



# Length-weight relationships and reproductive biology of commercially important fishes from Ribb Reservoir, Ethiopia

Agumassie Tesfahun Asres<sup>1,\*</sup>, Sale Alebachew<sup>2</sup>, Negesse Kebtieneh<sup>1</sup>

<sup>1</sup>Department of Biology, Debre Tabor University, Debre Tabor 272, Ethiopia

<sup>2</sup>Department of Animal Science, Debre Tabor University, Debre Tabor 272, Ethiopia

## Abstract

It is important to understand the biological aspects of fish for fishing management. This study was conducted from February through October 2021. A total of 1,629 fishes were collected using different fishing gears. The length-weight relationship is a power curve for all fishes and showed a significant ( $r^2 > 0.8$ ). All fishes revealed a negative allometric growth pattern except *Labeobarbus intermedius*. *Oreochromis niloticus* ( $1.714 \pm 0.009$ ) was found in better condition than other fish species (analysis of variance [ANOVA],  $p < 0.05$ ). The length at maturity was 24.0 cm and 25.4 cm total length (TL), 28.9 cm and 28.2 cm fork length, and 53.2 cm and 57.5 cm TL for females and males of *O. niloticus*, *L. intermedius* and *Clarias gariepinus*, respectively. Fecundity was ranged between 100–947 eggs/g with absolute fecundity (AF) of 468–3,832 eggs, 200–1,000 eggs/g with AF of 2,752–136,420 eggs, and 505–900 eggs/g with AF of 2,000–6,404 eggs for *O. niloticus*, *C. gariepinus*, and *L. intermedius*, respectively. Their respective mean fecundity was  $1,490 \pm 91$ ,  $23,330 \pm 5,070$ , and  $3,096 \pm 273$  eggs, respectively. Mean fecundity revealed a significant variation between size classes and species (ANOVA,  $p < 0.05$ ). The fecundity length and fecundity-body weight relationships except (*O. niloticus*) of fishes were curvilinear while the gonad weight (GW)-fecundity relationship was linear for all fish species. The fecundity was moderately associated with increasing length than body weight, and GW for all fishes ( $r^2 > 0.6$ ). In conclusion, a tangible management setup is required to sustain the use of fish in the reservoir.

**Keywords:** Condition factor, Fecundity, Length at maturity, Length-weight, Ribb Reservoir

## Introduction

The Nile tilapia (*Oreochromis niloticus* Linnaeus 1758), the African catfish (*Clarias gariepinus* Burchell 1822), and the African big barb (*Labeobarbus intermedius* Rüppell 1835) were

commercially important fish species in the Ribb Reservoir, Tana basin, South Gondar, Ethiopia. Fish biometrics, such as the length-weight relationship, the length-length relationship, and conditions factors, are widely used methods of fisheries management. They provide biological evidence of the health of

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\*Corresponding author: Agumassie Tesfahun Asres

Department of Biology, Debre Tabor University, Debre Tabor 272, Ethiopia

Tel: +251-916184242, E-mail: agumas2012@yahoo.com

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the fish, growth patterns, ontogenetic changes, and the dynamics of the fish stock (Kebede et al., 2018). The relationship length-weight is crucial to the estimation of weight based on length measurements. In addition, the relationship between length and weight is important to calculate the assessment of fish stocks through the development of the assessment model of fish stocks (Tesfaye et al., 2016).

In particular in developing countries, fish reproductive biology is significant in the fisheries management strategy. According to Tesfaye et al. (2016) notified that fishery managers should strictly follow size at first maturity and close the spawning season to sustain fishery practices. Otherwise, the fisheries would be over-exploited and inadequately managed.

In river ecosystems, water quality parameters are influenced by dams, which in turn affects fish reproduction and behavior (Anteneh et al., 2013). Changes in water temperature and river hydrodynamics have adverse effects on many freshwater fish species' reproductive performance and other biological parameters (Adams et al., 2015). For example, cold water temperatures below the reservoir can affect the development of the ovarian follicle, the diameter of the ovarian follicle, and the reproduction rate of fish species. In reservoirs, the reproductive performance of migratory fish and non-migratory fish was negatively affected by temperature and dissolved oxygen in the summer due to thermal stratification (Mequanent et al., 2021). In addition, fertility is considered a biological parameter closely related to the availability of food, physical and chemical variables in water.

In Lake Tana, 17 *Labeobarbus* fish species were found (Mequanent et al., 2021). Of these, seven species, namely *Labeobarbus acutirostris*, *Labeobarbus brevicephalus*, *L. intermedius*, *Labeobarbus megastoma*, *Labeobarbus macrophtalmus*, *Labeobarbus truttiformis*, and *Labeobarbus tsanensis* are migratory species. During the rainy season, these migratory breeding species can travel more than 60 km to tributary rivers and streams, to access better breeding grounds in July through October (Anteneh et al., 2013). These fish species require rapid, clear, well oxygenated river or river with gravel bed for the success of reproduction. However, nowadays the spawning grounds (rivers) are in increasing peril from anthropogenic activities. For example, the Ribb Dam (73 m high) and irrigation weirs have blocked the migratory spawning species of *Labeobarbus* (Mequanent et al., 2021). The fishes could not jump to migrate upstream without a fish ladder (corridor) to find a favorable environment for spawning purposes. In line with this, Anteneh et al. (2013) and

Getahun et al. (2008) pointed out that the weirs or dam with fish ladder are important particularly for the migratory spawning *Labeobarbus* species from Lake Tana to Ribb River. However, the fish ladder is not included. For this reason, our study was focused on the riverine origin fish species above the dam including *O. niloticus*, *C. gariepinus*, and one *Labeobarbus* (*L. intermedius*) species that probably which is isolated during damming.

The Ribb River is one of the rivers that feed Lake Tana. Ribb Reservoir is new and its construction is completed recently the fisheries activity also started in 2018. The reservoir also plays an important role in fisheries and irrigation practices, as well as in the livelihoods of the nearby communities. Very few studies have been conducted in the Ribb River about the effects of dams and dams on the migration of reproductive types of the *Labeobarbus* species (Anteneh et al., 2013; Getahun et al., 2008) and the impact of irrigation practices on fishing activities (Mequanent et al., 2021). However, there has been no study of the biological and reproductive aspects of *O. niloticus*, *C. gariepinus* and *L. intermedius* in the Ribb Reservoir. Therefore, the purpose of this study was to conduct some biological aspects and reproductive biology of commercially important fish species in the reservoir to address the scientific gap for better management of fish resources to sustain fisheries.

## Materials and Methods

### The study area

The Ribb Dam has recently been constructed and new fishing activity has been established in 2018. The reservoir has three inflow rivers (Melo, Ribb, and Hamus). The Ribb Dam is found in the Ribb River in the South Gondar Zone of the East side of the sub-basin of Lake Tana, Amhara region. The Ribb River is about 130 km long, its drainage area is almost 1,790 km<sup>2</sup>, and the average annual discharge is 14.6331 m<sup>3</sup>/s (Bezabih, 2021). Ribb Dam is neighbored by four kebeles including Medeb Gubda, Jarashikra, and Ayvaniva from Farta woreda and Amstya villages from Ebnat district. It has an area of about 685 km<sup>2</sup> in the dam. According to the Universal Transverse Mercator (UTM), Ribb Dam is located in the North-Western part of Ethiopia, by the geographic coordinate of 12° 02' 30" N and 37° 59' 45" E at altitudes ranging from 1,880 to 1,970 m. The climate in the Ribb basin is characterized by a rainy season that begins from May to October. Monthly rainfall ranges from 65 mm in May to 411 mm in July. The annual average rainfall is about 1,400 mm, with the lowest precipitation around 1,200 mm. During the year,

temperatures range from 19°C in December to 23°C in May, with maximum temperatures of 30°C and minimum temperatures of 11.5°C. The wind speed is low and the possible amount of evapotranspiration from December (95 mm/month) to April (140 mm/month) is reduced. The sunlight in July decreases to 6.0 hours and in August to 6.5 hours (Bezabih, 2021). Based on the composition of the fish species, the three Cyprinidae families (5 species, i.e., *L. brevicephalus*, *L. megastoma*, *Labeobarbus nedgia*, *L. truttiformis* and *L. tsanensis*), were reported so far at the dam site before the dam is built (Anteneh et al., 2013; Getahun et al., 2008). In addition, Cichlidae (*O. niloticus*) and Clariidae (*C. gariepinus*) were found on the Ribb River before and after the construction of the dam (Getahun et al., 2008).

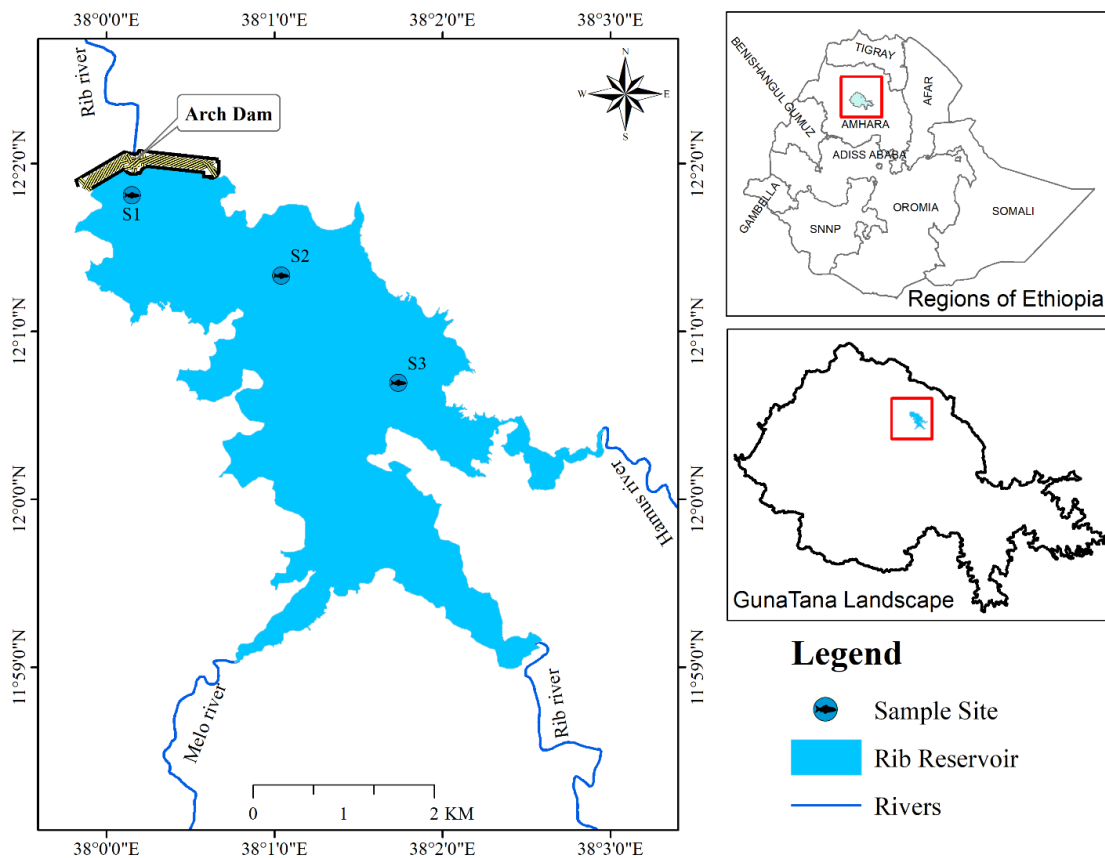
**Study design and sample site selection**

The study was conducted between February 2021 and October 2021. Between December and January 2020/21, the Fishery

Research Team of the Guna Tana Integrated Field Research Development Centre at the University of Debre Tabor conducted a reconnaissance survey. These preliminary observations are important for understanding and identifying the various habitats and fishing activities of the river basin. Therefore, on the basis of preliminary processes, three sites have been selected considering the feasibility of establishing fishing nets, commercial fishing locations, depths of water, areas with vulnerability to fishing efforts, human effects, and nursery habitats. The sites were the S1 dam site (near the arch dam), S2 middle (middle of the reservoir), and the S3 inlet (entrance of Hamus River) indicated (Fig. 1).

**Sampling and measurement protocols**

Fish sample collection was carried out from February to October 2021. During this time, the monofilament gill net with 3.5 cm, 5, 6, 8, and 10 cm of stretched mesh and hook and a long line



**Fig. 1. A map showing the sampling site of the Ribb Reservoir in Ethiopia.**

was used at three sampling sites at Ribb Reservoir. The nets were installed late at 3 o'clock and checked the next morning at 9 o'clock. The total length (TL, cm), fork length (FL, cm), standard length (SL, cm), and total weight (TW, g) of fish were measured using measuring boards with a sensitivity of 0.1 cm and 0.1 g by a sensitive balance. All fish specimens have been identified at the species level in the field.

### Length-weight relationship

The length-weight relationships among *O. niloticus*, *C. gariepinus*, and *L. intermedius* were calculated using a power function formula and the least square regression analysis was performed for both sexes (Tesch, 1978).

$$W = aL^b$$

Where, W = weight, b = exponent; b = 3; implies isometric growth; when b < 3 means negative allometric growth and when b > 3 means positive allometric growth, and L = length of fish.

### Fulton condition factor (FCF)

The condition factor of fishes in the reservoir was calculated using the equation below (Tesch, 1978).

$$K = (W) \times 100 / L^3$$

Where K = condition factor, W = total body weight, and L = TL or fish FL.

### Sex ratio

The females and males were computed as

$$\text{Sex ratio} = \text{Number of females} / \text{Number of males}$$

### Estimation of length at sexual maturity ( $L_{50}$ )

The average length at 50% maturity ( $L_{50}$ ) was calculated using the length-frequency distribution of fishes with matured gonads (stage III–stage V). Finally, the  $L_{50}$  for both sexes was plotted by fitting a logistic regression model (Gunderson et al., 1980).

$$P_m = 1 \times 100 / 1 + e^{(-aL+b)}$$

Here,  $P_m$  is the proportion of mature (%) at length (L) and a and b are fitted constants.

### Calculation of fish eggs

The calculation of fish eggs was performed considering ripe females (gonad stage IV). While gonad stage V was not considered because it is running. During the estimation of fecundity, the fishes were dissected and the ripe gonads were removed, measured to the nearest 0.01 g, and well maintained in 5% formalin solution in the field. Besides, those ripe ovaries were cut lengthways to permit the complete diffusion of the preservative at Debre Tabor University, Biology Department (Tesch, 1978). Accordingly, the preserved gonads were labeled and deposited in sampling jars for fecundity estimation. In laboratory experiments, the preserved ovarian cells were washed in tap water to remove ovarian sheaths by using a hand and sieve to protect flush out of the eggs. For the estimation of fecundity, a total count was used for the smallest gonads of *O. niloticus*. However, for the largest gonads, such as the *C. gariepinus* and *L. intermedius* species, the total number of eggs per ovaries was estimated by extrapolation by counting three sub-samples of 1 g of eggs per ovaries as indicated below.

$$\text{Fecundity} = \text{TW of ovary (g)} \times \text{Number of counted eggs in the sub-sample} / \text{Weight of sub-sample (g)}$$

### Morphometric relationships of the absolute fecundity (AF)

The relationships of absolute fecundity (AF) to TL or FL, AF to the TW, and AF to gonad weight (GW) were assessed using the least-squares regression method.

$$AF = aX^b$$

Where AF = AF, X = represents the weight of the body, the TL, and the GW, a = the scale constant represents the intercept, and b = the allometric coefficient.

### Data analysis

The data collected were interpreted and analyzed using version 20 of IBM SPSS statistical packages (IBM, Armonk, NY, USA). Descriptive statistics are used to present different data sets. The Chi-square test is used to test sex differences. One-way variation analysis (ANOVA) was used to observe differences in sex conditions factors. Finally, regression analysis is used to analyze and plan the relationship between fecundity with the total or FL, fecundity with total body weight, and, fecundity with GW of fish species in the reservoir.

## Results

### Length occurrence of fishes

Distributions of the length-frequency of the three important commercial fishes in the reservoir were indicated in (Fig. 2). In this study, 752 Nile tilapia *O. niloticus* were caught. Of this catch, 353 were females whereas 399 were males. As for TL, females and males are 18.0–40.0 cm and males are 14.5–44.0 cm, respectively. The TW was 75.1 g to 1,150 g for female and 28.6 g to 1,450 g for male. The highest caught *O. niloticus* was found between 20.0–25.0 cm in the TL size class, which represented 67.02% of the total catch.

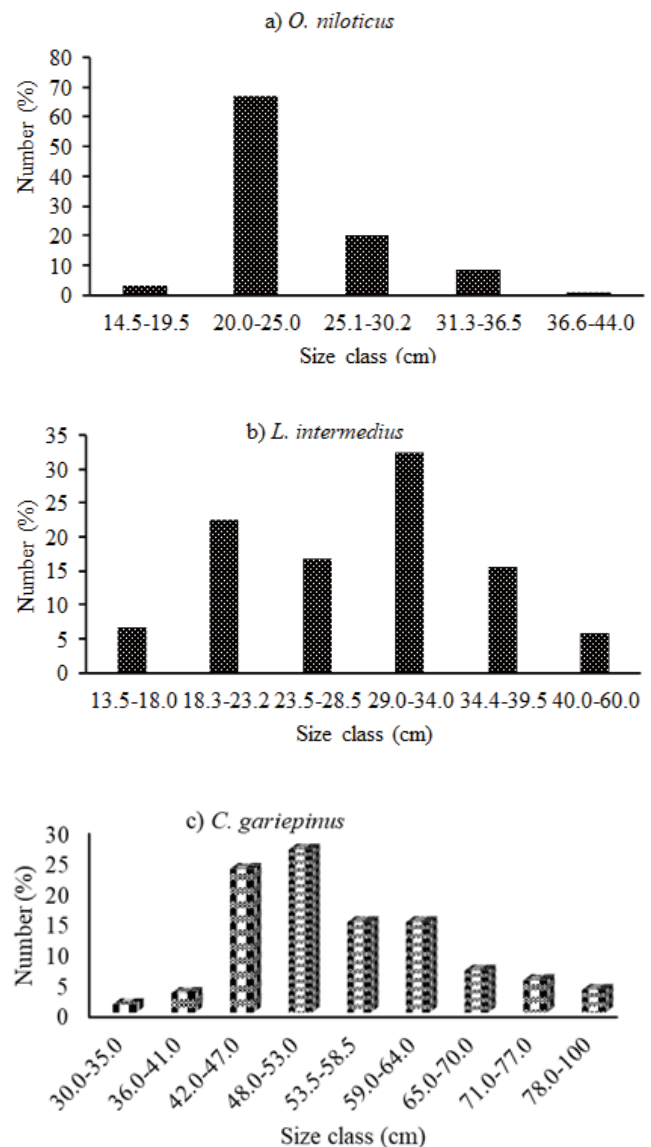
The overall 498 *L. intermedius* fish were collected. Their TL was found between 15.8 to 60.0 cm and 13.5 to 60.0 cm for females and males, respectively. The respective weight was found 29.4 to 1,200 g and 17.4 to 800 g for females and males, respectively. The 29.0–34 cm TL size class contributed the highest catch followed by the 18.3–23.2 cm TL size class. In this study, 379 *C. gariepinus* were collected. Accordingly, their TL was found between 31.0 to 85.0 cm TL and 30.0 to 100 cm TL and their body weight ranged from 98.0 to 4,100 g and 350 to 6,000 g for females and males, respectively. Among the size classes, 48.0–53.0 cm TL comprised the highest catch followed by the 42.0–47.0 cm TL size class.

### Length-weight relationship

The relationships were curvilinear and exhibited a very significant ( $r^2 > 0.8$ ) of combined sex, female and male for *O. niloticus*, *L. intermedius*, and *C. gariepinus*, respectively (Figs. 3–5). The regression model for combined sex of *O. niloticus* was  $TW = 0.035TL^{2.77}$ ;  $r^2 = 0.924$ ,  $n = 752$ ), for males  $TW = 0.0316TL^{2.8}$ ;  $r^2 = 0.938$ ,  $n = 399$ ) and for females  $TW = 0.04TL^{2.74}$ ;  $r^2 = 0.8957$ ,  $n = 353$ ). The results revealed that *O. niloticus* exhibited a negative allometric growth pattern in the reservoir. From the length-weight relationship data of *O. niloticus*, the fish grows in length rather than weight.

The length-weight relationship of the African big barb *L. intermedius* was curvilinear for the combined sexes ( $TW = 0.0064TL^{3.0799}$ ;  $r^2 = 0.8418$ ;  $n = 498$ ). For males  $TW = 0.0058TL^{3.117}$ ;  $r^2 = 0.887$ ,  $n = 181$ ) and females  $TW = 0.003TL^{3.3135}$ ;  $r^2 = 0.8007$ ,  $n = 317$ ). The results revealed that isometric growth for combined sexes and males while positive allometric growth pattern for females.

The data of the length-weight relationship showed that a negative allometric growth pattern was obtained in the mixed-



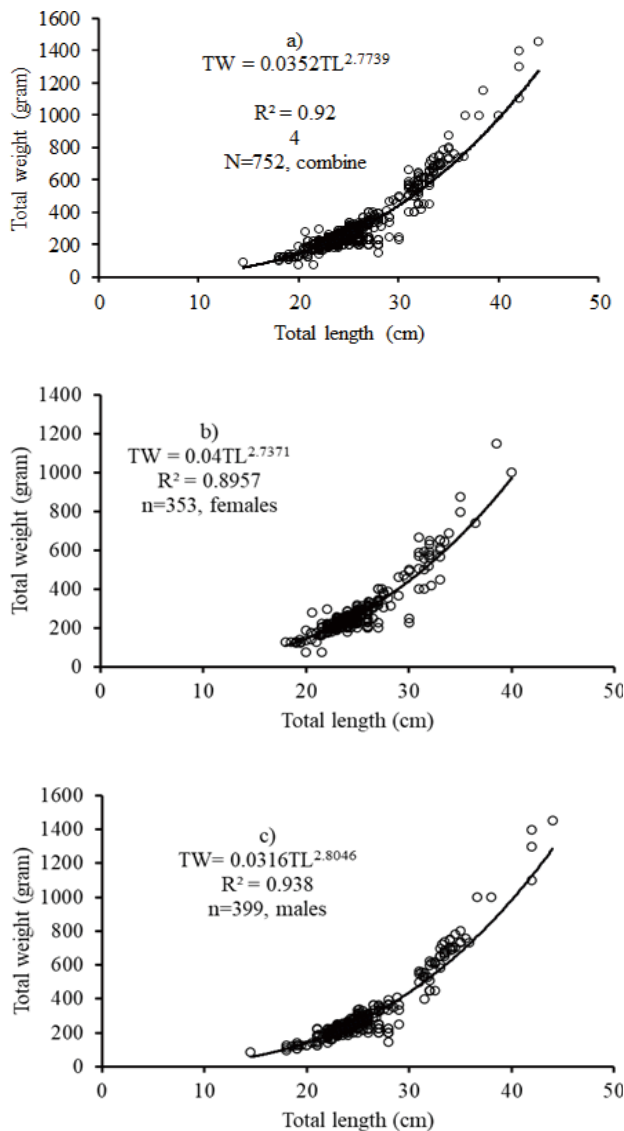
**Fig. 2. Size distribution of (a) *Oreochromis niloticus* (b) *Labeobarbus intermedius* and (c) *Clarias gariepinus* in Ribb Reservoir.**

sex African catfish *C. gariepinus* from the mixed-sex ( $TW = 0.0105TL^{2.833}$ ;  $r^2 = 0.8532$ ;  $n = 379$ ). For males  $TW = 0.0088TL^{2.876}$ ;  $r^2 = 0.8692$ ,  $n = 187$  and females  $TW = 0.0128TL^{2.784}$ ;  $r^2 = 0.8142$ ,  $n = 192$ . The results showed that a negative allometric growth pattern was obtained for combined sexes, males and females.

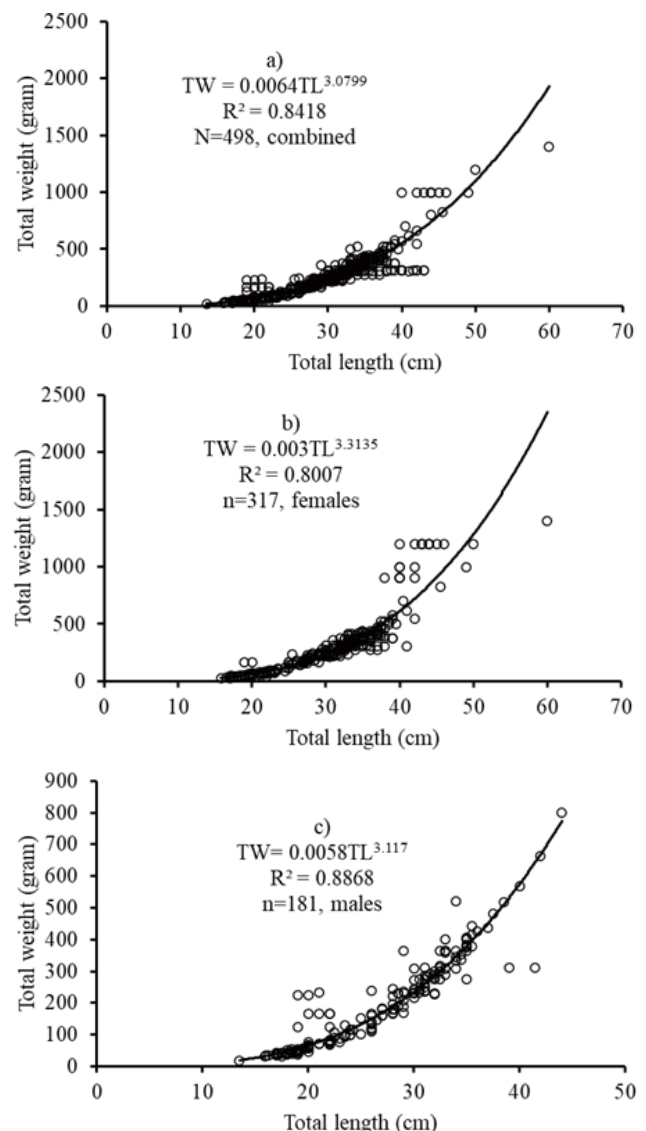
### Fulton condition factor (FCF)

The average condition factors of three important commercial





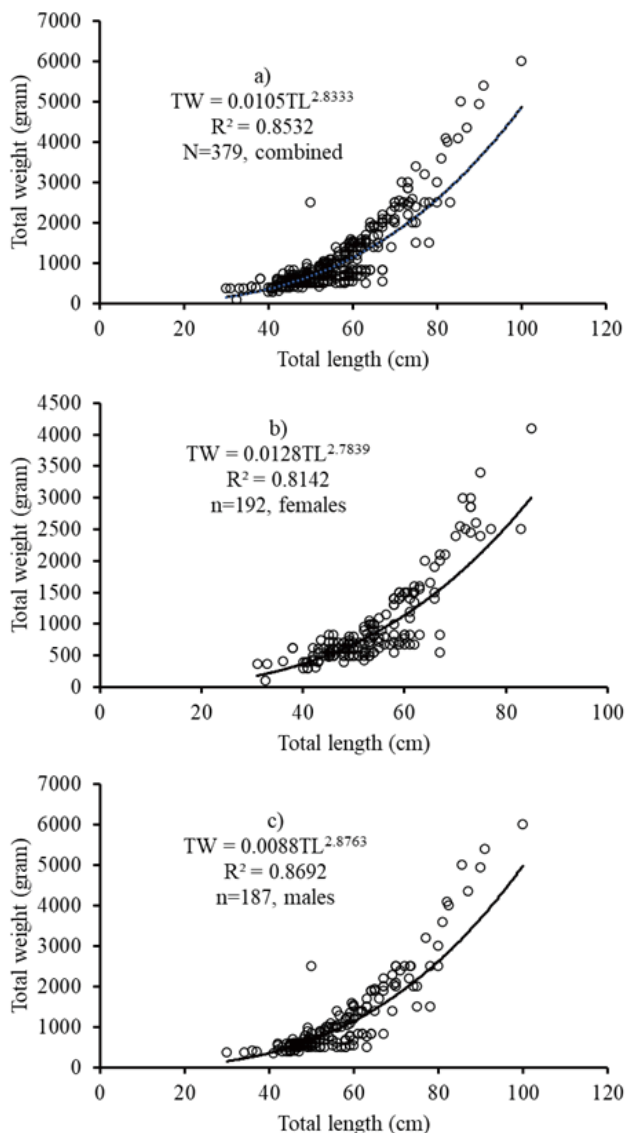
**Fig. 3.** Length-weight relationships of the (a) mixed sexes, (b) females and (c) males *Oreochromis niloticus* from Ribb Reservoir. TW, total weight; TL, total length.



**Fig. 4.** Length-weight relationships of the (a) mixed sexes (b) females and (c) males *Labeobarbus intermedius* from Ribb Reservoir. TW, total weight; TL, total length.

fish species were presented (Table 1). The mean condition factor for combined sexes of *O. niloticus* was  $1.714 \pm 0.009$ . In terms of separate sexes, the mean condition factors were  $1.74 \pm 0.01$  and  $1.69 \pm 0.013$  for females and males, respectively. The mean condition factor revealed a significant difference between the sexes of *O. niloticus* species (ANOVA,  $p < 0.05$ ). The condition factor of *L. intermedius* was  $0.85 \pm 0.01$  for mixed sexes. The condition factors  $0.83 \pm 0.01$  and  $0.88 \pm 0.03$  were belongs to females and males, respectively, and revealed a significant

variation among sexes of *L. intermedius* (ANOVA,  $p < 0.05$ ). The mean condition factor of the African catfish *C. gariepinus* was  $0.563 \pm 0.0085$  for mixed sexes. In terms of sex-based condition factors, females had  $0.56 \pm 0.01$  while males had  $0.560 \pm 0.013$ , which did not show significant variation between the sexes (ANOVA,  $p > 0.05$ ). The mean condition factors of the three species exhibited a highly significant variation (ANOVA,  $p < 0.05$ ). In this study, the Nile tilapia *O. niloticus* had better body condition than the African catfish *C. gariepinus* and the African



**Fig. 5. Length-weight relationships of the (a) mixed sexes, (b) females and (c) males *Clarias gariepinus* from Ribb Reservoir.** TW, total weight; TL, total length.

big barb *L. intermedius* in Ribb Reservoir.

**Sex ratio of the three fish species**

The sex ratio of three important commercial fish species was presented (Table 2). A total of 1,629 species of fish were collected. Out of these, 862 (52.9%) were females and 767 (47.1%) were males. The number of females and males species were 353 (40.95%), 317 (36.8%), 192 (22.3%), 399 (52.02%), 181 (23.6%), and 187 (24.4%) for *O. niloticus*, *L. intermedius*, and *C.*

*gariepinus*, respectively. *O. niloticus* and *C. gariepinus* sex ratios showed no significant differences compared to the hypothetical 1:1 ratio ( $p > 0.05$ ). However, *L. intermedius* showed that the sex ratio difference was significant ( $p < 0.05$ ).

**Sizes at first maturity ( $L_{50}$ ) of the three species**

Four hundred and ninety-two mature (gonad stages III to V) *O. niloticus* were caught. Of these, 307 (61.9%) were females and 185 (37.6%) were males. The smallest sexually mature fish captured were 18.0 cm and 21.0 cm TL for females and males, respectively. Their body weights were 126.0 g and 182.0 g, respectively.  $L_{50}$  *O. niloticus* was 24.0 cm TL for females and 25.4 cm TL males (Fig. 6). Females matured at a smaller size than males. Two hundred seventy-four matured (gonad stages III to V) *L. intermedius* were collected. Of the 209 fish caught (76.3%) were females and 65 (23.7%) were males. The smallest sexually matured fish caught were 17.0 cm and 18.0 cm FL for females and males, respectively and their weights were 48.4 g and 59.2 g, respectively. The  $L_{50}$  of the *L. intermedius* were 28.9 cm and 28.2 cm FL for females and males, respectively. Compared to females, males showed smaller size at first maturity than females (Fig. 7). Two hundred seventy-five matured (gonad stages III to V) *C. gariepinus* were collected. Of this sample, 151 (54.9%) were females and 124 (45.1%) males. The smallest sexually matured fish caught were 38.0 cm and 43.0 cm TL for females and males with body weights of 625 g and 510 g, respectively. The  $L_{50}$  of the *C. gariepinus* were 53.2 cm and 57.5 cm TL for females and males, respectively. Relatively, females matured at a smaller size than males (Fig. 8).

**Fishes egg count**

The purpose for fecundity estimation, 139 ripe gonads (stage IV) females were selected. Of these ripe gonads, *O. niloticus* (73), *C. gariepinus* (38), and *L. intermedius* (28). Their length ranged from 20.5 to 35.0 cm TL, 46.0 to 83.0 cm TL, and 26.0 to 35.0 cm FL for *O. niloticus*, *C. gariepinus* and *L. intermedius*, respectively. Their body weights were also found between 150.5 to 876.4 g, 722.1 to 2,600 g, and 231.0 to 375.1 g, respectively. The GWs were found between 1.3 to 25.0 g, 10 to 450 g, and 8.6 to 24 g for *O. niloticus*, *C. gariepinus*, and *L. intermedius*, respectively. The number of eggs ranged from 100–947 eggs/g with AF 468–3,832 eggs, 200–1,000 eggs g with AF 2,752–136,420 eggs, and 505–900 eggs/g with AF 2,000–6,404 eggs for *O. niloticus*, *C. gariepinus*, and *L. intermedius*, respectively. The mean fecundities were  $1,490 \pm 91$ ,  $23,330 \pm 5,070$ , and  $3,096 \pm 273$  eggs for *O. niloticus*, *C. gariepinus*, and *L. intermedius*, respectively. The mean fecundity

**Table 1. Mean condition factors of the three commercially important fish species in Ribb Reservoir**

Species	Sex-based condition factors		Mean	p-value
	Females	Males		
<i>Oreochromis niloticus</i>	1.74 ± 0.01 <sup>a</sup>	1.69 ± 0.013 <sup>b</sup>	1.714 ± 0.009 <sup>a</sup>	0.05 <sup>*</sup>
<i>Labeobarbus intermedius</i>	0.83 ± 0.01 <sup>a</sup>	0.88 ± 0.03 <sup>b</sup>	0.85 ± 0.01 <sup>a</sup>	0.017 <sup>*</sup>
<i>Clarias gariepinus</i>	0.564 ± 0.012 <sup>a</sup>	0.560 ± 0.013 <sup>a</sup>	0.563 ± 0.0083 <sup>a</sup>	0.945
Overall	-	-	-	0.000 <sup>*</sup>

<sup>ab</sup> Different superscript letters are significantly different.  
<sup>\*</sup> The average difference is significant at the level of 0.05.

**Table 2. The sex ratio of the three major commercial fish species from the Ribb Reservoir**

Species	Number of fishes			Sex ratio	χ <sup>2</sup>	p-value
	Total	Females	Males			
<i>Oreochromis niloticus</i>	752	353	399	0.88:1	102.4	0.157
<i>Labeobarbus intermedius</i>	498	317	181	1.75:1	111.53	0.011 <sup>*</sup>
<i>Clarias gariepinus</i>	379	192	187	1.03:1	82.23	0.472
Total	1,629	862	767	1.12:1	241.345	0.003 <sup>*</sup>

Chi-square test is significant at the level of  $p < 0.05$ .

revealed a significant difference among the size classes and within the fish species (ANOVA,  $p < 0.05$ ).

**Morphometric relationships with fecundity among fish species**

The biometric relationships such as fecundity-length and fecundity-body weight relationships except for *O. niloticus* were curvilinear while the GW-fecundity relationship was linear for *O. niloticus*, *L. intermedius* and *C. gariepinus* (Figs. 9–11). The AF was positively correlated with the TL, TW, and GW for *O. niloticus*, *L. intermedius* and *C. gariepinus*. The morphometric relationships showed significant relationships of AF with TL, TW, and GW for *O. niloticus*, *L. intermedius* and *C. gariepinus* ( $r^2 > 0.6$ ). The model with biometric data for TL, TW and GW were,  $AF = 0.2004 TL^{2.6764}$ ;  $r^2 = 0.6359$ ,  $AF = 3.7534 TW + 127.98$ ;  $r^2 = 0.6793$ , and  $(AF = 103.49 GW + 771.3$ ;  $r^2 = 0.5331)$ ,  $(AF = 0.6 TL^{2.8734}$ ;  $r^2 = 0.7964$ ;  $AF = 0.8985 TW^{1.4281}$ ;  $r^2 = 0.6301$  and  $AF = 286.66 GW - 2,183.2$ ;  $r^2 = 0.9747)$ , and  $(AF = 0.1709 FL^{2.8082}$ ;  $r^2 = 0.6975$ ,  $AF = 0.0516 TW^{1.8971}$ ;  $r^2 = 0.66526$ , and  $AF = 236.66 GW - 717.26$ ;  $r^2 = 0.7846)$  for *O. niloticus*, *C. gariepinus* and *L. intermedius*, respectively.

**Discussion**

**Distribution of size occurrence among fishes**

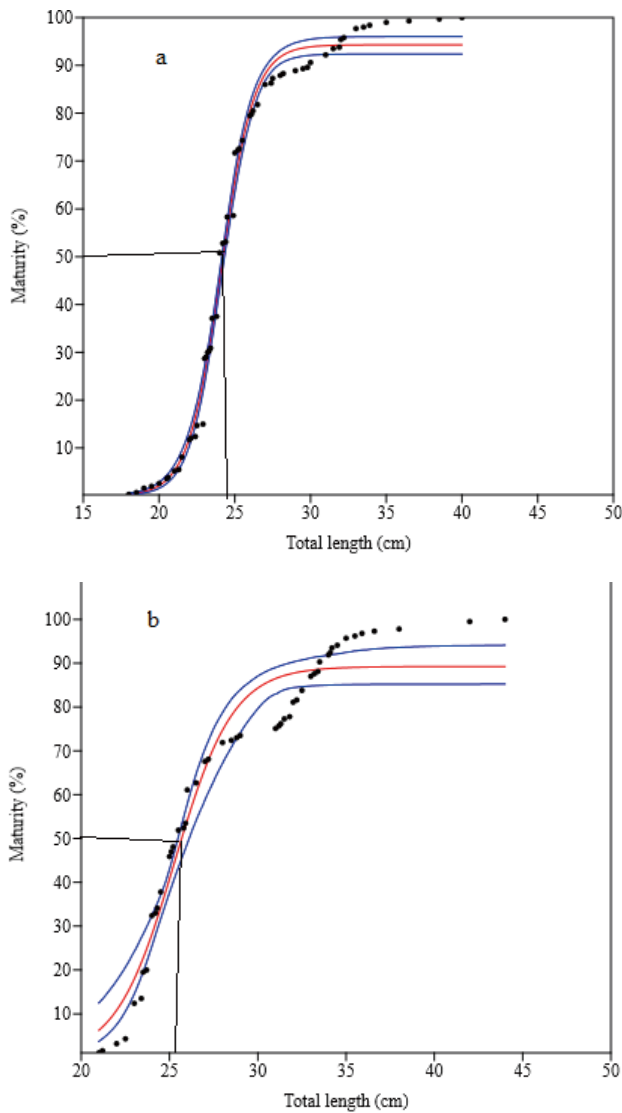
In this study, *O. niloticus* had a maximum length of 44.0 cm

TL. A similar size for the same species was also obtained from Lake Tana (Tefera et al., 2019). However, it was greater than the records reported in Tekeze Reservoir (38.5 cm) (Gebru, 2020), Lake Langeno (30.5) (Kebede et al., 2018), Lake Ziway (34 cm) (Abera et al., 2018), Koka Reservoir (35.2 cm) (Engdaw et al., 2013), Fincha Reservoir (42.0 cm) (Degefu et al., 2012), Amerti Reservoir (35.5 cm) (Hailu, 2014), Lake Babogaya (28.0 cm) (Hirpo, 2012), Lake Hayq (28.0 cm) (Worie & Getahun, 2014), and Lake Hawassa (39 cm) (Tesfaye et al., 2016). Conversely, it was smaller than the values reported in Lake Chamo (61 cm TL) (Teferi & Admassu, 2002), and Gilgel Gibe Reservoir (50 cm) (Wakjira, 2013) (Table 3).

In this study, the maximum TL for *L. intermedius* was 60.0 cm. However, the value obtained was greater than the value recorded in Tekeze Reservoir (53.5 cm TL) (Gebru, 2020), Lake Langeno (53.5 cm TL) (Kebede et al., 2018), Lake Tana (43.8 cm TL) (Engdaw, 2014), and Lake Ziway (44 cm) (Abera et al., 2018), Lake Koka (49.0 cm TL) (Dadebo et al., 2013) and Gilgel Gibe I Reservoir (54.0 cm TL) (Wakjira, 2013) (Table 3).

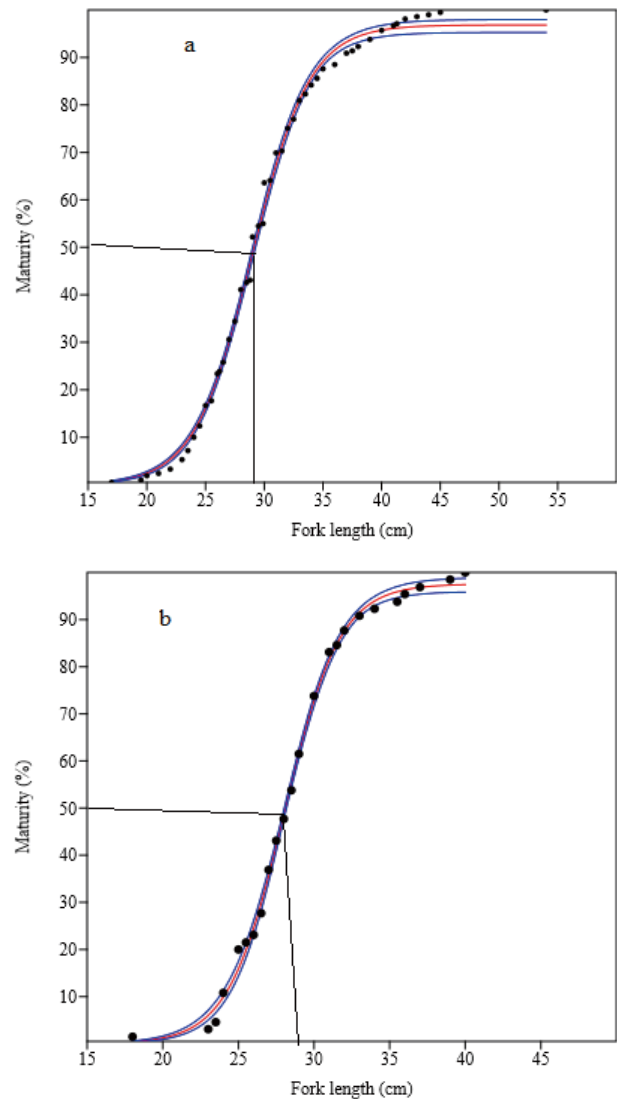
The maximum length noted for *C. gariepinus* was 100.0 cm TL. It was greater than the values reported from Lake Langeno (68.5 cm) (Kebede et al., 2018), Lake Zeway (96.0 cm) (Abera et al., 2018), and Lake Chamo (90.0 cm) (Dadebo et al., 2011). However, it was slightly smaller than previous findings reported in Lake Babogaya (102.0 cm) (Abera et al., 2014) (Table 3).





**Fig. 6.** The length at maturity of *Oreochromis niloticus* (a, females; b, males) in Ribb Reservoir. Scattered lines denote the original data, the red lines showed the logistic regression curve and the blue lines denote the confidence interval (95%).

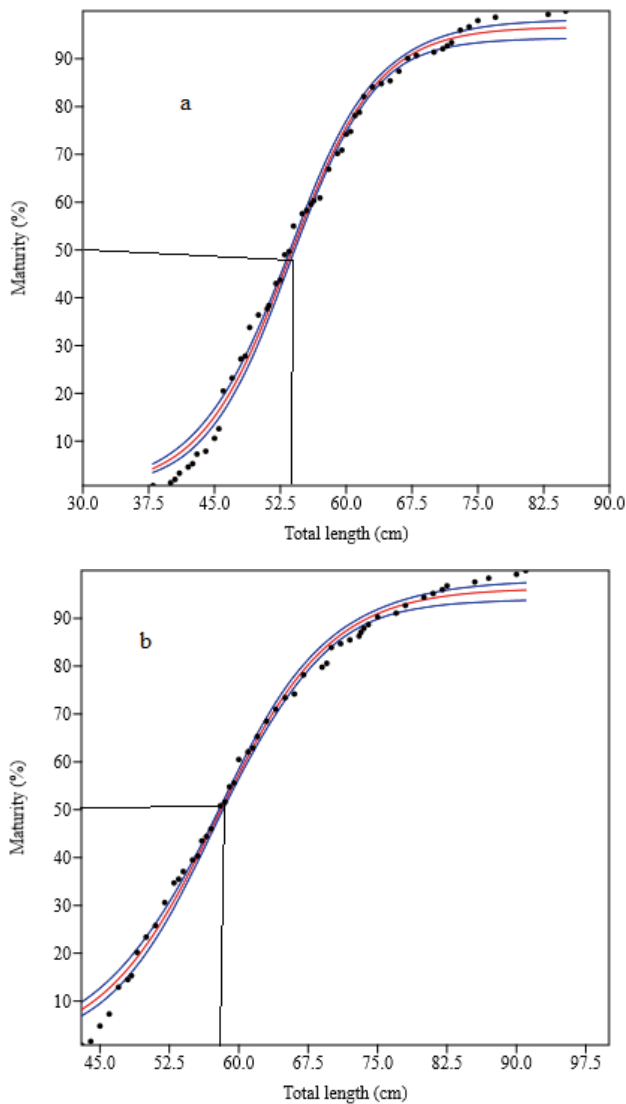
In different water bodies, the difference in fish size of similar species could probably be attributed to the variability of food access, anthropogenic pressures, fishing pressure, the type of fishing gear used, the availability of predators that prey on the smallest fish, and environmental variable of the water quality. The interaction of biological, physical, chemical and overfishing factors in the water could govern the sizes of fish species. In this study, the maximum sizes of fish were found in a good way.



**Fig. 7.** The length at maturity of *Labeobarbus intermedius* (a, females; b, males) in Ribb Reservoir. The scattered lines denote the original data, the red lines denote the logistic regression curve, and the blue lines denote the confidence interval (95%).

### Length-weight relationships among fish species

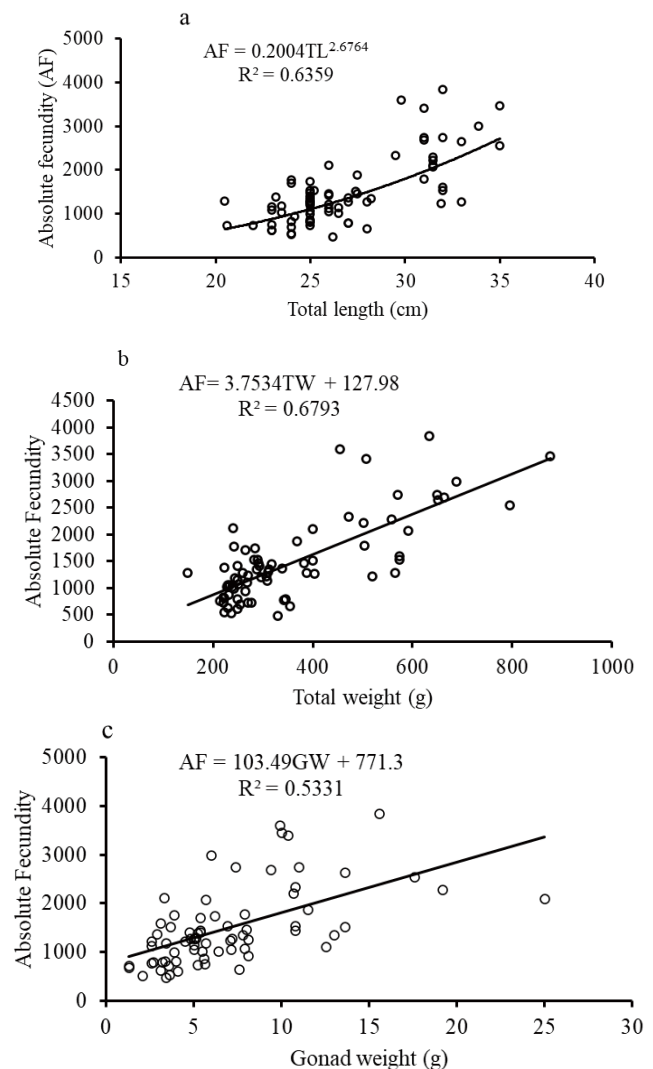
The TL of the biometric relationship with the TW of *O. niloticus* was curvilinear and showed a negative allometric growth pattern ( $b < 3$ ). A negative allometric growth pattern refers to the fish growing in length than weight, while positive allometric growth is defined as the fish growing in weight than length. The isometric growth pattern refers to body weight growing at a proportional rate as the size of the fish increases. Several



**Fig. 8. The length at maturity of *Clarias gariepinus* (a, females; b, males) in Ribb Reservoir.** The scattered lines denote the original data, the red lines denote the logistic regression curve, and the blue lines denote the confidence interval (95%).

investigators have documented allometric growth patterns of *O. niloticus* in different water bodies of Ethiopia Lake Tana (Tewabe, 2014), Lake Chamo (Teferi & Admassu, 2002), Koka Reservoir (Engdaw et al., 2013), Gilgel Gibe Reservoir (Wakjira, 2013) and Lake Langeno (Kebede et al., 2018).

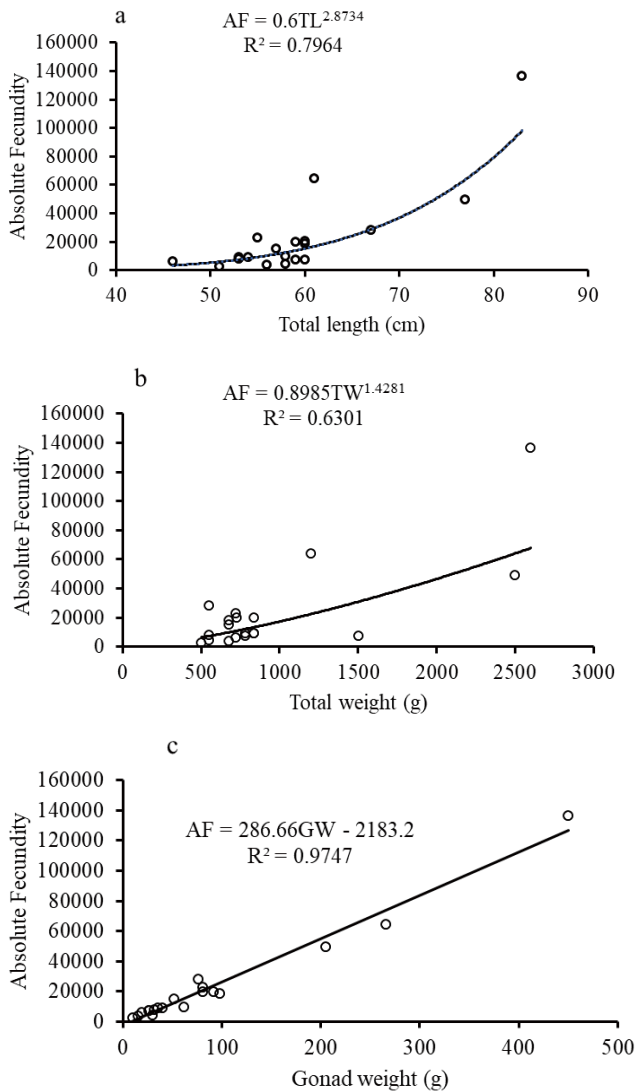
In this study, the recorded regression slope value ( $b = 3$ ) from the length-weight relationship data of *L. intermedius* has obeyed the cube law (Tesch, 1978). The value of the exponent



**Fig. 9. TL-AF (a) and TW-AF (b), and GW-AF (c) relationships of *Oreochromis niloticus* in Ribb Reservoir.** AF, absolute fecundity; TL, total length; TW, total weight; GW, gonad weight.

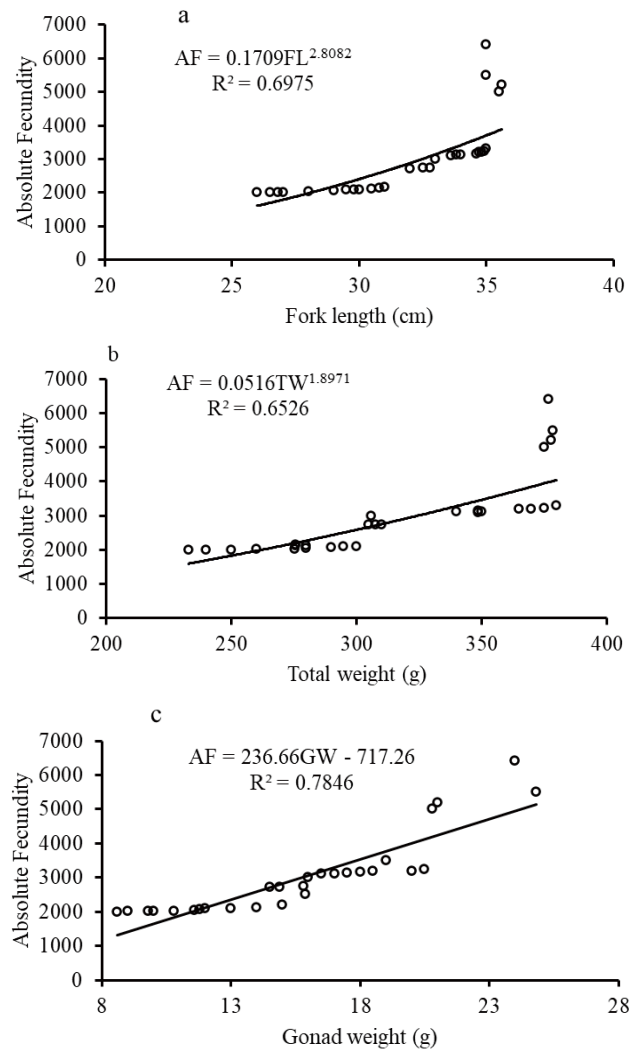
coefficient indicated the isometric growth pattern ( $b = 3$ ), indicating that the length and weight of the fish grow at almost the same rate. Comparable findings were made at Tekeze Reservoir (Gebru, 2020), some tributaries of Lake Tana (Teshome et al., 2015), Lake Tana (Engdaw, 2014), Blue Nile River (Awoke et al., 2015), Borkena and Mille Rivers (Tessema et al., 2012), and Ribb River (before the dam construction) (Getahun et al., 2008). A negative allometric growth patterns ( $b < 3$ ) were also reported in Lake Langeno (Kebede et al., 2018), and Gilgel Gibe Reservoir (Wakjira, 2013).

A negative allometric growth pattern ( $b < 3$ ) was recorded for



**Fig. 10. TL-AF (a) and TW-AF (b), and GW-AF (c) relationships of *Clarias gariepinus* in Ribb Reservoir.** AF, absolute fecundity; TL, total length; TW, total weight; GW, gonad weight.

*C. gariepinus*. Similar findings were also reported in Lake Lugo South Wollo (Mekonnen et al., 2019), Lake Langeno (Kebede et al., 2018), Lake Babogaya (Abera et al., 2014), Lake Zeway (Abera et al., 2018), and Lake Tana (Tewabe, 2014). Human pressures, such as irrigation practices and water abstraction around the watershed, lead to the alteration of environmental water quality variables. These could affect the availability of prey items in the reservoir, and this might hinder the fish growth pattern. The evidence is poor land use practices in the watershed of the Ribb basin, particularly in the reservoir (personal observation and communication). Therefore, the management of the watershed



**Fig. 11. Total length-AF (a) and TW-AF (b), and GW-AF (c) relationships of *Labeobarbus intermedius* in Ribb Reservoir.** AF, absolute fecundity; FL, fork length; TW, total weight; GW, gonad weight.

area is required to make suitable habitats for the harbored fish.

### Mean condition factors among fish species

In this finding, the mean condition factor for *O. niloticus* was 1.71. It was the smallest of the findings conducted in Lake Langeno (1.74) (Kebede et al., 2018), in the same lake (1.84) (Tesfaye & Tadesse, 2008), Lake Hayq (1.83) (Tessema et al., 2019), Lake Zeway (1.82) (Abera et al., 2018), Lake Tana (1.89) (Tewabe, 2014), Lake Babogaya (2.13) (Hirpo, 2012) and Fincha Reservoir (1.83) (Degefu et al., 2012). However, it was greater

**Table 3. Comparisons of the maximum length of fishes from Ribb Reservoir with respect to other water bodies of Ethiopia**

Species	Maximum length (cm, TL)	Water bodies	References
<i>Oreochromis niloticus</i>	44.0	Ribb Reservoir	Present study
	44.0	Lake Tana	Tefera et al., 2019
	38.5	Tekeze Reservoir	Gebbru, 2020
	30.5	Lake Langeno	Kebede et al., 2018
	34.0	Lake Zeway	Abera et al., 2018
	35.2	Lake Koka	Engdaw et al., 2013
	42.0	Fincha Reservoir	Degefu et al., 2012
	35.5	Amerti Reservoir	Hailu, 2014
	28.0	Lake Babogaya	Hirpo, 2012
	28.0	Lake Hayq	Worie & Getahun, 2014
	39.0	Lake Hawassa	Tesfaye et al., 2016
	61.0	Lake Chamo	Teferi & Admassu, 2002
	50.0	Gilgel Gibe I Reservoir	Wakjira, 2013
	<i>Labeobarbus intermedius</i>	60.0	Ribb Reservoir
53.5		Tekeze Reservoir	Gebbru, 2020
53.5		Lake Langeno	Kebede et al., 2018
43.8		Lake Tana	Engdaw, 2014
44.0		Lake Zeway	Abera et al., 2018
49.0		Lake Koka	Dadebo et al., 2013
54.0		Gilgel Gibe I Reservoir	Wakjira, 2013
<i>Clarias gariepinus</i>	100.0	Ribb Reservoir	Present study
	68.5	Lake Langeno	Kebede et al., 2018
	96.0	Lake Zeway	Abera et al., 2018
	90.0	Lake Chamo	Dadebo et al., 2011
	102.0	Lake Babogaya	Abera et al., 2014

TL, total length.

than the findings conducted at Tekeze Reservoir (1.43) (Gebbru, 2020) (Table 4). The result showed approximately good body condition of this species as compared to the earlier reports.

The mean body condition factor for *L. intermedius* was 0.85. It was by far the smallest value as compared to the reports made from Tekeze Reservoir (1.88) (Gebbru, 2020), Lake Langeno (1.33) (Kebede et al., 2018), Lake Tana (1.29) (Gebremedhin et al., 2014), and some tributary rivers of Lake Tana (1.21) (Teshome et al., 2015), and Lake Zeway (1.73) (Abera et al., 2018) (Table 4). The result revealed that this species of fish exhibited poor body condition compared to previous reports in different water bodies in Ethiopia.

The mean body condition factor for *C. gariepinus* was 0.56. It is almost similar to Lake Langeno (0.58) (Kebede et al., 2018). However, it was less than in Lake Babogaya (0.64) (Abera et al., 2014), and Lake Zeway (0.76) (Abera et al., 2018) (Table 4). The

body condition factor reflects the well-being of fish in water bodies. It is affected by variations in food availability, water level, water quality, and water temperature that governs the body condition of fishes (Gebbru, 2020). The larger mean value of the body condition factor describes the higher energy content, high food availability, reproductive potential, and favorable environmental conditions for fish species (Kebede et al., 2018). Tessema et al. (2012) documented that the poor body condition of fish species is associated with the low availability of food items such as insects, snails, and other invertebrates when missed in water bodies. Based on the obtained values of the condition factor, *O. niloticus* was by far the most well-adapted to the environmental conditions in the reservoir than other species of fish.

#### Sex ratio among the three fish species

In the present catch, the females were more dominant than

**Table 4. Comparisons of the condition factors of fishes from Ribb Reservoir with respect to other water bodies of Ethiopia**

Species	Condition factors	Water bodies	References
<i>Oreochromis niloticus</i>	1.71 ± 0.5	Ribb Reservoir	Present study
	1.74 ± 0.4	Lake Langeno	Kebede et al., 2018
	1.84 ± 0.34	Lake Langeno	Tesfaye & Tadesse, 2008
	1.83 ± 0.35	Lake Hayq	Tessema et al., 2019
	1.82 ± 0.5	Lake Zeway	Abera et al., 2018
	1.89 ± 0.6	Lake Tana	Tewabe, 2014
	2.13 ± 0.8	Lake Babogaya	Hirpo, 2012
	1.83 ± 0.4	Fincha Reservoir	Degefu et al., 2012
	1.43 ± 0.3	Tekeze Reservoir	Gebbru, 2020
<i>Labeobarbus intermedius</i>	0.85 ± 0.23	Ribb Reservoir	Present study
	1.88 ± 0.6	Tekeze Reservoir	Gebbru, 2020
	1.33 ± 0.4	Lake Langeno	Kebede et al., 2018
	1.29 ± 0.2	Lake Tana	Gebremedhin et al., 2014
	1.21 ± 0.5	Tributaries of Lake Tana	Teshome et al., 2015
<i>Clarias gariepinus</i>	1.73 ± 0.6	Lake Zeway	Abera et al., 2018
	0.56 ± 0.3	Ribb Reservoir	Present study
	0.58 ± 0.23	Lake Langeno	Kebede et al., 2018
	0.64 ± 0.3	Lake Babogaya	Abera et al., 2014
	0.76 ± 0.32	Lake Zeway	Abera et al., 2018

the males among the three species and significantly different from the 1:1 ratio (Table 2). The females of *C. gariepinus* and *L. intermedius* were dominated in the catch, while the males dominated more than the females in the case of *O. niloticus*. Differences in proportions of sex ratios were documented in some water bodies of Ethiopia in the Tekeze Reservoir (Gebbru, 2020), Lake Langeno (Kebede et al., 2018), Lake Babogaya (Hirpo, 2012), Lake Beseka (Hirpo, 2013), Lake Hayq (Tessema et al., 2019), Lake Tana (Tewabe, 2014). The probable reasons for the different sex ratio proportions within females and males might be due to the behavioral (breeding or other) differences among sexes or species, this might make one sex to be more exposed to the fishing gear, and ecology of the fishes also causes the deviation of sex ratio (Teferi & Admassu, 2002).

### Length at first maturity (L<sub>50</sub>) of the three fish species

L<sub>50</sub> refers to the smallest size reached at maturity of the 50% population. As a result, fish catch after reaching a L<sub>50</sub> is important for sustainable fisheries. It is recommended that the size at harvest would exceed the size at first maturity (Tefera et al., 2019) to sustain the fish stock. Length at first harvest and L<sub>50</sub> can determine the sustainability of fish resources in water bodies.

In this study, females of *O. niloticus* matured at a smaller size than males. Comparable studies were conducted in different water bodies of Ethiopia in Lake Tana (Tewabe, 2014), Lake Hawassa (Tesfaye et al., 2016), and Tekeze Reservoir (Gebbru, 2020). However, studies made in Lake Tana (Tefera et al., 2019), and Lake Langeno (Kebede et al., 2018) showed maturation at a smaller size of males rather than females.

The L<sub>50</sub> for *O. niloticus* were 24.0 cm and 25.4 cm TL for females and males, respectively. A comparable study was conducted in Tekeze Reservoir 24.2 cm and 24.8 cm TL (Gebbru, 2020) for females and males, respectively. In contrast, the L<sub>50</sub> values were greater than in Lake Tana (19.6 cm and 20.5 cm TL) (Tefera et al., 2019), Lake Langeno (17.4 cm and 17.2 cm TL) (Kebede et al., 2018), in Lake Langeno (19.5 cm TL for both sexes) (Tesfaye & Tadesse, 2008), Lake Hawassa (18.8 cm and 19.8 cm TL) (Tesfaye et al., 2016), Fincha Reservoir (21.2 cm and 23.4 cm TL) (Degefu et al., 2012), Lake Beseka (14.0 cm and 16.0 cm TL) (Hirpo, 2013) and Lake Hayq (14.5 cm and 15.5 cm TL) (Worie & Getahun, 2014) for females and males, respectively. The L<sub>50</sub> was less than when compared to the findings conducted from Lake Chamo (42.0 cm TL for both sexes) (Teferi et al., 2000), and Koka Reservoir (30.8 cm and 34.6 cm TL) (Tesfaye et al., 2016)



for females and males, respectively (Table 5).

The  $L_{50}$  values for *L. intermedius* were 28.9 cm and 28.2 cm FL for females and males, respectively. The males showed somewhat maturation at a smaller size than the females. The  $L_{50}$  was greater than in Tekeze Reservoir 20.84 cm and 22.05 cm SL (Gebru, 2020), Dirma and Megech tributary rivers 22.6 cm FL for both sexes (Anteneh et al., 2007), and some rivers of the Tekeze and Blue Nile basins 26.0 cm FL for both sexes (Tewabe et al., 2009) for females and males, respectively. However, it was less than the studies conducted in Lake Langeno of 30.5 cm and 29.5 cm FL (Kebede et al., 2018), and Lake Tana of 32.7 cm and 25.9 cm FL (Tewabe, 2014) for females and males, respectively (Table 5). Furthermore, the findings confirmed the early maturity of the males, in line with the present study.

*C. gariepinus* was attained at 53.2 cm and 57.5 cm TL  $L_{50}$  for

females and males, respectively. Consequently, females matured at a smaller size than males. A comparable study was conducted in Lake Chamo 52.0 cm and 58.0 cm TL for females and males (Dadebo et al., 2011). However, it was greater than the reports in Lake Langeno (31.5 cm and 32.5 cm TL) (Kebede et al., 2018), Lake Zeway (28.7 cm and 27.0 cm TL) (Abera et al., 2018), and Lake Babogaya (50.0 cm and 56.0 cm TL) (Abera et al., 2014) for females and males, respectively (Table 5). A study made in Lake Tana (57.7 cm and 43.2 cm TL for females and males) (Tewabe, 2014) showed the difference in  $L_{50}$  between the sexes. The maturity at a smaller size of fish species reflects those fishes living in a stressful environment, under fishing pressure, and the less availability of food items (Kebede et al., 2018). For example, fish in poor conditions mature to a shorter length than fish in better conditions (Tirunesh, 2015). Furthermore, in this study,

**Table 5. Comparisons of the size at maturity of fishes from Ribb Reservoir with respect to other water bodies of Ethiopia**

Species	Size at maturity ( $L_{50}$ , cm TL)		Water bodies	References
	Females	Males		
<i>Oreochromis niloticus</i>	24.0	25.4	Ribb Reservoir	Present study
	24.2	24.8	Tekeze Reservoir	Gebru, 2020
	19.6	20.5	Lake Tana	Tefera et al., 2019
	17.4	17.2	Lake Langeno	Kebede et al., 2018
	19.5	19.5	Lake Langeno	Tesfaye & Tadesse, 2008
	18.8	19.8	Lake Hawassa	Tesfaye et al., 2016
	21.2	23.4	Fincha Reservoir	Degefu et al., 2012
	14.0	16.0	Lake Beseka	Hirpo, 2013
	14.5	15.5	Lake Hayq	Worie & Getahun, 2014
	42.0	42.0	Lake Chamo	Teferi et al., 2000
<i>Clarias gariepinus</i>	30.8	34.6	Koka Reservoir	Tesfaye et al., 2016
	53.2	57.5	Ribb Reservoir	Present study
	52.0	58.0	Lake Chamo	Dadebo et al., 2011
	31.5	32.5	Lake Langeno	Kebede et al., 2018
	28.7	27.0	Lake Zeway	Abera et al., 2018
	50.0	56.0	Lake Babogaya	Abera et al., 2014
57.7	43.2	Lake Tana	Tewabe, 2014	
Species	Size at maturity ( $L_{50}$ , cm FL)		Water bodies	References
	Females	Males		
<i>Labeobarbus intermedius</i>	28.9	28.2	Ribb Reservoir	Present study
	20.84	22.05	Tekeze Reservoir	Gebru, 2020
	22.6	22.6	Dirma and Megech tributary rivers	Anteneh et al., 2007
	26.0	26.0	Tekeze and Blue Nile basins	Tewabe et al., 2009
	30.5	29.5	Lake Langeno	Kebede et al., 2018
	32.7	25.9	Lake Tana	Tewabe, 2014

TL, total length; FL, fork length.

the length-frequency distribution of fish species could be affected because fish migrate through the outlet when water is needed for irrigation purposes and the reservoir is full to release excess water. As a result, the smallest fishes preyed using birds at the outlet site (personal observation). This could affect the size at maturity of fishes in the reservoir.

**Fecundity estimation among fishes**

The number of eggs obtained for *O. niloticus* was found between (468–3,832 eggs/ovary) with a mean of  $1,490 \pm 91$  eggs/ovary. The fecundity (eggs/ovary) of this study was larger than in studies conducted in the Tekeze Reservoir (272 to 3,337) (Gebru, 2020), Lake Langeno (187 to 978) (Kebede et al., 2018), Lake Hawassa (304 to 967) (Dadebo et al., 2011), Lake Tana (495 to 1,243) (Tewabe, 2014), Lake Hayq (290 to 1,287) (Worie & Getahun, 2014). However, it was less than the fecundity (eggs/ovary) of the same species and in Lake Chamo (1,047 to 4,590) (Teferi et al., 2001) (Table 6).

In this study, the fecundity of *C. gariepinus* was (2,752–136,420 eggs/ovary) with a mean of  $23,330 \pm 5,070$  eggs. This is very small compared to other water bodies for the same fish species in Lake Langeno (22,600 to 211,442 eggs/ovary with

a mean of 141,466 eggs) (Kebede et al., 2018), Lake Babogaya (11,000 to 580,571 eggs/ovary) (Admassu & AberaL, 2015), and Lake Zeway (10,000 to 560,000 eggs/ovary) (Abera et al., 2014) and Lake Chamo (5,000 to 1,240,000 eggs/ovary) (Dadebo et al., 2011) (Table 6).

The fecundity recorded for *L. intermedius* of this study was (2,000–6,404 eggs/ovary) with a mean of  $3,096 \pm 273$  eggs, and this result is comparable to some other studies conducted in Lake Langeno (1,078 to 6,532 eggs/ovary with the mean fecundity of 3,055 eggs/ovary) (Kebede et al., 2018), Blue Nile River (1,345 to 7,235 eggs/ovary) (Awoke et al., 2015), and some tributaries of Lake Tana (1,761 to 8,367 eggs/ovary) (Anteneh et al., 2007). But it was smaller than reported in Tekeze Reservoir (1,457 to 10,658 eggs/ovary with a mean of 4,788 eggs) (Gebru, 2020), Lake Tana (1,935 to 11,224 eggs/ovary) (Gebremedhin et al., 2014), and Gelda and Gumara Rivers (1,265 to 13,289 eggs/ovary) (Teshome et al., 2015). In this study, the fecundity (eggs/ovary) (mean of 1,490, 23,330, and 3,096) for *O. niloticus*, *C. gariepinus*, and *L. intermedius* respectively (Table 6). These obtained fecundities were low among the fish species particularly, the fecundity recorded for *C. gariepinus* was by far very low. According to the current result, Ogunola et al. (2018)

**Table 6. Comparisons of the number of eggs per ovary of fishes from Ribb Reservoir with respect to other water bodies of Ethiopia**

Species	Eggs per ovary	Water bodies	References
<i>Oreochromis niloticus</i>	468–3,832	Ribb Reservoir	Present study
	272–3,337	Tekeze Reservoir	Gebru, 2020
	187–978	Lake Langeno	Kebede et al., 2018
	304–967	Lake Hawassa	Dadebo et al., 2011
	495–1,243	Lake Tana	Tewabe, 2014
	290–1,287	Lake Hayq	Worie & Getahun, 2014
	1,047–4,590	Lake Chamo	Teferi et al., 2001
<i>Labeobarbus intermedius</i>	2,000–4,604	Ribb Reservoir	Present study
	1,078–6,532	Lake Langeno	Kebede et al., 2018
	1,345–7,235	Blue Nile River	Awoke et al., 2015
	1,761–8,367	Tributaries of Lake Tana	Anteneh et al., 2007
	1,457–10,658	Tekeze Reservoir	Gebru, 2020
	1,935–11,224	Lake Tana	Gebremedhin et al., 2014
	1,265–13,289	Gelda and Gumara Rivers	Teshome et al., 2015
<i>Clarias gariepinus</i>	2,752–136,420	Ribb Reservoir	Present study
	22,600–211,442	Lake Langeno	Kebede et al., 2018
	11,000–580,571	Lake Babogaya	Admassu & AberaL, 2015
	5,000–1,240,000	Lake Chamo	Dadebo et al., 2011

stated that fecundity is species-specific, linked with genetic features, size, age, environmental aspects, and physiological circumstances of the fish. For example, large female fish in better condition tend to have higher fertility than fish in poor body condition. Furthermore, fertility and associated factors such as age, growth rate, size, genetic composition, adequate food supply, and environmental factors such as water temperature were documented by (Adams et al., 2015) a study conducted in Lake Eleiyele, Ibadan, Nigeria. For example, most of the fish show a gradual increase in fecundity with their age, while the fish become old, and the eggs to be produced start to decline (Adams et al., 2015). The water temperature also affects the reproductive biology of fishes by interfering with the spawning periodicity and recruitment achievement as well. Consequently, under unfavorable water temperatures, adult female fishes are exposed to balance their energy for survival and reproductive capability, which leads to less fecundity (Ogunola et al., 2018). The reason for the low fertility in this study might also be linked to fluctuations in water level and contaminants. Unexpected changes in water levels could also cause a decline in fecundity fish. For example, the study area experienced different water levels in the seasons of the year. Similarly, the reproductive performance of fishes is also negatively affected via various environmental pollutants (caused by anthropogenic pressures) such as heavy metals, pesticides, and polycyclic aromatic hydrocarbons. Furthermore, water pollutants, agricultural waste, pesticides, and trace metals could have histopathological negative effects on the reproductive tissues of fish gonads, thus decreasing the ability of the fish to reproduce. In a polluted reservoir, low fecundity was obtained between fish species. Fecundity is also related to the availability of quality food resources. The low or high fecundity of fishes could reflect the abundance of food and water quality parameters in the waters. Scarcity of food in water bodies can cause low fecundity. In conclusion, low fertility, in this study, could be traced to the fluctuation of water levels, variation of physicochemical water quality parameters, scarcity of quality food, and anthropogenic pressures in Ribb Reservoir.

In the current finding, the relationships of the fecundity with total or FL and fecundity with TWs of fishes except for *O. niloticus* were curvilinear while the relationship of fecundity with GW was linear. Several studies were conducted to confirm the association of biometric relationships (fecundity-TL or FL, fecundity body weight, and fecundity GW) (Awoke et al., 2015; Gebremedhin et al., 2014; Gebru, 2020; Kebede et al., 2018; Teferi et al., 2001).

## Conclusion

Among the length-frequency distributions, the maximum sizes were 44 cm, 60 cm, and 100 cm TL for *O. niloticus*, *L. intermedius*, and *C. gariepinus*, respectively. The length-weight relationships were curvilinear and showed a negative allometric growth pattern except for *L. intermedius* (isometric). *O. niloticus* was found to have better body condition than *L. intermedius* and *C. gariepinus*. Female fishes were dominated in the total catch except for *O. niloticus* where males dominated. Except for *L. intermedius* females exhibited early maturation than males. The fecundity for *C. gariepinus* was very low. The fecundity length and fecundity-body weight relationships except (*O. niloticus*) were curvilinear, while the GW-fecundity relationship was linear for *O. niloticus*, *C. gariepinus* and *L. intermedius*. In conclusion, the responsible limiting factors for biometric relationships and reproductive biology fish could be a shortage of quality foods, fluctuation of environmental variables, variations in water level, agriculture waste discharges and anthropogenic pressures (expansion of irrigation practices around the watershed) thus, appropriate management and community awareness are required to sustain fisheries in the reservoir.

## Competing interests

No potential conflict of interest relevant to this article was reported.

## Funding sources

Not applicable.

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## Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

## Ethics approval and consent to participate

This study conformed to the guidance of animal ethical treat-

ment for the care and use of experimental animals.

## ORCID

Agumassie Tesfahun Asres

<https://orcid.org/0000-0001-6387-0546>

Sale Alebachew

<https://orcid.org/0000-0002-4981-3198>

Negesse Kebtieneh

<https://orcid.org/0009-0005-0704-3518>

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