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Reproductive Biology of Commercially Important Fish Species in Lake Langeno, Ethiopia

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Abstract

The study on the reproductive biology of commercially important fish species in Lake Langeno, Ethiopia was conducted from March 2015 to February 2016. Fish samples were collected from different sampling sites by different mesh size of gillnets and long lines. A total of 4207 fish specimens were collected. The peak breeding time observed was April-June, May-July, June-July and March-May for *Oreochromis niloticus* (Linnaeus 1758), *Clarias gariepinus* (Burchell 1822), *Labeobarbus intermedius* (Rüppell 1835) and *Cyprinus carpio* Linnaeus 1758, respectively. Their respective L_{50} were 16.4 cm and 15.8 cm TL, 28.5 cm and 29.5 cm TL, 30.5 cm and 29.5 cm FL, and 28.2 cm and 27.6 cm FL for females and males, respectively. The mean fecundities of these fish species were 463.83 ± 114, 141466 ± 40982, 3055 ± 2234 and 105631 ± 46680 eggs.fish^{-1}, respectively. The relationship between fecundity and total or/fork length were curvilinear for all fish species, while the relationship between fecundity and total weight were linear for *O. niloticus*, *L. intermedius* and *C. carpio*, and curvilinear for *C. gariepinus* (r^2 > 90). The result showed a significant temporal variation of GSI for all fish species (ANOVA, $P < 0.05$). It also showed the domination of small-sized fishes with the small L_{50} of most fishes. Therefore, effective management is needed to improve the situation of fishes in the lake.

Keywords: Ethiopia, fecundity, gonadosomatic index, Lake Langeno, maturity

Introduction

In fish biology, knowledge of reproduction is important for the rational utilisation of fish stocks and their sustainable production (Cochrane 2002). The reproductive aspects of fish can be used to

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provide sound scientific advice in fishery management since the data give a better understanding of the fluctuations in the population (Shalloof and Salama 2008). Furthermore, studies on breeding season and their associated factors protect the recruits and predict recruitment variability (Gómez-Márquez et al. 2003). Fecundity assessment and description of fish reproductive strategies is the other important issues in fish biology (Domínguez-Petit et al. 2015).

Life history parameters, such as length at sexual maturity (L_{50}), sex ratio, fecundity and spawning time considerably vary between fish species (Fitzhugh et al. 2012). This variation involves the balancing of energy allocation between fish growth, reproduction and interactions with mortality (Morgan 2008). Observation of changes in seasonal gonad development is the most suitable method for determining the reproductive biology of fishes. Study of seasonal gonad development is mainly through observation of morphological changes that gonads undergo to attain full growth and ripeness (Sivakumaran et al. 2003).

Lake Langeno, located in the central Ethiopian rift valley, is one of the tropical lakes with commercially important fish species. The lake is known for its significant contribution of fish catches to the local and national markets of the country (Tesfaye and Wolff 2014). However, very limited studies have been conducted on the reproductive biology of some fish species. Previous studies only emphasise on the length at sexual maturity of *Oreochromis niloticus* (Linnaeus 1758) and *Clarias gariepinus* (Burchell 1822) in the lake (Teka 2001; Tesfaye and Tadesse 2008). Therefore, this study aimed at assessing the reproductive biology of commercially important fish species in Lake Langeno, Ethiopia, to fill the knowledge gap.

Materials and Methods

Description of the study area

Lake Langeno is one of the Ethiopian rift valley lakes located in Oromiya Regional state, between Western Arsi zone and East Shoa zonal Administration at 200 km south of the capital Addis Ababa. Arsi Negelle District is enclosed from south, west and East, and by Adami Tullu Giddo Kombolcha District from the north, between 7°36'N and 38°43'E at an altitude of 1585 m above sea level. The lake is considerably deep with a maximum depth of 48 m and an average depth of 17 m. It has a surface area of about 240 km^2. Eastern Langeno Nature Reserve known as Munisa Forest surrounds the eastern part of the lake. Runoff, hot springs and small perennial rivers coming from the highlands of Arsi Mountains, such as Lepis, Gedemso, Garabula, Metti, Tufa and Sedesedi rivers feed the lake. On the western side, River Hora-Kelo drains Lake Langeno to joins Lake Abijata (Hailu et al. 2010). The inflow water volume from these rivers and hot springs is estimated to be about 533.4 million m^3, and the outflow is about 527.9 million m^3 per year (Ayenew 2004).

The water chemistry of the lake is similar to other lakes in the Ethiopian rift valley, where Na^+ and CO_3^{2-} are the dominant cations and anions, respectively. The mean conductivity of the lake is about 1632 µS cm^{-1}. The salinity of the lake is also high about 9.4 mg L^{-1} (Gebremariam et al. 2002). The lake is serving as a home to many of animal and plant diversities. Dense phytoplankton blooms, mainly Cyanophytes, characterise the lake. However, the phytoplankton biomass (1.6 mg L^{-1}) and productivity (Chl *a* = 2 µg L^{-1}) of the lake is very low (Belay and Wood 1984). The zooplankton assemblage is dominated by Cladocera and Copepoda species (Wodajo and Belay 1984).

Study design and sample site selection

This study was conducted from March 2015 to February 2016. Based on the population of the fishermen in the area, distance from the shore, depth of the lake, distance from the road and human activities in the catchment area, six sampling sites were selected (one site from the middle and five sites from shore areas) for the collection of data. Morphometric variables of the lake, which includes the average and maximum depth were also measured both in the wet and dry season by a labeled rope tied with weight at each sampling site. Global Positioning System (GPS) was used to demarcate the locations of the sampling sites (Fig. 1).

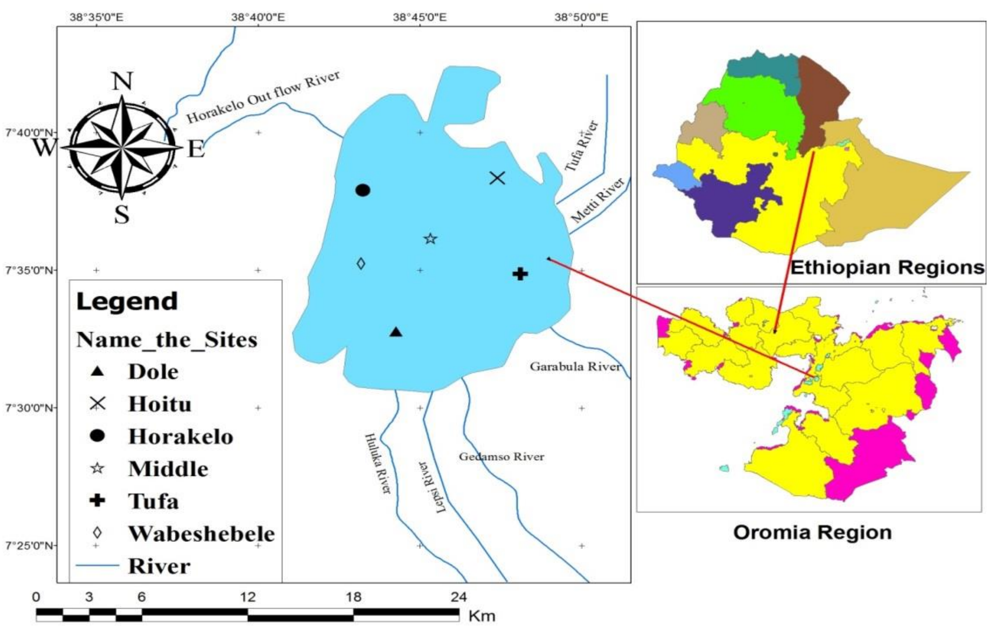

Fig. 1. Selected sites for collection of fish samples from Lake Langeno, Ethiopia.

Fish sampling method

From the six selected sites, fish samples were collected for one year from March 2015 to February 2016**.** Various mesh sizes of gillnet (6 cm, 8 cm, 10 cm and 12 cm) with 25 m panel length and 1.5 m depth was used at each sampling station to capture representative fish sizes and species. In addition, long lines with number 9 and 11 hook sizes were used to catch the large sized fish species.

At depths more than 10 m, two nets were used; one net at the top and one at the bottom. The bottom net was set between 10 and 15 m. Nets were set at an approximately 2 h before sunset, left suspended overnight, and catches were collected the following morning two hours after sunrise (Imam et al. 2010). The numbers of fish caught were recorded for each sampling occasion. Total length of fishes was measured to the nearest 0.1 cm using a measuring board, and the weight using a balance with a sensitivity of 0.1 g, immediately to compare it with their reproductive aspects. Sexes of individual fish specimens were differentiated visually by dissecting all of the collected fishes. Maturity stages of fish species were assessed based on size, appearance, shape, texture and colour of the gonads depending on the maturity indexes of fish (Admassu 1996; Armstrong et al. 2004). Gonads of the matured fishes were removed and preserved in 10 % formalin, immediately. The fish samples and the preserved gonads were placed in plastic jars containing 10 % formalin, labelled and transported to Zeway Fishery Resources Research Center (ZFRRC) for further analysis.

Identification of fish species

The specimens were soaked in tap water to wash off the formalin. After a few days, the specimens were transferred to 75 % ethanol before species identification was conducted. The captured fishes were identified to species and genera level at ZFRRC laboratory based on Golubtsov et al. (1995), Okaronon et al. (1998) and Habteselassie (2012).

Estimation of sex-ratio, breeding season and gonadosomatic index

The proportion of fishes representing the five-point maturity scales at each station was estimated by sex (Admasu 1996). Sex ratio (Female: Male) was calculated for each fish species and the total samples (Armstrong et al. 2004). The breeding season of all sampled fishes was determined from the percentage of fishes with ripe gonads sampled in each month, which was calculated as: $MS_i\% = \frac{MSi}{\sum_{i=1}^{5} \mathrm{MSi}} 100^4$ (Armstrong et al. 2004)

Where: MSi% = the percent fish with maturity stage 1

MSi = number of fish in maturity stage 1

$\sum$ MSi = total number of fish of all maturity stages (1 to 5)

The gonado somatic index (GSI) was also computed for each fish species to determine their breeding season (Armstrong et al. 2004; Wudneh 1998). The GSI was calculated as:

GSI = (GW/TW - GW) × 100
Where, GSI = Gonado somatic index
GW = Gonad weight in g

TW = Total weight in g, where mass of the gonad is the mass of the fresh gonad, blotted on absorbing paper

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

An investigation of length at 50 % sexual maturity (L_{50}) was done based on the length of fishes with matured gonads (Owiti and Dadzie 1989).

Estimation of fecundity

Estimation of fish fecundity was carried out for female fishes with matured gonads (maturity stage of V ovaries). The ripe gonads of matured female fishes were removed and preserved in Gilson's fluid (Simpson 1959). In the laboratory, after vigorous shaking, gonads (eggs) of each ripened female fishes were weighed to the nearest 0.01 g using a sensitive balance. The preserved ovaries were washed with tap water, and ovarian membranes were removed mechanically. For fecundity estimation of *O. niloticus*, the total numbers of eggs were counted. However, for *C. gariepinus, L. intermedius* and *C. carpio*, three sub-samples of 1 g eggs per ovary were counted, and the total number of eggs per ovary was estimated by extrapolation. The total numbers of eggs were computed using the following formula:

$N/n = W/w$, from which $N = (nW)/w$

Where, N - Total number of eggs, n - Number of eggs in sub sample (=1000), W - Weight of all eggs (g) and w - Mean weight of the sub sample (g)

Finally, the mean fecundity was determined for each fish species at their total or fork length and total weight.

Data analysis

Data were analysed using SPSS statistical software version 21.0, and presented by various descriptive statistics. Chi-square test was performed to see the monthly variation of sex ratio. One way ANOVA was also employed to see the monthly variation of GSI and fish fecundity. Finally, regression analysis was done to see the relationship between fecundity and the total/fork length, and the total weight of the fishes.

Results

Fish species composition

A total of 4207 fish specimens (1950 male and 2257 females) belonging to seven species categorised under three families (Cyprinidae, Cichlidae and Clariidae) were collected from the lake.

The fish communities were dominated by family Cyprinidae comprised of five species (made 55 % of the catch) followed by family Cichlidae. *Enteromius paludinosus* (Peters, 1852) (40.69 %) was the most abundant species followed by *Oreochromis niloticus* (Linnaeus, 1758) (39.41 %). Nevertheless, *Carassius carassius* (Linnaeus, 1758) and *Garra dembecha* Getahun & Stiassny, 2007 were the least abundant species (Table 1).

Table 1. The commercially important fish species composition collected from Lake Langeno, Ethiopia.

Family	Fish species	No. individuals			Percentage (%)
		Male	Female	Total	
Cyprinidae	*Enteromius paludinosus* (Peters 1852)	765	947	1712	40.69
	Labeobarbus intermedius (Rüppell 1835)	127	129	256	6.09
	Cyprinus carpio Linnaeus 1758	138	156	294	6.99
	Garra dembecha Getahun & Stiassny 2007	13	15	28	0.67
	Carassius carassius (Linnaeus 1758)	17	10	27	0.64
Cichlidae	*Oreochromis niloticus* (Linnaeus 1758)	778	880	1658	39.41
Clariidae	*Clarias gariepinus* (Burchell 1822)	112	120	232	5.51
Total		1950	2257	4207	100

Sex ratio of the collected fish species

The sex ratio was assessed for a total of 4152 fish specimen categorised under five fish species (*O. niloticus, E. paludinosus, C. gariepinus, L. intermedius* and *C. carpio*) because of the small number of specimens collected for *C. carassius* and *G. dembecha*. Of these, 46.24 % (n = 1920) were males and 53.76 % (n = 2232) were females**.** The sex ratio of all fish species was significantly different from the hypothetical ratio of 1:1 with the Chi-square greater than one (P < 0.05) except for *L. intermedius* (Table 2).

Table 2. Number and the corresponding sex ratios of commercially important fish species collected from Lake Langeno, Ethiopia from March 2015 through February 2016.

Fish species	No. of individuals				
	Total	Female	Male	Sex ratio	Chi square
Oreochromis niloticus (Linnaeus 1758)	1658	880	778	1.13:1	2.72
Enteromius paludinosus (Peters 1852)	1712	947	765	1.24:1	6.35
Clarias gariepinus (Burchell 1822)	232	120	112	1.07:1	1.29
Labeobarbus intermedius (Rüppell 1835)	256	129	127	1.02:1	0.82
Cyprinus carpio Linnaeus 1758	294	156	138	1.13:1	1.84
Total	4152	2257	1950	1:16:1	2.14

Chi-square test is significant at P < 0.05

Maturity and breeding season of fish species in the lake

A total of 2440 fish specimens (47.34 % (n = 1155) males and 52.67 % (n = 1285) females) were examined for this study because the study of reproductive biology was focused only on commercially important fish species (*O. niloticus*, *C. gariepinus*, *L. intermedius* and *C. carpio*). The result showed that fish with the maturity stage two (II) were dominant in both sexes of all fish species. The proportion of males and females with sexually mature gonads (IV) were 8.9 % and 10.3 % for *O. niloticus*, 28.3 % and 19.4 % for *C. gariepinus*, 17.7 % and 18.5 % for *L. intermedius* and 11 % and 23.1% for *C. carpio*, respectively (Fig. 2). The proportions of maturity stages between the two sexes were not significantly different for all fish species (χ^2, $P > 0.05$).

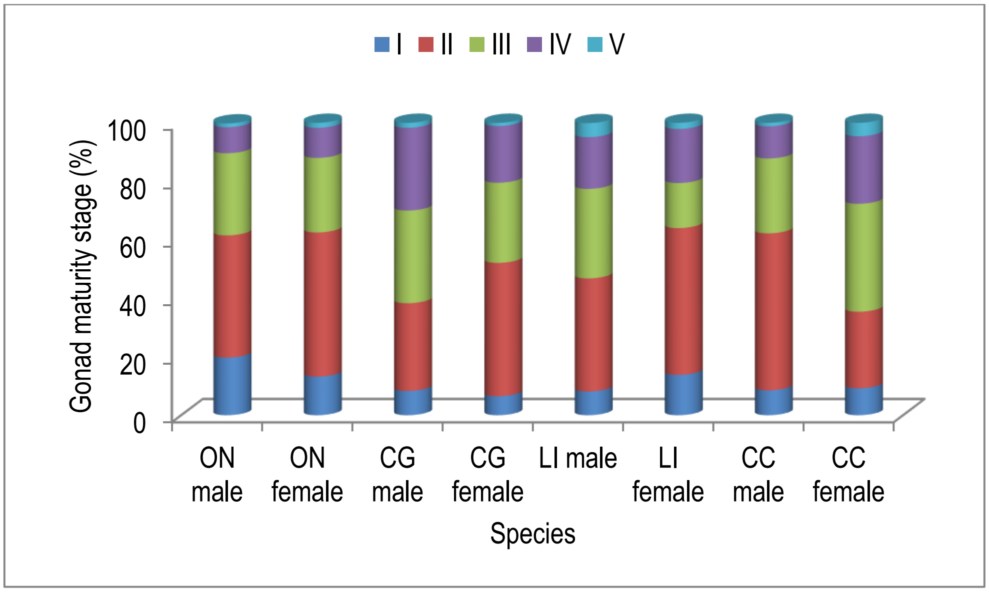

Fig. 2. The proportion of gonad maturity stages of commercially important fish species (%) in Lake Langeno, Ethiopia (ON = *Oreochromis niloticus*, CG = *Clarias gariepinus*, LI = *Labeobarbus intermedius* and CC = *Cyprinus carpio*).

On the other hand, the proportion of fishes with the fully mature gonads showed a significant temporal variation for all species (χ^2, $P < 0.05$). For instance, a high number of fishes with fully matured gonads (IV) was observed between April to June, May to July, June to July and March to May for *O. niloticus*, *C. gariepinus*, *L. intermedius* and *C. carpio*, respectively. The least number of fishes with the fully matured gonads were collected from October to November, October to December, October to December and September to November, respectively (Fig. 3).

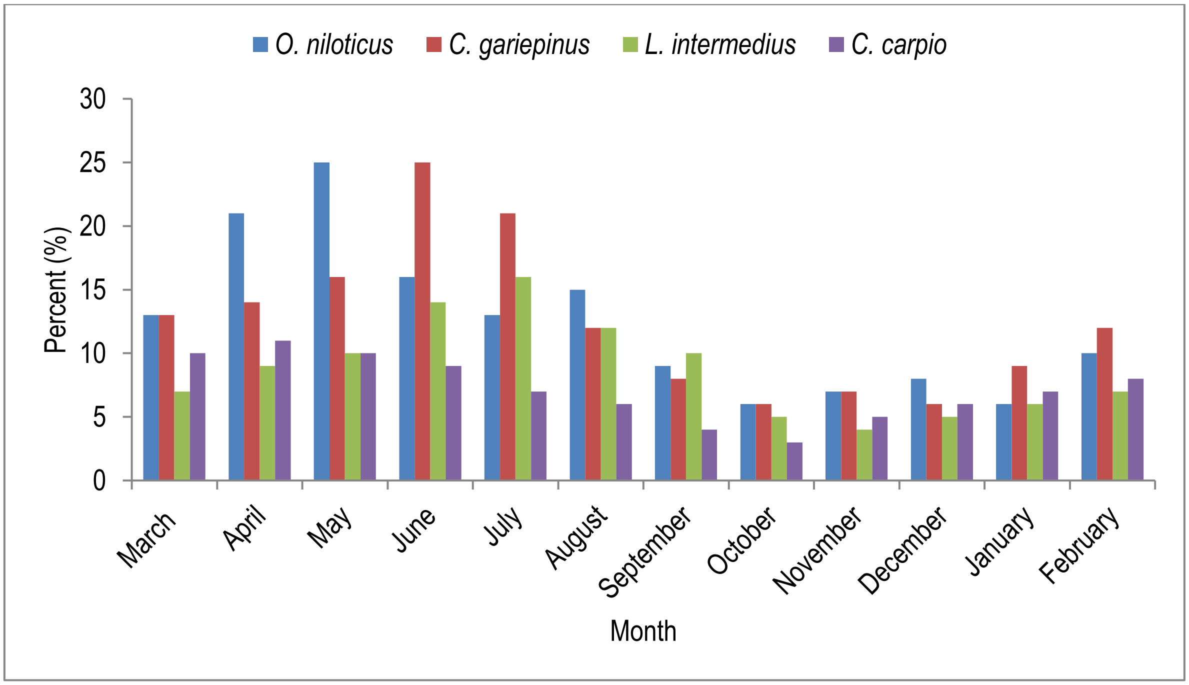

Fig. 3. Monthly distribution of commercially important fishes with ripe gonads collected from Lake Langeno, Ethiopia.

Gonadosomatic index (GSI) of fishes

The monthly variation of GSI for *O. niloticus* ranged from 2.1 to 5.31 (mean 3.75 ± 1.13) for females and 1.6 to 4.72 (mean 2.93 ± 1.04) for males. The highest GSI was observed in April, and the least was observed in November (Fig. 4A). Similarly, the GSI value of *C. gariepinus* ranged from 1.1 to 6.1 (mean 3.64 ± 1.89) for females and 0.4 to 1.2 (mean 0.79 ± 0.23) for males with the highest GSI value recorded in June and the least in December (Fig. 4B). *Labeobarbus intermedius* had GSI values ranged from 2.31 to 5.98 (mean 3.44 ± 1.09) for females, and 1.89 to 5.18 (mean 3.69 ± 1.07) for males with the highest and the least GSI value scored in July and December, respectively (Fig. 4C). The minimum and maximum GSI value of *C. carpio* was 7.3 and 12.2 (mean 9.72 ± 1.39) for females and 2.1 and 4.8 (mean 3.63 ± 0.85) for males. The highest GSI value was recorded in May, and the least value was in November (Fig. 4D). The result showed a significant temporal variation of GSI for all fish species (ANOVA, $P < 0.05$), but no significant variation observed among the sexes (ANOVA, $P > 0.05$).

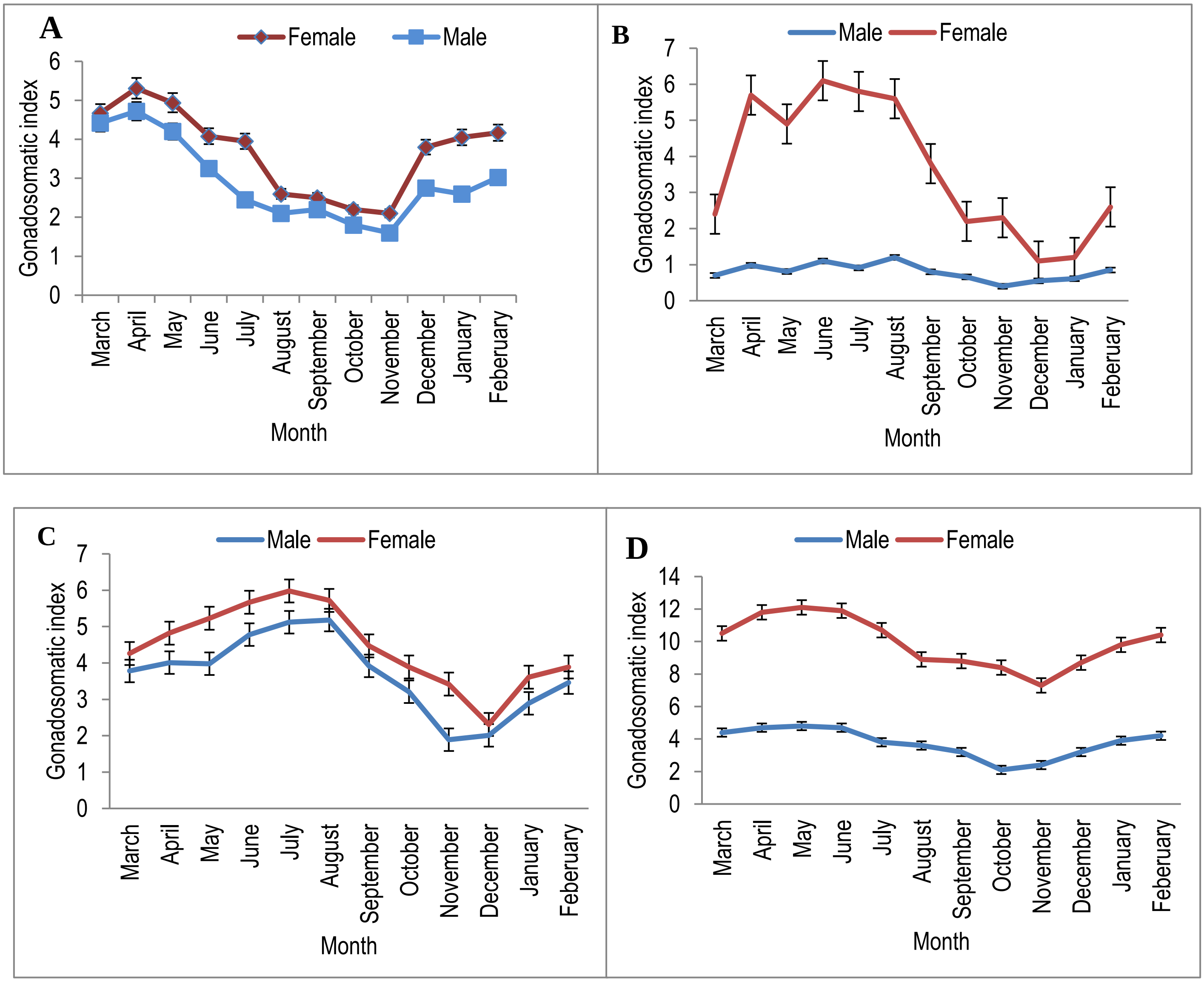

Fig. 4. Mean monthly variation of gonadosomatic index of commercially important fish species (A. *Oreochromis niloticus*, B. *Clarias gariepinus*, C. *Labeobarbus intermedius*, D. *Cyprinus carpio*) in Lake Langeno, Ethiopia.

Length at sexual maturity (L_{50})

The smallest sexually matured female and male caught in this study was 12.8 cm and 13.5 cm TL for *O. niloticus*, 24.5 cm and 25.5 cm TL for *C. gariepinus*, 17.5 cm and 18.3 FL for *L. intermedius*, and 19.3 cm and 20.5 cm FL for *C. carpio*. Their respective total weights were 52 g and 63.2 g, 318 g and 271 g, 149.6 g and 162 g, and 147.2 g and 165 g, respectively. The length at 50 % sexual maturity (L_{50}) obtained was 16.4 cm and 15.8 cm TL, 28.5 cm and 29.5 cm TL, 29.5 cm and 30.5 cm FL and 28.2 cm and 27.6 cm FL for both female and male of *O. niloticus*, *C. gariepinus*, *L. intermedius* and *C. carpio*, respectively (Figs. 5–8).

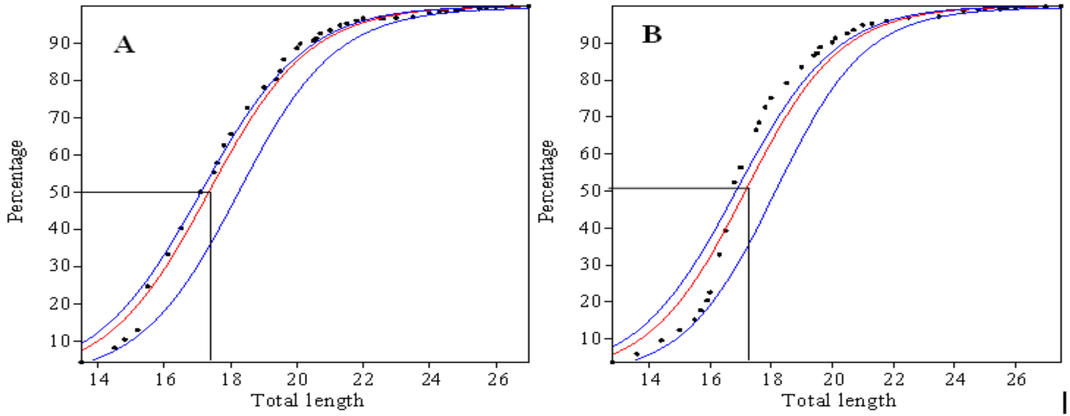

Fig. 5. Length at sexual maturity (L_{50}) of *Oreochromis niloticus* (A = male and B = female) in Lake Langeno, Ethiopia. The dotted line represents the observed value, the red line represents the logistic curve and the blue line represents the 95 % CL.

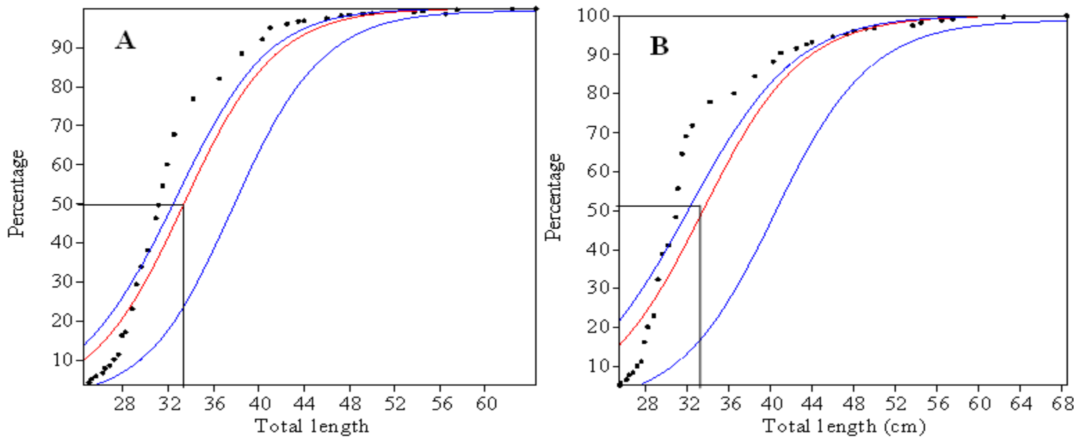

Fig. 6. Length at sexual maturity (L_{50}) of *Clarias gariepinus* (A = male and B = female) in Lake Langeno, Ethiopia. The dotted line represents the observed value, the red line represents the logistic curve, and the blue line represents the 95 % CL.

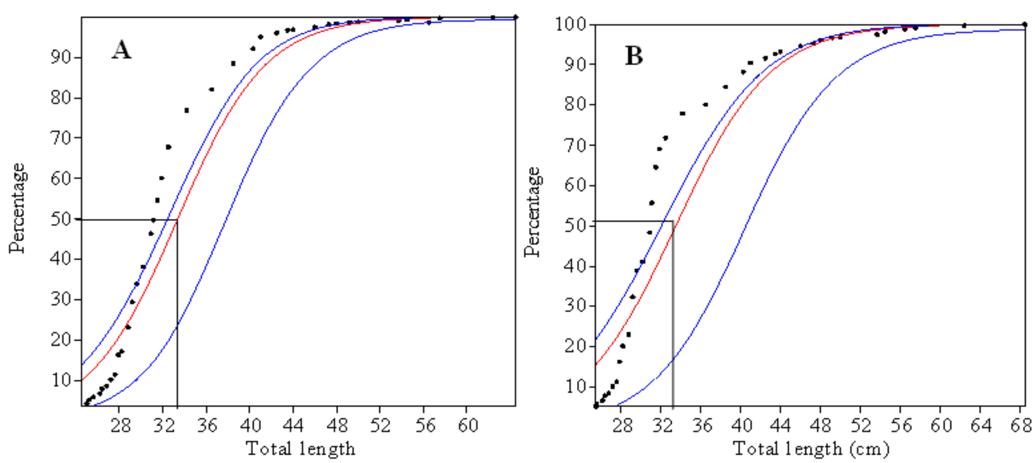

Fig. 7. Length at sexual maturity (L_{50}) of *Labeobarbus intermedius* (A = male and B = female) in Lake Langeno, Ethiopia. The dotted line represents the observed value, the red line represents the logistic curve, and the blue line represents the 95 % CL.

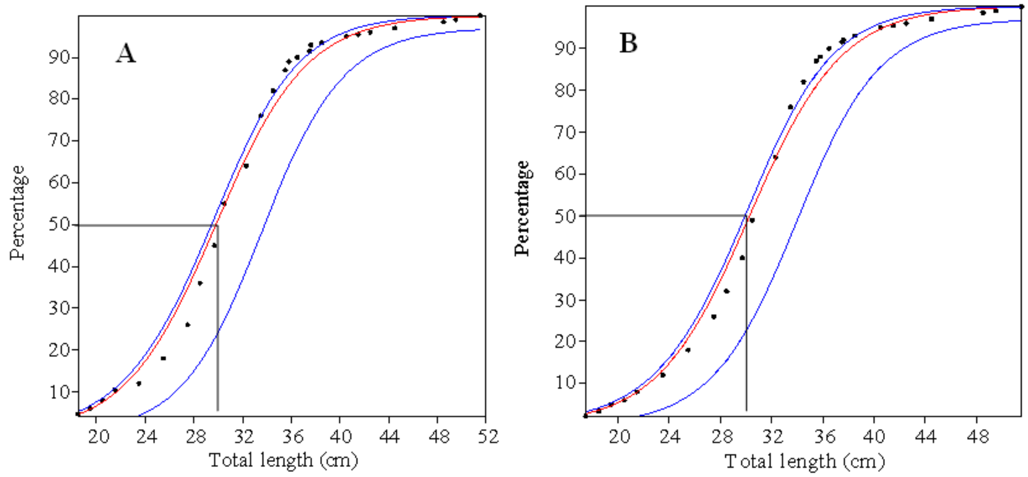

Fig. 8. Length at sexual maturity (L_{50}) of *Cyprinus carpio* (A = male and B = female) in Lake Langeno, Ethiopia. The dotted line represents the observed value, the red line represents the logistic curve, and the blue line represents the 95 % CL.

Fecundity

Fecundity was examined for 126 ripe females of *O. niloticus*, 32 females of *C. gariepinus*, 33 females of *L. intermedius* and 36 ripe females of C. *carpio*. The total or fork length of the examined fish species ranged between 12.8 cm to 27.5 cm TL, 24.5 cm to 68.5 cm TL, 17.5 cm to 51.5 cm FL, and 19.3 cm to 51.5 cm FL for *O. niloticus*, *C. gariepinus*, *L. intermedius* and *C. carpio,* respectively. Their respective total weights were also found in between ranges of 52.4 to 347 g, 318 to 2189 g, 162.5 to 1156 g and 147.2 to 1604.3 g, respectively. Their total fecundity also ranged between 187 to 978 eggs for *O. niloticus*, 427 to 1132 eggs.g^{-1} with absolute fecundity of 82600 to 211442 eggs for *C. gariepinus*, 1078 to 6532 eggs for *L. intermedius* and 681 to 1922 eggs.g^{-1} with absolute fecundity of 32749 to 392487 eggs for *C. carpio.* The mean fecundity of these fish species were 463.83 ± 114, 141466 ± 40982, 3055 ± 2234 and 105631 ± 46680 eggs, respectively. The result showed a significant variation in fecundity among the different lengths and species (ANOVA, $P < 0.05$).

Length-fecundity and the weight-fecundity relationship of fishes

The relationship between fecundity and total or fork length were curvilinear for all fish species, while the relationship between fecundity and total weight were linear for *O. niloticus*, *L. intermedius* and *C. carpio,* and curvilinear for *C. gariepinus.* The relation between fecundity and the total length or fork length or total weights were highly significant ($r^2 > 90$) except for fecundity-weight relationship of *C. gariepinus* (Figs. 9 to 12).

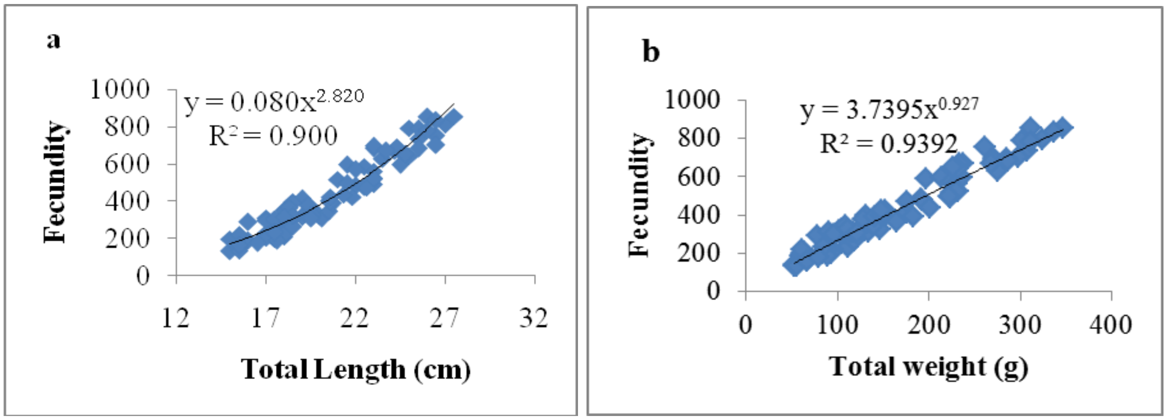

Fig. 9. (a) Length-fecundity and (b) weight-fecundity relationship of *Oreochromis niloticus* in Lake Langeno, Ethiopia.

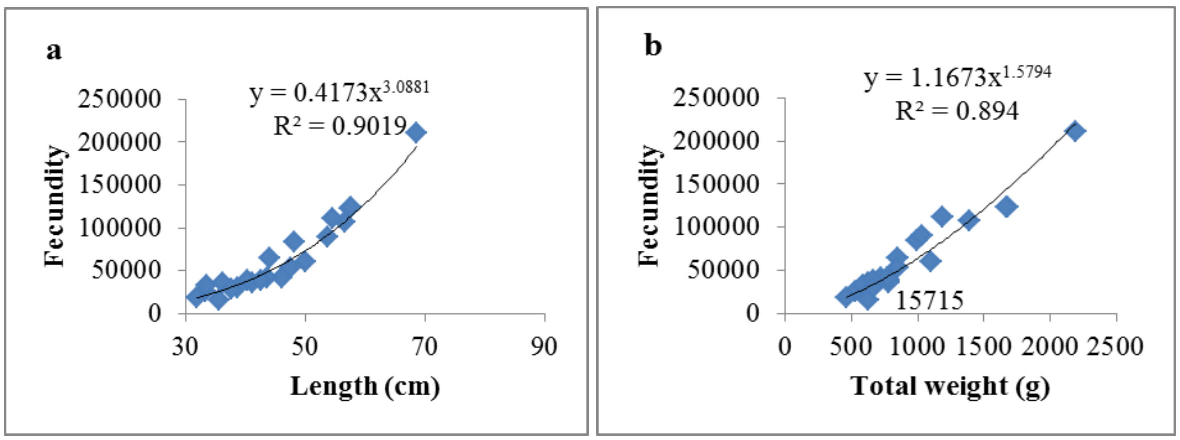

Fig. 10. (a) Length-fecundity and (b) weight-fecundity relationship of *Clarias gariepinus* in Lake Langeno, Ethiopia.

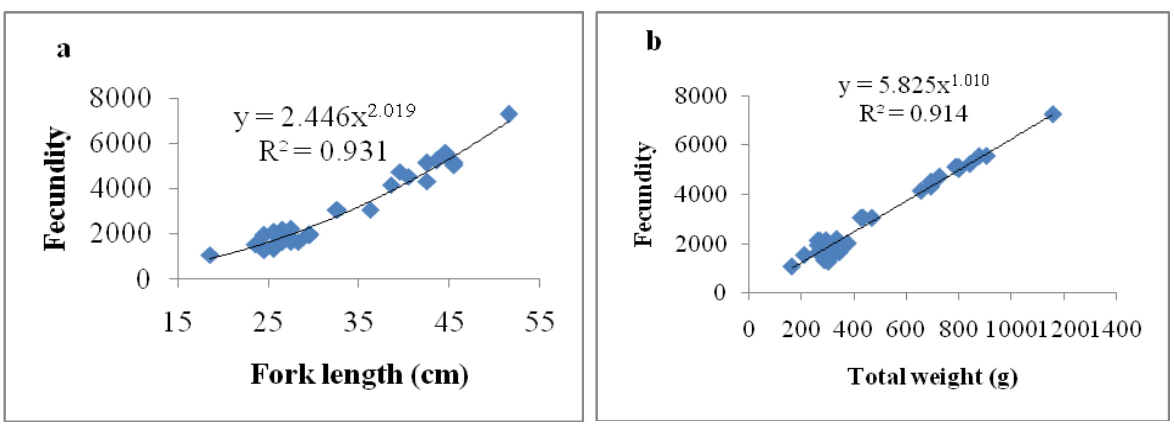

Fig. 11. (a) Length-fecundity and (b) weight-fecundity relationship of *Labeobarbus intermedius* in Lake Langeno, Ethiopia.

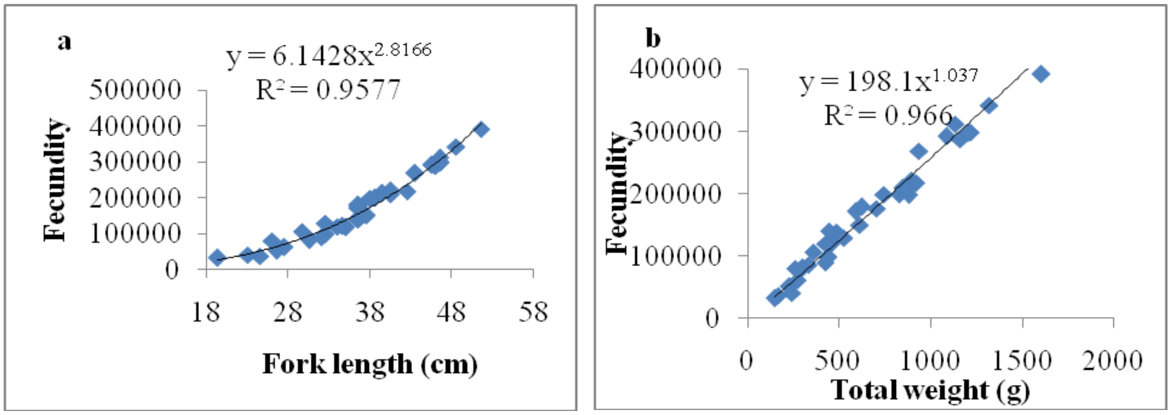

Fig. 12. (a) Length-fecundity and (b) weight fecundity relationship of *Cyprinus carpio* in Lake Langeno, Ethiopia.

Discussion

Sex ratio

The overall sex ratios of all fish species were significantly different from 1:1 ratio, where females were more dominant than males (Table 2). Similar findings were reported for *O. niloticus* from Lake Babogaya (Abera 2012), Lake Beseka (Abera 2013), Lake Hayq (Worie and Getahun 2014), Lake Hawassa (Admassu 1996) and Lake Albert Nile, Uganda (Nyakuni 2009). However, it is in contrast with the findings from Lake Tana (Tadesse 1997) and Lake Victoria (Njiru et al. 2004). On the other hand, sex ratio of *C. gariepinus* in this study is in contrast with the findings of Abera et al. (2014b) and Dadebo et al. (2011), who reported the dominance of males from Lake Babogaya and Lake Chamo, respectively, but it is in agreement with the finding of Abera et al. (2014a) from Lake Zeway. Similarly, Tewabe (2014), Teshome et al. (2015), Awoke et al. (2015) and Anteneh et al. (2007) reported the dominance of *L. intermedius* females in Lake Tana, in tributary rivers of Lake Tana, in Blue Nile River, and Dirma and Megech tributary rivers, respectively. The dominance of female *C. carpio* in this study area is also in agreement with that of Abera (2016) in Lake Zeway. In general, the unbalanced ratio between male and female could be due to the behavioural difference between sexes, which render one sex to be easily caught than the other or the difference in habitat preference due to the deviation in sexual maturity stages during the spawning season (Admasu 1994).

Sexual maturity, GSI and breeding season of fish species in Lake Langeno

The result of GSI showed that all of the fish species can breed throughout the year (Fig. 2, Fig. 3 and Figs. 4A–D). According to Lowe-McCconnell (1975), the seasonal fluctuations in water temperature and photoperiod are generally very low in tropics, and this is more favourable for many species to spawn at any time of the year. However, all of the fish species has different intensive breeding time in the year, which mainly depends on the availability of food and water temperature (Pawiroredjo 2001). For instance, *O. niloticus* had the peak breeding time from March to May for both sexes, i.e. at the onset of rainy seasons (Fig. 3 and Fig. 4A). Similarly, the peak breeding time for the same fish species was reported differently elsewhere, for instance, April to August, April to June, March to June, January to July and March to September from Lake Babogaya (Abera 2012), Lake Tana (Tewabe 2014), Lake Chamo (Teferi et al. 2001), Fincha Reservoir (Degefu et al. 2012) and Abu-Zabal Lake, Egypt (Shalloof and Salama 2008), which are very close to our finding. In contrast, Abera (2013) and Njiru et al. *(*2004) reported the peak breeding times of the same fish from September to August and January to April in Lake Beseka and Lake Victoria, respectively.

Similarly, the intensive breeding time of *C. gariepinus* obtained in this study (April to August) coincided with the rainy season, which is in agreement with the reports from Lake Hawassa (Dadebo 2000), Lake Tana (Tewabe 2014), Lake Babogaya (Admasu et al. 2015), Lake Chamo (Dadebo et al. 2011) and Tanoe-Ehy Swamp forest, South-Eastern Côte d'Ivoire (Konan et al. 2015). The peak breeding time of *L. intermedius* observed in our finding (June to August) also resemble with the findings of Mequanent et al. (2014) (August to September), Tewabe (2014) (May to August) and Anteneh et al. (2007) (July to October) in Blue Nile River, Lake Tana, and in Derma and Megech tributary rivers, respectively. The mean monthly variation of GSI is also evident that *C. carpio* can breed throughout the year with the peak breeding time between April and June (Fig 4D). The studies showed that when water temperature reaches its critical values in the spring, the final maturational stages of oocyte development are completed, and *C. carpio* starts spawning at this time (Hontela and Stacey 1995). Davies et al. (1986) reported that 20–25 ^{o}C is a favourable temperature range for spawning of *C. carpio* under experimental conditions, which is very similar with the water temperature of our study area. Similarly, the peak breeding time of *C. carpio* is reported as from February to April from Amerti Reservoir (Hailu 2013), February to May from Lake Zeway (Abera et al. 2015) and March to July from Fincha Reservoir (Degefu et al. 2012).

In general, the temperature is an important factor that influences the spawning time, survival of larvae and growth of juvenile fishes (Hontela and Stacey 1995). However, most of the tropical freshwater fishes, especially family Cyprinidae, spawn seasonally with the peak breeding time of the rainy season (Lowe-McConnell 1975). The beginning of rainy season and subtle change in water temperature mainly triggers the spawning period of many tropical fishes (Dadebo 2000).

Length at sexual maturity (L_{50})

The L_{50} obtained for *O. niloticus* was 16.4 cm TL for females and 15.8 cm TL for males (Fig. 5), which is smaller than the previous report of Tesfaye and Tadesse (2008) in the same study area (19.5 cm TL for both sexes). The values are also lower compared to the findings from Lake Chamo (42 cm TL) (Teferi et al. 2000), Lake Hawassa (18.8 cm and 19.8 cm TL) (Admasu 1994), Fincha Reservoir (21.2 cm and 23.4 cm TL) (Degefu et al. 2012), Lake Victoria (30.81cm and 34.56 cm TL) (Njiru et al. 2004) and Lake Albert Nile (22.4 cm and 23.0 cm TL) (Nyakuni 2009) for females and males of the same species, respectively. This indicated that *O. niloticus* in Lake Langeno exhibited a rapid first sexual maturity. Perhaps, it had a comparable L_{50} with the same species in Lake Beseka (14 cm and 17 cm TL for female and male) (Abera 2013) and Lake Hayq (Worie and Getahun 2014) (14.5 cm and 15.5 cm TL for females and males).

The L_{50} exhibited by *C. gariepinus* in this study (28.5 cm and 29.5 cm TL for females and males) (Fig. 6) is comparable with the finding of Abera (2016) in Lake Zeway (28.7 cm and 27 cm TL for females and males) for the same species. However, the L_{50} was observed early as compared to the same species in Lake Tana (57.7 cm and 43.2 cm TL for females and males) (Tewabe 2014), Lake Babogaya (50 cm and 56 cm TL for females and males) (Abera et al. 2014a) and Lake Chamo (52 cm and 58 cm TL for females and males) (Dadebo et al. 2011). The result of L_{50} recorded for *L. intermedius* in the present study (30.5 cm and 29.5 cm FL for females and males) (Fig. 7) was comparable with L_{50} recorded for the same species in Lake Tana (32.7 cm and 25.9 cm FL for females and males) (Tewabe 2014). However, L_{50} is seen later than the same species in Dirma and Megech tributary rivers (22.57 cm FL for both sexes) (Anteneh et al. 2007), and in Lake Tana (26 cm FL for both sexes) (Tewabe et al. 2010).

Similarly, the length at L_{50} obtained for *C. carpio* (28.2 cm and 27.6 cm FL for females and males) (Fig. 8) is very close to the findings of Abera et al. (2015) and Hailu (2013) from Lake Zeway (28.7 cm and 27.2 cm FL for females and males) and Amerti Reservoir (28.3 cm and 27.2 cm FL for females and males). However, Degefu et al. (2012) and Britton et al. (2007) reported the higher L_{50} than the present result from Fincha Reservoir (37.50 cm and 24.50 cm FL for female and male) and Lake Naivasha (42 cm and 34cm FL for females and males), respectively. The study indicated that fish live in stressful environments often exhibit an earlier sexual maturity because it is the strategy to maintain the maximum reproduction in response to high level of mortality (Cowx et al. 2003). Abundance and availability of food in combination with the other environmental factors and changes in water level can also determine the L_{50} of fish (Grammer et al. 2012).

Fecundity, length-fecundity and the weight-fecundity relationship of fishes

Fecundity obtained for *O. niloticus* in this study (187 to 978 eggs.fish^{-1} with the mean fecundity of 463.83 eggs.fish^{-1}) is comparable with the findings in Lake Hawassa (304 to 967 eggs.fish^{-1}) (Admasu 1994), Lake Tana (495 to 1243 eggs.fish^{-1}) (Tadesse 1997) and Lake Hayq (290 to 1287 eggs.fish^{-1}) (Worie and Getahun 2014). However, it was small as compared to the fecundity of same fish species in Lake Chamo (1047 to 4590 eggs.fish^{-1}) (Teferi et al. 2001), Lake Victoria (905 to 7619 eggs.fish^{-1}) (Njiru et al. 2004), Lake Albert Nile, Uganda (412 to 2380 eggs.fish^{-1}) (Nyakuni 2009) and Abu-zabal Lake, Egypt (289 to 1456 eggs.fish^{-1}) (Shalloof and Salama 2008). It also exhibited a greater fecundity than the same species in Lake Beseka (125 to 351 eggs.fish^{-1}) (Abera 2013). Fecundity of *O. niloticus* in the present study increased in proportion to 2.820 power of the length ($r^2 = 0.900$) and 0.929 power of the weight ($r^2 = 0.939$) (Fig. 9). In many tropical freshwater fish species, fecundity increased in proportion to 2.81–3.36 power of total length (Lowe-McConnell 1975). Bagenal and Tesch (1978) also reported that the value of "b" is about 3 when fecundity is related to length, and about one when it is related to weight. Therefore, the fecundity of *O. niloticus* in this study depends both on their total weight and total length, which agree with this theoretical idea.

The finding of the present study also revealed that the fecundity of *C. gariepinus* in this lake (82600 to 211442 eggs.g^{-1} with the mean absolute fecundity of 141466 eggs.fish^{-1}) was small as compared to the finding of Admasu et al. *(*2015) in Lake Babogaya (11,000 to 580,571 eggs.fish^{-1}), Dadebo et al. (2011) in Lake Chamo (5,000 to 1,240,000 eggs.fish^{-1}) and Abera et al. (2014a) in Lake Zeway (10,000 to 560,000 eggs.fish^{-1}) for the same species. The result indicated that fecundity of *C. gariepinus* is strongly associated with the increase in length than weights (3.088 power of the length (r^2 = 0.901) and 1.579 power of the weight (r^2 = 0.894)).

The result of fecundity obtained for *L. intermedius* in this study (1078 to 6532 eggs with the mean fecundity of 3055 eggs.fish^{-1}) was less than the results reported for the same species in Lake Tana (1935 to 11224 eggs.fish^{-1}) (Gebremedhin et al. 2014), Gilgel Beles River (1535 to 13864 eggs.fish^{-1}) (Berie 2007), and Gelda and Gumara Rivers (1265 to 13289 eggs.fish^{-1}) (Teshome et al. 2015). However, it is comparable with that of Awoke et al. (2015) and Anteneh et al. (2007) in the Blue Nile (1345 to 7235 eggs.fish^{-1}) and tributaries of Lake Tana (1761 to 8367 eggs.fish^{-1}). The studies show that highly oxygenated water and gravel beds are the general requirements for *Labeobarbus* sp. reproduction due to their critical importance in the development of eggs and larvae (de Graaf 2005). Fecundity of *L. intermedius* in this increased in proportion to 2.019 power of the length (r^2 = 0.931) and 1.010 power of the weight (r^2 = 0.914), which indicated that the fecundity of this species is strongly related to their weight than to their length (Fig. 11).

The absolute fecundity recorded for *C. carpio* in this study (32749 to 392487 eggs.g^{-1} with the mean fecundity of 105631 eggs.fish^{-1}) was close to the results obtained for the same species in Amerti Reservoir (36955 to 318584 eggs.fish^{-1}) (Hailu 2013). However, it is slightly less than the findings in Lake Zeway (75645 to 356743 eggs.fish^{-1}) (Abera et al. 2015), Southeastern Caspian Sea (33695 to 1234567 eggs.fish^{-1}) (Vazirzadeh and Yelghi 2015), Lake Victoria, Australia (75000 to 262000 eggs.fish^{-1}) (Sivakumaran et al. 2003) and New Zealand (29800 to 771000 eggs.fish^{-1}) (Tempero et al. 2006). Bajer and Sorensen (2010) stated that females of *C. carpio* can carry >1000000 eggs for length groups >60 cm FL. Therefore, *C. carpio* in Lake Langeno is very poor in fecundity as compared to this estimation and the results obtained by other researchers. The reproductive cycle and pattern of gonad development of *C. carpio* in natural ecosystems greatly depends on water temperature and food availability (Smith and Walker 2004; Tempero et al. 2006). Fecundity of *C. carpio* in this study is strongly associated with its weight and length (increased in proportion to 2.816 power of length (r^2 = 0.957) and 1.037 power of the weight (r^2 = 0.966)).

Conclusion

The result of the present study indicated that the breeding time of fish species in Lake Langeno is year round. However, their specific peak breeding time was highly different, which mainly depends on the seasonal fluctuation and availably of foods in the study area. The peak breeding time of most fish species was at the onset and at time of rainy season. In other words, most fish species in this lake exhibited very small length at sexual maturity as compared to those fish species in other similar water bodies. The fecundity of the most species was also lower than those living in other similar lakes. This indicated that fish species in this lake are living in a stressful environment, which could be either due to natural or human factors. The findings of this study call for an increasing focus on effective management setup, regular stakeholder's follow-up and further monitoring program to ensure the sustainability of the resources.

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References

Abera, L. 2012. Breeding season and condition factor of *Oreochromis niloticus* (Pisces: Cichlidae) in Lake Babogaya, Ethiopia. Journal of Agricultural Sciences 7:116–120.

Abera, L. 2013. Reproductive biology of *Oreochromis niloticus* in Lake Beseka, Ethiopia. Journal of Cell and Animal Biology 9:116–120.

Abera, L., A. Getahun and B. Lemma. 2014a. Composition of commercially important fish species and some perspectives into biology of African Catfish *Clarias gariepinus* (Burchell), Lake Zeway, Ethiopia. Journal of Advanced Research 2:864–871.

Abera, L., D. Admassu and Z. Tadesse. 2014b. Length-weight relationship, sex ratio, length at maturity and condition factor of African catfish *Clarias gariepinus* in Lake Babogaya, Ethiopia. Journal of Advanced Research of Biological Sciences 1:105–112.

Abera, L., A. Getahun and B. Lemma. 2015. Some aspects of reproductive biology of the common carp (*Cyprinus carpio*) in Lake Zeway, Ethiopia. Global Journal of Agricultural Research and Reviews 3:151–157.

Abera, L. 2016. Current status and trends of fishes and fishery of a shallow rift valley Lake, Lake Zeway, Ethiopia. PhD dissertation submitted to Department of Zoological Sciences, Addis Ababa University, Ethiopia. 206 pp.

Admassu, D. 1994. Maturity, fecundity, brood size and sex ratio of *Oreochromis niloticus* L. in Lake Hawassa. SINET: Ethiopian Journal of Science 17:53–69.

Admassu, D. 1996. The breeding season of tilapia, *Oreochromis niloticus* L. in Lake Hawassa (Ethiopian rift valley). Hydrobiologia 337:77–83.

Admassu, D., L. Abera and Z. Tadesse. 2015. Fecundity and breeding season of the African catfish, *Clarias gariepinus* in Lake Babogaya, Ethiopia. Global Journal of Agriculture and Agricultural Sciences 3:295–303.

Anteneh, W., A. Getahun and E. Dejen. 2007. Reproductive Biology of *Labeobarbus intermedius* in the Dirma and Megech Rivers of Lake Tana, Ethiopia. Ethiopian Science and Technology 4:13–26.

Armstrong, M. J., H. D. Gerritsen, M. Allen, W.J. McCurdy and J.A.D. Peel. 2004. Variability in maturity and growth in a heavily exploited stock: cod (*Gadus morhua* L.) in the Irish Sea. ICES Journal of Marine Science 61:98–112.

Awoke, T., M. Mingist and A. Getahun. 2015. Some aspects of biology of dominant fishes in blue Nile River, Ethiopia. International Journal of Fisheries and Aquatic Studies 3:62–67.

Ayenew, T. 2004. Environmental implications of changes in the levels of lakes in the Ethiopian Rift Since 1970. Regional Environmental Change 4:192–204.

Bagenal, T.B. and F.W. Tesch. 1978. Methods of assessment of fish production in fresh waters. IBP Handbook No 3, 3rd ed. Oxford Blackwell Scientific Publication, London. 184 pp.

Bajer P.G. and P.W. Sorensen. 2010. Recruitment and abundance of an invasive fish, the common carp, is driven by its propensity to invade and reproduce in basins that experience winter-time hypoxia in interconnected lakes. Biological Invasions 12:1101–1112

Belay, A. and R.B. Wood. 1984. Primary production of five Ethiopian Rift Valley Lakes. International Verein Limnology 22:1187–1192.

Berie, Z. 2007. Diversity, Relative Abundance and Biology of Fishes in Beles and Gilgel Beles Rivers, Abay Basin, Ethiopia. MSc thesis submitted to Addis Ababa University, Zoological Sciences Department, Ethiopia. 153 pp.

Britton, J.R., R.R. Boar, J. Grey, J. Foster, J. Lugonzo and D.M. Harper. 2007. From introduction to fishery dominance: the initial impacts of the invasive carp *Cyprinus carpio* in Lake Naivasha, Kenya, 1999 to 2006. Journal of Fish Biology 71:239–257.

Cochrane, K.L. 2002. A fishery manager’s guidebook. Management measures and their application. FAO Fisheries Technical Paper No. 424. FAO, Rome. 231 pp.

Cowx, I. G., M. VannDer Knaap, L.I. Muhoozi and R. Othina. 2003. Improving fishery catch statistics for Lake Victoria. Journal of Ecosystems Health Management 6:299–310.

Dadebo, E. 2000. Reproductive biology and feeding habits of *Clarias gariepinus* Burchell (Pisces: Clariidae) in Lake Hawassa, Ethiopia. SINET: Ethiopian Journal of Sciences 23:231–246.

Dadebo, E., Z. Gebremariam and S. Mengistou. 2011. Breeding Season, Maturation, Fecundity and Condition Factor of the African Catfish *Clarias gariepinus* Burchell 1822 in Lake Chamo, Ethiopia. Ethiopian Journal of Biological Sciences 10:1–17.

Davies, P.R., I. Hanyu, K. Furukawa and M. Nomura. 1986. Effect of temperature and photoperiod on sexual maturation and spawning of the common carp II. Under conditions of low temperature. Aquaculture 52:51–58.

de Graaf, M., E. Nentwich, J. Osse and F. Sibbing. 2005. Lacustrine spawning, a new reproductive strategy among large African cyprinid. Journal of Fish Biology 66:1214–1236.

Degefu, F., G. Tesfaye and F. Tefera. 2012. Study on the Adaptability Status and Reproductive Success of *Oreochromis niloticus* (Pisces: Cichlidae) and Carp (*Cyprinus carpio* L., 1758) in a Tropic reservoir (Fincha, Ethiopia). International Journal of Aquaculture 2:65–71.

Domínguez-Petit, R., H. Murua, F. Saborido-Rey and E. Trippel. 2015. Handbook of applied fisheries reproductive biology for stock assessment and management. Vigo, Spain. 102 pp.

Fitzhugh, G. R., K.W. Shertzer, G. Todd Kellison and D.M. Wyanski. 2012. Review of size- and age-dependence in batch spawning: implications for stock assessment of fish species exhibiting indeterminate fecundity. Fishery Bulletin 110:413–425.

Gebremariam, Z., E. Kebede and Z. Desta. 2002. Long-term changes in chemical features of waters of seven Ethiopian rift-valley lakes. Hydrobiologia 477:81–91.

Gebremedhin, S., A. Getahun, M. Mingist and W. Anteneh. 2014. Some Biological Aspects of *Labeobarbus* spp. (Pisces: Cyprinidae) at Arno-Gornor river, Lake Tana Sub-basin, Ethiopia. Journal of Fisheries and Aquatic Sciences 9:46–62.

Golubtsov, A. S., A.A. Darkov, Y.U. Dgebuadze and M.V. Mina. 1995. An artificial key to fish species of the Gambella region: the White Nile Basin in the limits of Ethiopia. Joint Ethio–Russian Biological Expedition, (JREBE), Addis Ababa. 84 pp.

Gómez-Márquez, J.L., B. Peña-Mendoza, I.H. Salgado-Ugarte and M. Guzmán-Arroyo. 2003. Reproductive aspects of *Oreochromis niloticus* (Perciformes: Cichlidae) at Coatetelco Lake, Morelos, Mexico. Revista de Biología Tropical 51:221–228.

Grammer, G.L., W.T. Slack, M.S. Peterson and M.A. Dugo. 2012. Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) establishment in temperate Mississippi, USA: multi-year survival confirmed by otolith ages. Aquatic Invasions 7:367–376.

Habteselassie, R. 2012. Fishes of Ethiopia: Annotated checklist with pictorial identification guide. 1st edn. Ethiopian Fisheries and Aquatic Science Association, Ethiopia. 250 pp.

Hailu, M. 2013. Reproductive aspects of common carp (*Cyprinus carpio* L, 1758) in Amerti reservoir, Ethiopia. Journal of Ecology and Natural Environment 5:260–264.

Hailu, M., G. Senbate, M. Hindabu and B. Tadese. 2010. Anthropogenic impacts on rift valley water bodies: case of Lakes Zeway, Langeno and Abijata. In: Management of shallow water for improved productivity and peoples' livelihoods in Ethiopia. (eds. S. Mengistou and B. Lemma), pp 181-210. Addis Ababa University Printing Press, Ethiopia.

Hontela, A. and N.E. Stacey. 1995. Cyprinidae. In: Reproductive seasonality in teleosts. (eds. A.D. Munro, A.P. Scott and T.J. Lam), pp. 53–78. Environmental Influences, CRC Press, Inc., Boca Raton, FL.

Imam, T.S., U. Bala, M.L. Balarabe and T.I. Oyeyi. 2010. Length-weight relationship and condition factor of four fish species from Wasai reservoir in Kano, Nigeria. African Journal of General Agriculture 6:125–130.

Konan, Y.A., T. Koné, M. Bamba and I. Koné. 2015. Reproductive Strategies of the Catfish *Clarias buettikoferi* (Pisces, Clariidae) in the Tanoe-Ehy Swamp Forest (South-Eastern Côte d'Ivoire). World Journal of Fish and Marine Sciences 6:16–23.

Lowe-McConnell, R.H. 1975. Fish communities in tropical freshwaters: their distribution, ecology, and evolution. Longman, London. 337 pp.

Mequanent, D., M. Mingist, A. Getahun and W. Anteneh. 2014. Spawning migration of Labeobarbus species of Lake Tana to Gilgel Abay River and its tributaries, Blue Nile Basin, Ethiopia. African Journal of Fisheries Science 2:176–184.

Morgan, M.J. 2008. Integrating reproductive biology into scientific advice for fisheries management. Journal of Northwest Atlantic Fishery Science 41:37–51.

Njiru, M., J.E. Ojuok, J.B. Okey-Owuor, J.M. Ntiba and I.G. Cowx. 2004. Some biological aspects and life history strategies of Nile tilapia *Oreochromis niloticus* (L.) in Lake Victoria, Kenya. African Journal of Ecology 44:30–37.

Nyakuni, L. 2009. Habitat Utilization and Reproductive Biology of *Oreochromis niloticus* in Lake Albert Nile. MSc thesis submitted to Makerere University, Department of Zoology, Uganda. 124 pp.

Okaronon, J. O., E.F.B. Katunzi and A.A. Asila. 1998. Fish species identification guide for Lake Victoria. Lake Victoria Fisheries Research Project. 55 pp.

Owiti, D.O. and S. Dadzie. 1989. Maturity, fecundity and effect of rainfall on spawning rhythm of a siluroid catfish, *Clarias mossambicus*. Aquaculture and Fisheries Management 20: 355–368.

Pawiroredjo, P.A. 2001. Temperature effects on spawning and fingerling production of channel catfish *Ictalurus Punctatus*. MSc thesis submitted to Louisiana State University, College of Agricultural and Mechanical, USA. 82 pp.

Shalloof, K.A. and H.M. Salama. 2008. Investigations on some aspects of reproductive biology in *O. niloticus* (Linnaeus) in Abu-Zabal Lake, Egypt. Global Veterinaria 2:351–359.

Simpson, A. C. 1959. Method used for separating and counting the eggs and fecundity studies on the plaice (*Pleuronectes platessa*) and herring (*Clupea herengus*). Occasional publication of Indo-Pacific countries, No. 59112. FAO Rome, Italy. 108 pp.

Sivakumaran, K.P., P. Brown, D. Stoessel and A. Giles. 2003. Maturation and reproductive biology of female wild carp, *C. carpio*, in Lake Victoria, Australia. Environmental Biology of Fishes 68:321–332.

Smith, B.B. and K.F. Walker. 2004. Spawning dynamics of common carp in the River Murray, South Australia, shown by macroscopic and histological staging of gonads. Journal of Fish Biology 64:336–354.

Tadesse, Z. 1997. Breeding season, Fecundity, Length-weight relationship & Condition factor of *Oreochromis niloticus* in Lake Tana, Ethiopia. SENIT: Ethiopian Journal of Science 20:31–47.

Teferi, Y., D. Admassu and S. Mengistou. 2000. The food and feeding habit of *O. niloticus* L. (P: Cichlidae) in Lake Chamo, Ethiopia. SENIT: Ethiopian Journal of Science 23:1–12.

Teferi, Y., D. Admassu and S. Mengistou. 2001. Breeding season, Maturity and Fecundity of *O. niloticus* in Lake Chamo, Ethiopia. SENIT: Ethiopian Journal of Science 24:255–264.

Teka, L. 2001. Sex Ratio, Length-weight relationship, Condition factor and the food habit of Catfish *Clarias gariepinus* (Burchell) in Lake Langeno, Ethiopia. MSc thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa. 64 pp.

Tempero, G.W., N. Ling, B.J. Hicks and M.W. Osborne. 2006. Age composition, growth, and reproduction of koi carp (*Cyprinus carpio*) in the lower Waikato region. New Zealand Journal of Marine and Freshwater Research 40:571–583.

Tesfaye, G. and Z. Tadesse. 2008. Length-weight relationship, Fulton's condition factor and size at first maturity of Tilapia, *Oreochromis niloticus* in Lakes Koka, Zeway and Langeno (Ethiopian rift valley). Ethiopian Journal of Biological Sciences 2:139–157.

Tesfaye, G. and M. Wolff. 2014. The state of inland fisheries in Ethiopia: a synopsis with updated estimates of potential yield. Ecohydrology and Hydrobiology 14:200–219.

Teshome, G., A. Getahun, M. Mengist and B. Hailu. 2015. Some biological aspects of spawning migratory *Labeobarbus* species in some tributary rivers of Lake Tana, Ethiopia. International Journal of Fisheries and Aquatic Studies 3:136–141.

Tewabe, D. 2014. Spatial and temporal distributions and some biological aspects of commercially important fish species of Lake Tana, Ethiopia. Journal of Coastal Life Medicine 2:589–595.

Tewabe, D., A. Getahun and E. Dejen. 2010. Diversity and abundance of fishes in Tekeze and Blue Nile basins, Ethiopia. Ethiopian Journal of Biological Science 8:145–163.

Vazirzadeh, A. and S. Yelghi. 2015. Long-term changes in the biological parameters of wild carp (*Cyprinus carpio*) from the south-eastern Caspian Sea. Iranian Journal of Science and Technology 39:391–397.

Wodajo, K. and A. Belay. 1984. Species composition and seasonal abundance of zooplankton in two Ethiopian Rift Valley Lakes-Lake Abiata and Langeno. Hydrobiologia 113:129–136.

Worie, W. and A. Getahun. 2014. Length-weight relationship, condition factor and some reproductive aspects of Nile Tilapia, *Oreochromis Niloticus*, in Lake Hayq, Ethiopia. International Journal of Zoology and Research 4:47–60.

Wudneh, T. 1998. Biology and management of fish stocks in Bahir Dar Gulf, Lake Tana, Ethiopia. Dissertation, Wageningen Agricultural University, The Netherlands. 218 pp.

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