A STUDY ON THE AGE AND GROWTH OF ADULT *Oreochromis niloticus* Linn. (PISCES: CICHLIDAE) IN LAKE AWASSA, ETHIOPIA

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BY
DEMEKE ADMASU
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TABLE OF CONTENTS

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ABSTRACT

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A study was conducted to determine what methods could be used to assess the age and growth of O. niloticus in Lake Awassa, Ethiopia. Furthermore, factors responsible for the seasonal growth cycle of the fish were investigated. Otoliths (sagittae) and scales were examined in relation to seasonal variation in some biological and environmental parameters.

Otoliths and scales were found to form translucent zones and checks twice a year, during January to February and June to July. Growth can, therefore, be slow in this period. Spawning activity, decrease in water temperature and the probable decrease in the quantity of food consumed during spawning and the poor quality food consumed during these months were considered to be responsible for slow growth. Otoliths and scales showed deposition of new tissue during March to May and August through to December. Growth was believed to resume at a relatively faster rate in these months due to completion of spawning, and increase in water temperature. The quantity and quality of the food consumed by the fish could also increase during periods of fast growth.

The first annulus in otoliths could not be identified. Therefore, average lengths-at-relative age were calculated for fish with 6, 8, 10, 12, 14 and 16 translucent zones in their otoliths. These data are each one year older and were used to estimate the parameters of the von Bertalanffy growth equation.

Loo was 30.0 cm for the males but, 29.4 for the females. K was 0.46 for the males and it was 0.38 for the females. The theoretical age, t_0, was found to be 0.15 year for the males and -0.08 year for the females.

Relative linear growth rates (G) estimates from otolith method, from length-frequency method and from marked fish closely agreed. This verified that results obtained from the otolith method could be used to describe the average growth pattern of O. niloticus population in the lake.

The sixth translucent zone in otoliths was believed to be formed at the end of the first year of life. Ages estimated using Gulland's (1969) method provided supportive evidence. Therefore, the 6th to the 16th translucent zones correspond to the 1st to the 6th year of life, respectively. Ages were assigned based on this finding. This indicated that more rapid growth in favour of the males was apparent at and after the second year of life.

Length-frequency distribution of experimental commercial catch indicated that the commercial gillnet caught fish in their second year of life and older. This gear does not catch immature fish.

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LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

The ability to increase in size is one of the most fundamental characteristics of all living things, and the study of the growth of organisms is basic to understanding of their biology (Fryer and Iles, 1972). In connection with fish which are exploited by man, growth studies are absolutely essential since it is the growth of fish that provides the catch (yield) taken by man. It is the primary aim of fisheries biologists to secure valuable information for management activities so that fish biomass is removed only as rapidly as it can be replaced. Such management goals can be achieved only if the growth of the fish is known. It is, therefore, apparent that fish growth studies are vital component of fisheries science.

Growth of fishes is usually expressed in single equations such as the von Bertalanffy growth function (VBGF) (von Bertalanffy, 1957, cited in Ricker, 1975), which, in terms of length, has the following form :

$$L_t = L_{oo}\ (1-e^{-K(t-to)})$$

'L_t' is average length at age 't'; 'L_{oo}' is the theoretical asymptotic maximum length to which the fishes grow; 'K' is growth coefficient which measures the rate at which 'L_{oo}' is approached. The parameter 't_0' is a theoretical age at which the fishes are said to have a zero length if they grow according to the equation. The parameters 'L_{oo}', 'K' and 't_0' are important because they are used in yield equations (Allen, 1966). Size-at-absolute age data are required to obtain accurate estimates of these parameters. Size-at-relative age data can still be used but, will not provide an accurate estimate of 't_0' (Pauly, 1979).

The ability to age fish is absolutely essential, as almost all management activities are based directly or indirectly on this ability. In addition to providing basic data to estimate growth, information relevant to management which can be secured from determining the age of fishes includes mortality rates (Garrod, 1963; Deriso, 1982; Essig and Cole, 1986), age at sexual maturity and number of spawnings per life span (Diana, 1983; Haist and Stocker, 1985; Kilambi, 1986), abundance of year classes and population structure (Hodgkiss and Man, 1977; Linfield, 1979; Harris and Grossman, 1985). Knowledge of rates of mortality and growth, and the relative numbers of juvenile and mature fish in a population, are required to answer questions about how exploitation affects the population. Information on age at sexual maturity is important to restrict fishing so that a sufficient number of the parent stock reproduce before being harvested.

Although the study of age and growth of fish is a practice started long ago methods are still subjective. However, all present management activities are based on these subjective methods. There are now three basic approaches to assess the age and growth of fishes: the empirical; the mathematical; and the anatomical. There are a number of comprehensive descriptions of these methods (De Bont, 1967; Bagenal and Tesch, 1978; Brothers, 1979; Jearld, 1983).

The empirical approach is based on direct observation of fishes held in confinement (ponds, cages, aquaria, etc.) or of fishes marked and released and then subsequently recaptured. Accurate 'known-age' data would be obtained if the fishes are artificially fertilized (Casselman, 1987) but, if they are captured from the natural environment, marked and released, upon recapture they provide 'partly known-age' data to the time between marking and recapture (Casselman, 1987). The empirical approach, though direct, is, therefore, based on some what artificial conditions and factors. It has, however, received the attention of numerous workers who mostly used it to test the validity of the other approaches (eg., Rinne, 1975; McCaughran, 1981; Smith, 1984).

The mathematical approach, also called 'length-frequency analysis' or 'Petersen's method', utilizes length-frequency distributions to assess age indirectly. The basis to this method is that if spawning is restricted to a relatively short period of time during the year, such that a regular influx of new recruits occurs, adequate and randomly taken length data depict a length-frequency distribution which features a series of modes corresponding to successive age groups (Iles, 1971; Tesch, 1971; Pauly, 1983).

The anatomical approach, also referred to as osseochronometry (Casselman, 1987), refers to age assessment from checks and zonations resulting from the cyclic growth of calcified fish tissues such as scales, otoliths, fin rays, vertebral centra and in flat bones like opercula and cleithra. That these calcified tissues do frequently bear checks or zones to which a regular time scale can be assigned makes oseochronometry the most commonly used method in the current science of fish growth. These checks and zones are used to assess the age of the fish if they conform to the definition of the 'annulus'. As defined by Casselman (1983) annulus is a mark on or in a calcified structure that is associated with the distal edge of a concentric ring in the form of a check in scale and a translucent zone in other calcified structures; and is considered to separate the check or zone associated with the principal annual cessation or reduction in growth from the tissue deposited when growth resumes or increases. The annuls has even been used to 'back-calculate' previous sizes-at-age of individual fish based on empirically determined relationship between body size and the size (diameter, radius, etc.) of these structures (eg., Hile, 1970; Bagenal and Tesch, 1978).

Most of the methods work reasonably well in temperate regions but, in the tropics application of these methods has often been difficult. The empirical approach does not require a seasonal environment but, it is used least in the tropics due to the lack of adequate facilities and resources. Most fish spawn through out the year in the tropics and their life cycle is often short (Welcomme, 1967). The length-frequency method is, therefore, less useful for such fish. Furthermore, due to the small seasonal fluctuation in tropical climates, regular checks and zones may not be formed in calcified tissues. However, seasonal variation does exist in many tropical waters, caused primarily by the seasonal nature of rainfall and winds (Lowe-McConnell, 1987). Due to these and other associated seasonal factors, certain tropical fishes have spawning activities restricted to a few months like many temperate fishes (see Balon, 1972), and some have seasonal fluctuations in growth resulting in formation of 'annuli' in their calcified tissues (eg., De Bont, 1967; Balon, 1972). A notable example is Tilapia esculenta from Lake Victoria (Garrod, 1959).

There is no doubt, therefore, that there is adequate seasonality in the growth of tropical fishes. This could be environmental induced or connected to reproductive activity because of subtle environmental clues to create cyclic growth. Since this cyclic growth has not been as prominent as in the temperate region fishes many considered age interpretation from tropical fish calcified tissues a problem. It is also evident that all checks and zones do not contain annulus. There is only one check or zone each year to which the annulus is associated. Therefore, the belief that two annuli are present each year in the calcified tissues of some fish species needs to be reconsidered (eg., Garrod, 1959; Balon, 1972; Hecht, 1980; Hopson, 1982). For such species of fishes the calcified tissues should be interpreted very carefully and precisely by much more detailed examination than before. Results will then be just as good as for temperate region fishes.

Although the specific physiological mechanisms involved in the formation of the 'annulus' are still far from being fully understood, a number of factors resulting in cessation of somatic growth of fish (resulting in the formation of growth checks in calcified tissues) have been identified. In temperate and "sub-temperate" regions drastic changes in temperature and associated biotic and abiotic factors are believed to cause formation of growth checks in fish calcified tissues (De Bont, 1967; Balon, 1972). In the tropics, factors associated with rainfall, wind regime and spawning activities have been suspected for this effect (eg., van Someren, 1950; Garrod, 1959; Fagade, 1974; Hopson, 1982). Balon (1972) believes that the timing and factors associated in the formation of 'annuli' in fish calcified tissues in all regions are connected to the main spawning period and/or to the period of increase in available food. Furthermore, temperature could also be an important clue in the cyclic growth of tropical fishes. This important factor has just been ignored due to the erroneous assumption that the environment is homothermous to the fishes. However, fishes could respond to very subtle changes in temperature (Casselman, 1978). The universal phenomenon that otoliths grow by daily additions of new tissue (daily increment) (Pannella, 1971 and 1974) provides more accurate age, particularly for young fishes, than was previously possible (see review by Campana and Neilson, 1985). This has now opened a new approach to determine the age of tropical fishes whose calcified tissues may not contain annuli.

It may be ,therefore, possible to use the same basic principles and methods used in the temperate zones to assess the age and growth of tropical fishes which have short spawning period (s) or form regular 'time markers' in their calcified tissues. The practical problems of the methods are also generally similar in all fish regardless of the environment. Numerous age and growth studies of tropical fish have been carried out, and that results obtained are consistent also provides a powerful proof to the validity of the methods (Fryer and Iles, 1972).

A number of comprehensive studies have justified the applicability of the methods in general. However, all methods are associated with certain difficulties. In length-frequency analysis, modes could also represent strong and weak year classes rather than age groups, and as fishes get older a number of age groups may attain approximately equal length and appear as a single mode (eg., Bagenal and Tesch, 1978). In osseochronometry, a simple count of checks or zones may not necessarily correspond to age in years. Their time of formation must be ascertained and they should be differentiated from 'pseudoannuli'. Older and slow growing fishes, especially, present considerable difficulty if osseochronometry is to be applied (Beamish and Harvey, 1969; Mills and Beamish, 1980). These practical problems would lead us to the need for validation of the methods (Beamish and McFarlane, 1983; Casselman, 1983).

Various techniques for testing the validity of age determination methods are available. The most powerful evidence comes from examining calcified tissues of fishes whose age is 'known' (Casselman, 1983). However, these are rarely available (eg., Erickson, 1983) and if available, they may be under laboratory conditions (eg., Taubert and Coble, 1977; Rice et al., 1985). Evidence from fishes whose age is 'partly known' is relatively easy to obtain and many workers have used such evidence to test the validity of their age assessment methods (eg., Casselman, 1974; Wild and Foreman, 1980; Smith, 1984; Laurs et al., 1985). A seasonal record of the conditions on the edge of calcified tissues has also been used to find the time at which checks and zones are formed (eg., Dudley, 1974; White and Chittenden, 1977; Harris and Grossman, 1985). Counting the number of daily increments between zones has been used to validate age assessment from otoliths (eg., Victor and Brothers, 1982) but, in addition to being equally subjective, one may not always get the expected number of daily growth increments if light microscopy is the only equipment available. Agreement between methods and among calcified structures have also been used to verify age assessment methods (Dudley, 1974; Bagenal and Tesch, 1978).

It is important to emphasize that carefully and systematically interpreted age and growth data are required to obtain a substantial body of scientific information applicable to proper management of tropical fish stocks. The cichlids, particularly the group commonly called tilapia, are economically the most important fish in the inland fisheries of Africa. Cichlids comprise up to 90% by weight of the total catch in these fisheries, and, among the cichlids 32-100 % is contributed by the group tilapia (Fryer and Iles, 1972, Table 17). Age and growth studies in the African cichlids are, however, not very advanced. Such basic science is urgently needed for the tilapia. Fortunately, many commercially important species in this group have spawning activity restricted to few months, and for such species age and growth has been assessed using length-frequency analysis (Iles, 1971; Dudley, 1974; Tweddle and Turner, 1977). Some calcified structures (eg., scales, otoliths and opercula) from certain species have also allowed osseochronometry to be applied (eg., Garrod, 1959; Holcik, 1974, Krupka, 1974). Based on a literature survey and their own observations, Fryer and Iles (1972) presented a generalized account on the growth of cichlids in Africa as well as in other tropical regions. This led to a better understanding of the biology and the fisheries of these important fishes, and concerned agencies have gained a lot of information for proper management and rational utilization of their stocks. Yet, such age and growth information is not available for Oreochromis niloticus (previously Tilapia nilotica) in East Africa.

This cichlid species makes the major portion of the landing from the economically important lakes of Ethiopia. Oreochromis niloticus constitutes about 50 to 60% by weight of the fish population in Lake Awassa, the site of this study (Herrmann, in preparation). Lake Awassa is economically one of the most important lakes in Ethiopia, supporting a fishery almost entirely dependent on *O. niloticus* through out much of the year. *Clarias mossambicus* is also exploited to a considerable extent during the fasting periods of the Ethiopian Coptic Orthodox Christians (during mid February to the first week of April, and during the first two weeks of August) (see also Elias, 1988). The other species in the lake are not commercially important. *Barbus intermidius* grows to a commercial size but is not in demand, possibly because it does not contain much flesh. It is, however, consumed by the local fishermen who also prefer *O. niloticus* and *C. mossambicus*. The only other species in the lake includes *Barbus amphigramma*, *Garra* sp. and *Apochalichthyes* sp.

Many workers have studied various aspects of the biology of this lake (see Description of The Study Area). Though this important lake is the most studied in the nation, information on the age and growth of the *O. niloticus* population is not available. Furthermore, no information is available on whether or not exploitation of this species is optimum, however, this species is being exploited continuously. Proper management and optimal utilization would, therefore, be an important development. Therefore, age and growth information on *O. niloticus* was badly needed. The present study was conducted to provide such information on the adult fish. Another complementary study dealing with the juveniles of this species has been carried out (Yosef, in preparation).

The purpose of this study was:

1. to determine what methods can be used to assess the age and growth of *O. niloticus* in Lake Awassa.

2. to determine what factors are responsible for the formation of 'annuli' in the calcified tissues, and how are these related to body growth.

3. to determine when the 'annuli' form, so that their validity to study growth can be tested.

4. to determine the von Bertalanffy growth parameters for *O. niloticus* in Lake Awassa.

5. to compare this growth with other populations of tilapia.

Results obtained, hopefully, will provide valuable scientific information which could be used for proper management leading to a rational utilization of *O. niloticus* in Lake Awassa. Furthermore, this study will provide base-line information for future stocking and aquaculture development in the country.

II. DESCRIPTION OF THE STUDY AREA

Lake Awassa ($6^{o}33'$ - $7^{o}33'$N and $38^{o}22'$ - $38^{o}29'$E) is located approximately in the southern third of the Ethiopian rift valley, about 275 km south of Addis Ababa (Figure 1). Some morphological characteristics of the lake are presented in Table 1.

Various aspects of the Ethiopian rift valley and its lakes have been described by many workers (Mohr, 1962 and 1966; Grove and Goudie, 1971; Grove et al., 1975; Beadle, 1981; Von Damm and Edmond, 1984). Lake Awassa is believed to be volcano-tectonic in origin and lies in a caldera approximately 30 Km in diameter and 1,350 km^2 in area (Makin et al., 1975). The surrounding volcano-lacustrine hills rise up to 2000 m (Mohr, 1962), but the lake is situated at an altitude of about 1680 m.

The land between the hills and the lake is cultivated mainly with maize and sisal, but a considerable area is also cultivated with sun-flower. Large herds of cattle and a small number of horses are watered daily on the east and west shores of the lake. Getachew (1987) also reported seedling culture activities near the lake shore.

Lake Awassa has no surface outlet, and the Tikur Wuha River at the north-eastern shore is the only inlet (see Fig. 1). This river brings water from Lake Shallo, which is swampy and a few kilometres north-east of Lake Awassa.

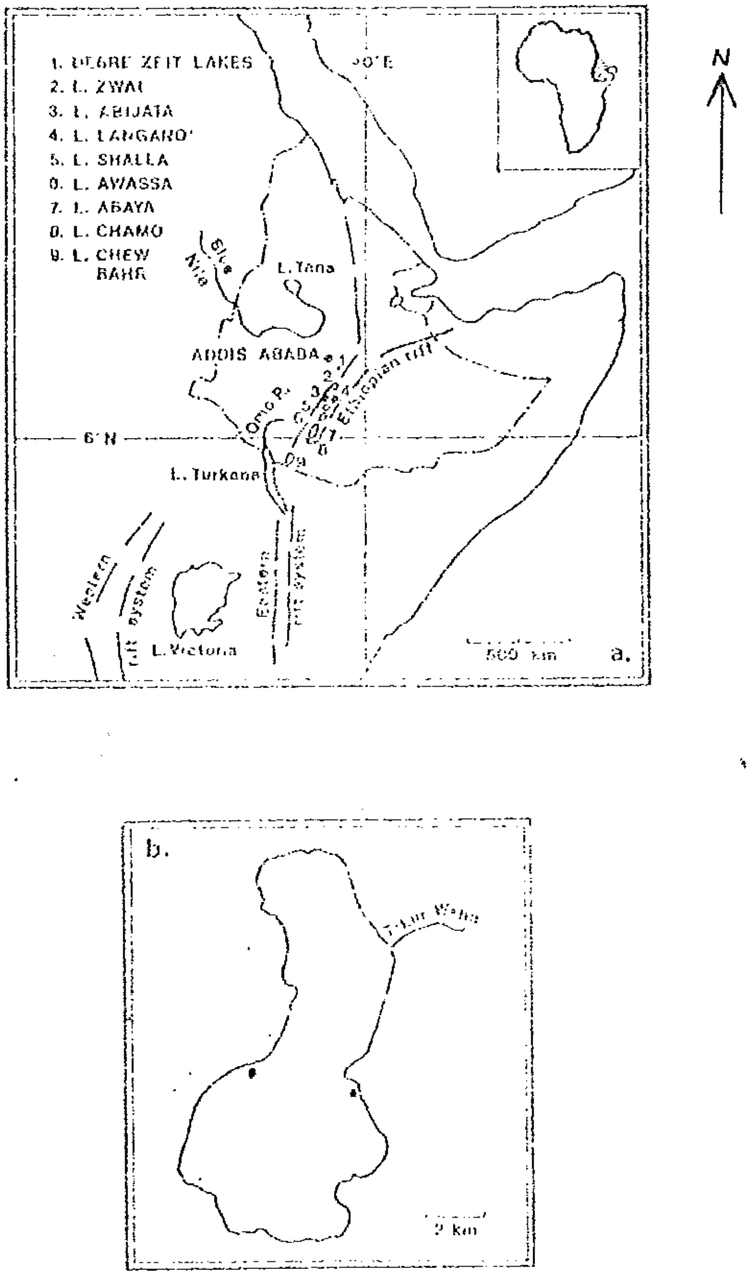

Figure 1. Map of East Africa showing the location of the major Ethiopian rift valley lakes (a). Lake Awassa with sampling stations indicated (b).

Table 1. Some physical and chemical characteristics of Lake Awassa.

characteristics	value (reference)
Area	88 km^2 (a)
Volume	1.3 km^3 (b)
Maximum length	16 km (a)
Maximum width	11 km (a)
Maximum depth	21 m (a)
Mean depth	11 m (a)
TDS	650.4 mg L^{-1} (c)
Conductivity (K_{20})	730 - 825 µmho cm^{-1} (d)
Potassium	0.83 mmol L^{-1} (b)
Sodium	9.23 mmol L^{-1} (b)
Magnesium	0.22 mmol L^{-1} (b)
Calcium	0.12 mmol L^{-1} (b)
Chloride	0.85 mmol L^{-1} (b)
Silica	1.65 mmol L^{-1} (b)
Sulphate	0.005 mmol L^{-1} (b)
NO_3-N	7.0 - 100 µg L^{-1} (d)
NO_2-N	1.0 - 5.1 µg L^{-1} (e)
PO_4-P	22.0 - 45 µg L^{-1} (d)
Total PO_4	98.0 µg L^{-1} (c)
CO_3 + HCO_3	7.33 - 10.52 meq L^{-1} (d)
pH	8.85 (e)

a. Herrman, in preparation
b. Von Damm and Edmond, 1984
c. Talling and Talling, 1965
d. Elizabeth, 1987
e. Demeke, 1985

This area has an eight month rainy season (March to October, peaking during July to September), and a four month dry season (November to February) (Daniel, 1977). Rainfall and temperature data of the region for the years 1986-1988 are presented in Table 2 and Table 3, respectively. The level of the lake increases shortly after the rains. Makin et al (1975), however, believe that surface run off, especially from the northern and western catchment, contributes very little due to the permeable nature of the soil. Although Lake Awassa is terminal (without a surface outlet), its water has relatively low salinity (Talling and Talling, 1965; Beadle, 1981). The presence of subterranean outflow by seepage through the lake bed (Beadle, 1981) and the Tikur Wuha River draining an extensive swamp (Amha and Wood, 1984) have been suspected to keep the water at a low salinity level.

Demeke (1985) reported that permanent thermal stratification does not occur. However, the lake may remain stratified for up to four months; January to April (Elizabeth, 1987), February to May (Zinabu, 1988). This stable stratification is broken and the lake assumes an isothermal condition during May to July, which is associated with cooler air temperatures and with the influx of cool rains during May to June (Elizabeth, 1987). During September to November Elizabeth (1987) and Zinabu (1988) have observed several unstable thermal stratifications lasting only for few days. Elizabeth (1987) noted another complete wind induced mixing during December.

The chemistry of Lake Awassa (Table 1) is basically similar to most African rift lakes with sodium as the predominant cation and bicarbonate-carbonate as the predominant anion (Talling and Talling, 1965). Carbonate-bicarbonate

Table 2. Total monthly rainfall (mm) in the Awassa region from 1986 to 1988. Data obtained from the Agro-meteorological Service of the Institute of Agricultural research at Awassa research station.

Month	1986	1987	1988
JAN	00.0	00.0	21.2
FEB	42.4	17.3	66.2
MAR	44.4	125.9	16.4
APR	115.3	87.1	102.0
MAY	257.9	246.9	93.9
JUN	152.6	59.1	106.9
JUL	195.7	104.5	121.3
AUG	167.0	105.5	129.4
SEP	160.2	75.7	215.5
OCT	46.1	95.3	71.0
NOV	20.1	00.0	2.4
DEC	32.2	2.3	6.0

Table 3. Mean monthly minimum and maximum air temperature (°C) in the Awassa region from 1986 to 1988. Mean is midpoint temperature. Data obtained from the Agro-meteorological Service of the Institute of Agricultural research at Awassa research station.

	1986			1987			1988		
Month	min	max	mean	min	max	mean	min	max	mean
JAN	7.7	29.0	18.4	9.4	28.3	18.9	10.4	29.7	20.1
FEB	12.2	29.4	20.8	10.7	29.8	20.3	13.2	30.3	21.8
MAR	11.7	29.1	20.4	14.1	28.0	21.1	12.3	31.4	21.9
APR	14.6	26.5	20.6	13.0	27.7	20.4	14.0	28.6	21.3
MAY	13.4	26.7	19.2	14.3	26.9	20.5	13.0	27.8	20.4
JUN	14.5	23.9	18.5	14.7	25.8	20.3	13.6	25.5	19.6
JUL	13.4	23.6	18.3	13.8	25.5	19.7	14.2	23.4	18.8
AUG	11.9	24.7	18.6	13.0	26.1	19.6	14.0	24.4	19.2
SEP	12.3	24.9	18.7	12.5	26.3	19.4	13.6	24.9	19.3
OCT	10.5	26.8	18.4	11.5	27.0	19.3	12.5	25.9	19.2
NOV	8.6	28.2	18.4	8.6	29.3	19.0	6.5	28.3	17.4
DEC	9.1	27.6	18.4	9.4	29.7	19.6	7.4	27.8	17.6

alkalinity ranges from 7.33 to 10.52 meq L^{-1}, with minimum and maximum values in late July and January, respectively (Elizabeth, 1987). High alkalinity values are associated with high evaporation during the dry season (Elizabeth, 1987).

The nutrient status of Lake Awassa has been found to show a seasonal trend paralleling that in rainfall and mixing. NO_3-N starts to increase with the onset of mixing and soon after the rains to reach a maximum in July (Elizabeth, 1987; Zinabu, 1988). Soluble reactive phosphate also increases soon after the rains began and is highest in May (Zinabu, 1988).

The phytoplankton in Lake Awassa is composed of about 100 species of which 48%, 30% and 11% are greens, blue greens and diatoms respectively (Elizabeth, 1987). The rest includes chrysophytes, dinoflagellates, cryptomonads and euglenoids (Elizabeth, 1987). This author reported the seasonal nature of variation in phytoplankton biomass which increases following the wind induced mixing in December and the thermal destratification during May to July.

Taylor and Zinabu (in press) believe that the zooplankton biomass is dominated by small cyclopoid Crustacea, whereas Cladocera are not abundant. Ciliates and rotifers are also abundant and believed to be the most important grazers (Taylor and Zinabu, in press). These authors also speculated that strong vertebrate planktivory, which operates in the absence of an effective piscivore, sustains the present plankton community of Lake Awassa.

The subzone extending from 20-40 m offshore consists of mixed macrophytes, mainly of *Cyprus* sp., water lilies (*Nymphea caerulea*), *Potamogeton* spp. and *Typha angustifolia* (Tilahun, 1985). *Paspalidium geminatum* dominates the zone from 50-100 m offshore at depths of 3-5 m (Tilahun, 1985). This same author pointed out that the benthic fauna of Lake Awassa is dominated by ostracods and chironomids, although cyclopoid copepods and cladocerans are also present. Species of Ephemeroptera, Odonata, Heteroptera, Coleoptera, caddis flies and gastropod snails constitute the main macroinvertebrate fauna which are usually found in the macrophyte zone (Tilahun, 1985).

Lake Awassa is inhabited by six species of fishes (Elias, 1988): *Oreochromis niloticus*; *Clarias mossambicus*; *Barbus intermidius*; *Barbus amphigrama*; *Garra* sp. and *Apochalichthyes* sp.. The feeding, reproductive biology and the fishery of the cat fish *Clarias mossambicus* have been studied by Elias (1988). The food and feeding habits of juvenile (Tudorancea *et al*., 1988) and adult (Getachew, 1987) *Oreochromis niloticus* has been studied. Getachew (1987) reported that the quality of the food in their gut varies seasonally with low values occurring during April to July.

Various species of fish-eating birds are also found around the lake. Hippopotamus and Otters have also been observed. The ecological role of these animals has not been studied.

III. MATERIALS AND METHODS

1. Sampling and measurements: Fish samples were taken monthly from December 1987 to November 1988 from two stations (Fig. 1). For several species of *Tilapia* it has been found that a gang of gillnets whose mesh size (stretched) differs by increments of 25.0 mm gives a representative sample, and that 12.5 mm increments are more than adequate (Fryer and Iles, 1972). The sampling gear used during this study was a gang of floating nylon monofilament gillnets consisting of mesh sizes (stretched) ranging from 50.0 to 112.5 mm by increments of 12.5 mm. Each gillnet was 2.4 m deep and 15.2 m long . Two gangs of gillnets containing each mesh size were connected end to end but separated by a 1.5 m long rope (Hamley, 1975). This sampling gear was set overnight at depths of 3 to 5 meters near the macrophyte vegetation.

Fish were separated by the mesh size in which they were caught and measurements were taken as soon as possible after the nets were retrieved. The sex of each specimen was identified whenever possible and the stage of gonadal development recorded based on the method of Harbott and Ogari (1982). Measurements taken include total length (TL), standard length (SL), total weight (TW) and eviscerated weight (EvW). Length measurements were taken to the nearest 1.0 mm using a measuring board. Weights were taken to the nearest 0.1 gram using a Mettler 2000 balance.

A preliminary examination of some calcified structures of *O. niloticus* from Lake Awassa was carried out in consultation with Dr. Casselman, Ontario Ministry of Natural Resources, Canada. From the work it was believed that scales and otoliths could be useful to determine the age of this species. Therefore, for this study only scale and otolith samples were collected. Scale samples were taken from the region above the lateral line and below the anterior base of the dorsal fin. Otoliths (sagittae) were removed and stored in vials after they were cleaned and air dried.

2. Length-weight and other morphometric relationships: The relationship between total length and total weight, total weight and eviscerated weight, and between total length and standard length were determined using the following least squares regression equations, respectively:

$$\mathrm{Log}_{10}\mathrm{TW} = \mathrm{Log}_{10}a + b\ \mathrm{log}_{10}\mathrm{TL} \qquad (1)$$

$$\mathrm{Log}_{10}\mathrm{TW} = \mathrm{Log}_{10}a + b\ \mathrm{Log}_{10}\mathrm{EvW} \qquad (2)$$

$$\mathrm{Log}_{10}\mathrm{TL} = \mathrm{Log}_{10}a + b\ \mathrm{Log}_{10}\mathrm{SL} \qquad (3)$$

where, TW = total weight in grams

TL = total length in centimetres

EvW = eviscerated weight in grams

SL = standard length in centimetres

'a' and 'b' are constants fitted by least squares regression.

3. Preparation and examination of calcified structures:

3.1 Otoliths

Prior to examination, otoliths were soaked in 72% ethanol for 20 minutes and then transferred into 45 % glycerol for 24 hr. This treatment made the zonations clearer and easier to decipher. They were then examined in 45%

glycerol against a black background using a reflected light source at a maximum magnification of 9X (WILD M8 Wild type stereoscope). If otoliths did not show clear zonation after this pretreatment, they were further prepared in the following ways:

3.1.1. Small to medium sized otoliths (up to a maximum diameter of 5 mm) were embedded in epoxy-araldite medium and ground using 400 and then 600 grit carborundum papers, and further polished to a high lustre using 12 µm aluminum oxide lapping films (Casselman and Barnes, 1987). After grinding to approximately 400 um thickness they were examined either unmounted or after they were mounted on a slide in the embedding medium.

3.1.2. The large otoliths were heated by the method of Christensen (1964) or in an oven at 110^0 to 120^0C for about 20 to 30 minutes. Whole heated otoliths were examined as described above, and cracked ones were supported on plasticine and the broken surfaces examined after flooding them with 45% glycerol or with oil (Christensen, 1964; Chilton and Beamish, 1982).

Some otoliths could not be interpreted after the above procedures (6%).

The degree of optical quality (ie. translucency and opacity) of otoliths was described using a subjective ranking system where [1] indicates extreme translucency and [10] indicates extreme opacity (Casselman, pers. comm).

3.2 Scales

Five symmetrical and non-regenerated scales were selected from each fish.

The selected scales were soaked in water for about 24 hr. They were then cleaned with water using tooth brush and dried. The dried scales were mounted between two glass slides. Microscopic examination was done at about 12X magnification (WILD M8 wild type stereoscope) using a reflected light source.

4. Validation:

4.1 Marginal tissue type: To test the validity of the age determination method conditions on the edge of scales and otoliths were recorded for the monthly samples. These data were used to know when translucent zones are formed in otoliths and checks are formed in scales. Plots were made by month of the proportion of fish with a translucent zone on the margin of their otolith and for the number of circuli after the last check in scales (Dudley, 1974; Barger, 1985; Samuel et al., 1987). The plot made for the number of circuli after the last check in scales was used to verify the time of formation of translucent zones in otoliths.

4.2 Mark-recapture experiment: Fish were caught using a beach seine, tagged and released into a cage about 300 m^2 in area which was built near the shore in an area 0.5 to 1.5 m depth. A few growth data were obtained to validate the results obtained from otolith examination.

4.3 Length-frequency analysis: Length frequency distributions were constructed and the data were analyzed using the computer program ELEFAN (Brey and Pauly, 1986) to estimate K and Loo of the VBGF. Based on these parameters, monthly growth increments were estimated and growth curves fitted to the observed monthly length-frequency distribution. For verification purposes the results from length-frequency analysis were compared with those from otolith examination.

5. Factors associated with check and zone formation

5.1 Fulton's condition factor:

Fulton's condition factor was calculated for the samples using the following formula:

$$C = \frac{TW}{TL^3} \times 100 \qquad (4)$$

where, C = Fulton's condition factor

TW = total weight in grams

TL = total length in centimetres

5.2 Reproductive cycle: The proportion (%) of fish engaged in reproductive activities in each month was calculated.

5.3 Rainfall and water level: Variations in monthly rainfall in the region and water level of the lake were investigated.

5.4 Surface water temperature: Surface water temperature of the lake was measured during sampling.

6. Age determination: Determination of the absolute age of the fish was not possible due to the difficulty in identifying the first annulus in the otoliths (see details in RESULT section). Therefore, the relative age of each fish was determined and average length-at-relative age was calculated.

7. Back-calculation:

a). Otolith posterior radius (OR) and the radius of each translucent zone which were used to determine relative age (ORn) was measured from the nucleus along the middle posterior region of the otolith. ORn was measured from the nucleus upto the outer boundary between the translucent and the opaque zone. Mean ORn values were then calculated.

The relationship between total length and total otolith radius was then constructed using least squares regression equation which had the following form:

$$\mathrm{Log}_{10}TL = \mathrm{Log}_{10}a + b\ \mathrm{Log}_{10}OR \qquad (5.1)$$

where, TL = total length in centimetres

OR = otolith posterior radius in centimetres

a and b are constants fitted by regression analysis.

The following formula was then used for back-calculation (Le Cren 1947, cited in Casselman, 1987):

$$TLn = TL * \frac{ORn^b}{OR^b} \qquad (5.2)$$

TLn = total length (cm) at relative age 'n'

TL = average total length (cm) at capture

ORn = average radius of the n^{th} translucent zone (cm)

OR = average total otolith radius (cm) at capture

b = the constant fitted by equation (5.1) above.

b).The radius of each scale check was measured from the focus along the middle anterior region. Body length and scale radius relationship was calculated using regression analysis which had the following form:

$$\mathrm{Log}_{10}TL = \mathrm{Log}_{10}a + b\ \mathrm{Log}_{10}ScR \qquad (6.1)$$

TL = total length (cm)

ScR = scale radius (cm)

a and b are constants fitted by regression.

The following equation was used to back-calculate growth from scales (Le Cren, 1947, cited in Casselman, 1987):

$$TLn = \frac{(ScRn)\ (TL-a)}{ScR} + a \qquad (6.2)$$

where, TLn = total length (cm) at the n^{th} check

TL = average total length (cm) at capture

ScR = total scale radius (cm) at capture

ScRn = radius of the n^{th} check

a = constant fitted by equation (6.1)

Some growth estimates were obtained and served to corroborate the results obtained from otolith examination.

8. <u>Growth parameters</u>: Since the sample did not include small fish, the length-at- relative age data obtained from otoliths were used to make a

Ford-Walford plot in order to estimate the length of small fish which were one year younger than the 'first relative age-group' (Everhart and Youngs, 1981). This avoided the possible errors that might be encountered in calculating growth parameters from data which do not include small fish. This plot was made using least squares regression which had the following form:

$$L_{t+1} = a + b\,L_t \qquad (7)$$

L_t = total length (cm) at relative age 't'

L_{t+1} = total length (cm) at relative age 't+1'

a and b are constants fitted by least squares regression.

The length estimated above was then included in the length-at-relative age data and equation (7) was used again to find the growth parameters of the von Bertalanffy equation, 'Loo' and 'K', using the following formulae (Pauly, 1983 and 1984):

$$K = -\mathrm{Log}_e b \qquad (8)$$

$$\mathrm{Loo} = \frac{a}{1-b} \qquad (9)$$

where 'a' and 'b' are constants fitted by equation (7) after including the lengths of small sized fish that were estimated from this equation.

The parameter 't_0' was calculated using two methods:

a). Because the ages determined from otoliths were relative, the empirical equation of Pauly (1979) was used to estimate 't_0'. This equation relates 'K' and 'Loo' to 't_0' in the following manner:

$$\mathrm{Log}_{10}(-t_0) = -0.3922 - 0.2752\ \mathrm{Log}_{10}\mathrm{Loo} - 1.038\ \mathrm{Log}_{10}K \qquad (10)$$

b). Assuming that the ages were absolute, Beverton's (1954, cited in Ricker, 1975) approach to estimate the parameters of the VBGF was used. This approach gives estimates of both 't_0' and 'K':

$$\mathrm{Log}_e(\mathrm{Loo}-L_t) = (\mathrm{Log}_e\mathrm{Loo} + Kt_0) - Kt \qquad (11.1)$$

Loo = asymptotic length (cm) estimated from equation (9).

L_t = length (cm) at age t

K = slope of the equation, which is also the growth coefficient in the VBGF.

($\mathrm{Log}_e\mathrm{Loo} + Kt_0$) is the intercept of the equation which could be equated to $\mathrm{Log}_e\mathrm{Loo}$ to solve for 't_0' in the following manner:

$$t_0 = \frac{(\mathrm{Log}_e\mathrm{Loo} + Kt_0) - \mathrm{Log}_e\mathrm{Loo}}{K} \qquad (11.2)$$

Different values of 't_0' were obtained from the two approaches. Both values were used in the VBGF and two sets of length-at-age data were calculated. These two sets of calculated length-at-age data were compared with respect to the observed data and the 't_0' which gave a VBGF which best fitted the observed data was used to express the growth of the fish.

Growth was first expressed in terms of length and then converted to weight growth by the length-weight relationship (equation 1).

9. Catch using experimental commercial gillnet:

Samples were collected monthly from January 1988 to August 1988 using an experimental commercial gillnet (multifilament cotton twine, 100 mm stretched mesh). This net was set at localities used by the local fishermen. Length-frequency distributions of the fish caught were constructed and used to describe the commercial catch.

10. Statistical analyses: Various sets of data were tested for homogeneity of variance using the computer program BIOM (Rohlf, 1985). No heterogeneity of variances was found. Analysis of variance (SYSTAT, Wilkinson, 1986) was used to test for the presence of variation in various sets of data. Residual analysis showed that all regression equations fitted to the various data were significant (Belloto and Sokoloski, 1985).

IV. RESULT

1. Length-weight and other morphometric relationships:

The relationship between total length (cm) and total weight (g) of fish ranging in size from 12.9 to 33.0 cm was analyzed. This was done for the sexes separately but, there was no significant difference between the regressions of the sexes ($P > 0.05$). The data were, therefore, combined and the following regression was fitted to these data:

$$\text{Log}_{10}\ TW = -1.762 + 3.00\ \text{Log}_{10}\ TL$$
$$r = 0.99,\ N = 2012.$$

The anti-log of the above equation (ie., $TW = 0.017 * TL^{3.00}$) was used to draw the curve presented in Figure 2A. It is evident that length and weight of O. niloticus in Lake Awassa conform to the cube law (Ricker, 1975), which is similar to that found by Zenebe (1988) for this species from L. Ziway, Ethiopia.

The relationship between total weight (g) and eviscerated weight (g) was linear (Figure 2B), and the regression equation describing this relationship was the following:

$$TW = 1.25 + 1.12\ (EvW)$$
$$r = 0.99,\ N = 968.$$

Figure 2C shows the relationship between total length (cm) and standard length (cm). This was linear and described by the following regression equation:

$$SL = 0.66 + 1.2\ (TL)$$
$$r = 0.99,\ N = 101.$$

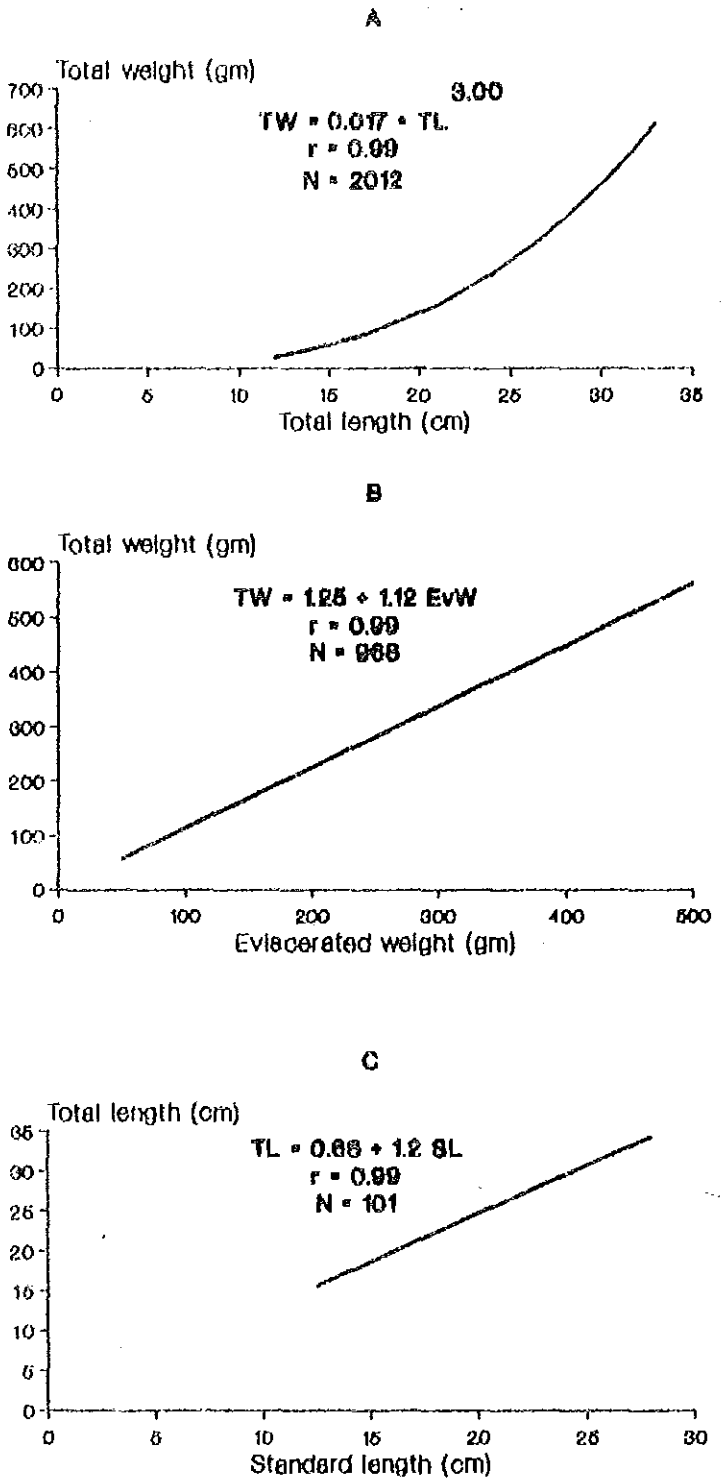

Figure 2. Relationships between total length (cm) and total weight (g) (A), eviscerated and total weight (g) (B), and total length and standard length (cm) (C) for *O. niloticus* from Lake Awassa, Samples were collected monthly from Dec. 1987 to Nov 1988. TL = Total length; SL = standard length; TW = total weight; EVW = eviscerated weight.

2.Description of zonations in otoliths:

Optical zonation in otoliths of O. niloticus was typical of most fish otoliths. When microscopically examined against a dark background by using a reflected light source, two characteristic zones can readily be recognized. The opaque zones appear as white bands in the otoliths. The translucent zones alternate with the opaque zones and appear as dark bands.

Based on the width and the relative translucency and opacity of zones, the otoliths of adult O. niloticus was divided into three regions. The inner region from the nucleus up to the third translucent zone consisted of narrowly spaced zones. The opaque zones in this inner region were very opaque (rank of [8] to [10]), but the translucent zones were moderately translucent (a rank of [5]). The middle region up to the sixth translucent zone was characterized by wide and very opaque zones (a rank of [8] to [10]). The translucent zones had similar appearance as those found in the inner region. The outer region (from the seventh translucent zone up to the margin) consisted of narrowly spaced, less opaque (a rank of [7]) and very translucent zones. The spacing of zones in this outer region progressively narrows towards the margin of the otolith.

The translucent zones vary according to their extent and location with in an otolith. The first seven translucent zones are formed along the entire circumference of the otolith. At a relatively higher magnifications (>12X) and especially in ground otoliths, translucent zones which affect less than 70% of the total otolith circumference can be recognized in between any of the first seven prominent translucent zones. These "subzones" are either incomplete or coalesce with the more prominent complete ones. Such "subzones" were considered not to be associated with annuli and, therefore, were not used for age assessment. After the seventh translucent zone, zonation was remarkably regular and "subzones" were not observed. However, the prominent zones closer to the margin of the otoliths (especially from large/old fish) were narrowly spaced, and were difficult to decipher along the ventral region of the otolith. Although these translucent zones seem to be incomplete, their regularity and prominence are strong proof to use them for age assessment. Casselman (1985) described such zones as "partial annuli" and recommended that they are as useful as "complete annuli" associated with complete translucent zones found around the entire structure.

3. Description of checks in scales:

The extent and location of checks in the scales of *O. niloticus* were difficult to be described precisely. However, two general types of checks were identified. One type was found along the entire anterior surface of the scale as a narrow region devoid of circuli. In the lateral regions of this check crossing-over of circuli was also frequently observed. The other type of check was similar in appearance to the first type but, was found usually in the anterior region of the scale. These incomplete type of checks are mostly located about 0.1 mm after the complete type. The radius of every check in the scales (both complete and incomplete types) was measured from the focus along the anterior field of the scales. Check radii were found to group towards certain average values when plotted as a combined frequency distribution (see eg., Bayley, 1982). The average radii to which they were grouped were at 0.08, 0.15, 0.21, 0.24 and 0.26 cm for the first, the second, the third, the fourth and the fifth mode, respectively. These values were not different from the average radii of the first, the second, the third, the fourth and the fifth complete check, respectively. Checks after the fifth were closely spaced and were very difficult to decipher. It was not possible even to describe the different types of checks in this region of the scales.

4.Time of translucent zone formation in otoliths:

Monthly records on the proportion (%) of fish with translucent otolith margin (Table 4) are illustrated in Figure 3. From Table 4 it is evident that 90 to 91 % and 76 to 83 % of the otolith samples during February to January and during June to July, respectively, had translucent margins. Majority of otolith samples taken in the other months had opaque margin.

It is evident that *O. niloticus* in Lake Awassa may form two translucent zones in their otoliths, per year. The juveniles of this species from the same lake have been found to form translucent zones in otoliths during December to January and during late May to July (Yosef, pers. comm.).

5.Time of check formation in scales:

The average numbers of circuli after the last check in monthly samples of

Table 4. The proportions (%) of fish with translucent zone on the margin of otolith and the number(mean ± 95 % confidence interval) of circuli after the last check in scales of _O. niloticus_ from L. Awassa. N is sample size.

Month	Otoliths with translucent margin (%)	N	Number of marginal circuli in scales	N
DEC '87	11.0	100	5.1 ± 0.40	30
JAN '88	91.0	71	1.8 ± 0.40	31
FEB '88	90.0	120	1.7 ± 0.15	25
MAR '88	25.0	120	2.9 ± 0.30	36
APR '88	12.6	103	4.3 ± 0.30	22
MAY '88	28.3	99	5.5 ± 0.20	43
JUN '88	76.0	100	6.8 ± 0.20	25
JUL '88	83.0	100	1.5 ± 0.22	32
AUG '88	28.6	140	1.7 ± 0.14	53
SEP '88	10.0	100	2.0 ± 0.15	21
OCT '88	14.0	100	3.0 ± 0.20	19
NOV '88	7.7	52	4.8 ± 0.24	22

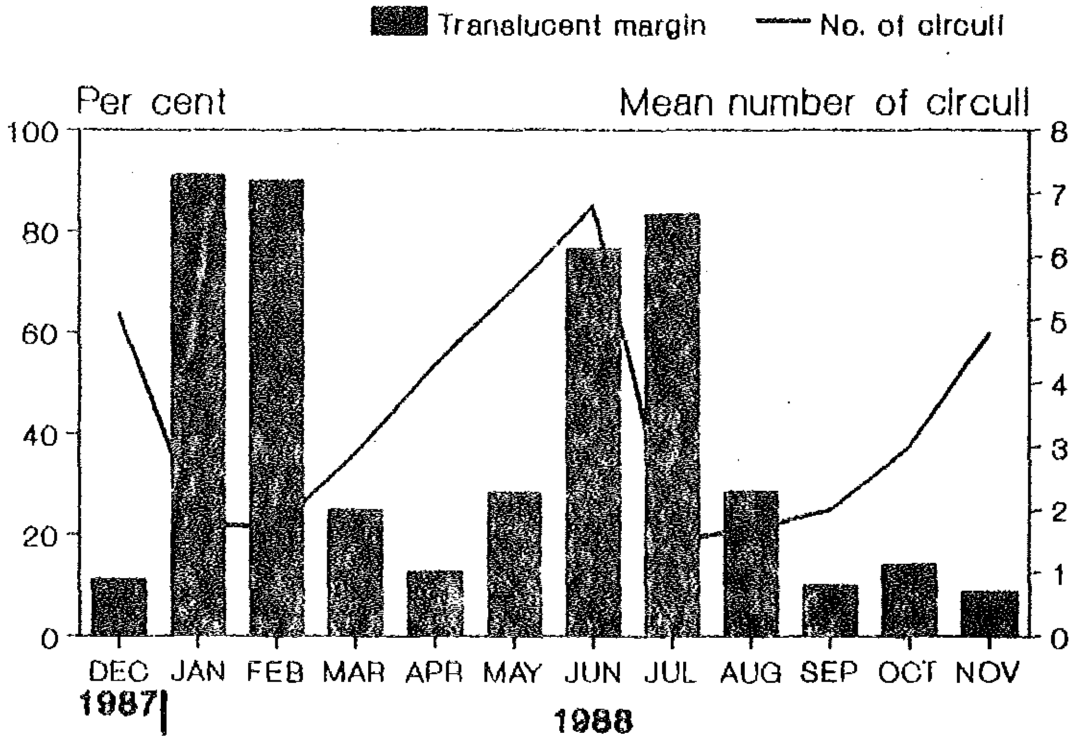

Figure 3. Variation in the proportion (%) of fish with otoliths with translucent [illegible] margins (bars), and in the mean number of circuli after the last check in scales (curve) of *O. niloticus* from L. Awassa. Samples were taken monthly from Dec. 1987 to Nov. 1988.

scales are presented in Table 4 and illustrated in Figure 3. Marginal circuli ranging in average number from 1.5 to 2 were counted in samples taken during January and February, and during July to September. The average number of circuli after the last check tends to increase from March until July and from October until December. It is, therefore, apparent that scale checks could be formed during December and January as well as during June and July.

6. Seasonality in some biological and environmental factors:

6.1 Fulton's condition factor:

Mean Fulton's condition factors calculated for monthly fish samples are presented in Table 5 and illustrated in Figure 4. ANOVA showed that the condition of the fish varied significantly between the sexes and between the months ($P < 0.05$). Interaction between sex and month was also significant ($P < 0.05$). Mean monthly condition factor ranged from 1.3 to 2.12 for males and from 1.1 to 2.0 for the females. There was a decrease in the condition of the males from January to February and from May to June. This improved during March to April and during July to December. Low condition factors were also recorded in September and October, but these were greater than values in February and June. The fluctuation in the condition of females also followed the same trend as those of the males, however, the females were almost always in poorer condition than the males. Females were in much more poor conditions in February, March and April. Furthermore, while the males gained improved condition immediately

Table 5. Values of Fulton's condition factor (mean ± 95 % conf. int.) of females and males *O. niloticus* from L. Awassa. N is sample size.

Month	Males	N	Females	N
DEC '87	1.99 ± 0.02	81	1.80 ± 0.02	107
JAN '88	1.80 ± 0.06	23	1.80 ± 0.02	71
FEB '88	1.50 ± 0.02	38	1.10 ± 0.02	105
MAR '88	1.30 ± 0.02	129	1.10 ± 0.02	189
APR '88	2.10 ± 0.02	81	1.23 ± 0.02	134
MAY '88	1.60 ± 0.02	66	1.70 ± 0.02	56
JUN '88	1.30 ± 0.02	67	1.15 ± 0.02	76
JUL '88	1.80 ± 0.02	56	1.80 ± 0.02	77
AUG '88	1.99 ± 0.02	68	1.89 ± 0.04	111
SEP '88	1.70 ± 0.02	77	1.70 ± 0.02	127
OCT '88	1.70 ± 0.02	107	1.70 ± 0.02	109
NOV '88	2.12 ± 0.02	28	2.00 ± 0.02	24

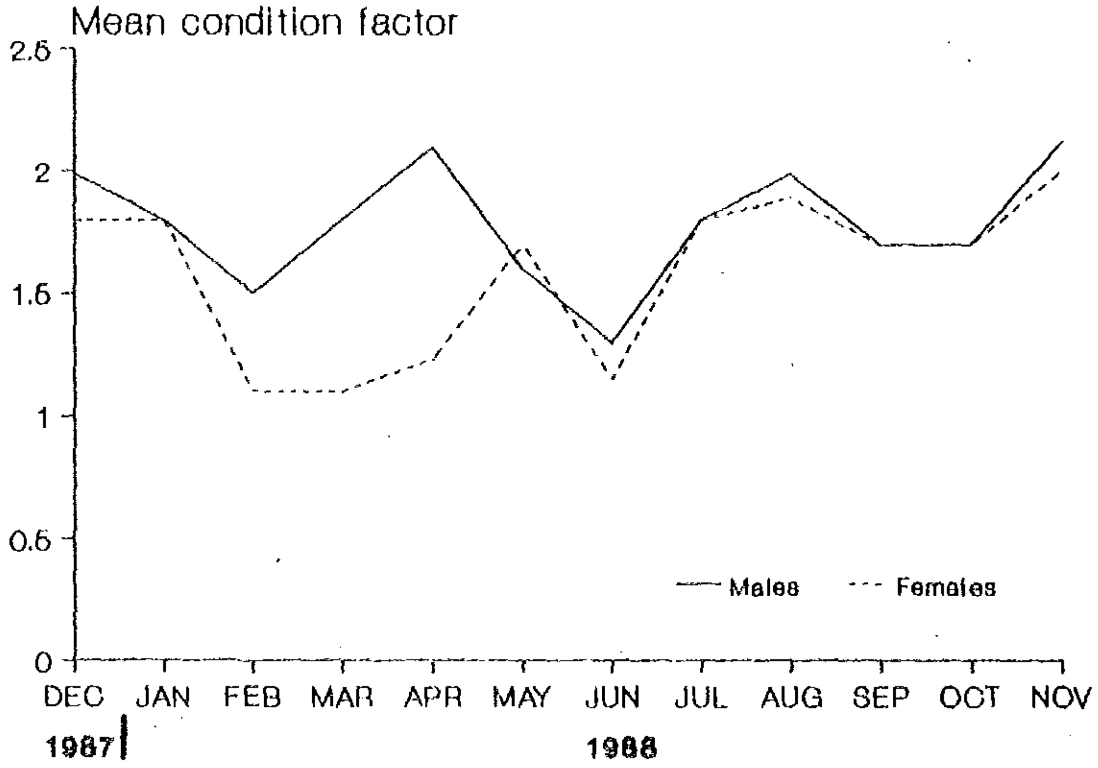

Figure 4. Fluctuation in mean Fulton's condition factor of females (broken line) and males (solid line) O. niloticus from L. Awassa. Monthly samples were collected during Dec. 1987 to Nov. 1988.

after February, the females remained in poor condition until April (Figure 4).

6.2 Reproductive activity and gonadal development:

The proportions (%) of fish at various stages of reproduction in each month are presented in Table 6. Proportion of fish under column II of this table were considered to be 'actively engaged' in reproductive activity, and hence whose growth may be affected by this activity. The figures under column II were illustrated in Figure 5. The results indicate that 65.6 to 94.2 % and about 39 to 60 % of the samples taken during January to March and during July to September, respectively, were actively engaged in reproductive activity. It is evident that the period of peak reproductive activity coincides with decreased condition factor (cf. Figure 4).

6.3 Rainfall and lake water level:

Total monthly rainfall (mm) in the region and monthly fluctuation in the lake water level (cm) during the sampling period are presented in Figure 6. The little rain started in January and decreased in amount in March. The heavy rain started in April which continued to rain and it reached it's peak in September. The lake water level was low from March to June and started rising in July and it reached its maximum level in October. It continuously dropped from November until March. The heavy rain which started in April seems to determine the rise in lake water level, and the drop also started few months after this rain stopped.

Table 6. Reproductive activity and gonadal development data for *O. niloticus* from L. Awassa. Numbers are percentages of the total number of fish examined in the month[1].

Month	I	II
DEC '87	84.1	15.9
JAN '88	33.4	66.6
FEB '88	26.0	74.3
MAR '88	5.8	94.2
APR '88	89.2	10.8
MAY '88	93.1	6.9
JUN '88	80.5	19.5
JUL '88	61.2	38.8
AUG '88	54.8	36.8
SEP '88	40.0	50.0
OCT '88	90.2	9.8
NOV '88	90.0	10.0

[1] Column I = immature + spent + resting; column II = total number of fish with gonads indicated the presence of reproductive activity.

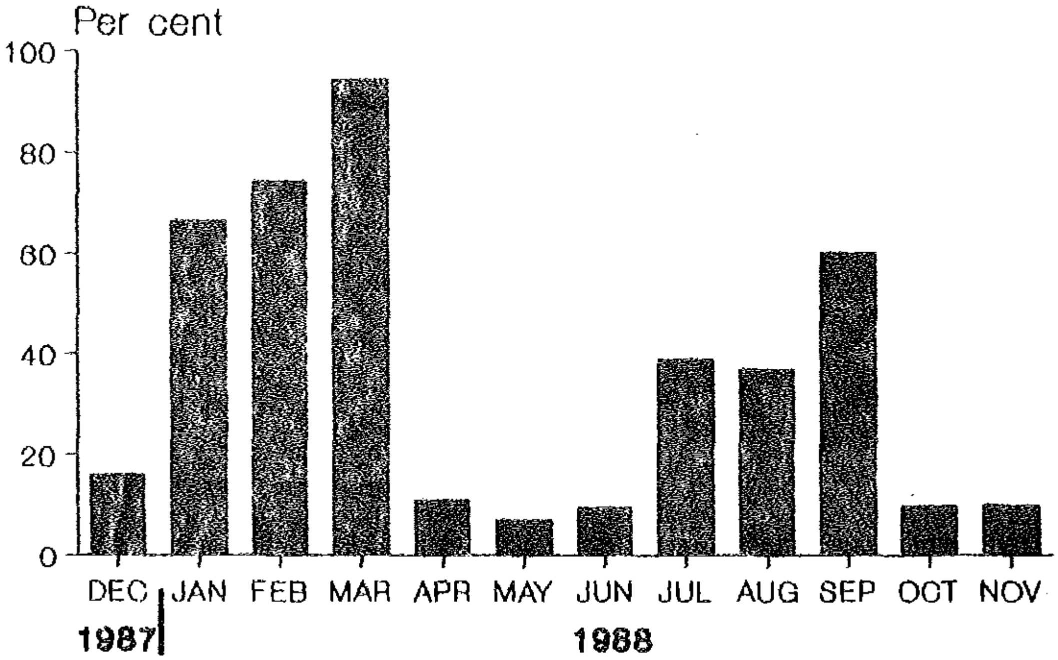

Figure 5. Variation in the proportion (%) of O. niloticus from L. Awassa that showed gonadal development and reproductive activity. Samples were collected monthly from Dec. 1987 to Nov. 1988.

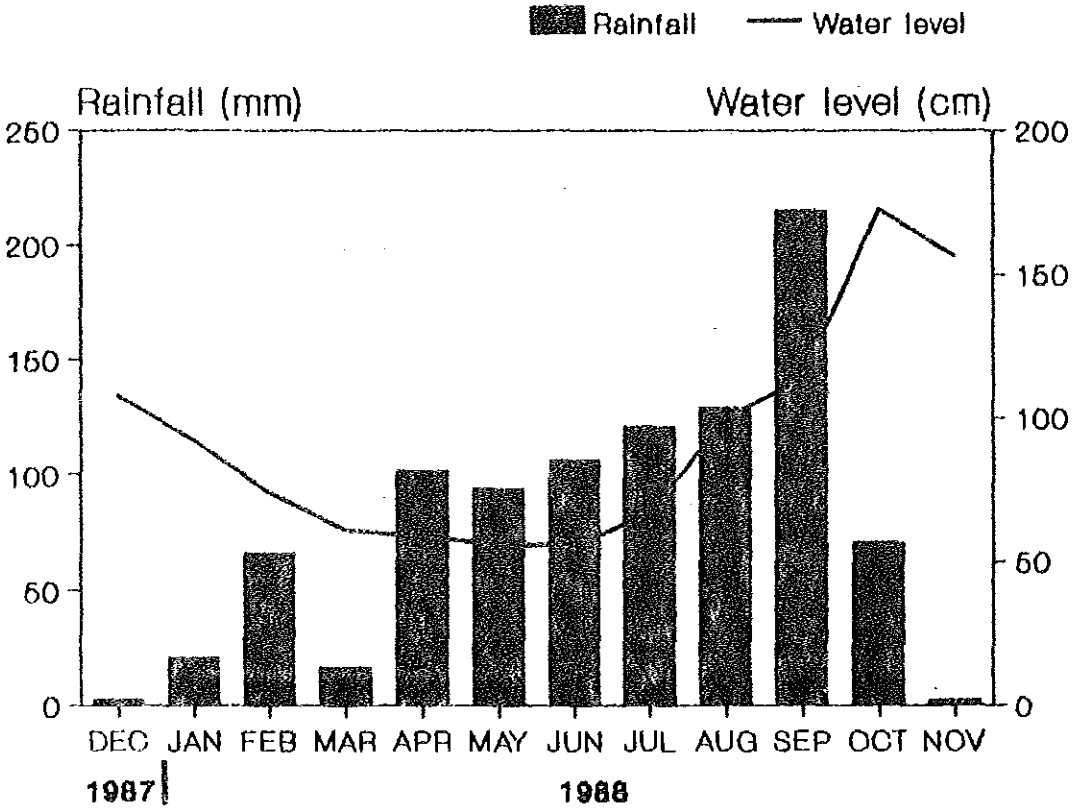

Figure 6. Variation in rainfall (mm) in the Awassa region and fluctuation in the water level (cm) of L. Awassa from Dec. 1987 to Nov. 1988.

6.4 Surface water temperature:

Monthly measurements of surface water temperature (^{0}C) are shown in Figure 7. It is apparent that the surface water is relatively cold during November to January and during June to July. Temperature ranged from 17.8^{0}C in July to 25.2^{0}C in March.

7.Age and growth determination:

One of the major difficulties in the study involved distinguishing between the two annual cohorts of new recruits. The two spawning periods of *O. niloticus* are during January to march and during July to September (Figure 5.) February and August could be assumed to be average "birthdates" for January-March and July-September recruits, respectively. From Figure 3 it is evident that there are two periods of translucent zone formation per year. It is also apparent that annulus could be formed in the otoliths in March or in August. Therefore, five to six months could elapse from "birth" up to the formation of the first annulus in both recruits. Since this period is approximately equal for both recruits, it can be assumed that otoliths from both broods can form approximately equal number of translucent zones before the first "twelve month annulus" is formed. It is thus probable that otoliths from both recruits can have the same number of translucent zones at any age.

It was difficult to accurately identify the first twelve months annulus in otoliths. In some otoliths the fourth and in some others the fifth and still in others the sixth translucent zone was wider and more translucent

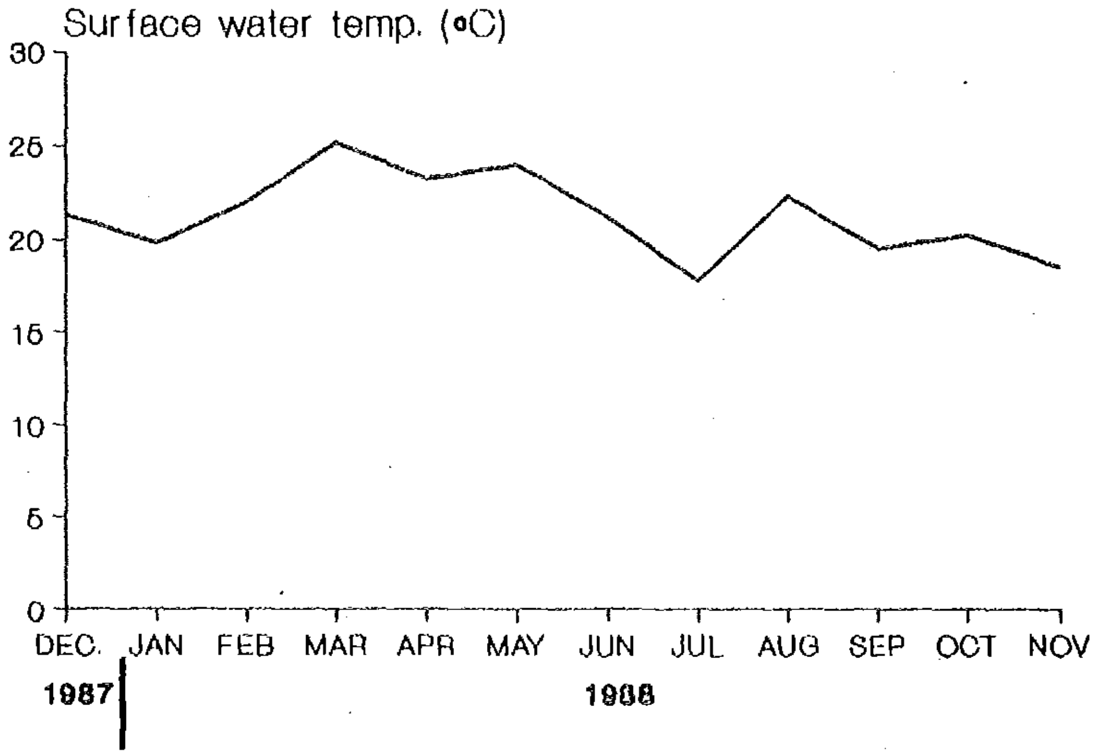

Figure 7. Fluctuation in surface water temperature (^{O}C) of L. Awassa during December 1987 to November 1988.

than the respective preceding translucent zones. The length of the fish was directly related to the number of translucent zones in their otoliths. Wideness and greater translucency was, however, more common for the sixth than the fourth and the fifth translucent zones. The annulus associated with the sixth translucent zone probably appears during March in recruits from February of the previous year and in August in recruits from August of the previous year. It is, therefore, apparent that it could be formed at about the end of the first year of life of both recruits.

Most workers assume a January 1 "birthdate" and use the annulus to express age in calendar years accordingly (eg. Balon, 1972). A January 1 "birthdate" can not, however, be applied in this study for O. niloticus because, lacking specific criteria fish from the two periods of recruitment can not be separated. However, assumption of actual average "birthdates" and consideration of the formation of two translucent zones per year will place both recruitments into the same time scale. Thus, at the end of the first year of life (ie., at about 12 months after "birth") both recruits would have approximately equal numbers of translucent zones in their otoliths. Likewise, otoliths from both recruits can have the same number of translucent zones at a given age. Hence, fish from both recruitments can be treated together to estimate growth.

It was not possible to identify the first annulus in the otoliths. Therefore, I was not able to determine the absolute age of the fish directly from their otoliths. However, since otoliths from both periods of recruitments contained approximately equal number of translucent zones at any age, they were treated together to assess the average growth of the population using average length-at-relative age data.

Research which is currently underway (Yosef, in preparation) was designed to provide on early otolith growth and age interpretation and will provide criteria for determining absolute age. Some of these preliminary data are used here.

The smallest, and probably the youngest, fish in the sample contained seven translucent zones in their otoliths. These fish were, however, small in number. Average lengths at relative age were, therefore, calculated starting from fish having 8 translucent zones in their otoliths. Since it was assumed that two translucent zones were formed each year (Figure 3) fish with otoliths having 8, 10, 12, 14 and 16 translucent zones were each considered to be one year older. Such average length-at-relative age data were calculated for the stations and for the sexes separately. ANOVA showed that there was no significant difference in length-at-relative age between the stations ($P > 0.05$) but, there was significant difference between the sexes ($P < 0.05$) (Table 7). The data from the stations were combined and presented in Tables 8A and 8B for males and females, respectively. The length data converted to weight using the length-weight relationship are presented in Table 9.

Small fish were not collected in this study, therefore, the average length one year earlier than the time of formation of the eighth translucent zone was estimated from Ford-Walford plots (Figure 8).

Table 7. Summary of ANOVA results determining the significance of variation in length-at-relative age between stations and between sexes (alpha = 0.05).

Source	F	Degree of freedom	Probability
Stations			
males	8.235	1	0.080 (NS)
females	1.542	1	0.282 (NS)
Sexes	27.215	1	0.006 **

NS = non-significant

** = highly significant

Table 8A. Average length-at-relative age (cm, mean ± 95 % conf. int.) of males *O. niloticus* from L. Awassa. #T is number of translucent zones in otoliths. N is sample size.

#T	Age (yrs)[1]	Length	N
(5.96)[2]	1.10	(9.2)[3]	-
8	2.00	16.6 ± 3.2	123
10	2.99	21.9 ± 2.3	325
12	4.20	25.4 ± 2.3	85
14	5.20	27.1 ± 2.8	29
16	5.79	27.7 ± 3.1	18

[1] Estimated from length by using the method of Gulland (1969).

[2] Mean number of translucent zones calculated from data obtained from Yosef (in preparation) (see text).

[3] Estimated from Ford-Walford plots (Figure 8A) (see text).

Table 8B. Average length-at-relative age (cm, mean ± 95 % conf. int.) of females O. niloticus from L. Awassa. #T is number of translucent zones in otoliths. N is sample size.

#T	Age (yrs)[1]	Length	N
(5.96)[2]	0.96	(9.5)[3]	-
8	2.00	16.1 ± 3.3	126
10	2.96	20.2 ± 2.4	349
12	4.01	23.2 ± 2.5	91
14	5.20	25.5 ± 2.2	31
16	5.80	26.3 ± 3.6	20

[1] Estimated from length by using the method of Gulland (1959).

[2] Mean number of translucent zones calculated from data obtained from Yosef (in preparation) (see text).

[3] Estimated from Ford-Walford plots (Figure 8B) (see text).

Table 9. Average weight-at-age (g.) of O. niloticus from L. Awassa calculated from length by using length-weight relationship. Age was rounded off to the nearest integer to express age in the number of years of life after an average "birthdate". G is relative growth rate in weight.

Age	Males	G	Females	G
1	13.2	2.6	15.0	2.7
2	77.1	1.8	70.9	1.6
3	178.6	0.8	139.1	0.7
4	276.9	0.4	212.3	0.4
5	336.5	0.2	281.9	0.3
6	361.3	0.1	307.5	0.1

The lengths estimated from these plots were 9.2 cm for males and 9.6 cm for females. Otolith samples from small fish obtained from a different study showed that fish ranging in length from 8.0 to 9.6 cm (average 9.1cm) had 5.96 ± 0.8 (mean ± 95 % conf. int.) translucent zones (Yosef, unpublished data). This value is closer to 6. Fryer and Iles (1972) reported that under natural conditions the size attained at the first year of life by several species of tilapias is from 9.0 to 12 cm. This agrees favourable with the estimates obtained for O. niloticus from Lake Awassa. Since otoliths from this size group contain approximately six translucent zones, it is reasonable to assume that the sixth translucent zone is formed towards the end of the first year of life. Therefore, the sixth, the eighth, the tenth, etc. translucent zones may correspond to the first, the second, the third, etc. years of life, respectively.

Age in years indicated in Tables 8A and 8B were estimated from length using the method of Gulland (1969) which relates age with the parameters of the von Bertalanffy growth equation. It is apparent that ages estimated from this method agree with the assumption that the sixth translucent zone was formed towards the end of the first year of life. The data in tables 8A and 8B show that growth is remarkably slow after the eighth translucent zone was formed (after about the second year of life). After this age the males grow faster than the females.

8.Relative age and growth from scales:

The relationship between total length (cm) and total scale radius (cm) of

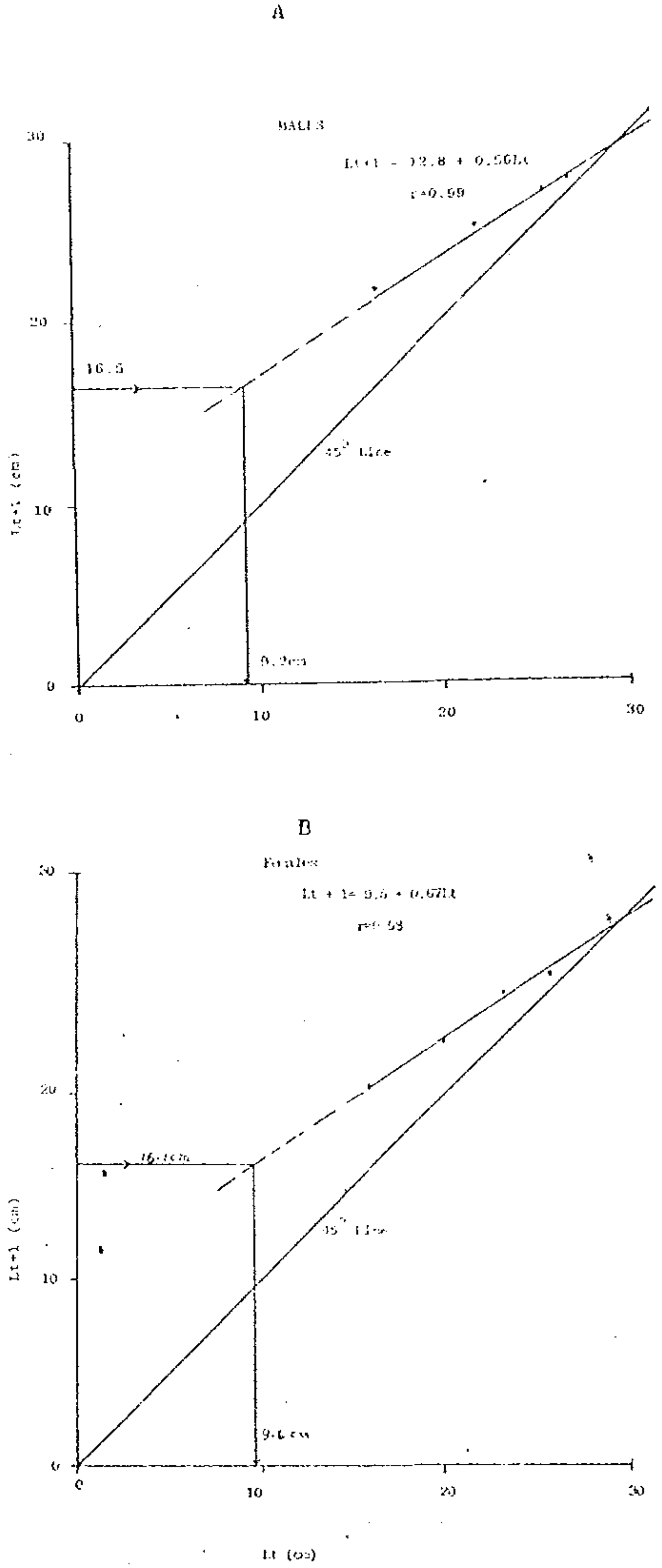

Figure 8. Ford-Walford plots used to estimate length of males (A) and females (B) <u>O. niloticus</u> that are one year younger than fish which had eight translucent zones in their otoliths.

O. niloticus ranging in total length from 13.5 to 28.5 cm was analyzed. There was no significant difference ($P > 0.05$) in this relationship between the sexes. The combined data fitted the following regression equation:

$$\mathrm{Log}_{10}TL = 1.54 + 0.65\ \mathrm{Log}_{10}ScR,\ r = 0.85,\ N = 230.$$

Back-calculated average lengths and relative ages speculated from scales are presented in Table 10. It is evident that these results provide a good corroboration of results obtained from otolith interpretations. Fish with one check in their scales, for instance, had four to six translucent zones in their otoliths. It is, therefore, evident that the first four to six translucent zones were formed before the first year of life was completed.

9.Length-frequency analysis:

Because of small sample size, monthly length-frequency data for the sexes were combined and presented in Figure 9. Superimposed growth curves were fitted by the computer program ELEFAN. The asymptotic length and K were estimated (using ELEFAN) to be 30.2 cm and 0.45, respectively. The growth curves were fitted using these parameters. It is apparent that there is a growth process taking place which can be observed as the modes progress from left to right in Figure 9. The left most curve (Figure 9) indicates that fish that were about 13.5 cm in length in June grew to about 16.4 cm in November. Fish that were 16.9 cm in December 1987 grew to 21.5 cm a year later in November 1988 (Figure 9, second curve). Furthermore, it is also evident from Figure 9 that fish that were 21.8 cm in length may grow to about 24.6 cm in a period of about one year.

Table 10. Back-calculated average length (cm, mean ± 95% conf.int.) and relative age speculated from scale samples of *O. niloticus* from L. Awassa. #T is the number of translucent zones in otoliths of fish at the corresponding back-calculated length (range in parentheses). The '+' and '++' signs indicate the relative width of the opaque zone at the edge of the otoliths.

Check No.	back-calculated av. length ± 95 %conf.int.	#T	relative age
1	8.2 ± 2.1	5 (4-6)	< 1 year
2	12.7 ± 2.5	7 (6-7)	about 1.5 year
3	14.2 ± 3.0	7+	about 2 yrs
4	17.3 ± 2.2	8++	slightly > 2 yrs
5	18.6 ± 2.9	9 (8-9)	closer to 3 yrs

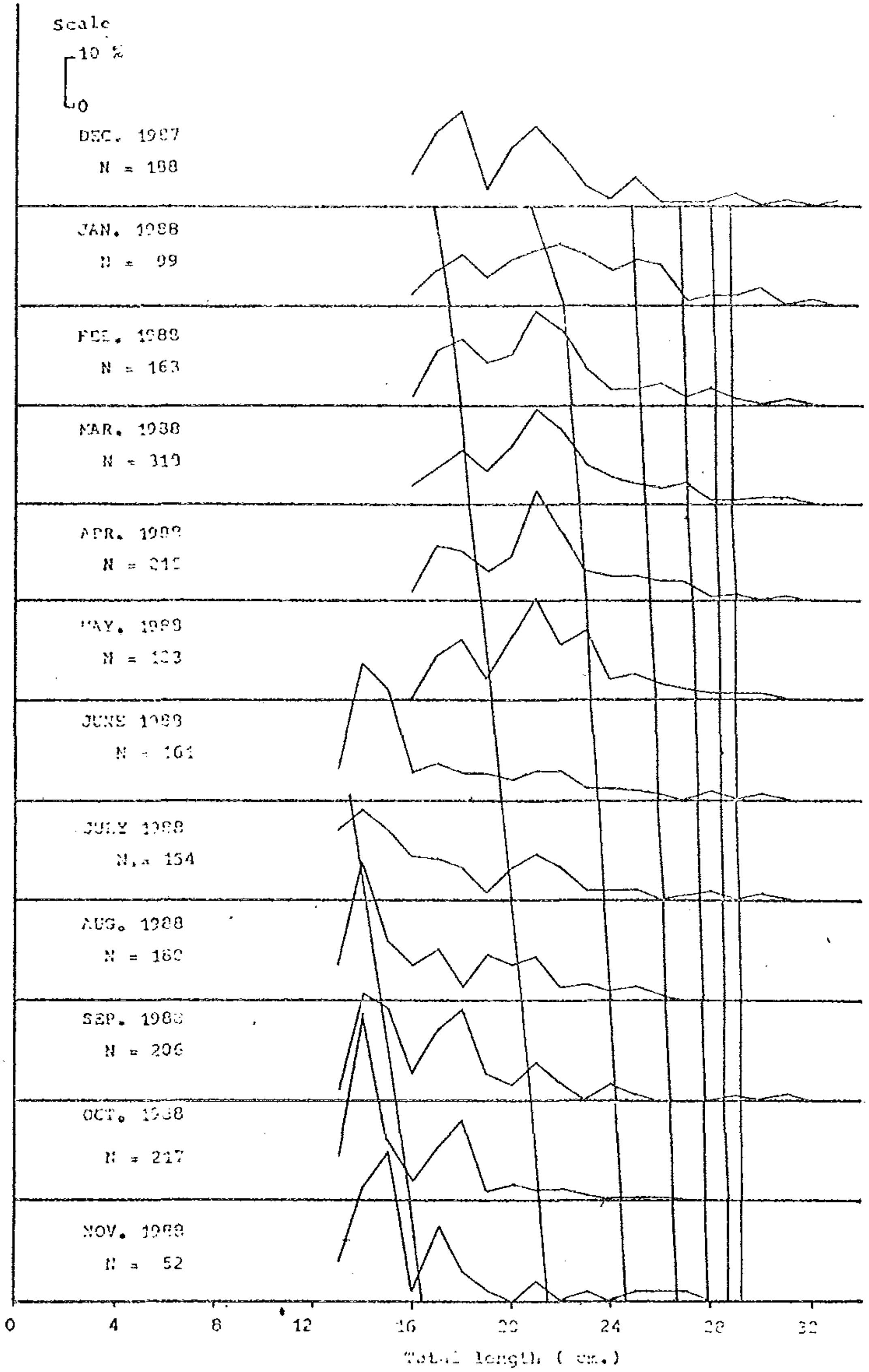

Figure 9. Length-frequency distribution of O. *niloticus* from L. Awas Sexes were combined. Superimposed growth curves are fitte by the computer program ELEFAN. N is sample size. Sample were collected monthly from Dec. 1987 to Nov. 1988.

10. Back-calculation:

There was no significant difference in total length-otolith posterior radius relationship between the sexes ($P > 0.05$). Figure 10 shows the relationship combined for both sexes ranging in length from 13.0 to 29.5 cm. The regression equation describing this relationship was as follows:

$$\mathrm{Log_{10}TL} = 1.57 + 1.02\ \mathrm{Log_{10}OR}$$

$$r = 0.96,\ N = 612.$$

The following equation was, therefore, used for back-calculation:

$$\mathrm{Ln} = \mathrm{TL}\ (\mathrm{ORn}^{1.02}/\mathrm{OR}^{1.02})$$

Lengths back-calculated from otoliths are presented in Tables 11 and 12 for males and females, respectively.

11. Growth parameters:

The parameters of the von Bertalanffy growth function were estimated from length-at-relative age data that are presented in Tables 8A and 8B. The Ford-Walford plots fitted to these data are shown in Figure 11A and Figure 11B for females and for males, respectively. These plots were fitted by the following regression equations:

$L_{t+1} = 9.7 + 0.67\ L_t$, $r = 0.99$ .....females (Figure 11A)

$L_{t+1} = 11.1 + 0.63\ L_t$, $r = 0.99$ ..... males (Figure 11B)

From the slopes and intercepts of the respective lines, Loo and K were estimated. Loo was 29.4 cm for females and 30.0 cm for males. The growth coefficient K was 0.40 for the females and 0.46 for the males. The

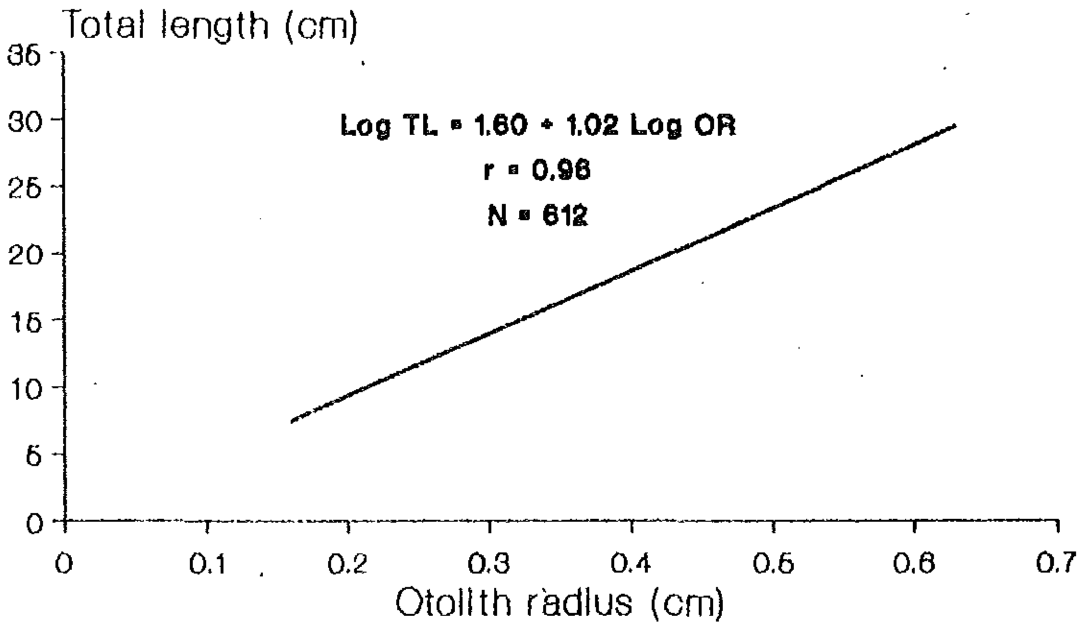

Figure 10. The relationship between total length (cm) and total otolith posterior radius (cm) of _O. niloticus_ from L. Awassa. Sexes were combined. TL = total length; OR = otolith posterior radius.

Table 11. Back-calculated average lengths (cm) of males *O. niloticus* from L. Awassa. #T is the number of translucent zones in otoliths. N is sample size.

#T	mean TL at capture	N	Length at boundary[1] number					
			6	8	10	12	14	16
8+[2]	16.6	80	7.1	15.3				
10+	22.0	85	7.4	15.9	19.3			
12+	25.7	62	7.5	16.2	19.6	25.4		
14+	27.5	21	7.1	15.4	18.7	24.3	26.6	
16+	28.0	18	6.9	14.9	18.1	23.5	25.8	27.2
		mean	7.3	15.5	18.9	24.4	26.2	27.2

[1] boundary refers to the boundary between a translucent and an opaque zone in otoliths.

[2] the '+' sign indicates the presence of new growth after the last translucent zone in the otoliths.

Table 12.Back-calculated average length (cm) of females O. niloticus from L. Awassa. #T is the number of translucent zones in otoliths. N is sample size.

#T	mean TL at capture	N	Length at boundary[1] number 6	8	10	12	14	16
8+[2]	16.4	82	7.6	15.4				
10+	21.2	74	7.4	15.0	18.8			
12+	24.0	55	7.3	14.9	18.7	23.1		
14+	26.2	25	7.2	14.5	18.2	22.5	25.3	
16+	27.3	15	7.1	14.4	18.1	22.2	25.0	26.8
		mean	7.3	14.8	18.5	22.6	25.2	26.8

[1] boundary refers to the boundary between a translucent and an opaque zone in otoliths.

[2] the '+' sign indicates the presence of new growth after the last translucent zone in otoliths.

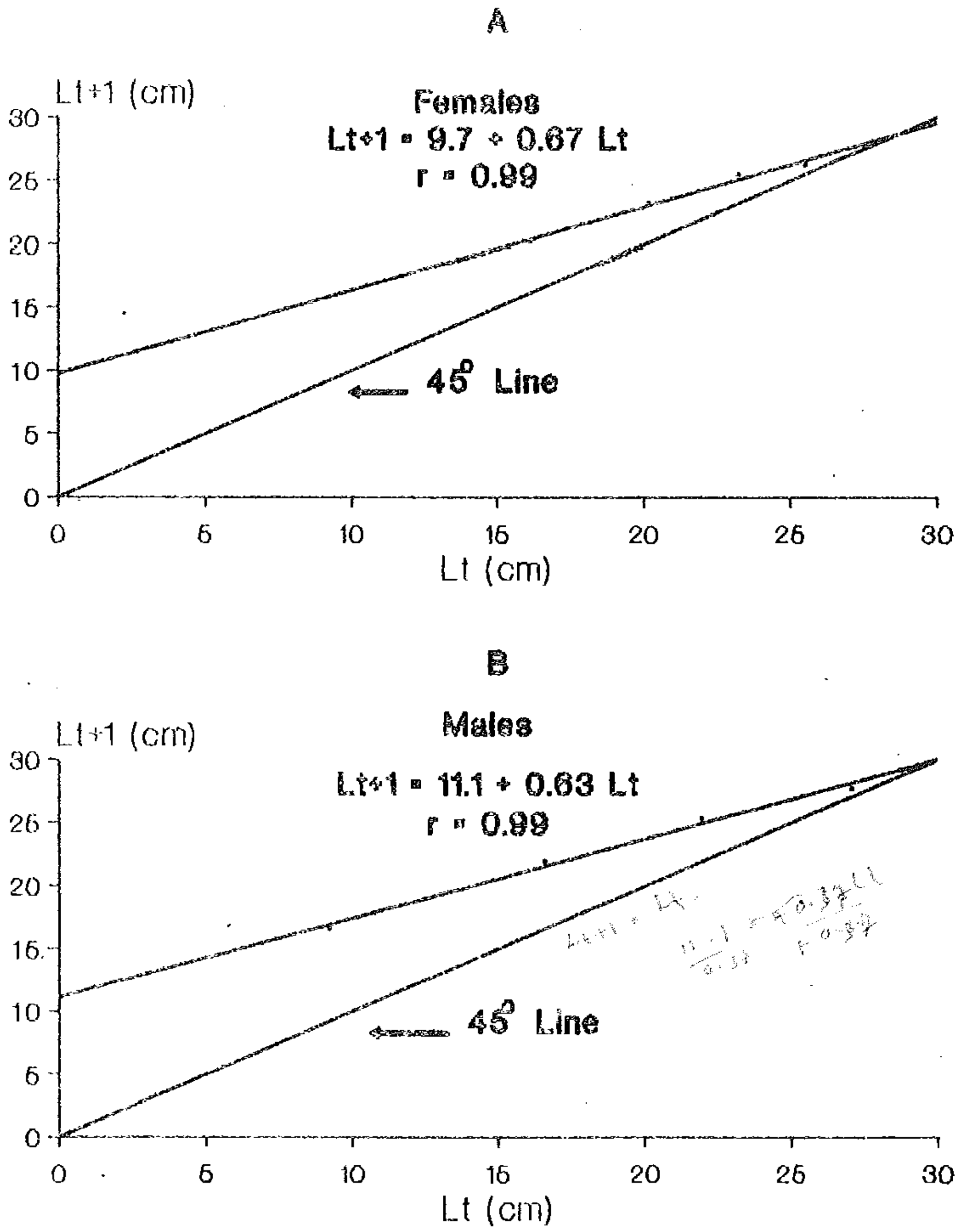

Figure 11. Ford-Walford plots that were used to estimate Loo and K for females (A) and for males (B) O. niloticus from L. Awassa.

theoretical age t_0 as estimated from equation (10) (MATERIALS AND METHODS section) was -0.41 for the females and -0.36 yr for the males. From equation (11.2) these values were -0.08 for the females and 0.15 for the males. The growth coefficients (K) estimated from equation (11.1) were 0.38 for the females and 0.46 for the males. The K values obtained from equations (8) and (11.1) are identical for the males but, these were different for the females. From the various estimates of the parameters the following von Bertalanffy growth equations were obtained:

males

1. $L_t = 30.0\ (1-e^{-0.46(t+0.36)})$, 2. $L_t = 30.0\ (1-e^{-0.46(t-0.15)})$

females

3. $L_t = 29.4\ (1-e^{-0.40(t+0.41)})$, 4. $L_t = 29.4\ (1-e^{-0.38(t+0.08)})$.

Length-at-age data calculated from the above equations are presented in Table 13. It is evident that lengths calculated from growth equations 2 and 4 (males and females, respectively) are in close agreement with the respective observed data (cf. Tables 8A and 8B). Therefore, these two equations were considered to be the best fitting von Bertalanffy growth equations for males and females *O. niloticus*. Growth curves for length and weight were drawn using these equations (Figure 12). Equations 2 and 4 were derived using the Beverton's method in which ages determined from otoliths were assumed to be absolute.

12. Length-frequency distribution of experimental commercial catch:

The commercial gillnets caught fish which were 19.0 cm and larger, the

Table 13. Length (cm) at age data of *O. niloticus* calculated from different von Bertalanffy growth equations. Equation 1 and 3 were based on relative age whereas equations 2 and 4 were based on absolute age.

	MALES		FEMALES	
Age (yrs)	Equation 1	Equation 2	Equation 3	Equation 4
1	13.9	9.7	12.7	9.9
2	19.9	17.2	18.2	16.1
3	23.6	21.9	21.9	20.3
4	26.0	24.9	24.4	23.2
5	27.5	26.8	26.0	25.2
6	28.4	27.3	27.1	26.5

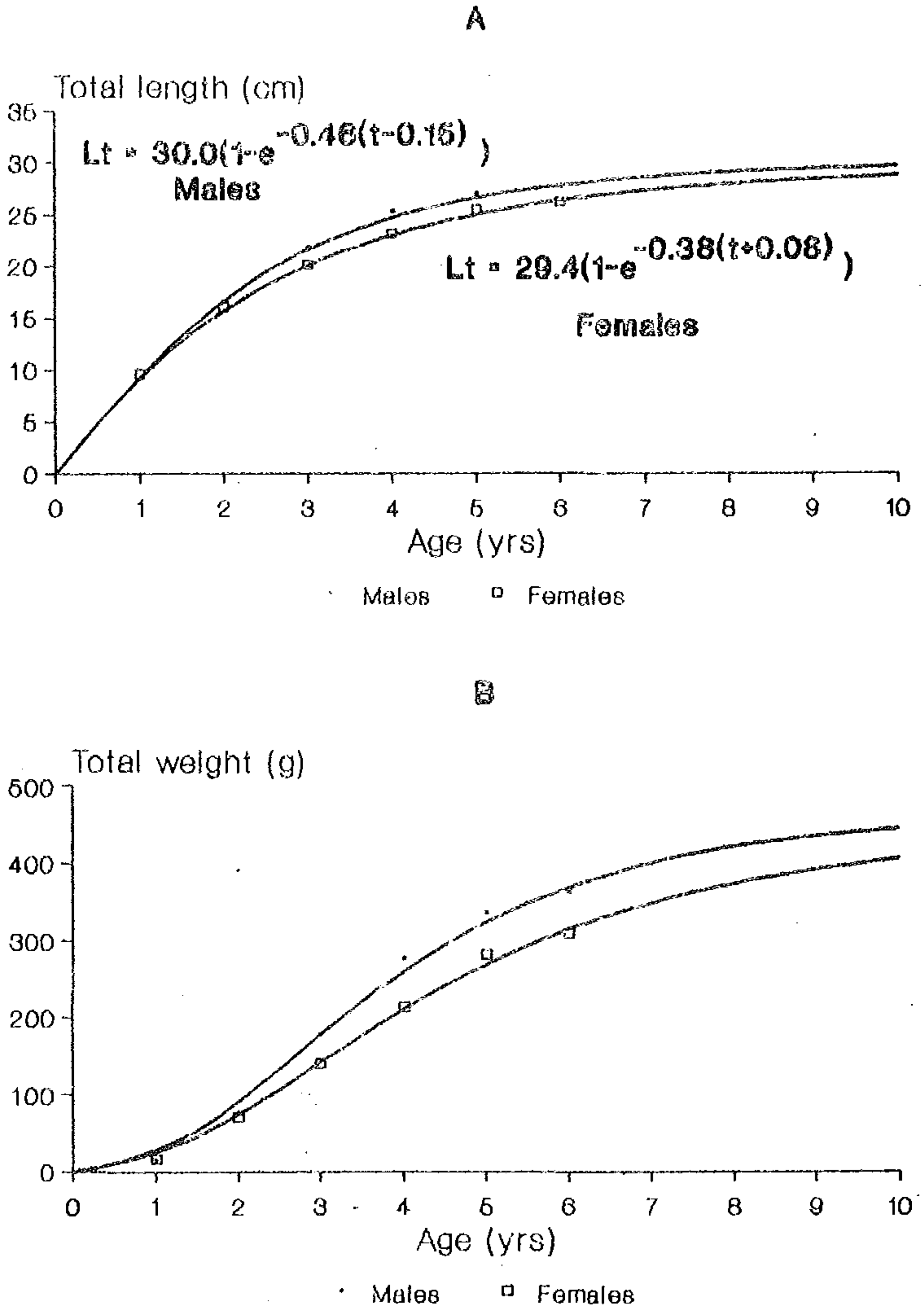

Figure 12. von Bertalanffy curves for growth in length (A) and in weight (B) of *O. niloticus* from L. Awassa. Weight used was from the length-weight relationship. Age in years are approximate years of life passed after an average "birthdate" (see text). Dots = males; squares = females

majority being between 25.0 and 27.0 cm (Figure 13). Samples of otoliths showed that fish between 25 and 27 cm in length had 14 to 16 translucent zones.

13. Comparison of growth rates estimated from various methods:

Relative linear growth rates estimated from length at age from otolith interpretation (Tables 8A and 8B), from length-frequency analysis (Figure 9) and from mark-recapture experiment were in the same order of magnitude (Table 14). However, growth rate in the second year of life that was calculated from mark-recapture experiment was underestimated. This could be due to the lack of marked small sized fish. In addition, handling during marking, the effects of the tag, etc. could have also affected the normal growth rate of the fish (Casselman, pers. comm.).

Although mark-recapture data were insufficient, the available ones, and the data from the other methods provided corroborating evidence to use the results obtained to describe the growth of the fish.

The growth and related results obtained in this study show good agreement with the already published data for various species of *Tilapia* (Table 15).

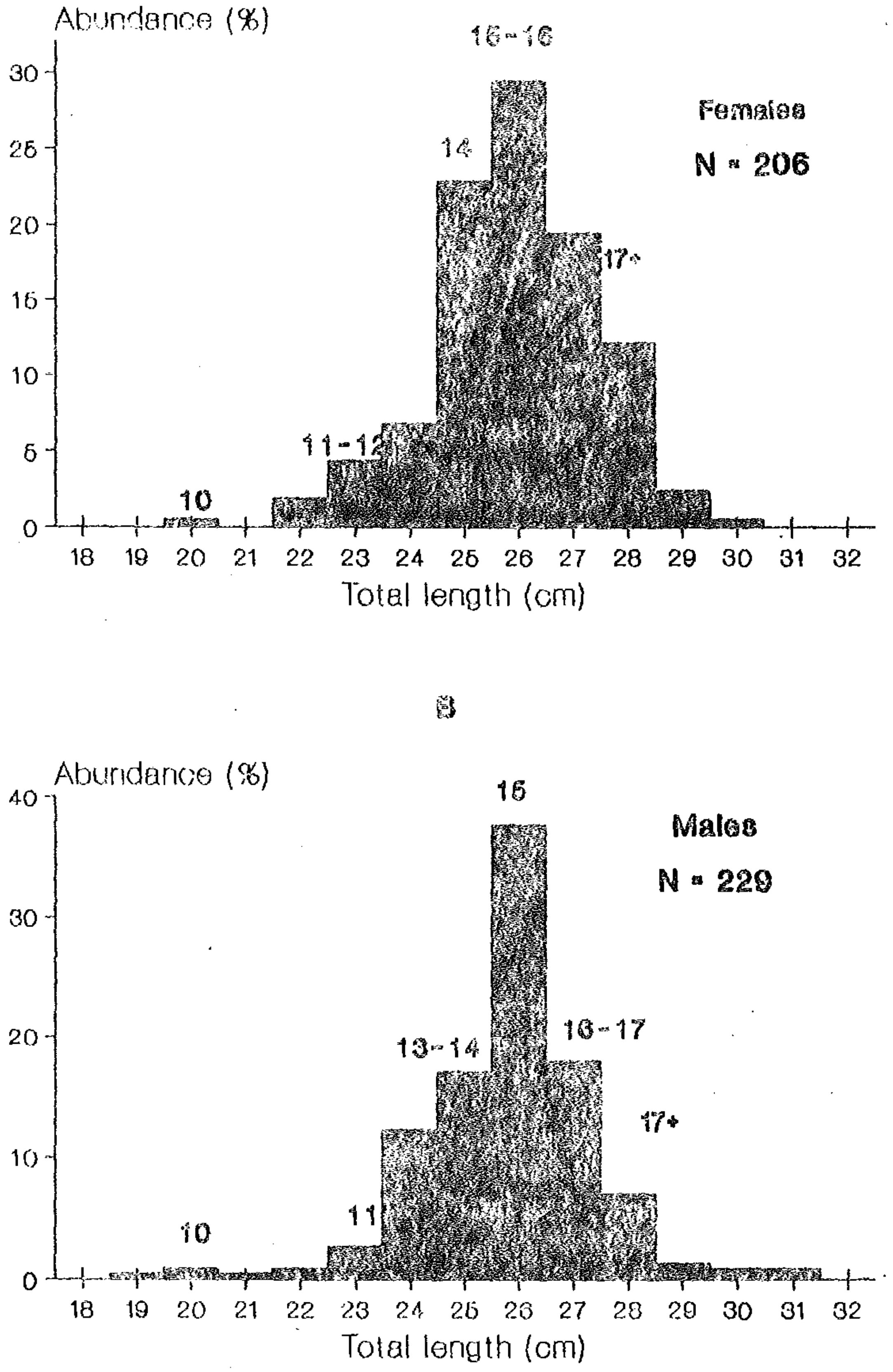

Figure 13. Length-frequency distribution of females (A) and males (B) O. niloticus from L. Awassa that were caught in an experiment commercial gillnet. Numbers on the top of some of the bars are the model number of translucent zones in otoliths from th size group. Samples were taken monthly during January 1988 - August 1988.

Table 14. Relative linear growth rates (G) for *O. niloticus* from L. Awassa that were calculated using length-at-age data obtained from various methods.

Method		Year (s) of life						
		2	3	4	5	6	7	8
Otolith	males	0.59	0.28	0.15	0.06	0.02	ND[1]	ND
	females	0.52	0.23	0.14	0.09	0.03	ND	ND
	sexes combined	0.56	0.26	0.15	0.07	0.03	-	-
Length-frequency		0.54	0.24	0.12	0.08	0.05	0.03	0.02
Mark-recapture		0.25	0.21	(0.15)[2]	ND	ND	ND	ND

[1] No data available.

[2] value based on a single fish.

Table 15. Growth and related data for various species of Tilapia reported in the published literature. The growth estimates obtained for O. niloticus in this study are also included.

Species	Locality	sex	TL (cm) at age (yrs) 1	2	3	4	5	6	7	age* at maturity	TL at maturity	TL max. caught	K	Loo (cm)	W* (g)	Author (s)
T. shirana	L.Malawi	both	10.0	18.0	22.0	25.5				2-3	20.0	29.0	0.49	30.0	13.7	Lowe-McConnell, 1952
T. squamipinnis	"	"	9.0	17.0	24.0	26.5				3	24.0	34.0	0.45	32.8	14.8	"
T. saka	"	"	12.0	22.0	27.5	30.0	30.5			3	27.5	34.0	0.72	31.5	22.7	"
T. esculenta	L.Victoria (north)	"	15.0	20.0	23.8	26.5	28.5	30.0	31.0	2-3	27.0	37.5	0.32	31.7	10.8	Garrod, 1959
	L.Victoria (south)	"	15.0	19.2	23.0	25.6	27.4	28.5	29.5	2.5-3	23-24	-	0.30	32.3	9.7	"
T. variabilis	"	"	11.4	17.1	19.6	21.2	22.2	22.9	23.3	3-4	21.0	31.0	0.43	25.0	12.0	Fryer, 1961
T. aurea	L.Tiberias	males	10.8	20.3	25.6	29.7	30.5			2	18-20	31.5	0.51	35.7	18.2	Ben-Tuvia, 1960, cited in Fryer & Iles, 1972
		fem.	10.4	19.7	24.2	28.5	30.2			2	18-20	31.5	0.51	33.0	16.8	" "
T. galilaea	Syria	both	9.1	20.6	26.6	31.5	33.4	34.7	[illegible]	-	-	-	0.59	34.9	20.2	El Bolock & Koura, 1961
	Egypt	"	8.3	21.6	[illegible]	27.7	33.1	29.9		-	-	-	0.94	28.9	26.5	Jensen, 1957
T. zillii	Syrian	"	7.2	12.7	16.0	18.3	20.2			-	-	-	0.40	23.3	9.3	El Bolock & Koura, 1961
	Egypt	"	7.4	13.3	13.4	[illegible]	23.3			-	-	-	0.36	25.3	10.2	Jensen, 1957
T. nilotica	L.Chad	"	13.4	22.9	28.0	31.8	33.2	35.1		-	-	-	0.72	37.2	15.5	Blache et al., 1964 cited in Fryer & Iles, 1972
	Syria	"	9.9	15.4	20.4	27.5				-	-	-	-	-		El-Bolock & Koura, 1961
	Egypt	"	9.2	20.5	25.7	28.8				-	-	-	0.69	31.5	21.2	Jensen, 1957
O. niloticus	L.Awassa	male	9.2	16.6	21.9	25.4	27.1	27.7		1.5-2	15+	32.2	0.46	28.0	17.8	present study
		fem.	9.6	15.1	20.2	23.2	25.5	26.3		1.5-2	13+	31.5	0.39	29.4	11.2	"

V. DISCUSSION

Due to the general belief that the tropical region does not experience climatic fluctuations cyclic growth of fish calcified tissues has often not been expected. However, many workers reported that this is possible (Garrod, 1959; Bishai and Gideini, 1965; Holcik, 1974; Hopson, 1982; Casselman, 1987). O. niloticus in L. Awassa was found to form two translucent zones in their otoliths and two checks in their scales per year. These were formed during January to February and June to July. It is believed that the growth of the fish could be slow during these months. The checks and translucent zones may, therefore, be deposited during these slow growth periods. Direct evidence from studying the seasonal growth cycle of tetracycline injected fish showed that this is the case (Casselman, 1978).

O. niloticus were in poor condition during January, February, June and July (Fig. 4). Getachew (1987) reported that this species in L. Awassa had reduced condition during these months. Various factors could interact and reduce the condition of the fish and result in the formation of growth changes in their calcified tissues. Lose of condition has been shown to be one factor associated with the formation of annuli (De Bont, 1967; Casselman, 1978). It is, therefore, apparent that annuli in calcified tissues of O. niloticus could be formed due to the lose of condition as a result of changes in some biological and environmental factors.

The main breeding season of O. niloticus in L. Awassa is during January to March but, a less pronounced spawning activity was also observed during July to September. Production of eggs and sperm represents a drain on the resources of fish. This is reflected in their metabolism in such a way as to cause recognizable growth checks in their calcified tissues (Fryer and Iles, 1972: Balarin and Hatton, 1979). Spawning can, therefore, be one of the factors to cause check formation in otoliths and scales of O. niloticus during January to February and June to July. This factor, however, would not explain their formation in immature fish.

Temperature is considered to be one of the most important factors to cause annulus formation in fish calcified tissues. The surface water temperature of L. Awassa was about 19^0C in January and 17.8^0C in July (Fig. 7). Chervinski (1982) reported that activity and feeding of tilapia is reduced at temperatures below 20^0C, and feeding stops completely around 16^0C. Coulton (1982) found that growth decreased significantly at temperatures below 20^0C. It is, therefore, evident that reduced temperature resulted in the formation of checks and translucent zones in calcified tissues of O. niloticus. Temperature is one of the most important factors for this effect in both immature and mature fishes in the temperate regions (Casselman, pers. comm.). O. niloticus in L. Awassa, regardless of its stage of maturity, may form checks and translucent zones during January and July.

Another important factor involved in the formation of checks and translucent zones in fish calcified tissues is availability of food (De Bont, 1967). The available food in L. Awassa may not be low to limit the growth of O. niloticus

(Getachew, pers. comm.). However, due to the spawning behaviour of the fish the amount of the food consumed could be low during the spawning periods. O. niloticus is a maternal mouth brooder, and the males are also believed to be engaged in building and guarding their nests (Lowe-McConnell, 1958). Therefore, it is probable that the fish may not be actively feeding if engaged in spawning activities. The quantity of the food consumed may, therefore, be reduced during December to February and June to July.

Food quality expressed as mg assimilable protein per kJ of assimilable energy is directly related to its ability to support growth (Bowen, 1982). Getachew (1987) reported that the quality of the food consumed by O. niloticus varied from 1.4 to 3.3 mg/kJ during April to July. In addition he also reported that this low quality food is reflected in the lose of condition of the fish after two month's lag. It is thus, evident that the formation of checks and translucent zones in scales and otoliths of O. niloticus could also be associated to slow growth due to the reduced quality food consumed. Bowen (1982) stated that fish growth would be optimum if the quality of the food is between 4 and 25 mg/kJ. The quality of the food of O. niloticus reported by Getachew (1987) during April to July can not, therefore, support optimum growth.

The checks and translucent zones formed in the scales and otoliths of O. niloticus during January to February and June to July can, therefore, be associated to the reduced growth due to lose of condition, spawning activity (for matured fish), reduced temperature and due to the reduction in the quantity and quality of food consumed.

Most of the specimens of O. niloticus sampled during March to May and August to December had opaque zone at the margin of their otolith. The average number of circuli after the last check also increased during these months. It is, therefore, believed that growth of O. niloticus may resume at a relatively faster rate in this part of the year. It also becomes evident that the annulus would be formed once growth resumes at faster rate (Casselman, pers. comm.). Improved condition after reproduction (Fig. 4) (see also Getachew, 1987) and the rise in temperature of the lake (Fig. 7) could be responsible for the increase in the growth of the fish in these months. The quantity of the food consumed can also be increased after spawning has been completed. The quality of the food as reported by Getachew (1987) was optimum few months earlier.

The fish grew at relatively better between August and November. In this period maximum rain and water level were reached (Fig. 6). Elizabeth (1987) found that there was a greater phytoplankton biomass after the rain due to the increase in nutrients. It is, therefore, possible that the fish can grow better after the rain due to the increase in available food. Holcik (1974) reported that the growth of Sargochromis codringtoni in L. Kariba was accelerated during the rainy season. The growth of Tilapia rendali in a South African water body was also faster during the rainy season and during high water level (Batchelor, 1978).

The growth of O. niloticus can, therefore, be accelerated during March to May and August to December due to completion of spawning, increase in temperature, and increase in quantity and quality of the food consumed.

The otoliths of O. niloticus indicated the formation of two translucent zones each year. This has been reported for a number of tropical (Bruton, 1979; Hecht, 1980; Hopson, 1982) as well as temperate fishes (Casselman, pers. comm.).

The sixth translucent zone in the otoliths of O. niloticus is probably formed at about the end of the first year of life (see Fryer and Iles, 1972). Ages estimated using Gulland's (1969) method also provided supportive evidence to this (Tables 8A and 8B). It thus becomes evident that the 8th, the 10th, the 12th, the 14th and the 16th translucent zones could be formed at about the end of the 2nd, the 3rd, the 4th, the 5th and the 6th years of life, respectively. Average lengths were calculated for these ages (Tables 8A and 8B). Similar data back-calculated from otoliths (Tables 11 and 12) are in close agreement with those directly obtained from otoliths.

O. niloticus in L. Awassa spawns twice a year, the main one in January to March and a less pronounced one in July to September (Fig. 5). Getachew (1987) reported that there were large number of spawning fish during February to March, and large numbers of young fish have been observed from February to April (Tudorancea et al., 1988) with lesser numbers during October and November. It is, therefore, apparent that spawning of these fish is sufficiently reduced to few months with in a year. This allows length-frequency analysis to be applied in order to study the growth of the fish (Lock, 1982; Casselman, 1987). Length-frequency distributions for O. niloticus indicated that there is a growth process taking place as the modes progress from left to right (Fig. 9). Relative growth rates estimated from this method verify those from otoliths (Table 14). Furthermore, the growth parameters estimated from these data using the computer program ELEFAN agreed well with those obtained from otolith interpretations. Many workers have used length-frequency method to study the growth of tropical fishes (Mathes, 1961; Iles, 1971; Dudley, 1974; Mraja, 1982; Ogari, 1982; Wright et al., 1986). Mathes (1961) used this method to derive reasonable estimates of growth rates for Boulengerochromis macrolepis in L. Tanganyika where this fish spawns three times a year.

Growth data from mark-recapture experiment provide the most direct technique to test the validity of age and growth rate estimates from other methods (Casselman, 1987). It is evident that the available growth data from marked and recaptured O. niloticus are in close agreement with results obtained from otolith and length-frequency methods. Otoliths are generally believed to provide the best assessed age and growth estimates for various species of fish (eg., Casselman, 1983; Crecco et al., 1983). Casselman (1987) reported that otoliths grow in a manner more associated with the passage of time and, therefore, they may provide a relatively accurate age and growth estimates. The growth data that were obtained from otoliths of O. niloticus were, therefore, believed to be suitable to express the growth of this species.

The asymptotic length (Loo) for both sexes were less than the maximum lengths actually caught during sampling. The largest male caught was 33.2 cm, and the largest female was 31.5 cm TL. Only 0.2% of the females and 0.8% of the males were greater than 29.5 cm and 30.5 cm, respectively. Loo calculated is an average theoretical maximum size to which the population grows. Therefore, individual fish can grow more than this calculated average theoretical size (Lock, 1982). The same phenomenon has been exhibited by several species of tilapia (see Table 14). On the other hand , it is also quite possible that the Loo values may be underestimated as it was difficult to interpret otoliths from large fish. The growth data of Tilapia nilotica from L. Chad (Table 14) indicate Loo value of about 33.2 cm. The same species in the Egyptian region had Loo of about 31.6 cm (Table 14).

The growth coefficients (K) of both sexes of O. niloticus were with in the range of values estimated for most tropical species of tilapia (Table 14). The growth data reported by Jensen (1957) for T. nilotica from an Egyptian pond provide a growth coefficient of about 0.59. This species from L. Chad probably has a growth coefficient of about 0.32 (Table 14). This is closer to the value estimated for females O. niloticus from L. Awassa.

Growth of fish is demonstrably plastic (Weatherley and Gill, 1987). Tilapia also exhibit marked plasticity in growth (Balarin and Hatton, 1979). Comparison between tilapias living under different conditions is, therefore, invalid. However, as pointed out by Balarin and Hatton (1979) comparisons can be made to serve as an indication of the relative measure of the differences between species. O. niloticus in L. Awassa may grow between 9 and 10 cm in the first year of life. Several species of tilapia grow between 9 and 12 cm in length in this age (Table 14). Lengths attained by O. niloticus in L. Awassa in the proceeding years of life were comparable to results obtained by others in some other lakes (see Table 14).

There was a significant difference in growth between the sexes ($P < 0.05$, Table 7). The males were found to grow to a relatively larger size than the females probably starting from the second year of life. The decrease in the growth of the females at the second year of life could be related to the onset of maturity. The smallest ripe female caught was 13.8 cm, and the smallest ripe male was 15.6 cm in total length. These lengths indicate that maturity in O. niloticus could be attained in the second year of life. The condition of the females O. niloticus was much lower than that of the males during the main spawning period (Fig. 4). This species is a maternal mouthbrooder. During brooding, therefore, the females could be fasting. Fasting is generally believed to be the reason for the reduced growth of females in maternal mouthbrooder tilapia (Fryer and Iles, 1972). However, males are not also actively feeding during spawning activity (Lowe-McConnell, 1958). On the other hand Balarin and Hatton (1979) stated that reduced growth of females in maternal mouthbrooders may not only be due to fasting but, also to the total egg weight produced. Others believe that this phenomenon has a genetic basis (eg., van Someren and Whitehead, 1960). The difference in growth of males and females is an interesting phenomenon probably related to the relative growth of the sexes. It is also far more complex than it could be dealt with in this study.

The largest O. niloticus that was caught in this study measures about 33.2 cm in length. This species shows a range of maximum sizes from 17 cm in a small lagoon near L. Albert to about 64 cm in L. Rudolf (now Turkana) (Lowe-McConnell, 1958). The same species about 59 cm (TL) has been caught from L. Chamo, about 270 km south of L. Awassa (Getachew, unpublished data). The reason for variation in growth rate of a given species living under different waters is still open for further investigation.

Length frequency distribution of O. niloticus that were caught in the experimental gillnet (Fig. 13) indicates that fish probably in their second year of life and above are being exploited. However, only 7% of the females and 6% of the males were probably below their fourth year of life, the rest being in their fourth year of life and above. A net of this mesh size is not catching immature fish. It could, therefore, be safe to use this gillnet in L. Awassa.

VI. CONCLUSION

Annuli in otoliths of *O. niloticus* could be formed and used to study the age and growth of this fish. Scales may be unreliable after the third year of life.

Seasonal growth cycle in the otoliths and the scales of this fish was connected to the fluctuations in temperature, food quantity and quality consumed and to spawning activity. That these factors appear to overlap in time indicates that they interact to result in the formation of checks and translucent zones.

Assuming actual average "birthdates" placed the two yearly recruits in the same time scale. Therefore, based on the formation of two translucent zones in otoliths, the 6th to the 16th translucent zones correspond to the 1st to the 5th years of life, respectively.

Relative linear growth rates estimated from otoliths, length-frequency method and from marked *O. niloticus* were in close agreement. Moreover, agreement was also evident, at least for young fish, among results from scales and otoliths. It can, therefore, be concluded that age and growth assesses from otoliths may express the average growth pattern of *O. niloticus* population in L. Awassa.

The gillnet currently being used to catch *O. niloticus* from L. Awassa does not catch immature fish. However, the catch was composed of wide range of age groups. The dominant fish represented in the catch were between their 5th and 7th years of life.

Further refinements of the growth results obtained from this study would be necessary. This should concentrate on identifying between the two yearly recruits and on identifying the first annulus in otoliths. Once these have been done a January 1 "birthdate" can be used and absolute age determined.

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