Ethiop. J. Biol. Sci., 7(2): 139-157, 2008
 ISSN: 1819-8678

LENGTH-WEIGHT RELATIONSHIP, FULTON'S CONDITION FACTOR AND SIZE AT FIRST MATURITY OF TILAPIA, *OREOCHROMIS NILOTICUS* L. IN LAKES KOKA, ZIWAY AND LANGANO (ETHIOPIAN RIFT VALLEY)

Gashaw Tesfaye [1,*] and Zenebe Tadesse [1]

ABSTRACT: In Ethiopia, the tilapia, *Oreochromis niloticus,* is an extremely important fish from ecological, economic and social point of view. Information on biological parameters like the size at first maturity (L_{50}), Fulton's condition factor (K) and length – weight relationship are very crucial for the sustainable management of the fishery. Therefore, the present study aims at providing information on the length-weight relationship, condition factor and size at first maturity (L_{50}) of *Oreochromis niloticus* in Lakes Koka, Ziway and Langano. Fish samples were collected on monthly basis from October 2005 to February 2006. Length-weight relationships (total length (L) in cm; total weight (W) in g were calculated for *O. niloticus* in Lakes Koka ($W = 2.61*10^{-2}L^{2.89}$; $n = 205$; $r^2 = 0.99$), Ziway ($W = 1.04*10^{-2}L^{3.19}$; n = 279; $r^2 = 0.97$) and Langano ($W = 1.64*10^{-2}L^{3.04}$; $n = 525$; $r^2 = 0.88$). The average K value of *O. niloticus* from Lake Koka (1.87) is slightly higher than Ziway (1.81) and Langano (1.84). The size at first maturity (L_{50}) of *O. niloticus* is smaller in Lake Ziway (Female =18.1cm, male=19.6cm) and Langano (both sexes 19.5cm) than Lake Koka (both sexes 23.5cm) which is contrary to the generally accepted principle that fish mature earlier in smaller water bodies than larger ones. Hence, the nutritional status and the level of fishing pressure appear to be important factors for the variations observed in the present study.

Key words/phrases: Condition factor; Lakes Koka, Ziway, Langano; L_{50}; Length-weight relationship; *O. niloticus.*

INTRODUCTION

Tilapia, *Oreochromis niloticus* is an ecologically very important fish species in Ethiopian lakes (Demeke Admasu, 1996) and its ecological roles are many fold. As a herbivore, it transfers high energy to the upper levels of the food chain. It plays a very important role in the direct grazing effect of phytoplankton and thereby controlling the density of the rapidly reproducing algae, which otherwise might cause sudden algal blooms in the whole system. It also indirectly controls the input of organic matter from dead plankton which further stimulates algal blooming. In addition, it is also a prey for catfish *Clarias gariepinus*, the second most economically important

[1]Ethiopian Institute of Agricultural Research-National Fisheries and other Aquatic Life Research Center, P.O. Box 64, Sebeta, Ethiopia. E-mail: gashatc@yahoo.co.uk; zenebetd@yahoo.com
*Author to whom all correspondence should be addressed.

fish in Lakes Koka, Ziway and Langano.

Tilapia is also the dominant fish that contributes about 60 % of the annual commercial fishery in Ethiopia. The total annual catch of *O. niloticus* increased during the 1990’s and accounted for 80% of the fish production from Lakes Ziway and Chamo (Reyntjens *et al*., 1998). About 90% of the landings of Lakes Ziway and Langano (Eyualem Abebe and Getachew Tefera, 1992; LFDP, 1997; Gashaw Tesfaye, 2006), and 61% of Lake Koka (LFDP, 1997) was contributed by *O. niloticus*. It is a highly preferred fish by consumers in Ethiopia. However, the high demand for a particular fish species may lead to over-fishing in the long run and a shift in fish species structure to less desirable ones in these lakes.

The length-weight relationships has been widely used in fish biology to estimate the mean weight of a fish based on the known length (Beyer, 1987); to give information on growth patterns of fish (Bagenal and Tesch, 1978); for conversion of the length equations in weight for equivalent of growth in weight; for interspecific and intrapopulational morphometric comparisons; and to assess the index of well-being (condition factor) of the fish populations (Bolger and Connolly, 1989). Anderson and Neumann (1996) refer to length-weight relationships of fish population as a basic parameter for any monitoring study of fisheries as it provides important information concerning the structure and function of populations.

Condition factor (K) is a quantitative parameter that indicates the well-being of fish. This factor varies with change in physiological conditions, different stages of development (Le Cren, 1951) and environmental changes (Bakhoum, 1994). Length at first maturity (symbolized as L_{50}) is also an important parameter of fish life history. It refers to the length at which 50% of the population matures. Knowledge of the life history of a species is an essential prerequisite for effective fisheries management. Therefore, the present study aims at providing information on the length-weight relationship, condition factor and size at first maturity (L_{50}) of *Oreochromis niloticus* in Lakes Koka, Ziway and Langano.

MATERIALS AND METHODS

Description of the study sites

The tropical Lakes Koka, Ziway and Langano are located in the Ethiopian Rift Valley, which is part of the Afro-Arabian Rift System, bounded by the Arabian plate to the north and the African plate to the west and east (Fig. 1).

Lake Koka is a man-made lake constructed mainly for the purpose of hydropower generation in the 1950's. It is located ($08^0 26'$ N; $39^0 10'$ E) at an altitude of 1660 m a. s. l., and about 90 km south of the capital city, Addis Ababa. It is fed by River Awash, one of the longest perennial rivers originating from the highlands of Ethiopia. It has a large area of floodplain. Lakes Ziway and Langano, further southward from Lake Koka are natural lakes located at $08^0 32'$N; $38^0 50'$E and $07^0 35'$N; $38^0 45'$E, respectively. Lake Ziway has larger open water surface area (434 km^2) than both Lakes Koka (255km^2) and Langano (241 km^2) (Zenebe Tadesse, 1999; IUCN, 2003). Lake Ziway is mainly fed by two rivers (Ketar and Meki) and surface runoff, whereas Lake Langano is fed by many hot springs and surface runoff. Although Lakes Ziway and Langano are located very close to each other, there is no connection between them. However, both lakes discharge water into the same terminal Lake Abijiata via the Rivers Bulbula and Hora Kello, respectively. The morphometric, physical and chemical features of the three lakes are given in Table 1.

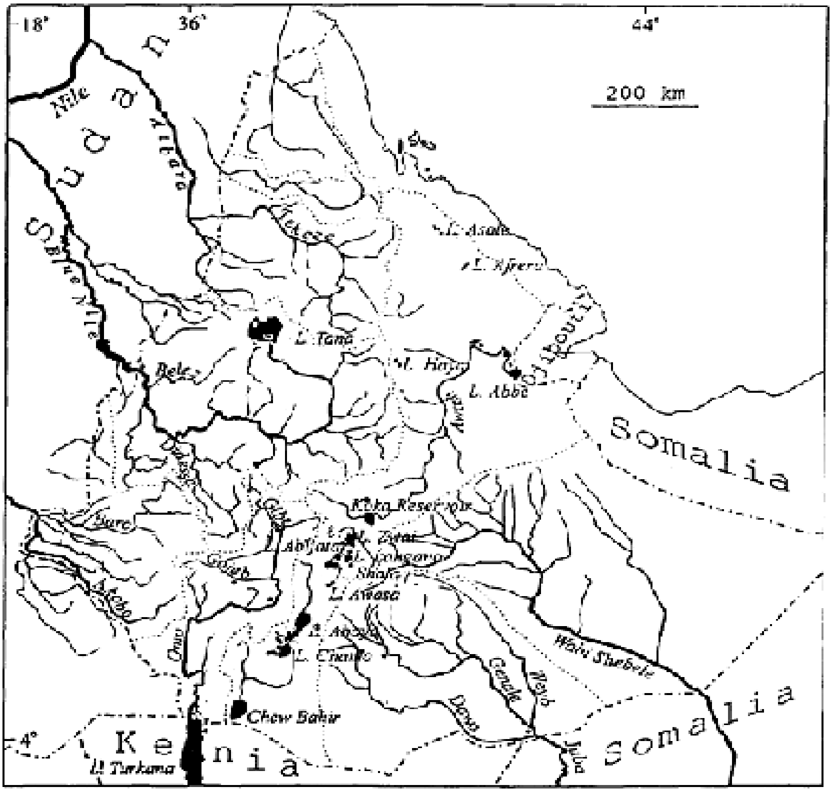


Fig. 1. Map of Ethiopia showing the central and southern Ethiopian Rift Valley Lakes.

Table 1 Morphometric, physical and chemical features of Lakes Koka, Ziway and Langano. (Sources: Melaku Mefin *et al*., 1988; Wood and Talling, 1988; Elizabeth Kebede *et al*., 1994; LFDP, 1996; Zenebe Tadesse, 1999; Zinabu Gebre-Mariam *et al*., 2002).

Characteristic features	Koka	Ziway	Langano
Altitude (m)	1660	1636	1582
Area (Km^2)	255	434	241
Maximum depth (m)	14	7	48
Mean depth (m)	9	2.5	17
Secchi depth (cm)	28	11.5	18-28.5
Conductivity (μscm^{-1})	200-380	350	1550-1700
Salinity ($^o/_{oo}$)	0.319	0.349	2.4
pH	8.5	8.5	9
Chlorophyll a (μgl^{-1})	22.4	82.4	14.3
Na^+ ($meql^{-1}$)	1.4	2.3-3.4	14.35 – 15.78
K^+ ($meql^{-1}$)	0.21	0.21- 0.35	0.54
Ca^{2+} ($meql^{-1}$)	0.86	0.55-1.15	0.24
Mg^{2+}($meql^{-1}$)	0.31	0.5-0.83	0.2
$HCO_3^- + CO_3^{2-}$($meql^{-1}$)	2.59	4.0	12.5
Cl^- ($meql^{-1}$)	0.49	0.26-0.46	3.66
SO_4^{2-} ($meql^{-1}$)	0.14	0.04-0.32	1.16
NO_3+NO_2- N(μgl^{-1})	1.4	3.9	44.9
NH_4^+- N(μgl^{-1})	-	36.3	50
PO_4-P (μgl^{-1})	9.5	-	20
Tot. P (μgl^{-1})	224	219	70.4
SiO_2 (mgl^{-1})	12.5-14.6	13.4-37.5	17-34

The Rift Valley climate is generally characterized by a four-month dry season (November-February) and an eight-month rainy season (March-October) (Elizabeth Kebede and Amha Belay, 1994). The total annual rainfall varies from 600 to 800mm in the Rift Valley area (Tenalem Ayenew, 2004). December is the coldest month and the mean annual temperature was found to be above 20^0C. The mean monthly minimum, maximum and mean temperature, and total rainfall for the years 2004 and 2005 are given in Table 2.

The Sechi depth of Lake Koka is low (28cm) which might be attributed to suspended silt coming in by the River Awash (Melaku Mesfin *et al*, 1988). The color of the water resembles that of Lake Langano (Wood *et al*., 1978), but in Lake Langano the silt is in stable suspension and does not precipitate unless the salt concentration of the water is altered (Amha Belay and Wood, 1984), whereas in Lake Koka the silt settles out on standing (Melaku Mesfin *et al*., 1988). The general chemical composition of Lake Koka is very similar to that of other lakes from the Ethiopia Rift Valley (Talling and Talling, 1965; Von Damm and Edmond, 1984 cited in Melaku Mesfin *et al*., 1988). In Lake Koka, the sediment is very fine, easily washable through a 200µ mesh net, and contains no undecomposed material and hence the organic content is high in comparison with certain other tropical African lakes (McLachland, 1974 cited in Melaku Mesfin *et al*., 1988). The chemical and limnological features of the rift valley lakes were studied by Melaku Mesfin *et al*.(1988), Wood and Talling (1988), Elizabeth Kebede *et al*. (1994), LFDP (1996), Tudorancea *et al*., (1999) and Zinabu Gebre-Mariam *et al*. (2002).

Table 2 Mean monthly maximum, minimum and mean temperature (^{o}C) and total rainfall (mm) around the studied lakes in 2004 and 2005. (Data from Ziway Meteorological station).

Years	Months	Meteorological elements			
		Max T (^{o}C)	Min T (^{o}C)	Mean T (^{o}C)	Rainfall (mm)
2004	January	27.7	14.7	21.2	92.0
	February	27.0	13.7	20.4	0.8
	March	29.4	14.4	21.9	24.7
	April	28.2	16.2	22.2	150.3
	May	31.0	16.6	23.8	0.0
	June	28.4	16.1	22.3	94.1
	July	26.2	15.1	20.7	171.7
	August	26.2	15.4	20.8	129.6
	September	27.0	15.1	21.1	92.7
	October	27.6	13.3	20.5	10.9
	November	27.8	12.6	20.2	2.7
	December	26.9	12.6	19.8	0.0
2005	January	27.6	12.9	20.3	48.5
	February	28.6	13.2	20.9	14.7
	March	29.7	16.1	22.9	84.6
	April	29.4	16.1	22.8	100.8
	May	27.5	16.4	22.0	197.0
	June	27.6	15.8	21.7	55.4
	July	25.7	15.7	20.7	103.0
	August	26.6	15.5	21.1	91.5
	September	27.2	15.3	21.3	140.2
	October	28.1	13.9	21.0	4.6
	November	27.3	12.1	19.7	1.4
	December	26.9	9.3	18.1	0.0

The fish species present in all the three lakes belong to the genera *Tilapia, Clarias*, *Cyprinus, Barbus and Garra* (Golubtsov *et al*. 2002). The common carp (*Cyprinus carpio)* and crucian carp (*Caracius caracius)* were introduced in the late 1950s (Tudorancea *et al*., 1999). The African catfish *C. gariepinus* is believed to be accidentally introduced to Lake Ziway from the nearby Fish Processing and Marketing Center (FPMC) (Per.comm.). However, the introduction of carp species was made by the Ministry of Agriculture with the intention of boosting fish production and effective utilization of the ecosystem. *Barbus ethiopicus* and *Garra mekiensis* are endemic species to Lake Ziway (Golubtsov *et al*., 2002). *O. niloticus* and *B. intermedius* are known to be native species to all the three lakes studied.

Methods

Fish samples were collected monthly from October 2005 to February 2006 using gill nets of different mesh size (60mm, 80mm, 100mm, 120mm and 140mm). A total of 1009 fish specimens were collected from all the lakes: Koka (n = 205), Ziway (n = 279) and Langano (n = 525). The total length and total weight of fresh fish samples were measured to the nearest 0.1cm and 0.1g, respectively. Length-weight relationship was calculated using power function (Le Cren, 1951):

$$W = aL^b$$

Where, "a" is the intercept,"b" is the slope of length-weight regression, W is total weight (g) and L is total length (cm).

Fulton's condition factor (K) is often used to reflect the nutritional status or "well-being" of an individual fish. Fulton's condition factor was calculated using the formula indicated below (Lagler, 1956):

$$K = \frac{Weight}{(Length)^3} * 100$$

The value of "K" was statistically tested using statistical software (Statistica, 2004) to determine variation between lakes, sex and months.

After the fish samples were dissected, the sexes were identified and stage of maturity recorded using excel sheet. A five point maturity index (immature/virgin (stage I), developing virgin/recovering spent (stage II), maturing/ripening (stage III), ripe and running (stage IV), and spent (stage

V) were used to determine the maturity stages based on the size and general morphological appearance of the gonads (Nikolskey, 1963 cited in Tesfaye Wudneh, 1998). The length at first/massive maturity (L_{50}) was estimated by classifying the gonads as immature and mature. Fishes with maturity stage I and II were considered as immature and maturity stage III and above were considered as mature. The relationship between the percentage of mature fish (P) per length class and fish length (X in cm) was described with a logistic curve and L_{50} was estimated according to Gunderson *et al*. (1980):

$$P_x = \frac{1}{\left(1 + e^{(bx+a)}\right)}$$

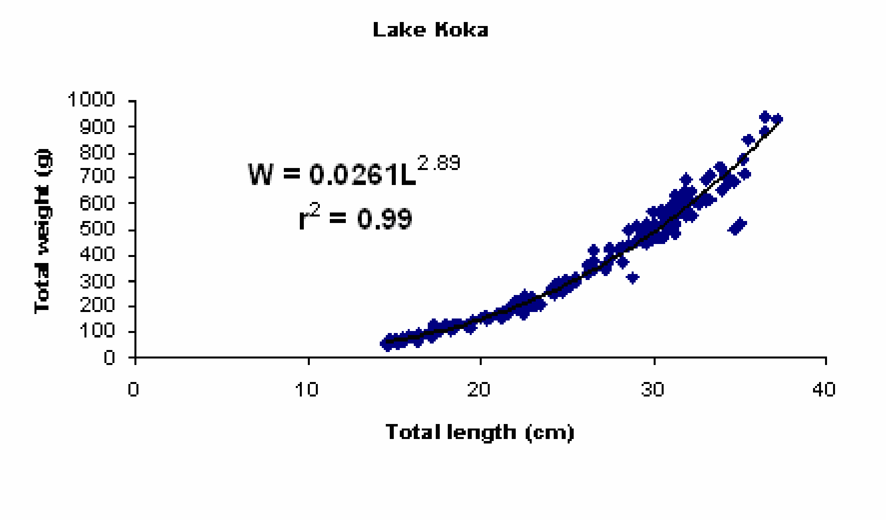
Where, P_x is the proportion of mature fish at length class x; a and b are model parameters (a, intercept and b, slope of the logistic regression). The L_{50} was then derived from the relationship of "a" and "b":

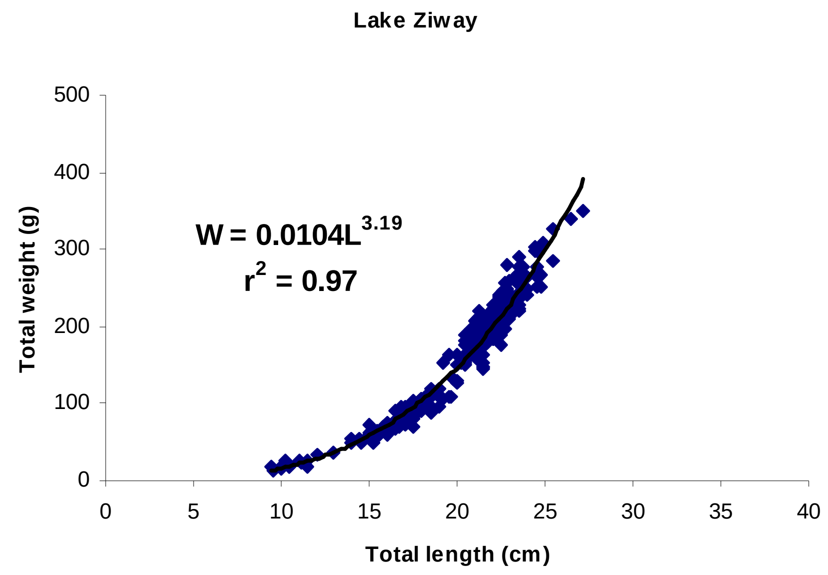
$$L_{50} = -\frac{a}{b}$$

RESULTS

Length-Weight relationship

The maximum length (L_{max}) sampled was considerably smaller in Lakes Ziway (27.2cm) and Langano (29cm) than Lake Koka (37.2cm). Mean length (L) and standard deviations (± s) were 20.1 ± 3.5 cm (Ziway), 19.2 ± 2.3 cm (Langano) and 25.1 ± 6.5 cm (Koka). The length–weight relationship of *O. niloticus* in all the three lakes was curvilinear (Fig. 2). Length-weight relationships were calculated for *O. niloticus* in Lakes Koka as ($W = 2.61*10^{-2}L^{2.89}$; $n = 205$; $r^2 = 0.99$), Ziway as ($W = 1.04*10^{-2}L^{3.19}$; n = 279; $r^2 = 0.97$) and Langano as ($W = 1.64*10^{-2}L^{3.04}$; $n = 525$; $r^2 = 0.88$).


Lake Koka
W = 0.0261L^2.89
r^2 = 0.99
Total weight (g)
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
Total length (cm)


Lake Ziway
W = 0.0104L^3.19
r^2 = 0.97
Total weight (g)
500
400
300
200
100
0
0
5
10
15
20
25
30
35
40
Total length (cm)

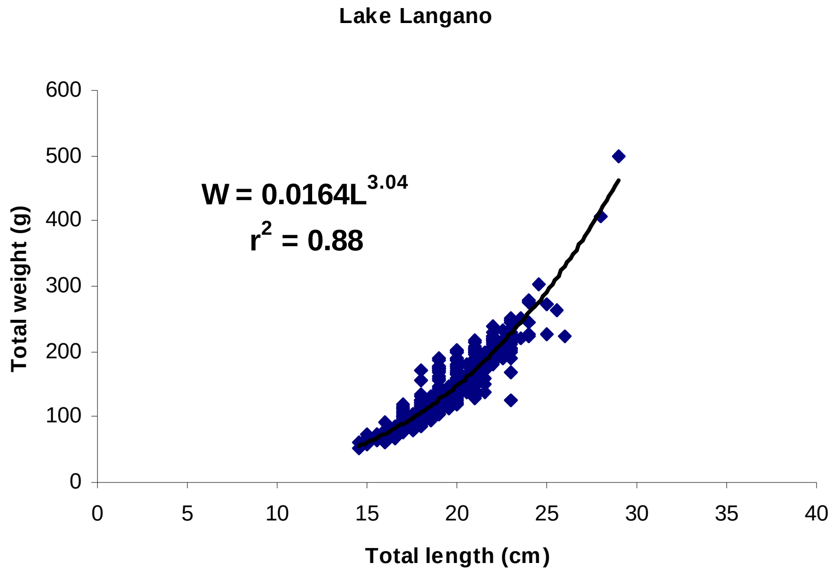
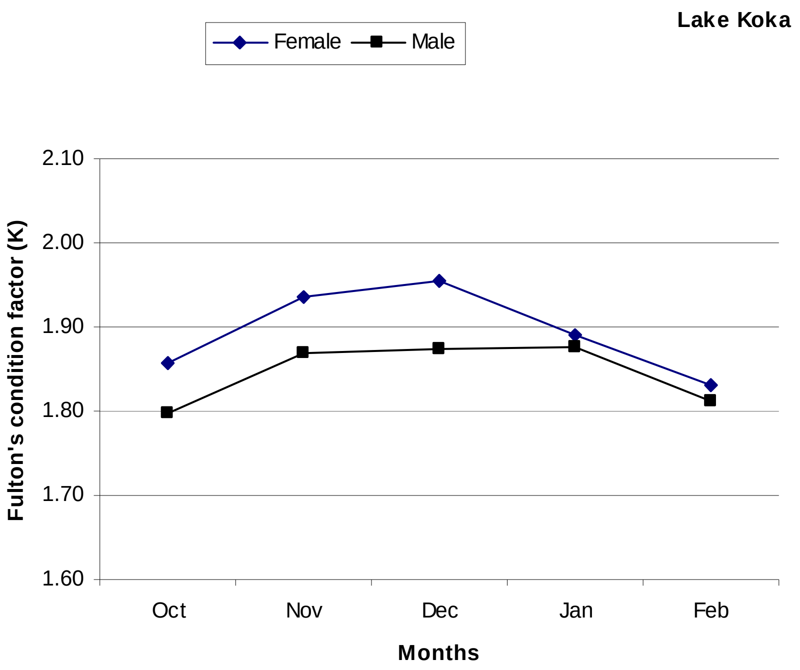
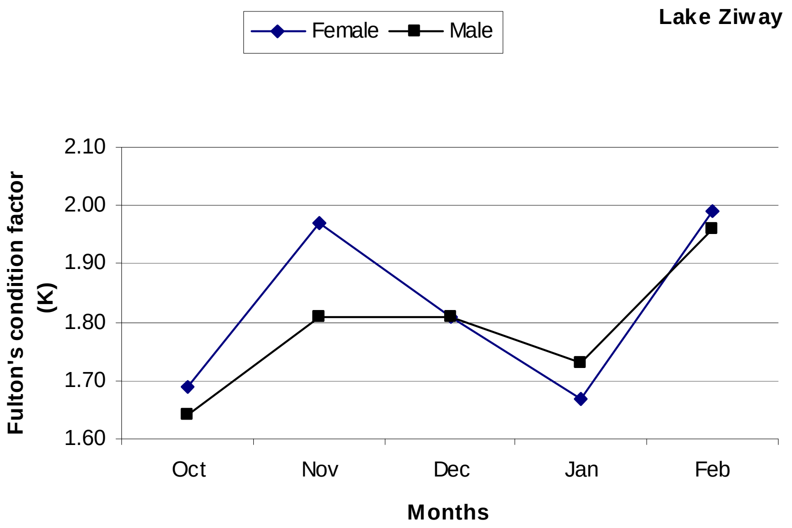


Fig.2. Length-weight relationship of *O. niloticus* in Lakes Koka, Ziway and Langano.

Fulton's condition factor (K)

The average K value of *O. niloticus* from Lake Koka (1.87) was slightly higher than Lakes Ziway (1.81) and Langano (1.84). Statistically, two types of comparisons were made to test if K values varied between months and sex: "within" comparison (within each lake) and "in between" comparison (among the three lakes). There was statistically significant difference between lakes and months interaction (one-way ANOVA, $P < 0.05$). The means were compared with Scheffe test and the K of *O. niloticus* in Lake Koka was significantly different from Lakes Ziway and Langano in October and January (Fig. 3). However, the comparison within lakes revealed that there was no significant difference between the sexes (t-test, $P > 0.05$) and months in Lake Koka (one-way ANOVA, $P > 0.05$) but there was significant difference in Lakes Langano and Ziway. Scheffe test for K of *O. niloticus* in Langano showed significant difference for all sampling occasions except between November and December. In Lake Ziway, there was no difference in k values between October and January but all the rest were significantly different.


Lake Koka
Female
Male
Fulton's condition factor (K)
2.10
2.00
1.90
1.80
1.70
1.60
Oct
Nov
Dec
Jan
Feb
Months


Lake Ziway
Female
Male
Fulton's condition factor (K)
2.10
2.00
1.90
1.80
1.70
1.60
Oct
Nov
Dec
Jan
Feb
Months

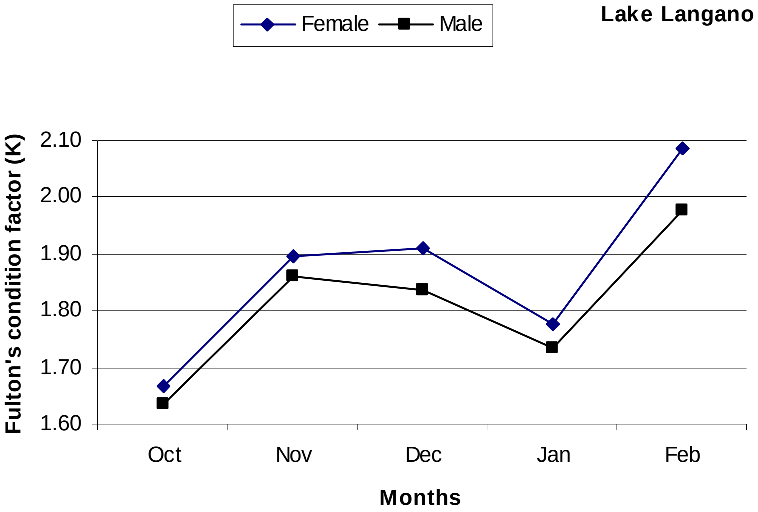
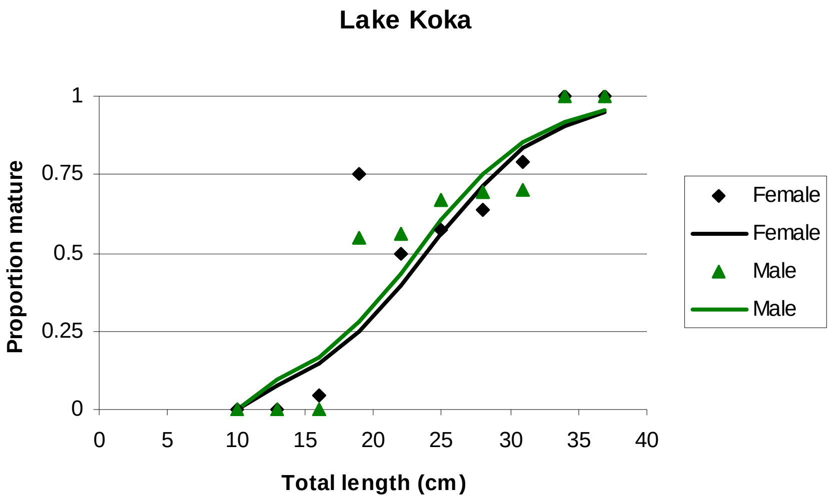
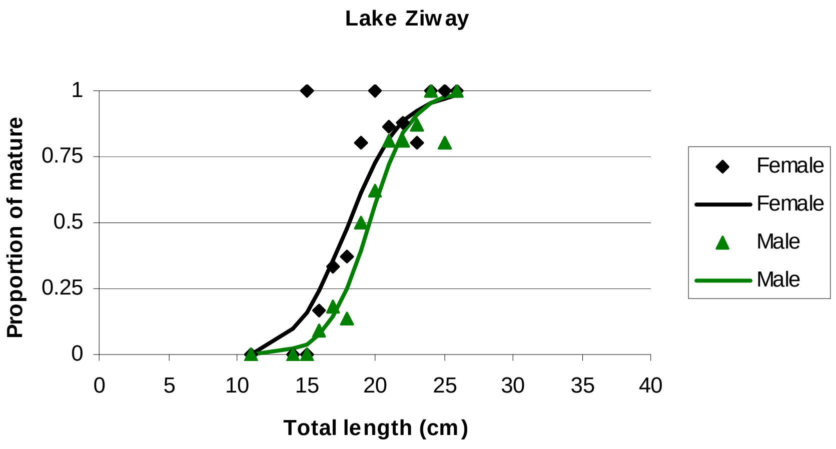


Fig.3. Fulton's condition factor of *O. niloticus* in Lakes Koka, Ziway and Langano.

Length at first maturity (L_{50})

The smallest sexually mature male and female *O. niloticus* caught during the sampling period were 18.2cm and 17.4cm TL from Lake Koka; 17.3cm and 16cm from Lake Ziway and 17cm and 16cm from Lake Langano, respectively. The L_{50} of male and female was 19.6 cm and 18.1 cm TL from Lake Ziway, respectively. But in Lakes Langano and Koka, it was about 19.5cm and 23.5cm TL for both sexes, respectively (Fig. 4). This indicates that females matured at smaller size than males in Lake Ziway but no size difference was observed between the sexes in Lakes Langano and Koka. Moreover, *O. niloticus* from Lakes Ziway and Langano matured at smaller size than in Lake Koka.


Lake Koka
1
0.75
0.5
0.25
0
Proportion mature
0
5
10
15
20
25
30
35
40
Total length (cm)
Female
Female
Male
Male


Lake Ziway
1
0.75
0.5
0.25
0
Proportion of mature
0
5
10
15
20
25
30
35
40
Total length (cm)
Female
Female
Male
Male

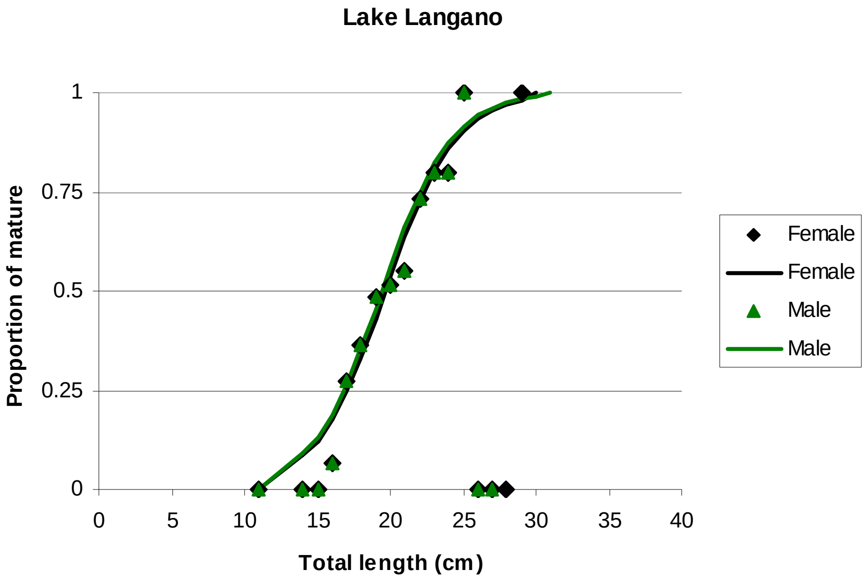


Fig.4. L_{50} of male and female *O. niloticus* in Lakes Koka, Langano and Ziway.

DISCUSSION

There is a curvilinear relationship between total length and total weight of *O. niloticus* in Lakes Ziway, Koka and Langano as has been reported earlier for the same species in Lakes Tana, Awassa and Chamo (Zenebe Tadesse, 1988; 1997; Demeke Admasu, 1990; Yirgaw Teferi and Demeke Admasu, 2002). Regression coefficients obtained from length-weight relationships which are indicative of isometric or allometric growths differ not only between species but also between stocks of the same species. The exponent 'b' of the length-weight relationship obtained in this study was near to the cube value (b = 2.89, 3.04 and 3.19 in Lakes Koka, Langano and Ziway, respectively) indicating isometric growth (Wolff and Aroca, 1995), which means that the fish grew well and gained weight proportional to their lengths. *O. niloticus* in Lakes Ziway, Awassa, Chamo and Tana was found to have "b" value of 3.03 (Zenebe Tadesse, 1988), 2.90 (Demeke Admasu, 1990), 2.98 (Yirgaw Teferi and Demeke Admasu, 2002) and 2.74 (Zenebe Tadesse, 1997), respectively, which is similar to the values obtained in the present study. The parameters a and b can also be used as input parameter for the length structure virtual population analysis (VPA) so as to determine the F-array representing the fishing mortality for each length group and the mean stock biomass by length class (Pauly, 1984).

The Fulton's condition factor (K) indicates the nutritional level and status of the fish over time and hence, indirectly measures the well being of the fish (Bagenal and Tesch, 1978). The average K value of *O. niloticus* in Lakes Koka (1.87), Ziway (1.81) and Langano (1.84) is slightly lower than values reported for the same fish from Lakes Awassa (2.03) and Chamo (2.35) (Eyualem Abebe and Getachew Tefera, 1992; Yirgaw Teferi and Demeke Admasu, 2002). The higher K value of *O. niloticus* in Lake Koka relative to Lakes Ziway and Langano might be due to the associated floodplain, which is known to be one of the most productive aquatic ecosystems. Unlike the present study, Zenebe Tadesse (1988; 1999) reported high value of K = 1.89 and lower values of K = 1.67 in Lakes Ziway and Langano, respectively. The difference between these studies might be due to change in the environmental condition of the lakes between the two periods and thereby change in the nutritional status of the fish. For instance, the presence of catfish (predator of *O. niloticus*) in Lake Ziway was never reported before 1994 (LFDP, 1995) and it is generally believed that it was accidentally introduced from the nearby Ziway Fish Processing and Marketing Center. This suggests that the study made by Zenebe Tadesse (1988) was done before the introduction of catfish into Lake Ziway. Therefore, the lower value of K for *O. niloticus* in Lake Ziway in the present study might be due to the presence of predator catfish which formed a new predator-prey interaction that cause additional cost of energy for the tilapia.

In general, K values of females were higher than males in all the studied lakes. This might be due to the higher gonad weight of females than males which result in higher total body weight. Seasons are also known to affect the condition of fish. The low K value in January coincides with the peak spawning season of the fish. In Lake Ziway, *O. niloticus* breeds throughout the year but the intensity increases from December to March (Zenebe Tadesse, 1988). The condition of fish can be affected by several factors such as the environment, stress, availability of food and food quality, feeding rate, degree of parasitism and reproductive activity (Getachew Tefera, 1987; Teshima *et al*., 1987; Stewart, 1988).

Stewart (1988) observed that stress due to reduction in the breeding and nursery grounds of *O. niloticus* in Lake Turkana resulted in lower condition of fish. Pollution was also seen to affect the condition factors of *O. niloticus* in Lake Mariut, Egypt (Bakhoum, 1994). Variations in condition factor with seasons and pollution has also been documented by Khallaf *et al*., (2003) in Shanawan drainage canal in Egypt. Maternal mouth brooders like *O. niloticus* fast or take less food during the early stages and probably throughout the brooding period (Fryer and Iles, 1972 cited in Yirgaw Teferi and Demeke Admasu, 2002). The males are also busy in building and guarding nests and fertilizing many females (Zenebe Tadesse, 1997; Fryer and Iles, 1972 cited in Demeke Admasu and Casselman, 2000). They mobilize energy from their body reserve for maintenance of their normal physiology. Similarly, the low K value in October probably indicates that the fish had not recovered from the previous peak breeding season that extends from July to September in the rift valley lakes (Tudorancea *et al*., 1988; Demeke Admasu, 1996).

Size at first sexual maturity of *O. niloticus* was higher in Lake Koka than in Langano and the largest of the three Lake Ziway (Table 1; Fig.4). This is unusual as many studies confirmed positive correlation between size at first maturity and the size of the water body for tilapia species (Lowe-McConnell, 1958, 1982; De Silva, 1986; Legendre and Ecoutin, 1989, 1996; Duponchelle and Panfili, 1998). Among the six stocks studied in Ethiopia (Table 3), *O. niloticus* from Lake Koka showed larger size at first sexual maturity (23.5cm TL) next to Lake Chamo (42cm). This might be due to their slower growth rate (von Bertalanffy growth parameter K = 0.26 to 0.36 $year^{-1}$) as compared to the other stocks ($K \geq 0.4\ year^{-1}$) and possibly due to the low fishing pressure (Gashaw Tesfaye, 2006).

Table 3 L_{50} of *O. niloticus* in different water bodies of Ethiopia and some other African countries.

Lake	Country	Male (TL, cm)	Female (TL, cm)	Reference
Awassa	Ethiopia	19.8	18.8	Demeke Admasu,1994
Tana	Ethiopia	20.7	18.1	Tesfaye Wudneh, 1998
Chamo	Ethiopia	42.0	42.0	Yirgaw Teferi *et al*.,2001
Turkana	Kenya	-	29.6	Harbott and Ogari, 1982
Victoria	Kenya	34.5	30.8	Njiru *et al*., 2006
Albert	Uganda	14.0	12.0	Trewaves, 1983
Ihema	Rwanda	18.0	18.7	Leveque, 1997
Koka	Ethiopia	23.1	23.9	Present study
Ziway	Ethiopia	19.6	18.1	Present study
Langano	Ethiopia	19.4	19.7	Present study

Earlier studies showed that L_{50} of *O. niloticus* could vary between lakes and sexes (Trewavas, 1983; Demeke Admasu, 1994; Tesfaye Wudneh, 1998; Njiru *et al*., 2006). However, similar L_{50} values have also been reported for both sexes (Leveque, 1997; Yirgaw Teferi *et al*., 2001). Size at first maturity appears to be a very plastic trait that stocks can adjust depending on demographic conditions and is determined by both genes and environment.

Balarin and Hatton (1979) and Yirgaw Teferi and Demeke Admasu (2002) also noted that L_{50} was related with the condition of the fish; and *O. niloticus* individuals that are in poor condition tend to breed at smaller sizes than those in good condition.

CONCLUSIONS

O. niloticus shows isometric growth in Lakes Koka, Ziway and Langano, not changing shape along ontogenetic phases. However, the body condition of the fish was found to be different between lakes and months but not between the sexes. The higher K value of *O. niloticus* in Lake Koka as compared to Lakes Ziway and Langano might be due to the associated floodplain that gives more space and food for the fish in Lake Koka. The mean size of *O. niloticus* in the catch and the L_{50} was higher in Lake Koka than in Lakes Ziway and Langano indicating that there was high fishing pressure in the latter two lakes. Generally, it has been established that fish mature earlier in smaller water bodies than in larger ones. This principle might hold true if the lakes were managed properly but was not the case in practical terms. Therefore, the nutritional status and the level of fishing pressure could be the overriding factors that affected the size of maturity of *O. niloticus* in the lakes studied.

ACKNOWLEDGEMENTS

Sebeta National Fisheries and other Aquatic Life Research Center (NFALRC) is greatly acknowledged for providing logistics for the field work. NFALRC staff particularly Mrs. Abeba W/Gebreal, Ato Fikadu Tefera, Ato Niguse Ergetie, Ato Kebede Bereda, Ato Birhan Jemal and Ato Tsegaye Dadi were helpful during the field work in fish sample collection, measuring and recording the data. The study was financed by the German Academic Exchange Service (DAAD).

REFERENCES

Anderson, O. R. and Neumnn R. M. (1996). Length-weight and associated structural indices, In: **Fisheries techniques**, pp 447 – 482 (Nielsen, L. A. and Johnson, D. L. eds), Bethesda, American Fisheries Society.

Amha Belay and Wood R. B. (1984). Primary productivity of five Ethiopian Rift Valley Lakes. *Verh. int. Ver. Limnol*. **22**: 1187-1192.

Balarin, J. D. and Hatton, J. (1979). **Tilapia: A guide to their biology and culture in Africa**. University of Stirling, Scotland. pp. 1-42

Bagenal, T.B. and Tesch A.T. (1978). **Conditions and growth patterns in fresh water habitats**. Blackwell Scientific Publications, Oxford.

Bakhoum, S.A. (1994). Comparative study on length-weight relationship and condition factors of the *Oreochromis* in polluted and non-polluted parts of Lake Mariut, Egypt. *Bull. Natl. Inst. Oceanogr. Fish.* **20**: 201-210.

Beyer, J. E. (1987). On length weight relationships. Part I: Computing the mean weight of the fish of a given length class. *Fishbyte, Manila* **5**: 11 – 13.

Bolger, T. and Connolly P. L. (1989). Selection of suitable indices for the measurement and analysis of fish condition. *J. Fish. Biol.* **34**: 171 – 182.

Demeke Admasu (1990). Some morphometric relationships and the condition factor of *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Awassa, Ethiopia. *SINET: Ethiop. J. Sci.* **13**: 83–96.

Demeke Admasu (1994). Maturity, fecundity, brood-size and sex ratio of Tilapia (*Oreochromis niloticus* L .) in Lake Awassa . *SINET: Ethiop. J . Sci* . **17**: 53-69.

Demeke Admasu (1996). The breeding season of tilapia, *Oreochromis niloticus* L. in Lake Awassa (Ethiopian Rift Valley). *Hydrobiologia* **337**: 77–83.

Demeke Admasu and Casselman J. M. (2000). Otolith age determination for adult tilapia, *Oreochromis niloticus* L. from Lake Awassa (Ethiopian Rift Valley) by interpreting biannuli and differentiating biannual recruitment. *Hydrobiologia* **418**: 15 – 24.

De silva S.S. (1986). Reproductive biology of *Oreochromis mossambicus* populations of man-made lakes in Sri Lanka: A comparative study. *Aquacult. Fish. Manag.*, **17**: 31-38.

Duponchelle, F. and Panfili J. (1998).Variations in age and size at maturity of female Nile tilapia, *Oreochromis niloticus,* populations from man-made lakes of Côte d'Ivoire. *Environ. Biol. Fish.* **52**: 453-465.

Elizabeth Kebede and Amha Belay (1994). Species composition and phytoplankton biomass in a tropical African lake (Lake Awassa, Ethiopia). *Hydrobiologia* **288**: 13-32.

Elizabeth Kebede, Zinabu Gebre-Mariam and Ahlgren I. (1994). The Ethiopian Rift valley lakes: chemical characteristics of a salinity-alkalinity series. *Hydrobiologia* **288**:1-12.

Eyualem Abebe and Getachew Tefera (1992). Seasonal changes in the nutritional status of *Oreochromis niloticus* L. (Pisces:Cichlidea) in Lake Ziway, Ethiopia. *Arch. Hydrobiol.* **124**(1):109-122

Gashaw Tesfaye (2006). **Population dynamics and stock assessment of Nile tilapia, *Oreochromis niloticus* L. in three Rift Valley Lakes (Koka, Ziway and Langano), Ethiopia.** M.Sc thesis. University of Bremen, Germany. 80 p

Getachew Tefera (1987). **Food, nutrition and digestive efficiency in *Oreochromis niloticus* L. (Pisces:Cichlidae) in Lake Awassa, Ethiopia.** Ph.D. thesis, University of Waterloo, Waterloo, Canada.

Golubtsov, A.S., Dgebuadze, Yu.Yu. and Mina M.V. (2002). Fishes of the Ethiopian Rift valley. In: **Ethiopian Rift Valley Lakes**, pp.167-256 (Tudorancea, C. and Taylor, W.D., eds.), Backhuys Publ., Leiden, Holland.

Gunderson, D. R., Callahan, P. and Goiney B. (1980). Maturity and fecundity of four species of *Sebastes*. *Mar. Fish. Rev*. **42**(3-4)**:**74–79.

Harbott, B.J. and Ogari J.T.N. (1982). The biology of the larger cichlid fish of Lake Turkana. In: **A report on the findings of the Lake Turkana Project 1972-1975**, pp 1331-1355 (Hopson, A.J., ed.), ODA, London. Univ. Sterling, Sterling.

IUCN (2003). Wetlands of Ethiopia. In: **Seminar on the Resources and Status of Ethiopian Wetlands**, p 116 (Yilma Dellelegn and Kim Geheb, eds.).

Khallaf, E.A., Galal, M. and Authman, M. (2003). The biology of *Oreochromis niloticus* in a polluted canal. *Ecotoxicology* **12**: 405-416.

Lagler, K. F. (1956). **Freshwater fishery biology**. 2nd ed. W.C. Brown Publishers, Dubuque, Iowa.

Le Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in perch *(Perna fluviatilis). J. Anim. Ecol.* **20**: 201-219.

Legendre, M. and Ecoutin, J.M. (1989). Suitability of brackish water tilapia species from the Ivory Coast for lagoon aquaculture. I-Reproduction. *Aquat. Living Resour.* **2**: 71-79.

Legendre, M. and Ecoutin, J.M. (1996). Aspects of the reproductive strategy of *Sarotherodon melanotheron*: Comparison between a natural population (Ebrie lagoon, Côte d'Ivoire) and different cultured populations. In: **3rd International Symposium on Tilapia Aquaculture**, pp.326-338 (Pullin, R.S.V., Lazard, J., Legendre, M., Amon Kothiasm, J.-B. and Pauly, D., eds.), Abidjan, Côte d'Ivoire.

Leveque, C.L. (1997). **Biodiversity dynamics and conservation: The freshwater fish of tropical Africa**. ORSTOM. Cambridge Univ. Press, U.K. 438 p.

LFDP (1995). **Fisheries statistical bulletin** No. 2. Working paper No. 19. Ministry of Agriculture, Addis Ababa. 30 p.

LFDP (1996). **Lake management plans**. Working paper, No**.23**. Ministry of Agriculture. Addis Ababa. 31 p.

LFDP (1997). In: **National fisheries seminar**. Working paper, No.25. Ministry of Agriculture. Addis Ababa. 170 p.

Lowe-McConnell, R . H . (1958). Observation on the biology of *Tilapia nilotica* L. in East Africa waters. Rev. *Zoo. Bot. Afr*. **57**:129-170

Lowe-McConnell, R. H. (1982). Tilapias in fish communities. In: **The biology and culture of tilapias**, pp. 83-113 (Pullin, R. S .V. and Lowe-McConnell, R. H., eds.), ICLARM conference Proceedings. Philippines, Manila.

Melaku Mesfin, Tudorancea C. and Baxter R. M. (1988). Some limnological observations on two Ethiopian hydroelectric reservoirs: Koka (Shewa administrative district) and Finchaa (Welega administrative district). *Hydrobiologia* **157**: 47 – 55.

Njiru, M., Ojuok, J. E., Okeyo-Owuor, J. B., Muchiri, M., Ntiba, M. J. and Cowx, I. G. (2006). Some biological aspects and life history strategies of Nile tilapia *Oreochromis niloticus* (L.) in Lake Victoria, Kenya. East African Wild Life Society. *Afr. J. Ecol*. **44**: 30–37.

Pauly, D. (1984). **Fish population dynamics in tropical waters: A manual for use with programmable calculators.** ICLARM Stud. Rev. (8): 325p.

Reyntjens, D., Tarekegn Mengistu and Tesfaye Wudneh (1998). Fisheries development in Ethiopia: Which way now? *Eur. Com. Fish. Bull.* **11**(1): 20-22.

Stewart, K.M. (1988). Changes in condition and maturation of the *Oreochromis niloticus* L. Population of Ferguson's Gulf, Lake Turkana, Kenya. *J. Fish Biol*. **33**: 181-188.

Tenalem Ayenew (2004). Environmental implications of changes in the levels of lakes in the Ethiopian Rift since 1970. *Reg. Environ. Change* **4**:192-204

Tesfaye Wudneh (1998). **Biology and management of fish stocks in Bahir Dar Gulf, Lake Tana, Ethiopia.** Ph.D. dissertation. Wageningen Agricultural University, The Netherlands. 144 p.

Teshima, S., Kanazawa, A. and Koshio, S. (1987). Effects of feeding rate, fish size, and dietary protein and cellulose levels on the growth of *Tilapia nilotica*. *Mim. Fac. Fish* **36**: 7-15

Trewavas, E. (1983). Tilapiine Fishes of the Genera *Sarotherodon*, *Oreochromis* and

Danakilia. British Mus. Nat. Hist., London, UK. 583 p.

Tudorancea, C., Fernando C. H. and Paggi, J. C. (1988). Food and feeding ecology of *Oreochromis niloticus* (Linnaeus, 1758) juveniles in Lake Awassa, Ethiopia. *Arch. Hydrobiol. Suppl*. **79** : 267-289.

Tudorancea, C., Zinabu Gebre-Mariam and Elias Dadebo (1999). Limnology in Ethiopia. In: **Limnology in developing countries,** pp 63-118 (Wetzel, R.D. and Gopal, B., eds.). International Association of Theoretical and Applied Limnology (SIL). New Delhi. 330 p.

Wolff, M. and Aroca, T. (1995). Population dynamics and fishery of Chilean squat lobster *Cervimunida johni* Porter, (decapoda, Galatheidae) off the coast of Coquimbo, northern Chile. *Revista de Biologia Marina Valparaiso* **30**(1)**:**57-70

Wood, R.B. and Talling, J.F. (1988). Chemical and algal relationship in a salinity series of Ethiopian inland waters. *Hydrobiologia* **158**:29-67.

Wood, R.B., Prosser, M.V. and Baxter, R.M. (1978). Optical characteristics of the Rift Valley Lakes, Ethiopia. *SINET: Ethiop. J. Sci*. **1**: 73-85.

Yirgaw Teferi and Demeke Admasu (2002). Length-weight relationship, body condition and sex ratio of Tilapia (*Oreochromis niloticus* L.) in Lake Chamo, Ethiopia. *SINET: Ethiop. J. Sci.* **25**(1):19-26

Yirgaw Teferi, Demeke Admasu and Seyoum Mengistu (2001). Breeding season, maturation and fecundity of *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Chamo, Ethiopia. *SINET: Ethiop. J. Sci.* **24**(2):255-264.

Zenebe Tadesse (1988). **Studies on some aspects of the biology of *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Ziway, Ethiopia.** M.Sc thesis, Addis Ababa University, Addis Ababa. 78p.

Zenebe Tadesse (1997). Breeding season, fecundity, length-weight relationship and condition factor of *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Tana, Ethiopia. *SINET: Ethiop. J. Sci*. **20**(1):31-47.

Zenebe Tadesse (1999). The nutritional status and digestibility of *Oreochromis niloticus* L. diet in Lake Langano, Ethiopia. *Hydrobiologia* **416**: 97–106.

Zinabu Gebre-Mariam, Elizabeth Kebede and Zerihun Desta (2002). Long-term changes in chemical features of waters of seven Ethiopian rift-valley lakes. *Hydrobiologia* **477:** 81–91