of the length-weight regression equation.

Significance of differences in condition factor of *C. gariepinus* between sexes, sampling periods, and size groups was tested using ANOVA. Multiple (pair wise) comparison of mean condition factor was conducted using the G-test (Sokal and Rohlf, 1981).

3.5 Food and feeding habit study

3.5.1 Stomach content analysis

Contents of the stomach of each *C.gariepinus* were transferred into petri-dishes. Large-enough food items were identified by un-aided eye. Small-sized food items were microscopically examined using a WILD type stereoscope (magnification: 6x to 50x), and each item was identified to the lowest taxon possible using description, illustrations and keys in the literature (Macan, 1959, 1976; Borror and DeLong, 1964; Harding and Smith, 1974; Edington and Hildrew, 1981; Defaye, 1988). In addition, 5 ml sub-sample from each stomach was examined at high magnifications (100x to 400x) under a compound research microscope to note whether or not much smaller food items, such as phytoplankton, were ingested.

After identification, a list of items found in the stomach content was prepared, and each item counted whenever appropriate. Counting was performed using the whole stomach content (i.e. no sub-sampling) for the majority of the samples. In some cases, however, counting was done on a sub-sample of 10 ml stomach content. All counts were converted to number per total volume of stomach content (without preservative volume).

3.5.2 Determination of relative importance of food items

The relative importance and contribution of each food item to the diet of *C. gariepinus* was determined using the standard methods, i.e., the frequency of occurrence method, percent composition by number (the numerical abundance) and the gravimetric method (Hynes, 1950; Windell and Bowen, 1978; Hyslop, 1980). Brief description of each method is given below.

3.5.1.1 Frequency of occurrence

In the frequency of occurrence method the number of stomachs in which each of the item occurred were listed. The percentages of these were calculated relative to the number of stomachs containing food. This value, therefore, gave the frequency of occurrence for the food type.

3.5.1.2 Percent composition by number (= Numerical abundance)

In numerical method the number of each type of food item in each stomach were counted and recorded. The total numbers of individuals of each food item was then expressed as a percentage of the total number of all food organisms found in all fish examined.

3.5.1.3 Gravimetric method

Average wet weight (WW) of food items was determined from fresh samples that were taken from the natural habitat. Depending on size of the food item, a sample of 5 to 100 individuals was weighed to the nearest 0.0001 gm on a Sartorius sensitive balance. The weights of at least three such samples were used to estimate average weight of each food item. Length of fish prey found in the stomach sample was measured. The weight of fish prey (*O. niloticus*) was established from length-weight equation of the species in Lake Langeno (Demeke Admassu, unpublished data). Total weight of a food item in the stomach content was then estimated as the product of number counted and its average weight. Weight of each food item was expressed in percentage.

3.5.3 Fish–size and food habit relationship

To study whether or not there is ontogenetic shift in food habit of *C. gariepinus*, results from each method were plotted against length of *C. gariepinus*. Food items were grouped into major taxonomic groupings for this purpose.

3.5.4 Predator-prey size relationship

An attempt was made to study the relationship between the size of *C. gariepinus* (predator) and that of its major prey fish. This was done by plotting (scatter plot) the total length of the prey fish against the total length of *C. gariepinus*. As it will be shown later, *O. niloticus* was found to be the prey fish of *C. gariepinus* in Lake Langeno. The length of prey fish (*O. niloticus*) was measured from freshly ingested and undigested individuals. The scatter plot was then compared with theoretical lines passing through known prey to predator size ratios (Hailu Anja, 1996 and references therein).

3.5.5 Seasonal feeding periodicity

Seasonal difference in the food habit of *C. gariepinus* was studied from the frequency of empty stomachs, and also on results from relative contribution of major items as determined from frequency of occurrence, numerical abundance and gravimetric methods. These data were compared between the low and the high water level seasons.

4. RESULTS

4.1 Size composition of the sample

A total of 859 (357 males and 502 females) *C. gariepinus* individuals were caught throughout the study. Total length in the sample ranged from 28 to 96 cm for males, and from 28 to 104 cm for females. The corresponding total weight range was 200 to 6000 grams for males, and from 150 to 8000 grams for females.

As shown in Figure 5, the greater proportion of the sampled male fish range in size between 45 and 74 cm whereas more females were caught between sizes 35 and 64 cm the peak being between 45 and 54 cm for both sexes. This length group alone was about 27% for males and 30% for females. Fish below 35 cm, and those above 84 cm were least represented in the sample (Fig. 5).

4.2 Sex-ratio

The study showed that sex-ratio (female to male) in the total sample was significantly different (Chi-square, $P = 0.00$) from 1:1 (Table 3). The result suggested a preponderance of females over males in *C. gariepinus* of Lake Langeno. In addition, it was found that there was a preponderance of females over males in samples taken during both low water level and high water level seasons (Table 3).

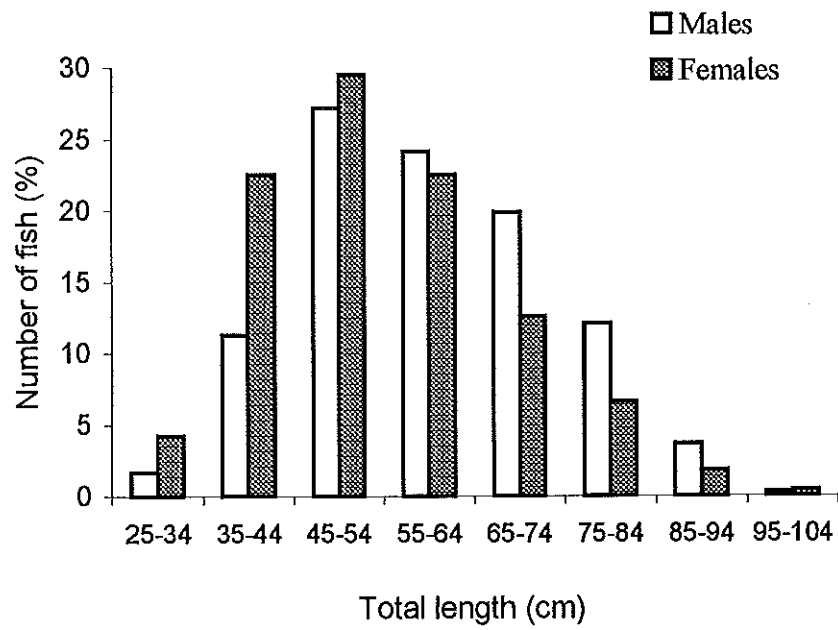


Figure 5. Length-frequency distribution of *C. gariepinus* in the sample used for the present study.

Table 3. Monthly sex-ratio of *C. gariepinus* in Lake Langeno. Sex-ratio in samples taken at low and high lake water level seasons are also shown. * = significant at 5% level. Sex-ratio in May and June were not statistically tested due to small sample size.

Month	Females	Males	Ratio (F: M)	χ^2
April	149	83	1.80:1	18.77*
May	9	9	1.00:1	
June	8	4	2.00:1	
July	76	71	1.07:1	0.17
August	194	105	1.85:1	26.49*
October	66	85	0.78:1	2.39
Low lake water level				
(Apr., May, Jun.)	166	96	1.73:1	18.7*
High lake water level				
(Jul., Aug., Oct.)	336	261	1.29:1	17.58*
Total	502	357	1.41:1	24.47*

Sex-ratio in different length groups of *C. gariepinus* are presented in Table 4. Evidently, females significantly outnumbered males in length classes between 25 and 54 cm TL. Sex-ratio in larger length classes was not significantly different ($P > 0.05$) from one-to-one (Table 4).

4.3 Length-weight relationship

The relationship between total length and total weight of *C. gariepinus* in Lake Langeno was best described by the following regression equations.

$$\text{Males: } TW = 0.0076 \times TL^{2.928}, R^2 = 0.973, n = 357.$$

$$\text{Females: } TW = 0.0073 \times TL^{2.960}, R^2 = 0.982, n = 502.$$

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

Comparison of the above equations showed that there is no significant difference (ANCOVA, $P > 0.05$) in length–weight relationship between the sexes. Therefore, an equation common to the sexes was fitted (Figure 6). The common equation was significant (ANOVA, $P < 0.05$), and the slope ($b=2.914$) was very close to 3. The equation was fitted for length range of 28 to 104 cm and weight range of 150 to 8000 grams.

Table 4. Sex-ratio in different length groups of *C. gariepinus* in Lake Langeno. * = significant at 5% level. Sex-ratio in length classes between 85 and 104cm TL were not statistically tested due to small sample size.

Size-group (cm)	Females	Males	Ratio (F: M)	χ^2
25-34	21	6	3.50:1	8.33*
35-44	113	40	2.83:1	34.83*
45-54	148	97	1.53:1	10.61*
55-64	113	86	1.31:1	3.66
65-74	63	71	0.89:1	0.47
75-84	33	43	0.77:1	1.31
85-94	9	13	0.69:1	
95-104	2	1	2.00:1	
Total	502	357	1.41:1	24.47*

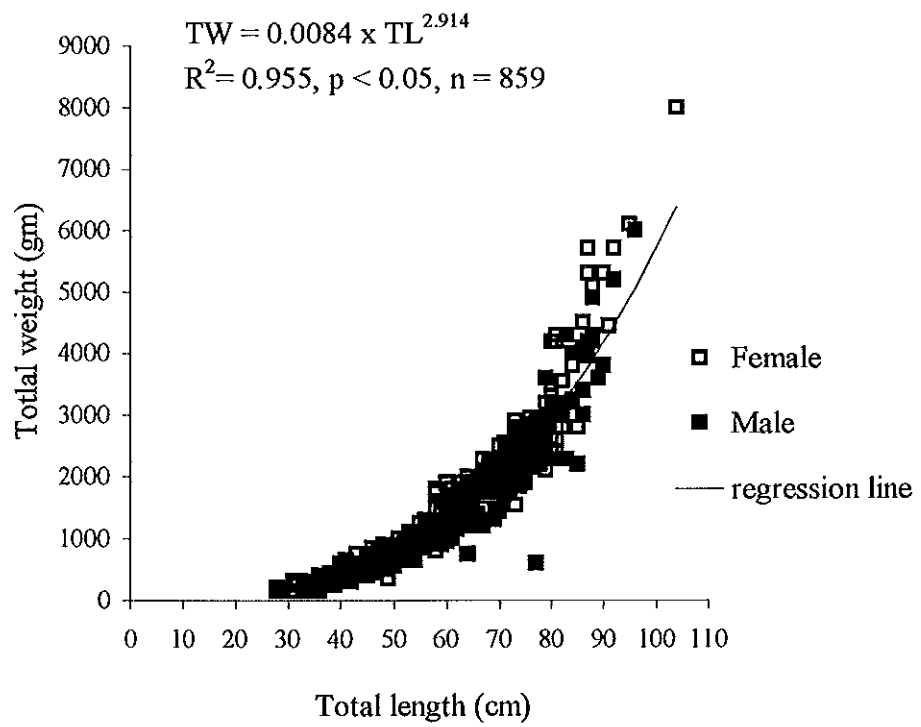


Figure 6. Length-weight relationship of *C. gariepinus* from Lake Langeno.

4.4 Condition factor

4.4.1 Fulton condition factor

Fulton condition factor (FCF) values of *C. gariepinus* ranged from 0.13 to 0.94 for males and from 0.30 to 1.01 for females. Mean \pm SE FCF was found to be 0.58 ± 0.00 and 0.63 ± 0.00 for males and females, respectively. The overall mean \pm FCF was 0.54 ± 0.00 .

Mean \pm SE monthly FCF values ranged from 0.55 ± 0.04 (in June) to 0.65 ± 0.03 (in May) for male *C. gariepinus*. The same for females of *C. gariepinus* ranged from 0.61 ± 0.01 (in June, July and October) to 0.66 ± 0.04 (in May) (Table 5).

Two way ANOVA indicated that FCF values were significantly different between males and females ($P = 0.00$), and between sampling months ($P = 0.0004$). There was no significant sex by month interaction (ANOVA, $P = 0.1671$) suggesting that one of the sexes had higher FCF values throughout the sampling months. Thus, as shown in Table 5, females had larger mean FCF value than the males in all months.

The difference in FCF between the low water level and the high water level seasons (Table 5) was found to be non-significant (ANOVA, $P = 0.1334$). However, sex-based difference and the interaction between sex and season were significant (ANOVA, $P = 0.0067$). Thus, FCF was larger at low water level than at high water level for males but the reverse is true for females. During both seasons, however, females had larger FCF than male of *C. gariepinus* (Table 5).

Table 5. Fulton's condition factor (mean \pm standard error) of *C. gariepinus* in Lake Langeno by sampling month and season. n is sample size.

Month / season	Males	n	Females	n
April	0.58 \pm 0.01	83	0.62 \pm 0.01	149
May	0.65 \pm 0.03	9	0.66 \pm 0.04	9
June	0.55 \pm 0.04	4	0.61 \pm 0.01	8
July	0.56 \pm 0.01	71	0.61 \pm 0.01	76
August	0.58 \pm 0.01	105	0.65 \pm 0.01	194
October	0.58 \pm 0.01	85	0.61 \pm 0.01	66
Low lake water level season				
(Apr., May, Jun.)	0.58 \pm 0.01	96	0.62 \pm 0.01	166
High lake water level season				
(Jul., Aug., Oct.)	0.57 \pm 0.01	261	0.64 \pm 0.00	336
Total	0.58 \pm 0.00	357	0.63 \pm 0.00	502

Mean comparison by the G-method showed that mean FCF of males was significantly low in June, but it was similar during the rest of the sampling months (Table 6).

Mean FCF of female *C. gariepinus* was significantly largest in May, but it was not significantly different among the rest of the sampling months (Table 6).

Mean \pm SE values of FCF for different length groups are presented in Table 7. It was found that the difference in FCF among length-groups, and between sexes, was statistically significant (ANOVA, $P = 0.00$). Length by sex interaction was found to be non-significant (ANOVA, $P = 0.0981$). Mean FCF of females was larger than that of males in all length groups except length group 25-34 cm in which case males had slightly larger FCF than the females (Table 7).

Comparison of mean FCF among length groups suggested that the value was significantly lowest for males between 75 and 84 cm TL, but it was relatively high and similar for those in the rest of the length groups (Table 8). Mean FCF was significantly high for females between 95 and 104 cm TL, but it was relatively low and similar in smaller length groups (Table 8).

Table 6. Mean comparison (G-method) of Fulton condition factor by month for male and female *C. gariepinus* in Lake Langeno. Months arranged in increasing order of FCF. FCF is not significantly different between months underlined by the same line.

Sex	Month					
Male	June	July	April	August	October	May
Female	June	July	October	April	August	May

Table 7. Fulton's condition factor (mean \pm standard error) in different length groups of *C. gariepinus* in Lake Langeno. n is sample size.

Size-group (cm)	Males	n	Females	n
25-34	0.69 \pm 0.06	6	0.68 \pm 0.03	21
35-44	0.60 \pm 0.02	40	0.63 \pm 0.01	113
45-54	0.57 \pm 0.01	97	0.63 \pm 0.01	148
55-64	0.57 \pm 0.01	86	0.63 \pm 0.01	113
65-74	0.58 \pm 0.01	71	0.62 \pm 0.01	63
75-84	0.55 \pm 0.01	43	0.59 \pm 0.02	33
85-94	0.58 \pm 0.03	13	0.71 \pm 0.04	9
95-104	0.68	1	0.71	2
Total	0.58 \pm 0.00	357	0.63 \pm 0.00	502

Table 8. Mean comparison of Fulton condition factor by length groups for male and female *C.gariepinus* in Lake Langeno. Size groups arranged in increasing order of FCF. FCF is not significantly different between size groups underlined by the same line.

Sex	Size-group							
Male	75-84	45-54	55-64	65-74	85-94	35-44	95-104	25-34
Female	75-84	65-74	35-44	45-54	55-64	25-34	85-94	95-104

4.4.2 Relative condition factor

Relative condition factor (RCF) values of *C. gariepinus* ranged from 0.23 to 1.53 for males and from 0.49 to 1.61 for females. Mean \pm SE RCF was found to be 0.97 ± 0.01 and 1.05 ± 0.01 for males and females, respectively. Mean RCF was greater than unity in all the sampling months except in June for females, but mean RCF of males was greater than unity only in May (Table 9).

Mean \pm SE monthly RCF values ranged from 0.91 ± 0.06 (in June) to 1.09 ± 0.04 (in May) for male *C. gariepinus*. The same for female *C. gariepinus* ranged from 0.99 ± 0.02 (in June) to 1.10 ± 0.07 (in May) (Table 9).

Two way ANOVA indicated that RCF values were significantly different between males and females ($P = 0.00$), and between sampling months ($P = 0.00$). There was no significant difference in sex by month interaction (ANOVA, $P = 0.1254$) suggesting that one of the sexes had higher RCF values throughout the sampling months. Thus, as shown in Table 9, in each month the females had larger mean RCF value than the males.

The difference in RCF between the low water level and the high water level seasons (Table 9) was found to be significant (ANOVA, $P = 0.0196$). Difference between sexes and the interaction between sex and season were also significant (ANOVA, $P = 0.0025$). Thus, mean RCF was high at low water level than at high water level for males whereas at high water level than low water level for females (Table 9). Mean RCF was larger for females than males during both seasons.

Table 9. Relative condition factor (mean \pm standard error) of male and female *C. gariepinus* in monthly samples and in low/high lake water level season. n is sample size.

Month	Males	n	Females	n
April	0.96 \pm 0.02	83	1.02 \pm 0.01	49
May	1.09 \pm 0.04	9	1.10 \pm 0.07	9
June	0.91 \pm 0.06	4	0.99 \pm 0.02	8
July	0.95 \pm 0.02	71	1.03 \pm 0.01	76
August	0.98 \pm 0.01	105	1.09 \pm 0.01	194
October	0.99 \pm 0.01	85	1.04 \pm 0.02	66
Low water level				
(Apr., May, Jun.)	0.98 \pm 0.01	96	1.03 \pm 0.01	166
High water level				
(Jul., Aug., Oct.)	0.97 \pm 0.01	261	1.08 \pm 0.01	336
Total	0.97 \pm 0.01	357	1.05 \pm 0.01	502

Mean comparison by the G-method showed that RCF of males was significantly lowest in June, and it was not significantly different between April, August, October and May during which time it was highest. RCF in July was intermediate (Table 10).

Mean RCF of female *C. gariepinus* was significantly low in June, but it was similar and highest during the rest of the sampling months (Table 10).

Mean \pm SE values of RCF for different length groups are presented in Table 11. It was found that the difference in RCF among length-groups, and between sexes, was statistically significant (ANOVA, $P < 0.05$). Length by sex interaction was found to be non-significant (ANOVA, $P = 0.0806$). RCF of females was generally larger than that of males for all length classes except the smallest class in which case males had slightly larger value (Table 11).

Comparison of mean RCF among length groups suggested that RCF of males was similar and highest for the smallest and the two largest classes (Table 12). It was also similar for the remaining length classes. RCF of female *C. gariepinus* was also similar and highest for the two largest length classes, and it was similar for the remaining length classes (Table 12).

Table 10. Mean comparison of Relative condition factor by month for male and female *C. gariiepinus* in Lake Langeno. Months arranged in increasing order of RCF. RCF is not significantly different between months underlined by the same line.

Sex	Month					
Male	June	July	April	August	October	May
Female	June	April	July	October	August	May

Table 11. Relative condition factor (mean \pm standard error) of different length groups of males and females *C. gariepinus* in Lake Langeno. n is sample size.

Size-group (cm)	Males	n	Females	n
25-34	1.11 \pm 0.10	6	1.10 \pm 0.05	21
35-44	0.98 \pm 0.03	40	1.02 \pm 0.01	113
45-54	0.95 \pm 0.01	97	1.06 \pm 0.01	148
55-64	0.97 \pm 0.01	86	1.06 \pm 0.01	113
65-74	1.00 \pm 0.01	71	1.06 \pm 0.01	63
75-84	0.96 \pm 0.03	43	1.03 \pm 0.03	33
85-94	1.02 \pm 0.05	13	1.23 \pm 0.07	9
95-104	1.20	1	1.26	2
Total	0.97 \pm 0.01	357	1.05 \pm 0.01	502

Table 12. Mean comparison of Relative condition factor by length group for males and females *C.gariepinus* in Lake Langeno. Size groups arranged in increasing order of RCF. RCF is not significantly different between size groups underlined by the same line.

Sex	Size-groups							
Female	35-44	75-84	45-54	55-64	65-74	25-34	85-94	95-104
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Male	45-54	75-84	55-64	35-44	65-74	85-94	25-34	95-104
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4.5 Food and feeding habits

4.5.1 Composition of stomach contents

A total of 764 stomach samples were analyzed during the present study, of which 370 were empty. The list of items that were observed in the stomach contents of *C. gariepinus* is presented in Table 13. Items ingested by the fish included organisms belonging to six taxa or groups, detritus and sand grains. In addition, unidentified plant and animal remains or pieces were also observed.

Contents of the stomach were composed of items of both plant and animal origins. Filamentous algae, *Microcystis* sp. and macrophytes are of plant origin. Macrophytes were represented by pieces of shoots, roots, fruits and seeds. Items of animal origin were represented by diverse groups ranging from crustaceans including ostracods to relatively higher vertebrate species (i.e. fish).

Crustacean members that were ingested by *C. gariepinus* included two genera/species of Cladocera, one genus of Copepoda and an unidentified Ostracod species. Insect food items of *C. gariepinus* were composed of various developmental stages of Trichoptera, Hemiptera, Diptera, Ephemeroptera, Odonota, Coleoptera, Plecoptera and Hymenoptera. An unknown Hydracarine species was also ingested. *O. niloticus* was the only fish species ingested by the sampled *C. gariepinus* individuals.

Table 13. List of items identified from stomach content samples of *C. gariepinus* from Lake Langeno.

Taxon (Food item)
Algae
(Filamentous alga and <i>Microcystis</i> sp)
Crustacea
Copepoda
<i>Mesocyclops</i> sp.
Cladocera
<i>Diaphanosoma</i> sp.
<i>Ceriodaphnia</i> sp.
Ostracoda
Insecta
Trichoptera larvae
Hemiptera
Notonectidae.
Ephemeroptera nymphs
Diptera larvae and pupae
Chironomidae
Culicidae
Unidentified
Odonata nymphs
Isoptera
Anisoptera
Coleoptera larvae
Plecoptera nymphs
Hymenoptera
Hydracarina
Nematoda
Pisces
<i>Oreochromis niloticus</i> , fish eggs
Macrophytes
(Fruits, seeds, shoots and roots)
Detritus
Sand grains
Unidentified plant & animal remains

4.5.2 Relative contribution of food items

(i) Frequency of occurrence

Based on the frequency of occurrence method, the majority of *C. gariepinus* studied had ingested nymphs and larval/pupae stages of different groups of insects (Table 14). The next food items, which were ingested by several *C. gariepinus* individuals, were Crustacea. These were followed in descending order of occurrence by fish and macrophytes (Table 14). Detritus and sand were each present in about 8 % of the individuals.

Among insects, Diptera were ingested by 72%, and Hemiptera by 62%, of the studied *C. gariepinus*. The frequency of the other insects ranged from about 1% to 12% of the investigated *C. gariepinus* (Table 14).

Among Crustaceans, Cladocera and Copepoda were eaten by about 59%, and Ostracods were ingested by 24% of the studied *C. gariepinus* (Table 14).

(ii) Percent composition by number

Excluding plant food items and detritus, which were not counted, crustaceans were found to be numerically the most important food items to the diet of *C. gariepinus* in lake Langeno (Table 14). The next numerically important food items were insects. As compared to crustaceans and insects, fish were numerically the least important food of *C. gariepinus* in Lake Langeno (Table 14).

Cladocera and Copepoda were found to be the most numerous crustaceans that were consumed by *C. gariepinus* (Table 14).

Table 14. Relative importance of various food items to *C. gariepinus* in Lake Langeno based on the frequency of occurrence, numerical abundance and gravimetric methods. Figures are percentages. n is number of fish in which the items were found.

Food item	Frequency (%)	Number (%)	Wet weight (%)	n
Crustacea				
Copepoda	58.6	87.9	4.4	231
Ostracoda	23.9	11.4	2.5	94
Insecta				
Diptera	71.6	0.5	45.5	282
Hemiptera	62.2	0.1	36.0	245
Odonata	12.4	0.01	10.7	48
Trichoptera	11.7	0.01	0.3	46
Ephemeroptera	8.1	< 0.001	0.03	32
Coleoptera	5.8	< 0.001	0.2	23
Hymenoptera	1.3	< 0.001	< 0.0001	5
Plecoptera	0.8	< 0.001	< 0.0001	3
Pisces	19.0	0.01	0.4	76
Macrophytes	10.2	---	---	40
Detritus	7.6	---	---	30
Sand	7.6	----	----	30

Among insect groups, Diptera were the most numerous members that were ingested by *C. gariepinus*. These were followed by Hemiptera, Trichoptera and Odonota. The remaining insects were each less than 0.001% of the total number of food items encountered in the stomach contents of *C. gariepinus* (Table 14).

(iii) Percent composition by weight (Gravimetric method)

Results from the gravimetric method for items whose mean weight could be determined are presented in Table 14. Evidently, based on weight or biomass, insects were found to be the most important components of the diet of *C. gariepinus* in Lake Langeno. Crustaceans were the next important food items. As compared to weight contribution of crustaceans and insects, fish were found to be the least important because, they contributed only less than 0.5% of the total weight of the food ingested by *C. gariepinus*.

Diptera and Hemiptera were the most important insects in terms of weight (Table 14). The biomass contribution of the other insects was below 1% each, and that of Plecoptera and Hymenoptera was the least. Cladocera and Copepoda were the most important crustacean groups in the diet of *C. gariepinus*.

In summary, Insecta, Crustacea and fish were found to be the most important food items of *C. gariepinus* in Lake Langeno. Each method suggested that fish were least important as compared to crustaceans and insects. Insects were the most important based on the frequency of occurrence and the gravimetric methods, but crustaceans were the most important based on composition by number. In addition, the results from each method showed that from insects, Diptera and

Hemiptera, and from crustaceans, Cladocera and Copepoda were the most important components in the diet of *C. gariepinus* in Lake Langeno.

4.5.3 Food habit and *Clarias*-size relationship

The relative contribution of major food items, i.e., insects, crustaceans and fish, in the diet of different length groups of *C. gariepinus* is shown in Figures 7, 8 and 9. Although each food item was ingested by some fish belonging to each length group, the importance of a food item was more pronounced for a certain length group than the other.

Based on the frequency of occurrence method (Fig. 7), crustaceans appeared most important for *C. gariepinus* between 45 and 64 cm TL (Fig. 7a). In addition, insects were most important for small-sized (below 54 cm TL) *C. gariepinus* (Fig. 7b) and fish were most important for large-sized (>64 cm TL) *C. gariepinus* (Fig. 7c).

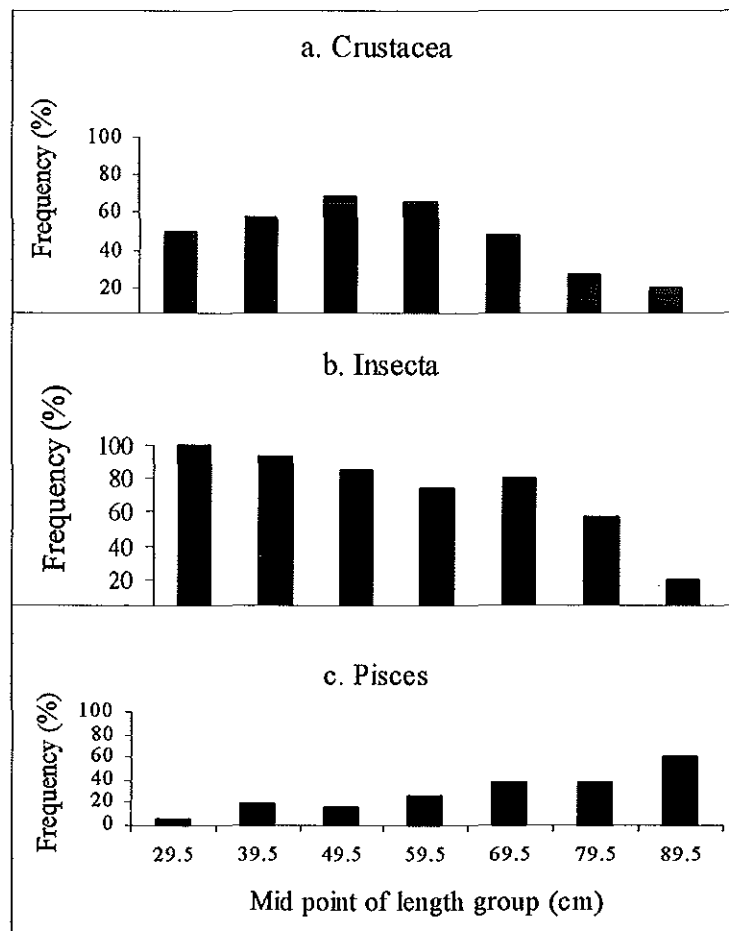


Figure 7. Relationship between food habit and length of *C. gariiepinus* based on the frequency of occurrence method. Length of *C. gariiepinus* expressed by mid-points of length classes.

As shown in Figure 8, crustaceans were the most numerous food items for *C. gariepinus* of all length groups including the largest ones. Fish and insects were more prominent (numerically) in the diet of large (>84 cm TL) *C. gariepinus* (Fig. 8) than the remaining length classes.

Based on the gravimetric method, insects were the most important food of all length groups of *C. gariepinus* (Fig. 9). There was a relative increase in the importance of crustaceans for *C. gariepinus* between 45 cm and 74 cm, and in the importance of fish for large (>84 cm TL) *C. gariepinus* (Fig. 9).

4.5.4 Predator to prey-size ratio

Prey to predator (i.e., *O. niloticus* to *C. gariepinus*) length ratios varied widely. For instance, a *C. gariepinus* of 37 cm TL had ingested an *O. niloticus* of 16 cm TL, and another *C. gariepinus* of 77 cm TL had ingested *O. niloticus* individual of 1.5 cm TL. For about 30% and 20% of the *C. gariepinus* individuals that had ingested *O. niloticus*, prey to predator ratio was between 1:5 and 1:10, and between 1:20 and 1:30, respectively (Fig. 10). The ratio was either above 1:5 or below 1:30 for about 8% of the *C. gariepinus* studied (Fig. 10).

4.5.5. Seasonal feeding periodicity

Fish with empty stomach were most frequent in July, August and in October, the highest frequency being in August. All *C. gariepinus* that were caught in May and June had food in their stomach.

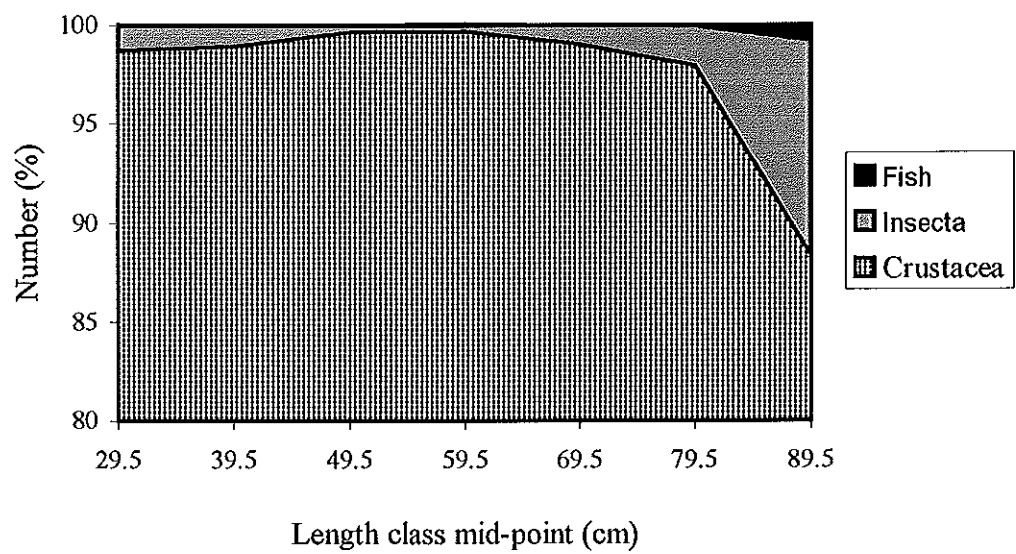


Figure 8. Relationship between food habit and length of *C. gariepinus* based on the numerical abundance method.

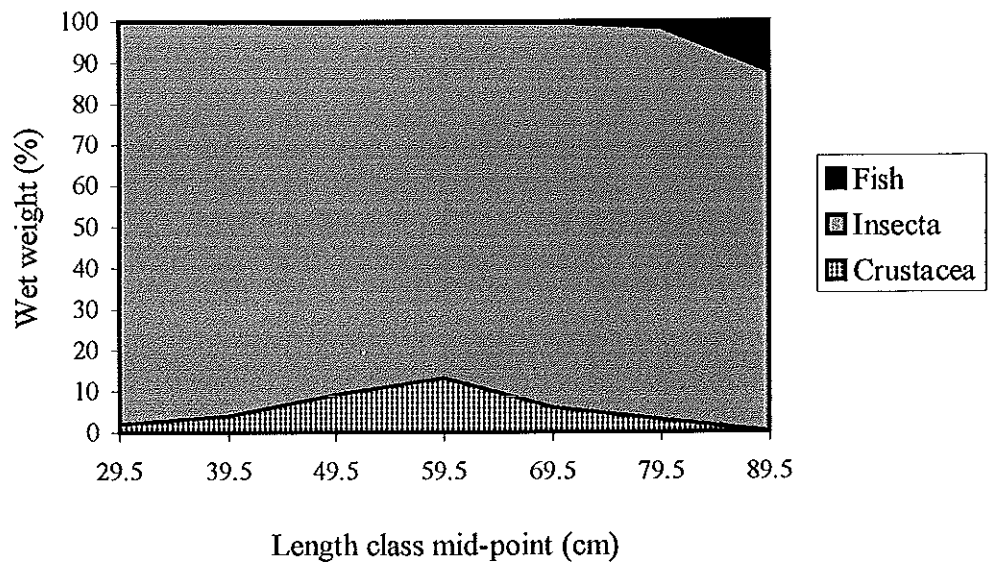


Figure 9. Relationship between food habit and length of *C. gariepinus* based on the gravimetric method.

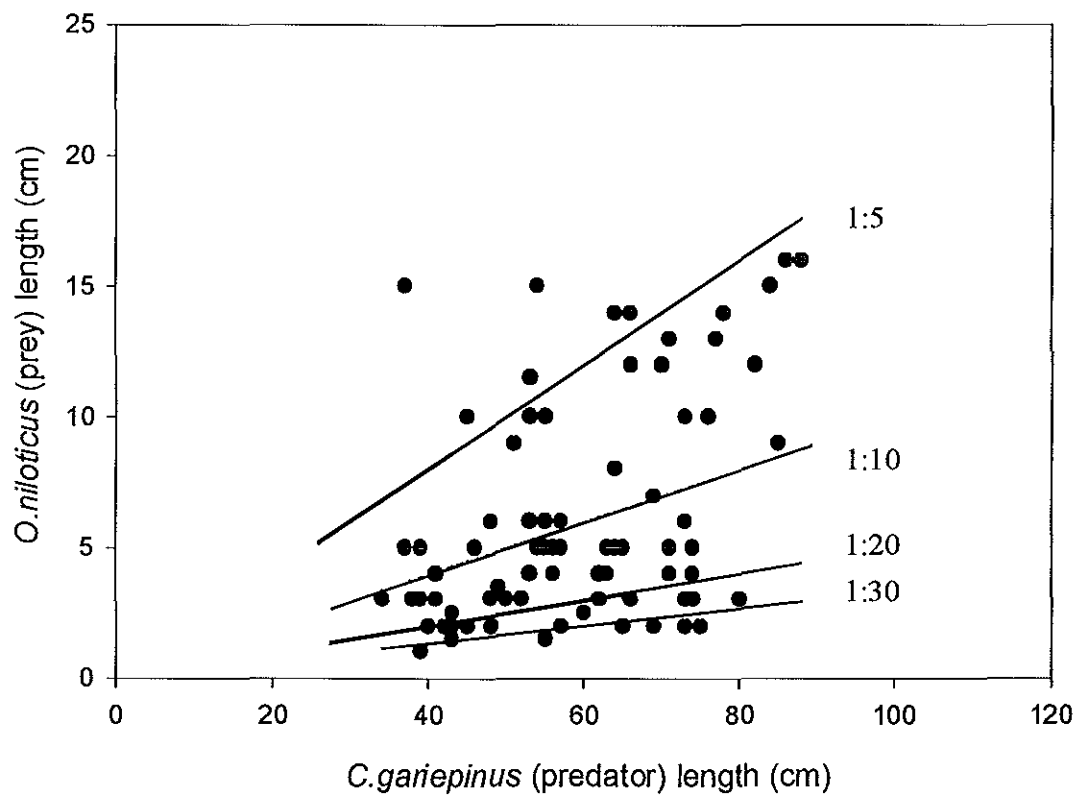


Figure 10. Relationship between length of *C. gariepinus* (predator) and length of its prey (*O. niloticus*).

Generally, empty stomachs were highly frequent (about 95% of all empty stomachs in the study) during the season of high water level, i.e., during July, August and October.

The number of *C. gariepinus* individuals which had ingested crustaceans and insects was about the same at low and high water-level, however, the number of *C. gariepinus* which had ingested *O. niloticus* was higher at high than at low water-level season (Fig. 11a). In addition, the importance of crustaceans and insects was similar in the two seasons both numerically (Fig. 11b) and gravimetrically (Fig. 11c). The numerical and weight contribution of *O. niloticus* in the diet of *C. gariepinus* was more pronounced at high than at low water level (Figs. 11b & 11c).

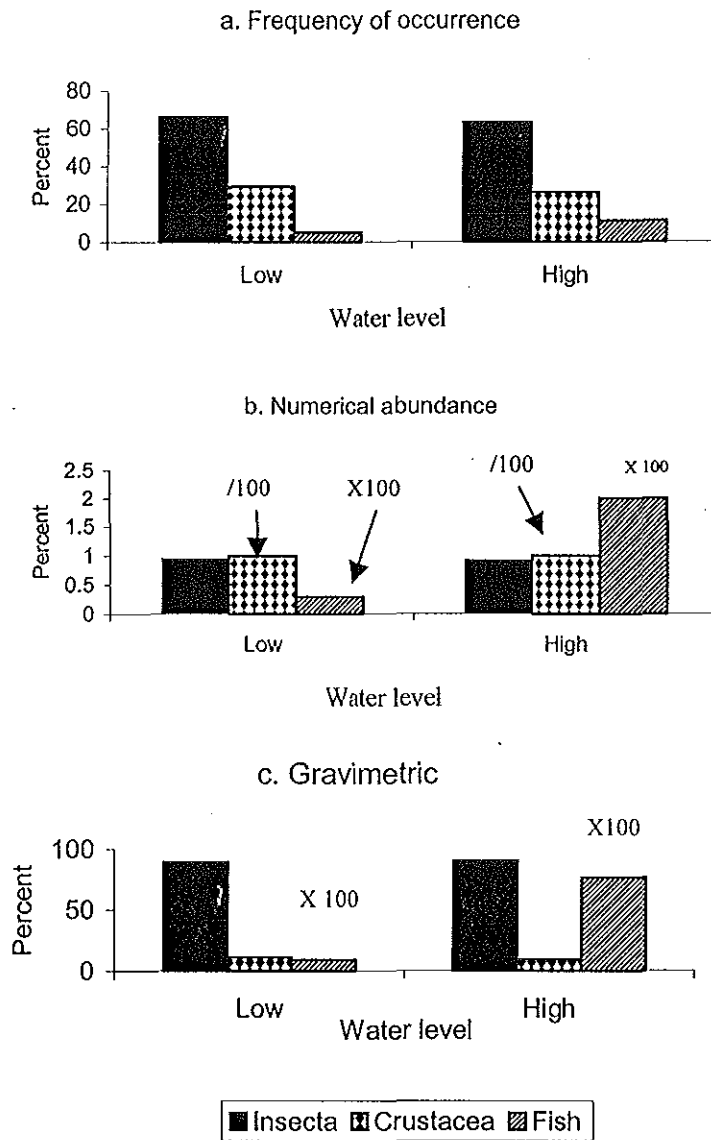


Figure 11. Relative contribution of food items (major grouping) to the diet of *C. gariepinus* in Lake Langeno at low water level (April to June) and at high water level (Jul., Aug., Oct.) seasons based on a) occurrence b) number and c) weight methods (Note that values in b) for Crustacea/100 and for Fish x 100, and in c) for Fish x 100).

5. DISCUSSION

The study showed that there is an overall preponderance of females over males in the *C. gariepinus* samples caught. Thus, females were about 1.41 x more numerous than males. The result is contrary to the *C. gariepinus* population of Lakes Awassa (Elias Dadebo, 1988) and Chamo (Elias Dadebo, Unpublished manuscript) where sex ratio is reported to be not significantly different from 1:1. The reason for the unbalanced sex ratio in the present study is not known. Studies on other species, however, have shown that unbalanced sex ratio may result from sex-reversal (Hughes, 1992), activity differences between the sexes during spawning (Demeke Admassu, 1994.), and the type of gear and sampling site used (Demeke Admassu, 1994). The phenomenon of sex-reversal that was reported for some species such as Nile perch (*Lates niloticus*) (Hughes, 1992) is not known for *C. gariepinus*. Demeke Admassu (1994) reported that unbalanced sex ratio in *O. niloticus* from Lake Awassa was due to the difference in spawning activity and sites between the sexes. He noted that females move about whereas males stay at the bottom, and thus the sexes are segregated when engaged in spawning activity. Therefore, his surface-set gillnets, which are passive gears, caught significantly more females than males during the spawning seasons. The sampling gear used in the present study, i. e. hook and line, is also a passive gear, and it caught more females in April, June, July and August. It is not known if the fish in Lake Langeno breeds intensively in these months. However, in the close-by Lake Awassa it breeds throughout the year, but at a very low intensity between September and January and at high intensity between February and June (Elias Dadebo, 1988; 2000). If the same is true for *C. gariepinus* in Lake Langeno, the proportion of females in the sample could be a reflection of the spawning season. However, this should be confirmed after

detailed knowledge on the spawning season of the fish for it can have significant bearing on a fishery taking the two sexes at an unbalanced manner/number.

The regression equation relating TL and TW in *C. gariepinus* of Lake Langeno can be used to estimate one variable from the other for fish between 28 cm and 104 cm in TL and 150 g and 8000 g in TW. That the value of the slope ($b = 2.914$) is close to the cube indicates that *C. gariepinus* in Lake Langeno grows isometrically, i. e., no change in body shape with growth (Ricker, 1975; Bagenal and Tesch, 1978). An overall mean RCF of 1.01 also indicates isometric growth. Other authors working on *C. gariepinus* have reported similar results. For instance, the length-weight regression slope for *C. gariepinus* in Lake Awassa was close to the cube (3.04) (Elias Dadebo, 1988). The same for the population in Lake Chamo was found to be 3.19 (Elias Dadebo, Unpublished manuscript). The regression slope for *C. gariepinus* in Elephant Marsh, Southern Malawi, was also found to be 3.14 (Willoughby and Tweddle, 1978).

Mean FCF of *C. gariepinus* in the present study was 0.58 for males and 0.63 for females. The overall mean FCF for the population was 0.61. According to Elias Dadebo (1988), corresponding values for the Lake Awassa population are 0.69 for males, 0.70 for females and 0.70 for the population in general. Thus, *C. gariepinus* in Lake Langeno has a relatively lower condition factor (well-being) than that in Lake Awassa. Lake Awassa, at least in terms of primary productivity, is about 8 times more productive than Lake Langeno, the latter of which is considered to be least productive (Elizabeth Kebede, 1996). Thus, quantity and quality of the food in Lake Langeno may be lower than that in Lake Awassa to result difference in condition between the two *C. gariepinus* populations. Demeke Admassu and Ahlgren (2000) who reported lower condition for the Lake Langeno juvenile *O. niloticus* population as well as for adult group

(Zenebe Tadesse, 1999) than for the Lake Chamo and Lake Zwai populations attributed the difference to differences in productivity.

Additional evidence can also be obtained by using length-weight equations fitted in the present study and that by Elias Dadebo (1988). Considering a 30 cm fish length, *C. gariepinus* would be 190 g in Lake Awassa, but 169.3 g in Lake Langeno. For a 90 cm TL, *C. gariepinus* in Lake Awassa would be about 5.4 kg, but that in Lake Langeno would be about 4.2 kg. Generally, *C. gariepinus* between 30 cm and 90 cm TL in Lake Awassa would be on average 1.22 x (range: 1.12x - 1.30x) heavier than similar sized fish in Lake Langeno. Thus, it can be concluded that the Lake Awassa *C. gariepinus* population grows relatively faster than that in Lake Langeno. The reason for the difference may be related to the difference in productivity between the two Lakes, which in turn determines food quantity and quality variations.

Another factor may be the relatively low contribution of fish to the diet of *C. gariepinus* in Lake Langeno. Fish (i. e. *O. niloticus*) makes up the bulk of the food of *C. gariepinus* in Lake Awassa (Elias Dadebo, 1988). It is believed that piscivores generally grow faster than non-piscivores (Wootton, 1990).

Results on FCF and RCF of *C. gariepinus* from Lake Langeno suggest that females are in relatively better condition than males. The finding agrees with sex-based differences in FCF reported for *C. gariepinus* of Lake Awassa (Elias Dadebo, 1988). In general, for fish populations, males tend to grow better, and hence have higher condition than females, and this is attributed to reproduction being energy-costly in females (Wootton, 1990). However, it is also common to find populations whose female members grow superiorly and have better condition.

(Fryer and Iles, 1972). Although the difference could be genetically determined, it is difficult to explain the phenomenon in present study.

Fulton condition factor of *C. gariepinus* (average to the sexes) was relatively highest (0.66) in May but lowest (0.58) in June. Seasonal fluctuations in environmental factors such as temperature, spawning activity, food quality and quantity, etc. may be responsible (e.g. Yirgaw Teferi, 1997; Demeke Admassu, 1998; Zenebe Tadesse, 1998; Demeke Admassu and Ahlgren, 2000). Water temperature data are not available for the study period. However, assuming little inter-annual variations to use previous water temperature data (Fig. 4b), high condition factor in May and low in June may be attributed to high and low water temperature, respectively. Further study is necessary to reveal the effects of other factors such as spawning, food quality and quantity, etc.

The study showed that *C. gariepinus* in Lake Langeno ingests a variety of organisms and items. Organisms identified from the stomach contents of the fish varied from phytoplankton (e.g. *Microcystis*) to higher plants (Macrophyte pieces), and from macroinvertebrates (e.g. Crustacea) to a higher vertebrate (i.e. *O. niloticus*). These organisms are also ingested by the same species in Lake Sibaya, South Africa (Bruton, 1978), in Lake Kinneret, Israel (Spataru *et al.*, 1987), in Lake Awassa (Elias Dadebo, 1988; 2000) in Lake Chamo (Elias Dadebo. unpublished data) and in Lake Tana (Tesfaye Wudneh, 1998).

As it will be explained later, algae, macrophytes, detritus, sand grains and nematodes are not considered to be food items. However, crustaceans, insects and fish are important food items of

C. gariepinus in Lake Langeno. The same has been reported for the species in other water bodies (Bruton, 1979; Spataru *et al.*, 1987; Elias Dadebo, 1988; 2000).

Molluscus and Oligochaetes were not observed in the stomach content in the present study as it was also the case for *C. gariepinus* in Lake Awassa (Elias Dadebo, 1988; 2000). However, these organisms are reported to be important food of the species in other water bodies (Bruton, 1979; Spataru *et al.*, 1987). Although food habit may vary with the habitat, the absence of molluscus and Oligochaetes in the stomach content could be attributed to their absence from Lake Langeno due to the high turbidity of the lake. Digestion (particularly for soft-bodied animals such as Oligochaetes) before sampling could also have introduced errors (Kirk, 1967; Windell and Bowen, 1978).

Based on biomass contribution (Gravimetric method), insects are the most important food of *C. gariepinus* in Lake Langeno. Crustaceans are next to insects whereas fish (*O. niloticus*) was least important. Similarly, Zooplankton and/or insects are found to be more important than fish to the diet of *C. gariepinus* in Lake Tana (Tesfaye Wudneh, 1998) and in Lake Chamo (Elias Dadebo, Unpublished manuscript). Contrary to this, however, other studies have reported fish to be the most important food of *Clarias*. Elias Dadebo (1988; 2000), for instance, reported that *O. niloticus* is 79% of the bulk of the food ingested by the fish in Lake Awassa. In addition, Thomas (1966) reported that Cichlid fishes are the most important food of *C. senegalensis* in man-made lake in the Ghanaian Savanna.

C. gariepinus is considered to be inefficient piscivore (Tesfaye Wudneh, 1998). Therefore, *C. gariepinus* is likely to avoid hunting for prey fish if these are in low abundance, but look for

other abundant food items instead. The same is likely to hold true if other efficient predators are present. Elias Dadebo (Unpublished manuscript) found that in Lake Chamo, where voracious piscivores like the Nile perch are found; fish is not the most important prey of *C. gariepinus*. In addition, in the presence of piscivorous large Barbus, *C. gariepinus* is not piscivorous in Lake Tana (Tesfaye Wudneh, 1998). However, there are no piscivores in Lake Awassa, and *O. niloticus* is the most important food of *C. gariepinus* there (Elias Dadebo, 2000). Lake Langeno also does not contain piscivorous fish. Therefore, the low importance of *O. niloticus* in the diet of *C. gariepinus* in Lake Langeno may be related to the relatively low abundance of *O. niloticus* in this lake than other lakes. That the importance of *O. niloticus* showed an increase in the high water level season may indicate increase in the abundance of juvenile *O. niloticus* which could have occurred due to breeding in previous months. Breeding in *O. niloticus* occurs so that juveniles are recruited to coincide with favourable conditions (such as high water level) for growth and survival (Demeke Admassu, 1996 and references therein).

Detritus, algae, macrophytes, and sand grains are believed to be accidentally ingested by *C. gariepinus* in Lake Langeno. *C. gariepinus* is an indiscriminate feeder (Bruton, 1979; Elias Dadebo, 2000), therefore, it might have ingested these items while pursuing prey that are associated with macrophytes and with the sediment. Similar conclusions have also been made by other workers (Groenewald, 1964; Thomas, 1966; Kirk, 1967; Spataru *et al.*, 1987; Elias Dadebo, 2000). *C. gariepinus* is considered as carnivorous and predator which accidentally consumes algal filaments, macrophyte fragments and detritus from the bottom together with larvae/pupae of benthic organisms (Groenewald, 1964; Kirk, 1967). Thomas (1966) who studied the related *C. senegalensis* also grouped the fish as carnivorous. In contrast, however, some workers (Jubb, 1967; Willoughby and Tweddle, 1978) believe that *C. gariepinus* is an omnivorous fish which, in

addition to animals, feeds also on humus, plant detritus and filamentous algae. It is not known whether the fish studied by these authors ingested these items very frequently. In the present study, however, items of plant origin occurred at very low frequencies. Thus, plant food items do not seem to be nutritionally important to *C. gariepinus* in Lake Langeno. Nevertheless, further study based on both stomach content and rectum content analysis should be conducted to reveal the importance of plant food items.

The study showed that the diet of large *C. gariepinus* included progressively more and more fish than the small-sized *C. gariepinus*. This could be due to the fact that large *C. gariepinus* inhabit deeper waters whereas small ones live in shallow waters among macrophytes where densities of benthic organisms are usually high (Bruton, 1978; Elias Dadebo, 1988; 2000). Similarly, Corbet (1961) showed that *Clarias* in Lake Victoria feeds mainly on ostracods and insects when young but they tend to feed progressively more on fishes as they grow older. In addition, Munro (1967) also reported that insects are more important in the diet of small *C. gariepinus*. Furthermore, Elias Dadebo (2000), who found slight size-based differences in food habit, reported that juvenile *C. gariepinus* feed more on insects than did the adults. Therefore, despite the overall low contribution of *O. niloticus* to the Lake Langeno *C. gariepinus*, the contribution was high for large than for small *C. gariepinus*.

Most piscivorous predators tend to prey on progressively large-sized fish as they grow larger. However, there was no definite relationship between the size of *C. gariepinus* and that of its prey fish. The great majority (about 84%) of the *C. gariepinus* had ingested *O. niloticus* whose length is between 1/5th and 1/30th of their own length. The lack of relationship could be related to *C. gariepinus* being an inefficient piscivore (Tesfaye Wudneh, 1998) and/or to *O. niloticus* being the

least important food of *C. gariepinus* in Lake Langeno. Thus, the choice of *C. gariepinus* to control excessive recruitment in tilapia culture should consider the benefits/costs with regard to using other fish such as Nile perch.

The high frequency of *C. gariepinus* individuals with empty stomach during the season of high water level may be associated with spawning activity. Heavy rainfall and subsequent rise in water level trigger spawning of *C. gariepinus* in many African water bodies (Greenwood, 1955; Van der Waal, 1974; Willoughby and Tweddle, 1978) including Lakes Tana (Tesfaye Wudneh, 1998), Awassa (Elias Dadebo, 2000) and Chamo (Elias Dadebo, Unpublished manuscript) in Ethiopia. Thus, the fish may be engaged more on spawning activity than on hunting for prey. Similar findings and conclusions have also been reported for other fish species (Zenebe Tadesse, 1988; 1998). Regurgitation and digestion before sampling have been implicated as factors resulting in high incidence of empty stomachs in *C. gariepinus* samples (Kirk, 1967). However, although these factors, particularly regurgitation, could have introduced some error, they are unlikely to explain the consistently high incidence of empty stomachs observed in July, August and October.

6. CONCLUSION

C. gariepinus females outnumbered males in the total as well as in both low and high water level seasons in Lake Langeno.

The relationship between total length and total weight was found to be curvilinear. The value of b (2.914) which was very close to 3 indicates that *C. gariepinus* in Lake Langeno has an isometric growth.

Females were in better condition than males; and the average FCF for the population was found to be 0.61. FCF of *C. gariepinus* in Lake Langeno was found to be lower than that in Lake Awassa and Chamo. The low condition of *C. gariepinus* in Lake Langeno may be related to low productivity of the Lake.

Relatively low condition in June may be related with low water temperature and the relatively high condition in May to high water temperature.

C. gariepinus in Lake Langeno was found to be carnivorous predator, mainly benthic feeder, on insects, crustaceans and to some extent on fish (*O. niloticus*). *C. gariepinus* in Lake Langeno is inefficient piscivore, but in addition to insects and crustaceans, large *C. gariepinus* fed on more and more *O. niloticus*. In addition, *O. niloticus* was more important prey of large *C. gariepinus* at high than at low water level possibly due to increased recruitment of juvenile *O. niloticus*. Although these items were not equally represented in the diet, the wide choice available to the fish suggests that when one food item is in short supply, others in abundance could be eaten.

7. REFERENCES

- Bagenal, T. B. and Tesch, F. W. (1978). Age and growth. In T. B. Bagenal (ed.). *Methods for Assessment of Fish Production in Fresh Waters*, pp. 101-136. IBP. Handbook No. 3, Blackwell Scientific Publications, Oxford, England.
- Borror, D.J. and DeLong, D.M. (1964). *An introduction to the study of insects*. Holt, Rinehart and Winston, Inc. London. 819 pp.
- Bruton, M. N. (1978). The habitat and habitat preference of *C. gariepinus* (Pisces: Clariidae) in a clear coastal lake (Lake Sibaya, South Africa). *J. Limnol. Soc. Sth. Afr.* **4** (2): 81-88.
- Bruton, M. N. (1979). The food and feeding behavior of *C. gariepinus* (Pisces: Clariidae) in Lake Sibaya, South Africa, with emphasis on its role as a predator of cichlids. *Trans. Zool. Soc. Lond.* **35**: 47-114.
- Cannicci, G. and Almagia, F. (1947). Notizie suulla "facies" planctonica di alcuni laghi della Fossa Galla, *Boll. Pesca. Piscic. Idrobiol.*, **23**: 54-77.
- Clay, D. (1979). Population biology, growth and feeding of African catfish (*Clarias gariepinus*) with special reference to juvenile and their importance in fish culture. *Arch. Hydrobiol. Supp.* **87** (4): 453-482.
- Corbet, P. S. (1961). The food of non-cichlid fishes in the Lake Victoria Basin, with remarks on their evolution and adaptation to lacustrine conditions. *Proc. Zool. Soc. Lond.* **136**: 1-101.
- Daniel Gamachu (1977). *Aspects of climate and water budget in Ethiopia*. Addis Ababa Univ. Press, Addis Ababa. 71pp.
- Defaye Daniel (1988). Contribution a la connaissance des crustaces Copepodes d' Ethiopie. *Hydrobiologia* **164**: 103-147.

- Demeke Admassu (1994). Maturity, fecundity, brood-size and sex-ratio of tilapia (*Oreochromis niloticus* L.) in Lake Awassa, Ethiopia. *SINET: Ethiop. J. Sci.*, **17** (1): 53-69.
- Demeke Admassu (1996). The breeding season of tilapia, *Oreochromis niloticus* L., in Lake Awassa (Ethiopian rift valley). *Hydrobiologia* **333**: 77-83.
- Demeke Admassu (1998). Age and growth determination of tilapia, *Oreochromis niloticus* L. (Pisces: Cichlidae) in some lakes in Ethiopia. Ph.D. dissertation, School of Graduate Studies, Addis Ababa University, Addis Ababa. 115 pp.
- Demeke Admassu and Ahlgren I. (2000). Growth of juvenile tilapia, *Oreochromis niloticus* L. from Lakes Zwai, Langeno and Chamo (Ethiopian rift valley) based on otolith microincrement analysis. *Ecol. Fresh. Fish* **9**: 127-137.
- Edington, J. M. and Hildrew, A. G. (1981). *A key to the Caseless Caddis larvae of the British Isles: with notes on their ecology*. Fresh water Biological Association Scientific Publication No.43. Department of Zoology and Comparative physiology, University of London, Titus Wilson and Son Ltd., London, 91 pp.
- Elias Dadebo (1988). Studies on the biology and commercial catch of *Clarias mossambicus* Peters (Pisces: Clariidae) in Lake Awassa, Ethiopia. M. SC. thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa. 73 pp.
- Elias Dadebo (2000). Reproductive biology and feeding habits of catfish *Clarias gariepinus* Burchell (Pisces: Clariidae) in Lake Awassa, Ethiopia. *SINET: Ethip. J. Sci.* **23**: 231-246.
- Elizabeth Kebede, Zenabu G/ Mariam, and Ingemar Ahlgren (1994). The Ethiopian Rift Valley Lakes: chemical characteristics of a salinity-alkalinity series. *Hydrobiologia* **288**: 1-12.
- Elizabeth Kebede, (1996). Phytoplankton in a salinity-alkalinity series of lakes in the Ethiopian Rift Valley. Act. Univ. Ups., *Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology* 185. 34 pp.

- Fryer, G. (1959). The trophic inter-relationships and ecology of some littoral communities of Lake Nyasa with special reference to the fishes and a discussion of the evolution of a group of rock frequenting Cichlidae. *Proc. Zool. Soc. Lond.* **132** (2): 154-281.
- Fryer, G. and Iles, T. D. (1972). *The Cichlid Fishes of the Great Lakes of Africa. Their Biology and Evolution*. Oliver and Boyd, Edinburgh.
- Getachew Tefera, (1987). Food, nutrition and digestive efficiency in *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Awassa, Ethiopia. Ph.D. dissertation, University of Waterloo, Ontario, Canada. 109 pp.
- Getachew Tefera (1993). The composition and nutritional status of the diet of *Oreochromis niloticus* in Lake Chamo, Ethiopia. *J. Fish Biol.* **42**: 864-874.
- Greenwood, P. H. (1955). Reproduction in the Catfish, *Clarias mossambicus* (Peters). *Nature, Lond.* **176**: 516-518.
- Groenewald, A. A. V.J. (1964). Observation on the food habits of *C. gariepinus* Burchell, the South African fresh water barbel (Pisces: Clariidae) in Transvaal. *Hydrobiologia* **23**: 287-291.
- Hailu Anja (1996). Studies on some aspects of the catfish *Bagrus docmac* Forsk. (Pisces: Bagridae) in Lake Chamo, Ethiopia. M.Sc. thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa. 67 pp.
- Harding, J.P. and Smith W.A. (1974). *A key to the British freshwater Cyclopid and Calanoid Copepods*. Freshwater Biological Association Scientific Publication No. 18. Titus Wilson and Son Ltd. London. 54 pp.
- Hecht, T. and Appelbaum, S. (1987). Notes on the growth of Israeli sharptooth catfish (*Clarias gariepinus*) during the primary nursing phase. *Aquaculture* **63**: 195-204.

- Hughes, N. F. (1992). Growth and reproduction of the Nile perch, *Lates niloticus*, an introduced predator, in the Nyanza Gulf, Lake Victoria, East Africa. In: Witte, F. and Van Densen, W. L. T. (eds.), *Fish stocks and Fisheries of Lake Victoria: A hand book for field observations*, pp. 318-319, Samara Publishing Ltd., London.
- Hynes, H. B. N. (1950). The food of fresh water Sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungiteus*), with a review of methods used in studies of the food of fishes. *J. Anim. Ecol.* **19**: 36-58.
- Hyslop, E. J. (1980). Stomach contents analysis-a review of methods and their application. *J. Fish. Biol.* **17**: 411-429.
- Jubb, R. A. (1967). *Fresh water fishes of southern Africa*. Amsterdam: A. A. Balkema.
- Kassahun Wodajo (1982). Comparative limnology of Lake Abijata and Lake Langeno in relation to primary and secondary production. M.Sc. thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa. 112pp.
- Kassahun Wodajo and Amaha Belay (1984). Species composition and seasonal abundance of zooplankton in two Ethiopian Rift Valley lakes- Lakes Abijata and Langeno. *Hydrobiologia* **113**: 129-136.
- Kirk, R. A. (1967). The fishes of Lake Chilwa. *J. Soc. Malawi*, **20**: 1-14.
- Lackey, R. T. and Neilson, L. A. (eds.) (1980). *Fisheries management*. Blackwell Scientific Publication, 422 pp.
- Le Cren, E. D. (1951). The length-weight relationship and seasonal cycle in gonadal weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol.* **20**: 201-219.
- LFDP (Lake Fisheries Development Project) (1998). Fisheries Report, Phase II. Animal and Fisheries Resource Development Department (MOA), 61 pp.

- Macan, T. T. (1959). *A Guide to Freshwater Invertebrate Animals*. Longmans, Green and Co. Ltd., London. 118 pp.
- Macan, T. T. (1976). *A key to British Water Bugs (Hemiptera-Heteroptera): with Notes on Their Ecology*. Freshwater Biological Association Scientific Publication No. 16. Titus Wilson and Son Ltd. London. 77 pp.
- Mebrat Alem (1993). Overview of the fisheries sector in Ethiopia. In: *Proceedings of the National Seminar on Fishery Policy and Strategy*, pp 45-53. The FAO, Rome.
- Munro, J. L. (1967). The food of a community of East African fresh water fishes. *J. Zool. Lond.* **151**: 389-415.
- Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Bd Can.* **191**: 203-233.
- Shibru Tedla (1973). *Fresh water fishes of Ethiopia*. Haile Selassie I University, Dept. of Biology, Addis Ababa, Ethiopia. 107pp.
- Sokal, R. R. and Rohlf, F. J. (1981). *Biometry*. W. H. Freeman and Company, San Francisco.
- Spataru, P., Viveen, W. J. A. R. and Gophen, M. (1987). Food composition of *C. gariepinus* (*C. lazera*) (Cypriniformes, Clariidae) in Lake Kinnert (Israel). *Hydrobiologia* **144**: 77-82.
- Talling, J. F. (1965). The photosynthetic activity of the phytoplankton in East African Lakes. *Int. Rev. ges. Hydrobiol. Hydrogr.* **50**: 1-32.
- Tesfaye Wudneh, (1998). Biology and management of fish stocks in Bahir Dar Gulf, Lake Tana, Ethiopia. Ph.D. thesis, Wageningen Agricultural University, Wageningen 142 pp.
- Thomas, J. D. (1966). On the biology of the Catfish *Clarias senegalensis* in a man-made lake in the Ghanaian Savanna with particular reference to its feeding habits. *J. Zool.* **148**: 476-514.

- Yirgaw Teferi (1997). The condition factor, feeding and reproductive biology of *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Chamo, Ethiopia. M.Sc. thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa, 83 pp.
- Zenebe Tadesse (1998). Food and feeding ecology of tilapia, *Oreochromis niloticus* L. and effects of diet on the lipid quality of fish in some lakes in Ethiopia. Ph.D. dissertation. School of Graduate Studies, Addis Ababa University, Addis Ababa, 138 pp.
- Zenebe Tadesse, Ahlgren, G. and Boberg, M. (1998). Fatty acid content of some freshwater fish of commercial importance from tropical lakes in the Ethiopian Rift Valley. *J. Fish Biol.* **53**: 987-1005.
- Zenebe Tadesse (1999). The nutritional status and digestibility of *Oreochromis niloticus* L. diet in Lake Langeno, Ethiopia. *Hydrobiologia* **416**: 97-106.