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BREEDING SEASON, FECUNDITY, LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR OF *OREOCHROMIS NILOTICUS* L. (PISCES: CICHLIDAE) IN LAKE TANA, ETHIOPIA

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ABSTRACT: The breeding season, fecundity, length-weight relationship and condition factor of *Oreochromis niloticus* from Lake Tana, Ethiopia, were studied from monthly samples collected using a bottom trawl between March, 1992 and March, 1993. In Lake Tana *Oreochromis niloticus* spawns throughout the year, with a high activity between April and August peaking in June and July. The peak spawning coincided with the onset of the rainy season. There was a curvilinear relationship between fecundity and total length (TL) (logF = -0.01 + 2.O1LogTL, $r=0.86$, $p<0.001$) and a linear relationship between fecundity and body weight (W) (F = 234.65+1.51TW, $r=0.84$, $p<0.001$) and gonad weight (GW) (F = 394.55+29.1GW, $r=0.67$, $p<0.001$). The length-weight relationship was less than a cube, LogTW = -1.373+2.742LogTL, $n=680$, $r=0.97$, $p<0.001$ indicating allometric growth of the fish. The length-weight regression coefficients for both males (2.748) and females (2.747) were almost the same. A significant seasonal fluctuation (ANOVA, $p<0.001$) was observed in the condition of the fish. The relatively low values during April to August may be due to the high energy cost of spawning.

Key words/phrases: Allometric growth, breeding season, Fulton's condition factor, fecundity, *Oreochromis niloticus*

INTRODUCTION

Tilapia (Cichlidae) are widely distributed in tropical and sub-tropical waters of Africa, South America and Asia (Fryer and Iles, 1972). The tilapia, *Oreochromis niloticus*, occurs in almost all the lakes and streams of Ethiopia (Shibru Tedla, 1973), and accounts for about 60% of the annual commercial fishery (LFDP, 1995).

Reproductive biology of *O. niloticus* from Ethiopian Rift Valley Lakes was studied by Zenebe Tadesse (1988) and Demeke Admassu (1994; 1997). Food and feeding habits were studied by Getachew Teferra (1987), Getachew Teferra and Fernando (1989), Eyualem Abebe and Getachew Teferra (1992), Getachew Teferra (1993) and Zenebe Tadesse and Getachew Teferra (1997) and age and growth was studied by Demeke Admassu (1989) and Yosef Tekle-Giorgis (1990).

O. niloticus is a maternal mouth brooding species that breeds continuously throughout the year in the Rift Valley Lakes, Ziway (Zenebe Tadesse, 1988) and Awassa (Demeke Admassu, 1997). There are peak breeding months where spawning is intensive and these months are associated with changes in environmental factors such as rainfall, temperature, and photoperiod (Zenebe Tadesse, 1988; Demeke Admassu, 1997).

Most studies of *O. niloticus* have been limited to the Rift Valley Lakes Ziway, Awassa and Chamo. By contrast, very little is known about this important fish of the non-rift valley lake, Lake Tana. Earlier reports about the fish fauna and limnology of this lake are very old and incomplete (Talling and Rzoska, 1967; Rzoska, 1976). However, recent studies have described 14 distinct morphotypes of large barbs (*Barbus* spp.) from Lake Tana based on differences in general morphology, distribution and feeding habit (Mina *et al.*, 1993; Nagelkerke *et al.*, 1995a). Mina *et al.* (1993) suggested that these morphological differences are evident after the fish attained sexual maturity. In contrast, Nagelkerke *et al.* (1995b) reported the possibility of distinguishing between most of the morphotypes at an earlier stage (< 12 cm fork length). Eventhough, their taxonomic status is still uncertain.

Oreochromis niloticus is the preferred fish for consumption by the local population and accounts for about 37% of the commercial fishery of Lake Tana (LFDP, 1995). Proper management and rational utilization of this resource requires basic biological knowledge on the fish such as feeding, reproduction and growth. However, such basic data are not available for *O. niloticus* from Lake Tana. Thus, studies on the basic biology and ecology of this fish are essential.

The main objectives of this study were to assess fecundity rate and breeding season of the fish and to estimate the length-weight relationship and condition factor of *O. niloticus in* Lake Tana.

DESCRIPTION OF THE STUDY AREA

Lake Tana (12°N, and 37°20'E) is located at an altitude of 1829 m in the north-western part of Ethiopia. It is the largest lake in the country and covers an area of 3150 km^2. It has a maximum depth of 14 m and a mean depth of 8.9 m (Rzoska, 1976). The lake was probably formed during the late Pliocene or early Pleistocene as a result of volcanic action which uplifted the surrounding mountains (Rzoska, 1976). The diel temperature varies from 23 to 30° C during the day time and falls below 10° C in the night (Fig. la). The annual rain fall may reach up to 2000 mm: the main rainy season extends from June to October peaking during June to August (Rzoska, 1976).

Among the 60 rivers that flow into the lake, the little Abbay, the Rib and the Gumera rivers are the largest. Lake Tana is the source of the River Abbay (the Blue Nile) which outflows at the south-eastern corner of the lake. The shores are partly rocky but especially at the mouth of affluent rivers there is an extensive macrophyte vegetation including *Cyperus*, *Scirpus*, *Paspalidium*, *Phragmites*, *Ceratophylum* and *Nymphea*. The vegetation provides spawning and nursery grounds for *O. niloticus*.

The bicarbonate plus carbonate, calcium, magnesium and sodium ions dominate the water chemistry of the lake. In contrast, nitrate-nitrogen is very low reaching below detection level (Talling and Rzoska, 1967). The major genera of phytoplankton in the lake include *Microcystis*, *Anabaena*, *Melosira*, *Surirella*, *Staurastrum* and *Pediastrum* (Talling, 1976). The known genera of zooplankton are *Mesocyclops*, *Thermocyclop*, *Diaphanosoma*, *Bosmina*, *Daphnia*, *Keratella*, *Brachionus* and others (Tesfaye Wudneh, pers. comm.). In addition to the 14 barbus-morphotypes (Nagelkerke *et al.*, 1995b) the fish fauna of Lake Tana is composed of *O. niloticus*, *Clarias gariepinus*, *Varicorhinus beso*, *Gara quadrimaculata* and *G. dembeensis*. The most important fish species which account for about 98% the fishery are *O. niloticus*, *Barbus* spp. and *C.* gariepinus (LFDP, 1995).

MATERIALS AND METHODS

Monthly samples from two sites were collected between March 1992 and March 1993 with a bottom trawl of a code end mesh size of 40 mm. Trawling was done for about 30 minutes during each sampling occasion. All fish collected were mixed and a random sub-sample of 30 to 60 fish were taken for analysis. Total length (TL) and total weight (TW) of each fish were measured to the nearest 0.1 cm and 0.1 g, respectively. Sex of each fish was determined by examination of gonads and the weight of gonads was recorded to the nearest 0.1g. Gonado-somatic index (GSI), gonad weight as a percentage of total body weight, was calculated for each fish. Maturity of the gonads was determined according to Siddiqui (1977) and Babiker and Ibrahim (1979). Fecundity was determined by counting all ripe eggs in ovaries that were preserved in Gilson's fluid (Synder, 1983). Length-weight relationship was constructed using least squares regression fitted to log transformed length and weight data, i.e., LogTW = loga + blogTL, where a and b are constants fitted by least squares regression.

Fulton's condition factor was calculated (Le Cren, 1951; Bagenal and Tesch, 1978). Fulton's condition factor = (TW/TL3) x 100 where, TW is in grams and TL is in centimetres.

A chi-square test was employed to determine if the sex-ratio varied between months and with fish size. Fluctuations in Fulton's condition factor as well as in GSI values were statistically (ANOVA) tested if they varied in samples between months (Sokal and Rohlf, 1981).

RESULTS

A total of 680 *O. niloticus* individuals were examined in 13 sampling occasions. Males were more numerous than females (chi-square, $p < 0.05$) in the total catch as well as in samples from April, May and June (Table 1). There was also a preponderance of males in length-groups that were larger than 27.0 cm TL (Table 2).

Table 1. The number of males, females and sex-ratio in monthly samples of *O. niloticus* caught from Lake Tana. The last column shows chi-square values. *, Significant (p<0.05).

Month	Males	Females	Sex ratio (male: female)	Chi-square
Mar. '92	22	17	1:0.77	0.64
Apr.	44	15	1:0.34	14.25*
May	36	21	1:0.58	3.95
Jun.	42	17	1:0.41	10.59*
Jul.	25	22	1:0.88	0.19
Aug.	23	26	1:1.13	0.18
Sep.	17	16	1:0.94	0.03
Oct.	31	23	1:0.74	0.19
Nov.	25	22	1:0.88	0.19
Dec.	25	36	1:1.44	1.98
Jan. '93	28	26	1:0.93	0.07
Feb.	32	29	1:0.91	0.15
Mar.	33	28	1:0.85	0.41
Total	383	297	1:0.78	10.88*

The gonado-somatic indices varied significantly (ANOVA, $p < 0.001$) between months. GSI values of females ranged from 0.43 ± 0.03 to 2.45 ± 0.25 (mean $\pm$ SE) whereas those of males ranged from 0.09 ± 0.01 to 0.99 ± 0.08. High GSI values were evident between April and August for both sexes. The peak occurred in June for females and in June and July for males (Fig. lb). The values were generally low during the rest of the sampling period except for the slight increase that was observed between January and March, 1993. This increase was more pronounced in males than females (Fig. lb). However, sex by month interaction was insignificant (ANOVA, $p = 0.068$) suggesting that the pattern of seasonal fluctuation on GSI was similar in both sexes.

Oreochromis niloticus with ripe gonads were caught throughout the year, however, their frequency in the catch varied seasonally (Fig. 1c). Ripe females were more frequent during April to August than during the rest of the year. However, the frequency of ripe males slightly increased between January and March in 1993 (Fig. 1c). The results from seasonal fluctuation in GSI and the frequency of ripe fish suggest that *O. niloticus in* Lake Tana breeds intensively between April and August, but some individuals may breed throughout the year.

Table 2. The number of males, females and sex-ratio in samples of *O. niloticus* caught from Lake Tana. Samples were grouped in 2.0 cm length classes. The last column shows chi-square values. *, Significant ($p<0.05$).

Length (cm)	Males	Females	Sex-ratio (male: female)	Chi-square
13	3	1	1:0.33	1.00
15	7	4	1:0.57	0.82
17	16	7	1:0.44	3.52
19	33	47	1:1.42	2.45
21	44	61	1:1.39	2.75
23	73	52	1:0.68	3.53
25	78	62	1:0.79	1.83
27	53	44	1:0.83	0.84
29	38	12	1:0.32	13.52*
31	22	5	1:0.23	10.70*
>32	16	2	1:0.13	10.89*
Total	383	297	1:0.78	10.88*

Fecundity of *O. niloticus* in Lake Tana ranged from 495 to 1243 eggs for females whose length was between 21 and 31.5 cm and weight was between 190 and 570 g. The mean fecundity was 730 eggs (standard deviation = 168, $n=45$). Fecundity was curvilinearly related with TL (Fig. 2a), and linearly related with TW (Fig. 2b) as well as with gonad weight (Fig. 2c).

There was a significant ($p < 0.001$, $n = 680$) curvilinear relationship between TL and TW of *O. niloticus* in Lake Tana. The regression equation which was fitted for fish between 12 and 34.8 cm TL and 40 and 743 g TW was as follows:

Males: $\text{Log}TW = -1.383 + 2.748\text{Log}TL$ ($r=0.974$, $p<0.001$, $n=383$).
Females: $\text{Log}TW = -1.377 + 2.747\text{Log}TL$ ($r=0.965$, $p<0.001$, $n=297$).
Males and females: $\text{Log}\,TW = -1.373 + 2.742\text{Log}\,TL$ ($r=0.971$, $p<0.001$, $n=680$).

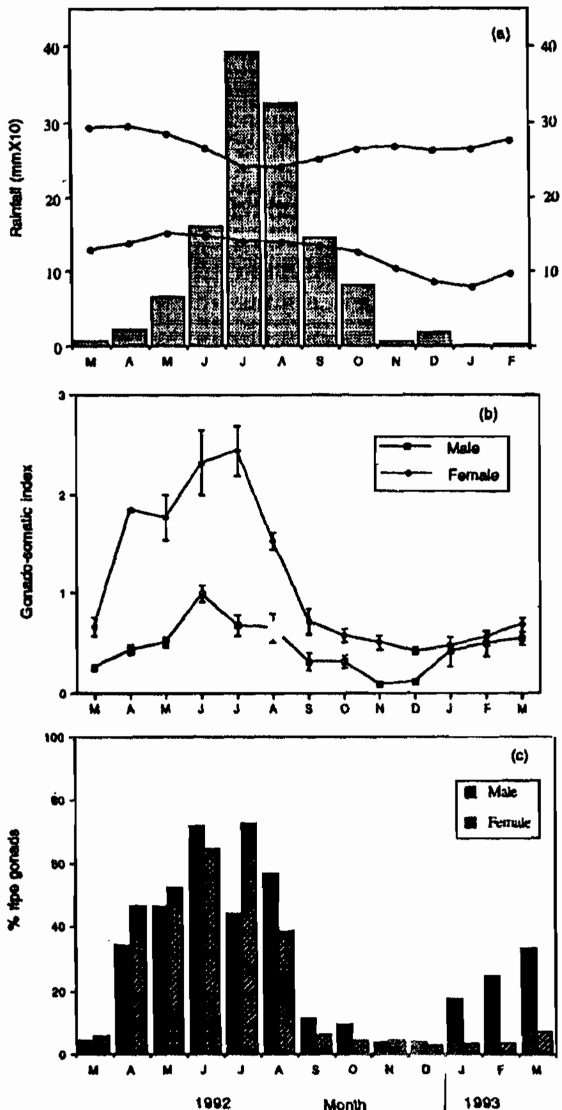

Fig. 1. Monthly mean total rainfall (bar) and air temperature (line) around Lake Tana between 1979 and 1988 (a), seasonal variation in gonado-somatic index (b) and frequency of ripe gonads (c) of *Oreochromis niloticus*. Vertical bars indicate standard error of the mean.

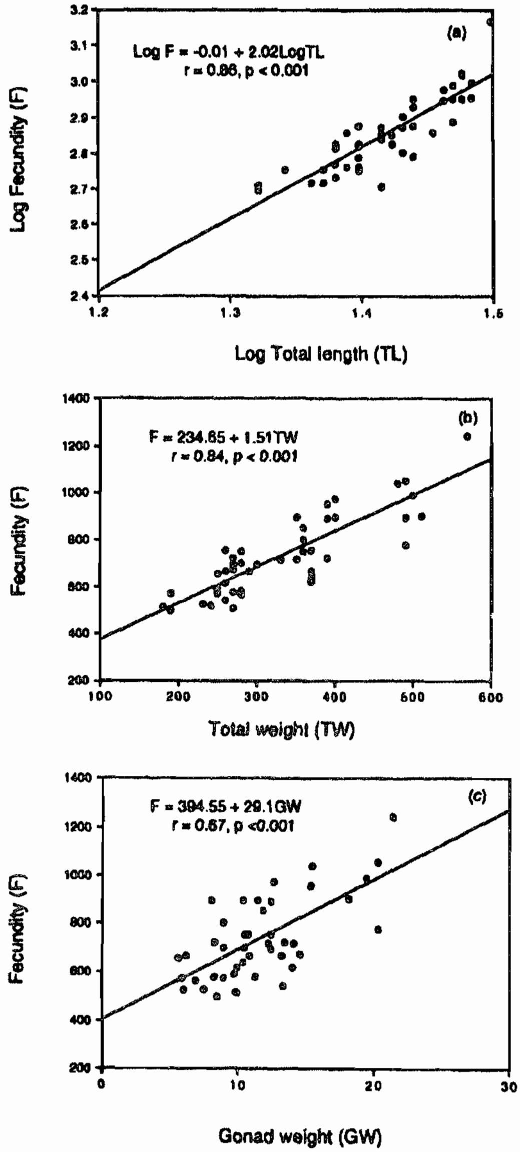

Fig. 2. Relationship between fecundity and total length (a), fecundity and total weight (b) and fecundity and gonad weight (c). n=45.

Fulton's condition factor of the fish ranged from 1.47 to 2.29 for females and from 1.44 to 2.37 for males. The values were found to be significantly different between months (ANOVA, $p < 0.001$). Thus, the values were relatively lower between May and August (Fig. 3) which seem to coincide with the peak breeding season of the fish (cf. Figs 1b and 1c).

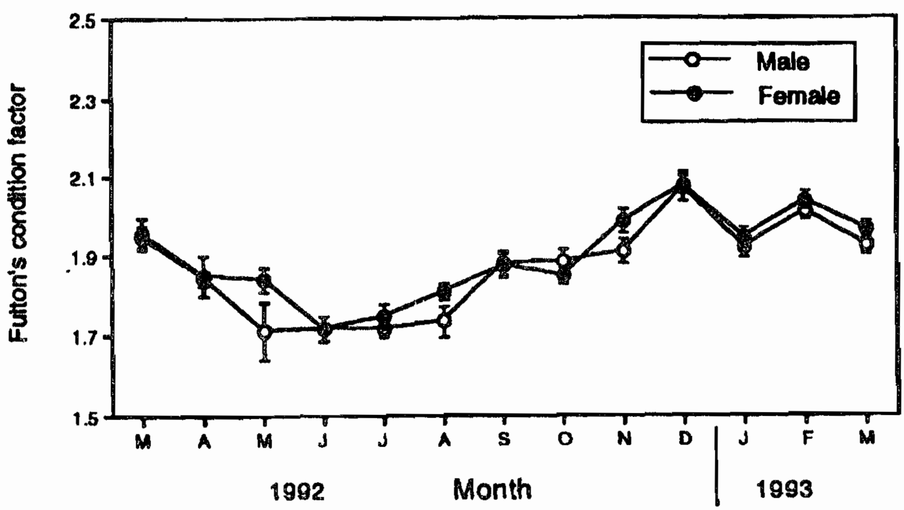

Fig. 3. Seasonal variation in the Fulton's condition factor of *Oreochromis niloticus*. Vertical bars represent standard error of the mean.

DISCUSSION

This study demonstrates that males predominated in the catch that was taken during the peak spawning period of the fish and this could be one of the reasons why males were more numerous than females in the total catch as well as in size groups above 27 cm TL (Tables 1 and 2, Figs 1b and 1c). The preponderance of males over females in the catch taken during the peak breeding season may be explained by the interactive effects of the reproductive behaviour of the fish and the sampling gear. During the spawning season, male tilapia build their spawning nests at the bottom and guard them against intruders

(Lowe-McConnell, 1958; 1959). In addition, the males are polygamous and thus stay at their breeding nests to court several females (Lowe-McConell, 1958; 1959). The females, on the other hand, move to their brooding sites in the vegetation zones up in the water column immediately after fertilization (Lowe-McConell, 1958; 1959). Thus, the males stay longer at the bottom of the water making them more vulnerable than the females to be caught by the gear used in this study (bottom trawl). This may also be the reason why males dominated over the females particularly in sexually mature fish (> 27 cm TL). In contrast, gill nets set at the water surface are likely to catch more females than males. This was reported by Demeke Admassu (1994) who found a preponderance of females over males in *O. niloticus* from Lake Awassa in gill net catches taken during the peak fish breeding seasons. He also attributed his results to the breeding behaviour of the fish and to the type of gear he used. Sex-ratio in favour of males has been reported to the related mouth brooding species *T. leucostica* in Lake Naivasha (Siddiqui, 1977). Lowe-McConnell (1959) has also suggested that in tilapia a preponderance of males in catches may indicate peak breeding season.

Oreochromis niloticus in Lake Tana breeds intensively during April to August (Figs 1b and 1c). However, some breeding activity may take place at other times of the year as well. Environmental factors such as temperature and photoperiod influence gonadal development in tilapia (Balarin and Hatton, 1979), but this is only possible in the temperate regions where there is a marked seasonal fluctuation in these factors. In the tropics however, seasonal fluctuations in temperature and photoperiod are generally very low, and this might be favourable for some tropical fish to spawn at any time of the year (Lowe-McConnell, 1982). Similarly, this may be the reason why breeding *O. niloticus* in Lake Tana were present throughout the year. Other species of *Tilapia* were also found to spawn year round (Siddiqui, 1977; 1979). Rainfall is another environmental factor associated with spawning in tropical fish in general and in tilapia in particular (Zenebe Tadesse, 1988; Demeke Admassu, 1997). The rainy season at Lake Tana was coincident with the peak spawning activity of *O. niloticus* (Figs la,b and c). Evidently, rainfall increases production (phytoplankton, zooplankton) of waters because of the resulting nutrient load by run off (Elizabeth Kebede *et al.*, 1994). This in turn insures the availability of sufficient food for better growth and survival of the off-springs of tilapia fish

(Jalabert and Zohar, 1982). In addition, the quality of the available food may also be improved after the rainy season. A study that was conducted concurrently with the present (Getachew Teferra pers. comm.), for instance, showed that the food ingested by *O. niloticus* in Lake Tana after the rainy season contained high levels of organic matter and protein and low levels of hydrolysis resistant organic matter. In addition, rainfall increases water level which in turn provides suitable spawning grounds for adults and feeding and nursery grounds for the young (Jalabert and Zohar, 1982). Since the macrophyte vegetation of Lake Tana grows extensively following the rainy season, the juvenile *O. niloticus* would be provided with suitable shelter and minimize the risk of predation by piscivores. Thus, rainfall appears to be an important environmental cue associated with the intensive spawning activity of *O. niloticus* in Lake Tana between April and August (Fig. 1a).

Similar studies (Zenebe Tadesse, 1988; Tudorancea *et al.*, 1988; Demeke Admassu, in press) have shown that the fish in the rift valley lakes of Ethiopia spawn throughout the year. However, breeding was intensive between December and March in Lake Ziway (Zenebe Tadesse, 1988) and during January to March and July to September in Lake Awassa (Tudorancea *et al.*, 1988; Demeke Admassu, 1997). Stewart (1988) also reported that the species in Lake Turkana breeds continuously but peak breeding occurs during March to July. Peak spawning activity of *O. niloticus* in the above studies has been attributed to rainfall and to factors associated with it, and agree well with the present study.

Fecundity of *O. niloticus* in Lake Tana was related nearly to the square (b = 2.01) of fish length (Fig. 2a). This is low when compared with substrate spawners where fecundity is related to the cube of their length (Simpson, 1951; Lowe-McConnell, 1959). The low fecundity of *O. niloticus* could be due to the mouth brooding behaviour of the fish as the number of spawn will be limited by the size of the buccal cavity (Lowe-McConnell, 1955; Babiker and Ibrahim, 1979). Moreover, Lowe-McConnell (1955) stated that mouth-brooding tilapia tend to produce large but few eggs due to better parental care they provide for their offspring. A comparably low fecundity has been reported for the same species from Lakes Ziway (b=2.16) Zenebe Tadesse (1988), Lake Awassa (b=2.39), Demeke Admassu (1994) and from the White Nile (b=2.02) Babiker and Ibrahim (1979) supporting the result obtained in this study. Siddiqui (1977) also reported a low value (b=2.17) of fecundity for the related mouth brooding *T. leucostica*. Fecundity was linearly related to total weight (Fig. 2b) as well as to gonad weight (Fig. 2c). Similar relationships were also reported by other workers for the same species (Demeke Admassu, 1994), and the related *T. leucostica* (Siddiqui, 1977). The relatively weak correlation (r = 0.67) between fecundity and gonad weight might be due to differences in the size of ripe oocytes. Large ovaries were found to contain fewer oocytes (Welcomme, 1967), and this might account for the poor correlation observed between fecundity and ovary weight.

The curvilinear relationship between weight and length of *O. niloticus* in Lake Tana was less than a cube (b = 2.74) for both sexes. This coefficient is expected to be near three since growth in weight represents an increase in three dimensions whereas length measurements are taken in one dimension (Bwanthondi and Pratap, 1981). However, the apparently low value of the coefficient might be because of shortage of food (phytoplankton) available for the fish in the lake. In a similar study, a value close to cube was obtained from the Rift valley lakes, Ziway (b=3.03 (Zenebe Tadesse, 1988)) and Awassa (b=3.01 (Demeke Admassu, 1990)) for the same species. These two lakes contain a relatively high algal biomass (Awassa 18.3 $\mu g(l)^{-1}$; Ziway, 154.2 $\mu g(l)^{-1}$ (Elizabeth Kebede *et al.*, 1994)) when compared with Lake Tana (3.7 $\mu g(l)^{-1}$ (Talling, 1976)). Thus, although food is seldom limiting under natural conditions, the relatively low algal biomass in Lake Tana, might be less than sufficient for optimum growth of the fish.

The condition factor of the fish varied significantly (ANOVA, $p < 0.001$) between months (Fig. 3). Low condition factor of *O. niloticus* in Lake Tana is coincident with the peak spawning season of the fish. Spawning drains metabolic resources for the production of sperm and eggs (Fryer and Iles, 1972). In addition, in species such as *O. niloticus* females brood their young in the buccal cavity and the males are actively engaged in building and guarding nests and in fertilizing several females (Lowe-McConell, 1958, 1959). Thus, feeding intensity of *O. niloticus* may be reduced if the fish is actively engaged in breeding activities. This could be the reason why the condition factor of *O. niloticus* in Lake Tana was relatively low during the fish peak breeding season. Similar conclusions were made for the same species from Lakes Ziway (Zenebe Tadesse, 1988) and Lake Awassa (Demeke Admassu, 1994). Stewart (1988) also correlated the decreased condition of *O. niloticus* during the peak breeding period in Lake Turkana with increased reproductive activity of the fish which causes erratic feeding and depletion of bodily reserves.

Studies on the breeding season, fecundity and related parameters have practical significance for *O. niloticus* fishery. The legal minimum mesh size (stretched) of the gill net for the tilapia fishery of Lake Tana and of most other lakes in Ethiopia is 100 mm. This gill net at Lake Awassa for instance, is reported to catch a considerable number of spawning fish during their breeding period (Demeke Admassu, 1994). In addition, the length of 50% maturity of *O. niloticus* in Lake Awassa, i.e., 18.8 cm for females and 19.8 cm for males (Demeke Admassu, 1994), is similar to the fish in Lake Tana, i.e., 18.1 cm for females and 20.7 cm for males (Tesfaye Wudneh pers. comm.). Thus, it is highly probable that the gill net being used at Lake Tana may remove a significant number of spawning fish during their peak breeding season. Hence, it is essential to investigate the effect of commercial gill netting on the *O. niloticus* stock of Lake Tana so that appropriate management actions can be taken to sustain the yield.

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