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# REPRODUCTIVE BIOLOGY OF THE FISH *LABEOBARBUS INTERMEDIUS* IN THE DIRMA AND MEGECH TRIBUTARY RIVERS OF LAKE TANA (ETHIOPIA)

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**Abstract:** Spawning habits of *Labeobarbus intermedius* were studied from samples collected on the river mouths of Dirma and Megech, tributaries of Lake Tana, during December 2003 to November 2004. Fish were caught using 6, 8, 10 and 12 cm stretched mesh size gill nets. In the monthly samples, fish with reproductively mature and immature gonads were captured. Nevertheless, breeding fish were more frequent in the catch and gonadosomatic index (GSI) values peaked from August to November for both sexes. Fulton's condition factor was also significantly lower during these months (Mann-Whitney U test; $P<0.001$). These reproductive parameter variations indicate that *L intermedius* reproduces throughout the year, but, it reproduces intensively from August to November. The sex ratio was 1:3.01 (male: Female) and significantly different ($X^2$: $P<0.001$). Length at maturity was 22.57 cm for females. The mean fecundity was 3588 eggs (ranged between 1761 and 8367 eggs) per female. Mean ova diameter was 1.99 mm (ranged between 1.65 to 2.30 mm). There was exponential relationship between fecundity (F) and fork length (FL) ($FL=0.2691FL^3$, $r^2=0.75$) while fecundity and gonad weight were related linearly (GW) ($F=216.56GW-160.45$, $r^2=0.95$). Polynomial relationship was observed between fecundity and total weight (TW) ($F=0.0016TW^2 + 19.769TW + 240.15$, $r^2=0.78$). Closing the gill net commercial fishery in these river mouths throughout the year or at least from August to November is strongly recommended to prevent recruitment over fishing on *L. intermedius* in Lake Tana.

**Keywords**: Fecundity, Gonad maturity, Sex-ratio, Spawning migration, River mouths,

## Introduction

Although Ethiopia is a land of abounding faunal and floral biodiversity, millions of rain dependent farmers are suffering with starvation due to recurring drought. To minimize the food insecurity problem, sustainable utilization of aquatic resources, particularly the fishery resource, as a cheap substitute of animal protein, requires due attention. Although the country is land-locked since 1991, there are various inland water bodies from where aquatic food resources could be produced. Of these inland water resources, Lake Tana is the largest (ca. 3200km$^2$) and constitutes almost half of the country's freshwater body (Reyntjes et al., 1998; Eshete Dejen et al., 2003; De Graaf et al., 2004).

In Lake Tana six genera of fishes were identified: *Barbus, Clarias, Garra, Labeobarbus, Oreochromis* and *Varicorhinus*. The genus *Labeobarbus* is considered as the largest and forms the only known intact endemic cyprinid species flock (Nagelkerke and Sibbing, 1996). The *Labeobarbus* species of Lake Tana have previously been classified under the genus *Barbus*, by adding the prefix 'large'. However, large, diverse, hexaploid African *Barbus* are renamed as *Labeobarbus* (labeobarbs) (Skelton, 2001; Skelton, 2002; Snoeks, 2004). According to the latest taxonomic revision done by Nagelkerke (1997) and Nagelkerke and Sibbing (2000), 15 biologically distinct *Labeobarbus* species that form a species flock are described in the lake.

*Labeobarbus intermedius*, which is the most abundant among *Labeobarbus* in Lake Tana and its tributary rivers, has many irregular morphological and physiological characteristics from other members of the genus (Nagelkerke, 1997). Even though its reproductive season was reported by various authors (Nagelkerke and Sibbing, 2000; De Graaf et al., 2004), the samples were collected only in the southern Gulf of Lake Tana area which represents about a tenth of the total lake area whereas the northern part of the lake (the largest area), due to environmental and logistic problems, was not the focus of research. In addition to this, data about length-weight relationship, sex-ratio, fecundity and condition factors of *L. intermedius* in Lake Tana, which are very important in the fish stock management, are scarce. The aim of this work was therefore to investigate the reproductive biology *L. intermedius* consequently to recommend sound management options for this species in Lake Tana.

## Material and Methods

### Study area

Lake Tana, the headwater of the Blue Nile River, is located in the northwestern highlands of Ethiopia (1830 m above sea level). The lake has an area of about 3200 km$^2$ and it is the largest water body in the country. It is shallow lake with an average depth of 8 m and maximum depth of 14 m. The catchment area of Lake Tana (16,500 km$^2$) has a dendritic type of drainage network. The only outflowing river from Lake Tana is the Blue Nile. Seven big perennial rivers which cross Fogera and Dembia floodplains flow into Lake Tana: Gelgel Abbay, Gelda, Gumara, Rib, Arno-Garno, Megech and Dirma (Fig. 1).

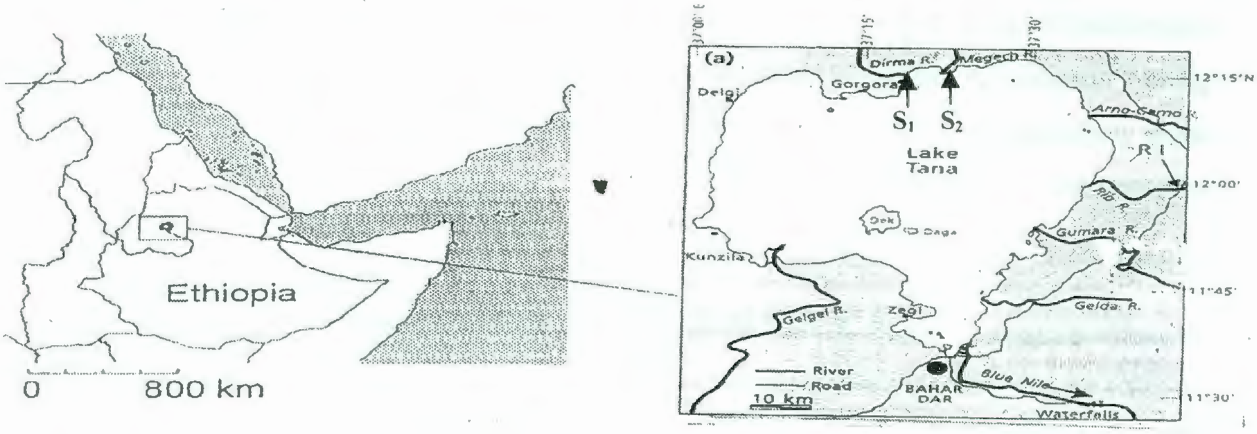



Figure 1. Location of Lake Tana in Ethiopia, its inflowing and outflowing tributary rivers, and the sampling stations ($S_1$ = Dirma River mouth and $S_2$ =Megech River mouth). (Map adapted from Tesfaye Wudneh, 1998)

In some months of the dry season (February, March, April and May) both Megech and Dirma Rivers are completely dried at their mouths due to excess water extraction for irrigation by the local farmers in the upper stretches. During the rainy season (July to November), both rivers recover in volume due to the heavy rains in the area. During this rainy season the river mouths are muddy and covered by dense macrophytes. However, upper stretches of the rivers (about 30 to 40 km away from each river mouth) are gravel-bedded and the water is clear.

**Fish collection and Gonadosomatic index (GSI %) estimation**

Fish were collected monthly during the months (December 2003 to June 2004 and November 2004) from the river mouths of Dirma (12$^0$15'40.8"N; 37$^0$ 15' 43.9"E) and Megech (12$^0$ 16' 03.2"N; 37$^0$ 24' 03.9"E) (Fig. 1). In July 2004 samples were taken twice from each river mouth and during August to October 2004, samples were taken every week at both river mouths. Polyfilament gill nets (6, 8, 10, and 12 cm stretched mesh size) with a panel length of 100 m and depth of 3 m were used in every over night sampling. Fish collected in the river mouths were transported fresh to the laboratory of Gorgora Fish and other Aquatic Life Research Sub Center. In the laboratory fork length (0.1 cm), total weight (0.1 g), and gonad weight (0.01 g) of each specimen of *L. intermedius* were measured. Each fish was dissected, the gonads were examined visually and sexed. The gonad maturity stage of each *Labeobarbus* was determined visually according to De Silva *et al.* (1985). Fish with gonad stages I-IV were considered as immature while gonad stages V, VI, and VII were regarded as ripe, running and spent respectively. GSI was calculated as percentage gonad weight of total weight.

**Length-weight, Length at first maturity ($FL_{50}$) and Fulton's condition factor**

Length-weight relationship was calculated using least square regression analysis (Bagenal and Tesch, 1978). The percentage of mature fish per length-class with class-width 2 cm was calculated and $FL_{50}$ was estimated according to King (1995). Fulton's condition factor (K) was calculated as total weight in percent of fork length cube ($K = \frac{TW \times 100}{FL^3}$) (Bagenal and Tesch, 1978). Mann-Whitney U test was used to test the significant differences between Peak and non-peak spawning seasons in K. For statistical data analysis SPSS for windows software (Version 11.5) was used.

**Fecundity determination**

Fecundity estimation was carried out using the gravimetric method (MacGregor, 1957) by weighing all the eggs from each of the ovaries of gravid (ripe) fish species (gonad maturity stage V). Females at running condition (gonad maturation stage VI), distinguished by slightly pressing their abdomens to check for the release of eggs, were excluded from the fecundity estimation. Samples of eggs were taken from different size classes of the fish on various ovary areas. These eggs were preserved using 4% formalin solution. To count the eggs and to measure ova diameter, the ovarian membranes were first removed mechanically using tap water from the preserved ovaries. After vigorous shaking, three sub-samples of 1 g of eggs per ovary were counted and the total number of eggs per ovary was estimated by extrapolation. For random measurement of ova diameter, every 1g of eggs counted was poured into a Petri dish, calibrated by a grid every 5 mm. The water from the Petri dish was carefully and completely removed without disturbing the eggs distribution in the dish. Only those eggs which touched the grid lines, having a diameter of ≥1.25 mm, were measured to the nearest 0.05 mm using an ocular micrometer placed in a dissecting microscope

## Results and Discussion

### Sex-ratio

A total of 2306 (575 males and 1731 females) *L. intermedius* were captured (Table 1). The sex- ratio (male: female), 1:3.01, was significantly different ($X^2$; p< 0 05) from the theoretical 1:1. Preponderance of females was not observed in the fish having fork lengths less than 15 cm (Table 2). In the months from August to October and in the larger sized fish (FL>17 cm) females significantly (P<0.05) dominated the catch (Tables 1 and 2).

Table 1: The sex-ratio analysis of *L. intermedius* on monthly basis from Lake Tana.

| Month | Males | Females | Sex ratio (Male: Female) | $X^2$ | Prob. |
|---|---|---|---|---|---|
| Jan | 13 | 28 | 1:2.15 | 5.488 | 0.019 |
| Feb | 14 | 11 | 1:2.81 | 0.360 | 0.549 |
| Mar | 12 | 35 | 1:2.92 | 11.255 | 0.001 |
| Apr | 20 | 35 | 1:1.75 | 4.091 | 0.430 |
| May | 15 | 23 | 1:1.53 | 1.684 | 0.194 |
| Jun | 31 | 31 | 1:1.00 | 0.000 | 1.000 |
| July | 41 | 60 | 1:1.46 | 3.574 | 0.059 |
| **Aug** | **169** | **463** | **1:2.74** | **136.766** | **0.000*** |
| **Sep** | **111** | **524** | **1:4.72** | **268.613** | **0.000*** |
| **Oct** | **83** | **462** | **1:5.57** | **263.561** | **0.000*** |
| **Nov** | **13** | **40** | **1:3.08** | **13.755** | **0.000*** |
| Dec | 34 | 38 | 1:1.11 | 0.222 | 0.637 |
| Total | 575 | 1731 | 1:3 01 | 579.504 | 0.000 |

*, significant (P<0.001).

The sex-ratio imbalance was most probably related to spawning habits of this fish species. Females may stay longer time in the breeding areas than males. Al-Kholy (1972) observed a similar result, that cyprinid *Puntius barberinus* females in Lake Lanao live longer time in the spawning areas than males. Segregation by sex during spawning, which was also observed in weakfish (Alheit et al., 1984), and increased vulnerability of females by some gears due to increased ovarian development (Taylor and Villoso, 1994), can also be the cause for the deviation from 1:1 sex-ratio. A combination of the above factors can also happen i.e., spawning stocks in Megech and Dirma River mouths may be dominated by females in the spawning months and these females may be restricted to certain depths, consequently differing in their vulnerability to different fishing gears.

Table 2. The number of males, females and sex-ratio of *L. intermedius* in the samples collected from Lake Tana. Samples were grouped in 2.00 cm length class. $X^2$ shows the chi-square values.

| FL (cm) | Males | Females | Sex-ratio (male :female) | $X^2$ | Prob. |
|---|---|---|---|---|---|
| ≤ 15 | 5 | 3 | 1:0.60 | 0.692 | 0.405 |
| 15.1-17 | 8 | 2 | 1:0.25 | 4.500 | 0.034 |
| 17.1-19 | 32 | 10 | 1:0.31 | 11.308 | 0.001* |
| 19.1-21 | 96 | 287 | 1:2.99 | 95.251 | 0.000* |
| 21.1-23 | 107 | 669 | 1:2:25 | 407.015 | 0.000* |
| 23.1-25 | 104 | 286 | 1:2.75 | 84.933 | 0.000* |
| 25.1-27 | 81 | 141 | 1:1.75 | 16.216 | 0,000* |
| 27.1-29 | 54 | 115 | 1:2.13 | 22.018 | 0.000* |
| 29.1-31 | 44 | 77 | 1:1.75 | 9.000 | 0.003* |
| 31.1-33 | 26 | 61 | 1:2.35 | 14.080 | 0.000* |
| 33.1-35 | 11 | 30 | 1:2.73 | 8.805 | 0.000* |
| ≥ 35.1 | 7 | 50 | 1:7.14 | 32.439 | 0.000* |
| **Total** | **575** | **1731** | **1:3.01** | **579.504** | **0.000*** |

*Significant, P<0.001.

**Length-weight relationship and Length at first maturity ($FL_{50}$)**

Fork length and total weight of *L. intermedius* in Lake Tàna showed curvilinear relationship (Fig. 2a) and were significantly different ($p<0.05$). The regression equation was $TW = 0.0096FL^{3.10}$, where TW= total weight and FL= fork length.

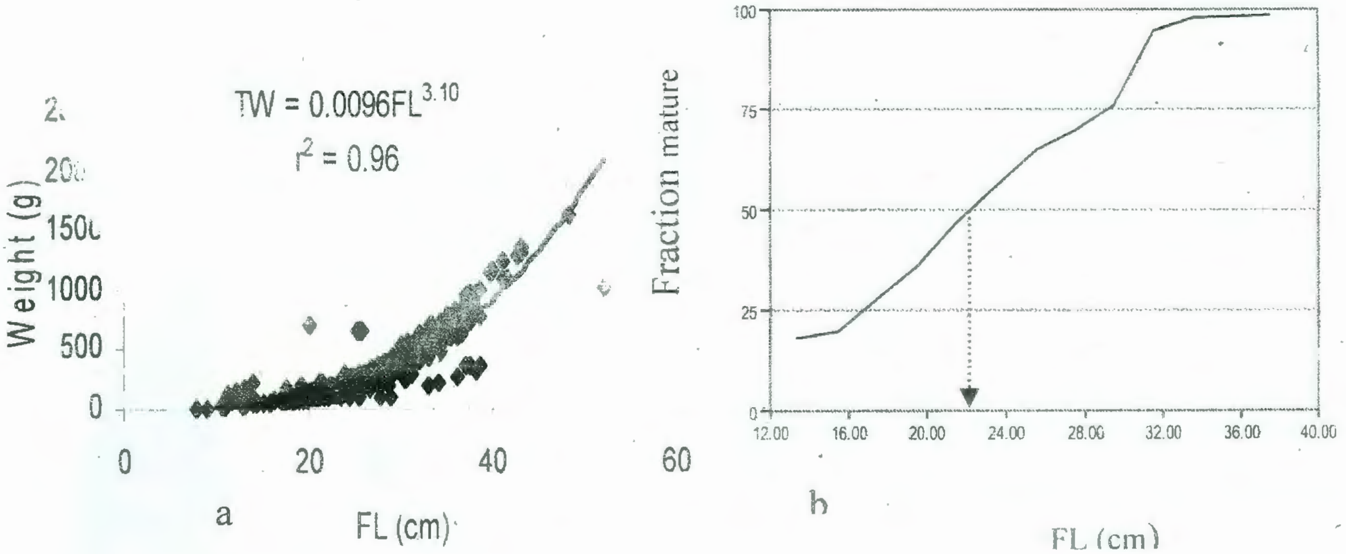
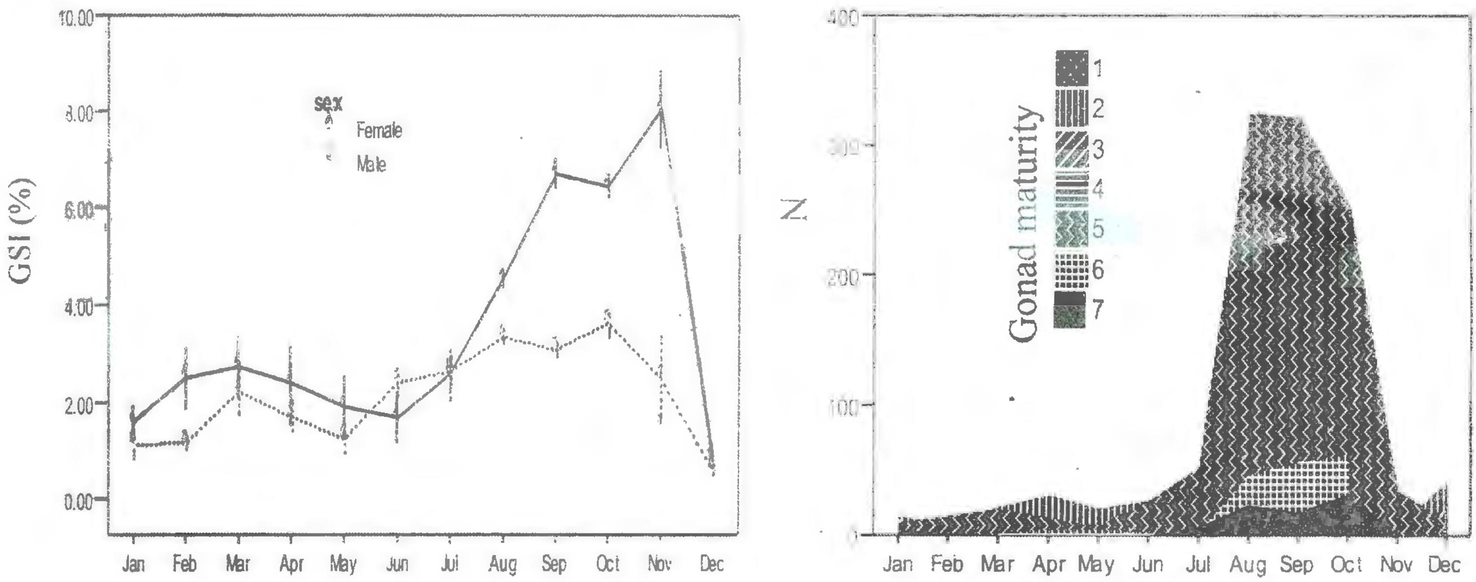



Figure 2. (a) Length-weight relationship and (b) Length at first maturity ($L_{50}$) curve for *L. intermedius* in Lake Tana.

The coefficient of regression (b=3.01) observed in the length-weight equation was near the cube value (b = 3). The findings obtained are in agreement with the "theoretical" cube law which means growth in these fish species is isometric (weight increases at a rate of about a cube of increase in length). A similar result was obtained for these species by Naglekerke et al. (1994) in the southern Gulf of Lake Tana. The result is also in agreement with the findings obtained by Demeke Admassu and Elias Dadebo (1997) for *L. intermedius* from Lake Awassa. The length at which 50% of females reach at sexual maturity was found to be 22.57cm (Fig. 2b); however, due to the lack of enough number of immature males in the samples, it was impossible to calculate $FL_{50}$ for males.

### Gonadosomatic index (GSI %) and Fulton's condition factor

GSI (%) values ranged from 0.03 to 13.71 for males whereas it was from 0.12 to 30.78 for females. As fish body weight variation between months is insignificant (ANOVA, $p=0.63$), the variation in GSI in different months is attributed to the change in gonad weight. Mean monthly GSI values start to rise at July for both sexes (Fig. 3a). It reached peak at October for males and at November for females.




a) b)

Figure 3. (a) Mean monthly variation in GSI of females (triangles connected by dots) and males (circles connected by solid lines). (b) Abundance (N) of different gonad maturity stages (1-7) per month of *L. intermedius* in Lake Tana.

The mean GSI of a stock tends to increase as female and male gonads reach maturity, just prior to spawning. The GSI has been employed mostly to determine spawning season of fish stocks (Bagenal, 1978; De Silva et al., 1985) and thought to be a reliable criterion, especially when supported by other evidences. Looking at the year-round gonadal development (Fig. 3a) and frequency of fish with ripe gonads (Fig. 3b), it appears that *L. intermedius* reproduces throughout the year. However, the GSI-peaks (Fig. 3a), high frequency of ripe gonads (Fig. 3b) and low

Fulton's condition factor (Fig. 4) indicate that intensive spawning activity takes place from August to November. The downward trend in GSI at the end of November (Fig. 3a), combined with the appearance of high percentage of spent females (gonad stage VII) (Fig. 3b) and low overall abundance in the catch indicate the end of peak spawning period.

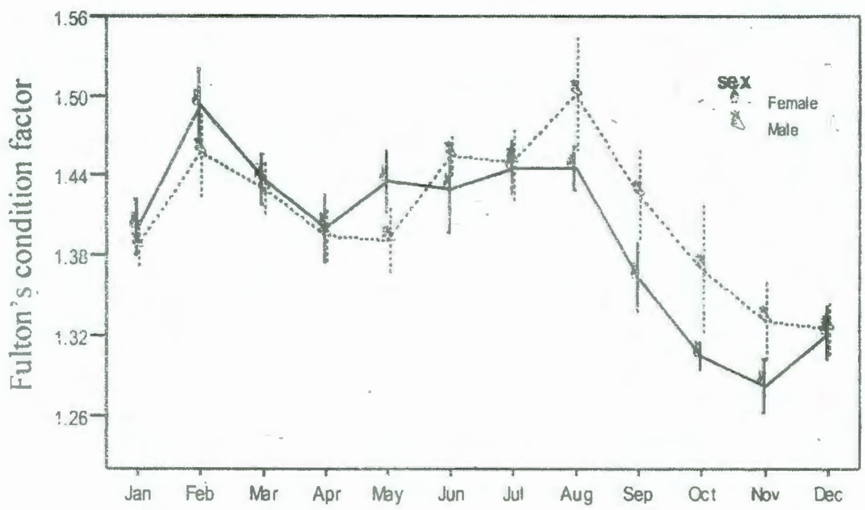



Figure 4. Male and female *L. intermedius* monthly variations in Fulton's condition factor in Lake Tana.

The mean Fulton's condition factor (FCF) of *L. intermedius* in Lake Tana was 1.39 ± 0.08 and showed seasonal variation (Mann-Whitney U test, $P < 0.05$). It was significantly lower during the peak spawning season (August to November) in both sexes (Fig. 4). The reduction was higher in the case of females than males. This is probably because the energy expenditure for eggs is costly than sperm. The condition of the fish can be affected by various factors such as environment, food quantity and quality, rate of feeding, disease and reproductive activity (Bowen, 1979; Getachew Teferra, 1987; Payne, 1986). During the breeding season the spawning stocks mobilize and transfer body reserves to the gonads. In addition to energy transfer, feeding is minimized as the feeding and breeding grounds mostly do not coincide. However the FCF computed for *L. intermedius* in Lake Awassa was 0.95 ± 0.13 SE in the dry season and 0.85 ± 0.18 in the wet season (Demeke Admassu and Elias Dadebo, 1997). The relatively higher value of FCF in Lake Tana as compared to Lake Awassa for *L. intermedius* may be genetic difference (as they are virtually different species) or may be the size difference of the two lakes. In Lake Tana, being the largest lake, this fish will have minimized competition for feeding and breeding grounds.

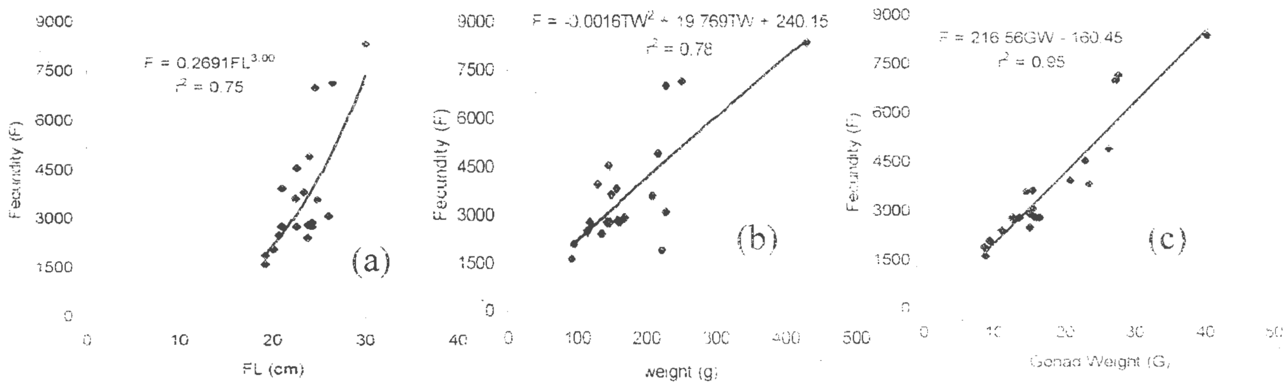



Figure 5. The relationship between fecundity (F) and fork length, fecundity and total weight (b) and fecundity and gonad weight (c).

**Fecundity**

From samples taken from 22 specimens of *L. intermedius*, the mean fecundity was 3588 eggs per female and it was ranged between 1761and 8367 eggs. Mean ova diameter was 1.99 mm (ranged between 1.65 to 2.30 mm). There was exponential relationship between fecundity (F) and fork length (FL) ($FL=0.2691FL^3$, $r^2=0.75$), while fecundity and gonad weight were related linearly (GW) ($F=216.56GW-160.45$, $r^2=0.95$). Polynomial relationship was observed between fecundity and total weight (TW) ($F=0.0016TW^2 + 19.769TW + 240.15$, $r^2=0.78$) (Fig. 5). In some fish species such as *O. niloticus* heavier gonads were fond to have fewer but larger sized eggs (Zenebe Tadesse, 1997), However this did not happen in L. intermedius as there was strong correlation ($r^2=0.95$) (Fig. 5) between fecundity and gonad weight.

The information about fecundity of pelagic fish species in African lakes is scarce (Marshall, 1995). This problem is severe in the case of the endemic *Labeobarbus* species of Lake Tana. An attempt was made to estimate the fecundity of *L. intermedius*. The eggs were adhesive and similar in their color (whitish-yellow).

Within a mature ovary all the eggs were almost of similar in size. From samples taken in 22 specimens of *L. intermedius*, the mean fecundity was 3588 eggs per female and it was ranged between 1761 and 8367 eggs. Mean ova diameter was 1.99 mm (ranged between 1.65 and 2.30 mm). There was exponential relationship between fecundity (F) and fork length (FL) ($FL=0.2691FL^3$, $r^2=0.75$), while fecundity and gonad weight (GW) were related linearly ($F=216.56GW-160.45$, $r^2=0.95$). Polynomial relationship was observed between fecundity and total weight (TW) ($F=0.0016TW^2 + 19.769TW + 240.15$, $r^2=0.78$).

Fecundity of *Labeobarbus* in other African lakes is moderately high (Skelton *et al.*, 1991). Other *Labeobarbus* like *Labeobarbus aeneus* and *L. kimberleyensis* in Vaal-Orange River drainage system fecundity estimated is as many as 60, 000 eggs (Gaigher, 1976; Skelton, 2001) for larger females on average. However, the mean absolute fecundity result (3588 eggs) obtained for *L. intermedius* is much lower as compared to the above *Labeobarbus* species. The main cause for such variation may be due to the instability of the Orange River as fast growth, early maturity and high fecundity are characteristics of such environments (Oliva-Paterna et al., 2002).

Although the current fishing activities in the northern part of Lake Tana (Enfranz, Gorgora, and Delgi areas) still use reed boats, the number of fishermen (about 185 with 4 nylon gill nets each on average) is growing in the area (Unpublished data). Due to lack of motorized boats, the local fishermen (mostly the Woito ethnic group) living around the shore areas target the fishes at the mouths of Dirma and Megech Rivers in the Gorgora area (Wassie, 2005). The most preferred fish by the local inhabitants are the *Labeobarbus* species; hence they are the most targeted fish by fishermen as they fetch more money. *Labeobarbus intermedius* contributes more than fifty percent of the commercial catch. Therefore, from arrays of fishery management options, closing the gill net fishery in Dirma and Megech River mouths at least during spawning months (from August to November), as recommended for Gumara River (De Graaf et al., 2004) or even throughout the year is strongly recommended to minimize recruitment over fishing.

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