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Some biological aspects and immature fishing of the African big barb *Labeobarbus intermedius* (R.) in Lake Koka, Ethiopia

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Abstract
The investigations were carried out based on the total samples of 266 *L. intermedius* randomly collected from the fishermen's catch from April through August, 2011. Of these 55.6% (n=148) were males and 44.4% (n=118) were females thus male to female sex ratio was 1:0.79 but not significant (χ^2, p>0.05). The peak spawning season of the *L. intermedius* was during the wet season (August). The smallest female fish with ripe gonads was 25.6 cm FL while the smallest male fish was 25.0 cm FL in the lake. The 50% maturity length (L_{50}) was 32.4 cm FL for females and 29.0 cm FL for males. *Labeobarbus intermedius* caught by fishermen about (61.66%) were matured. While (38.34%) were below sexual maturity (immature) and vulnerable to fishing gears before reaching sexual maturity. Therefore, mesh size of the fishing gears needs to be enlarged and avoid fishing during the spawning season for protecting juveniles, fingerlings and mega spawners for sustainable fish resource utilization in Lake Koka.

Keywords: Fishing gears, immature fishing, length at maturity, *Labeobarbus intermedius*

1. Introduction

The African big barb *Labeobarbus intermedius* is a widely distributed fish species in Northern Kenya and in most parts of Ethiopian drainage basins (Dadebo *et al*., 2013) [6]. It is present in Ethiopian rift valley basin, Abay basin and Baro-Akobo basin part of Ethiopia, where Lake Tana harbored the largest population (Vijverberg *et al*., 2012; Awoke, 2015) [2, 38]. It is one of the most commercially important fish species in the country (Desta *et al*., 2006; Bjørklis, 2004) [5, 11]. The total annual yield of *L. intermedius* from the total inland water bodies is estimated to be about 365 tonnes per year (LFDP, 1997) [21]. However, recently the consumption of *L. intermedius* from rift valley lakes (Lake Hawassa and Lake Koka) declined, because it was found to be unsafe for human consumption due to its high mercury concentration (Mengesha, 2009) [23]. In addition, the declining of the fish in natural environments due to overfishing and parasitic infection has resulted the less accessibility of the fish on the local markets (Desta *et al*., 2006; Mengesha, 2009; Dadebo *et al*., 2013) [6, 11, 23].

According to Muluye *et al*. (2016) [29] the number of eggs spawned to recruit a number of young fish in a given aquatic ecosystems and this is related to the availability of sexually mature fish. Sexually matured fish are a key for recruitment and the next harvestable fish stock (LFDP, 1997) [21]. Therefore, the number of fishes attaining recruitment is depends on sexually matured fishes in the water bodies (LFDP, 1997; Muluye *et al*., 2016) [21, 29]. In other way, when the immature fishes migrate into the fishing areas, if these fishes might be captured by inappropriate fishing gears; which in turn results in a depletion of sexually matured fishes in a water body. Similarly, a given aquatic ecosystem might be faced with over exploitation of the fish resources for the upcoming generation (Muluye *et al*., 2016) [29]. Biological parameters and the extent of immature fishery of fish are necessary for sustainable fish management. They can provide valuable information, such as the effect of environmental factors, habitat changes, species interaction and food availability in ecosystem, which used for aquatic ecosystem modeling (Dan-kishiya, 2013) [7]. In addition, knowledge on the reproductive biology of the exploited fish species is vital for effective management of the fish stock and length at first maturity (L_{50}) is important for fish life history that determines the reproductive potential of the unit stock of fish (Tesfaye *et al*., 2016) [36]. Stress, sex, season, availability of food, fishing effort (mesh sizes) and other water quality parameters can affect the biological aspects of fish (Ighwela *et al*., 2011; Tesfaye *et al*., 2016) [17, 36].

Information on the biological aspects and immature fishery of most tropical and sub-tropical fish species is still very limited (Hossain, 2010) [16]. Accordingly, Lake Koka is one of the tropical lakes harboring different types of fish species. Biological aspects of *L. intermedius* (Anteneh *et al*., 2007; Awoke *et al*., 2015; Berie, 2007; Gebremedhin *et al*., 2012) [1, 2, 4, 14], length at first maturity (Anteneh *et al*., 2007; de Graaf *et al*., 2003; Tesfaye *et al*., 2016) [1, 9, 36] were studied in Ethiopian water bodies. However, little is known about sex ratio, spawning season, length at maturity and the level of immature fishing of *L. intermedius* in Lake Koka. Therefore, the present study was conducted to fill this gap and to provide useful information for the proper management of fish to continued fishing in Lake Koka.

2. Materials and Methods

2.1 Descriptions of the study area

Lake Koka is located in the central Ethiopian Rift Valley100 km away from the capital Addis Ababa at an altitude of 1590 m a.s.l (Fig. 1). It covers about 180 km^2surface area with the mean depth of 9 m (Kibret, 2010) [18]. The area is characterized by a semi-arid to sub-humid climate (Peder, 2009) [33]. The main rainy season starts in June and extends to the end of September, while the short rainy season occurs from March to May. The maximum and minimum annual mean temperature of the surrounding air is 30.4 ˚C and 14 ˚C, respectively. The pH and conductivity of the lake is about 8.03 and 412 µS cm^{-1}, respectively. The phytoplankton biomass of the lake is about 5.9 mm^3L^{-1}, which dominated by Microcystis (Mesfin, 1998) [26]. The zooplankton diversity is, however, very low (Peder, 2009) [33]. The lake is serving for different purposes, such as hydroelectric generation and irrigation (which accounted for about 6000 ha.Wonji Sugarcane Project). As a result, the holding capacity of the lake has reduced from 1650 million m^3 in 1959 to 1186 million m^3 due to sedimentation over 25 the years. The lake is also important for fishing activities, mainly for the people living in the vicinity of the lake. The fishery of Lake Koka is dominated by five fish species: Nile tilapia *(Oreochromis niloticus*), Common carp (*Cyprinus carpio),* the African catfish (*Clarias gariepinus),* African big barb (*L. intermedius)* and small cyprinodont minnow (*Aplocheilichthyes antinorii*). The total annual fish landing from the lakes is estimated to be about 625 tonnes/ year, where Nile tilapia takes the largest part of the catch (cover about 59% (327 tonnes) of the total landings per year) (LFDP, 1997) [21].

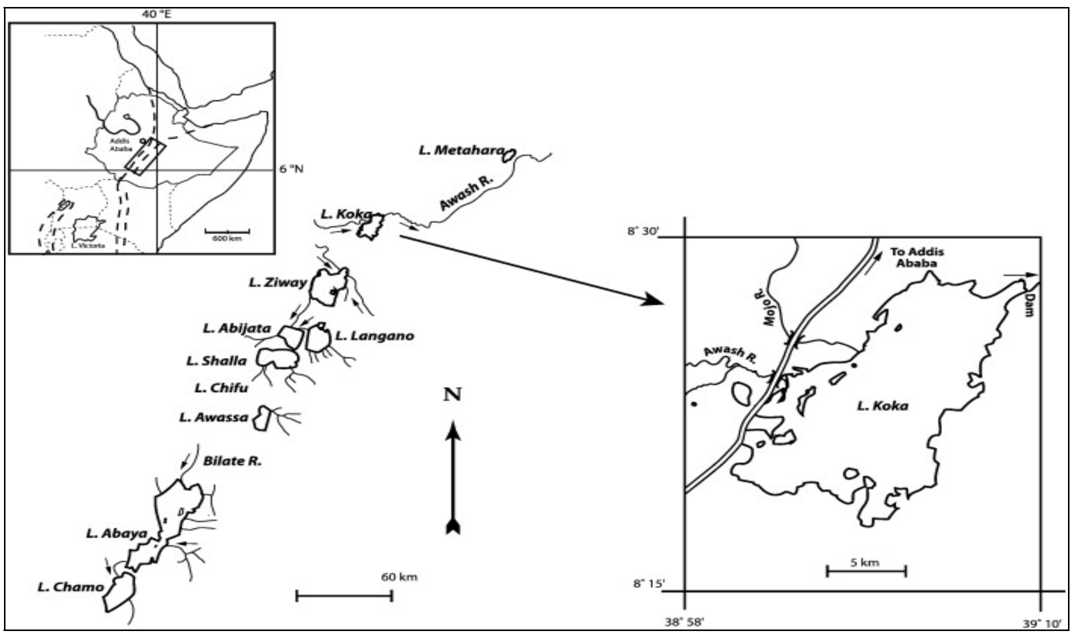

Fig 1: Map of the study area

2.2 Fish sample collection and measurements

A total of 266 *L. intermedius* samples were randomly taken from the fishermen's catch from April through August, 2011. The total length (TL, cm) and total weight (TW, g) of fish were measured using a measuring board to the nearest 0.1 cm, and sensitive balance with sensitivity of 0.1 g.

Fig 2: Photos captured during fish measurement in the laboratory.

2.3 Estimating of gonad maturity stages

Sex, gonad maturity stages and their descriptions of *L. intermedius* were determined using the method gonad maturity stages and descriptions for cyprinids which were employed by (Nagelkerke, 1997) [30] (Table 1). Each fish was dissected to determine sex and maturity by visual examination of the gonads using a five point maturity scale. According to Nagelkerke (1997) [30] the maturity stage of a given fish was described based on the size, shape, color, texture, and the space the gonads occupy in the body cavity of fish. Similarly, fish were grouped as immature (I), recovering spent or developing virgin (II), ripening (III), ripe (IV) and spent (V). All fish with gonad maturity stage of I and II were categorized as immature fish while fish with maturity stages of III and above were grouped as mature (Omotosho, 1993; Wudneh, 1998) [32, 39].

Table 1: Gonad maturity stages and their description for cyprinids (Nagelkerke, 1997)

Gonad stages	Male	Female
I	Immature, impossible to distinguish females from males. Gonads are a pair of transparent strings running along the body cavity.	Immature, impossible to distinguish females from males. Gonads are a pair of transparent strings running along the body cavity.
II	Unambiguously male, very small testes, white-reddish, not lobed, tube-shaped strings.	Unambiguously female, very small ovaries, tube-shaped and reddish, eggs not visible.
III	Larger testes, white-reddish, somewhat lobed starting to flatten sideways.	Ovary somewhat larger and starting to flatten sideways, eggs visible, but very small.
IV	Large testes, white-reddish, lobed, flattened sideways.	Large ovary, flattened sideways and almost covering body cavity wall, eggs yellowish.
V	Spent, empty testes, reddish and wrinkled	Spent, wrinkled ovary, reddish, containing a few yellow eggs

2.4 Determination of Spawning Season

The breeding season of *L. intermedius* was determined from the seasonal catch of fish with ripe gonads. The proportion of fish with their respective gonad stages was computed within dry and wet season.

2.5 Estimating of length at maturity

The average length at which 50% of the fish had mature gonads (L_{50}) was estimated for the fish using a logistic relationship established between the proportion of mature fish per length class and fish length (King, 1995) [19].

$$PM = \frac{1}{(1 + \exp - (a + b * L))}$$

Where, PM = the proportion of mature fish in the length groups

L = the length groups (cm)

a and b are the intercept and the slope of the relationship

Parameter estimates for the above relationship were obtained by fitting a logistic regression using a non-linear curve fitting procedure. The average length at which 50% (L_{50}) of the fish possessed mature gonads was estimated by dividing the intercept (a) by the slope of the above relationship and it is considered as the length of first sexual maturity (Omotosho, 1993) [32].

2.6 Sex ratio

Sex ratio male to female was determined using the following formula

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

2.7 Data analysis

SPSS version 16.0 was used to determine length at first maturity (L_{50}) of mature fish by using logistic regression curve. In addition to this, Chi-square was computed to estimate sex ratio between the sexes.

3. Results

3.1 Sex ratio

The male to female ratio was 1:0.79. Generally, males were slightly numerous than females in the total sexed specimen. The sex proportion of *L. intermedius* was however insignificant (χ^2, $P>0.05$).

3.2 Spawning season of *L. intermedius*

The proportion of *L. intermedius* with respective of their gonads was peak in wet season. In other way, most of the fish had ripe gonads (stage four) accounted for nearly 75% in wet than dry season (fig. 3).

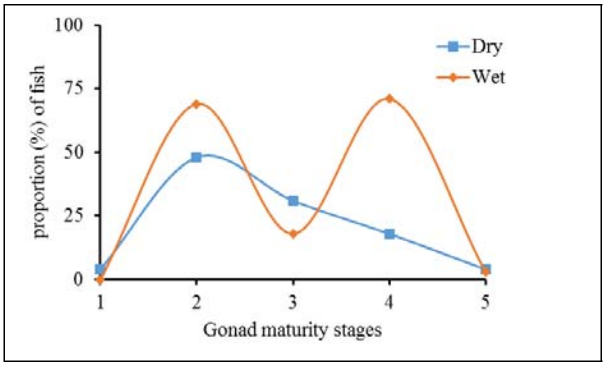

Fig 3: Proportions of *L. intermedius* caught during the dry and the wet season in relation to Gonad stages.

Note: For detailed information about gonad maturity stages and their descriptions of *L. intermedius* refer (table 1 above).

3.3 Length at sexual maturity

The smallest female fish found with ripe gonads was 25.6 cm FL and weighed 162.2 g while the smallest male in breeding condition was 25.0 cm FL and weighed 205.3 g. The 50% maturity length (L_{50}) was estimated to be 32.4 cm FL for females and 29.0 cm FL for males (Fig. 4). In addition, for combined sex the length at first sexual maturity was 30.2 cm FL. On the average, males appeared to attained sexual maturity at smaller size than females.

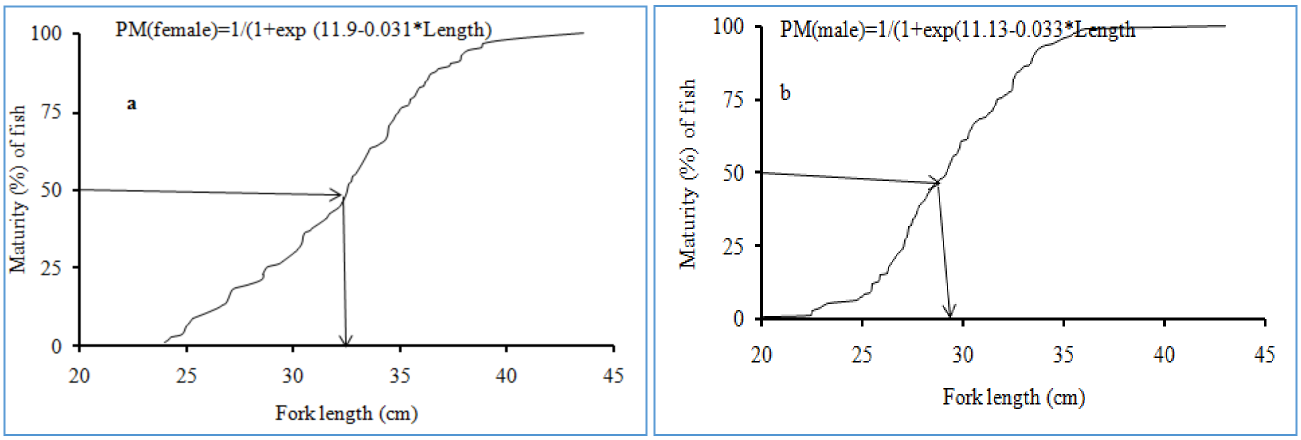

Fig 4: The proportion in different length groups of mature females (a) and males (b) of *L. intermedius* in Lake Koka.

NB: the logistic curve that gives the expected proportion of maturity (PM) at each length is shown for female (a) and male (b) fish with their equation. Solid arrow line indicates the length at which 50% of the fish possess mature gonad (average lengths at first maturity).

3.4 The level of immature fishing in the lake

The average length at which 50% of the fish reached maturity for the first time (L_{50}) was 29.0 cm and 32.4 cm FL for males and females, respectively (Fig 4). Table 2 indicates that parameter estimates for the regression fit and the lower and upper 95% confidence intervals for length at first maturity (L_{50}) of male (25.8 and 32.58 cm, respectively) and female (28.08 cm and 36.52 cm, respectively). This indicates that the (L_{50}) estimates for males (29.0 cm FL) were early matured than females (32.4 cm FL). Out of the total 266 *L. intermedius* were randomly collected from the fishermen's catch, 38.34% were below 29.0-34.4 cm FL of size class, they considered as below length at first sexual maturity (i.e., immature fish), indicating the presence of immature fishing pressure of *L. intermedius* in the lake. Whereas, (61.64%) of *L. intermedius* caught by fishermen were matured because of the fish size above 29.0-34.4 cm FL size class. This indicates that only one fifth (61.64%) of the *L. intermedius* population has the opportunity to reproduce while (38.34%) are caught before reaching sexual maturity by the fishermen (Table 3).

Table 2. Maturity parameters for *L. intermedius*

Maturity parameters	Values	Standard Error	95% confidence interval (CI)	
Female *L. intermedius*			Lower 95% (CI)	Upper 95% (CI)
• a	11.9	0.097	11.69	12.08
• b	0.031	0.00	0.030	0.031
• L (50) FL (cm)	32.3		28.08	36.52
• R^2	0.99			
Male *L. intermedius*				
• a	11.13	0.86	10.96	11.3
• b	0.033	0.00	0.032	0.033
• L (50) FL (cm)	29.0		25.58	32.58
• R^2	0.99			

Table 3. Length classes of *L. intermedius* collected from the fishermen's catch.

Length classes fork length (cm)	Number of fish	Number of fish (%)	
20.1-24.7	**13**	**4.88**	**38.34% (immature)**
24.8-27.4	**57**	**21.43**	
27.5-28.9	**32**	**12.03**	
29.0-34.4	118	44.36	61.66% (matured)
34.5-36.7	31	11.65	
36.8-43.6	15	5.64	
Total	266	100	

4. Discussion

Males were slightly numerous than females during the present study. The unequal sex ratio was reported in different parts of Ethiopian water bodies. Accordingly, various authors reported (Gebremedhin *et al*., 2012) [14] in Arno-Garno River, (Tesfaye, 2006) [37] in Angereb and Sanja Rivers, (Berie, 2007) [4] in Beles and Gilgel Beles Rivers, (Melaku *et al*., 2017) [24] Geba and Sor Rivers, (Gebremedhin and Mengist, 2014) [13] in Aveya River, (Awoke *et al*., 2015) [2] in some tributary rivers of LakeTana that sex ratio was deviated from 1:1. This difference might be obtained by different biological mechanisms such as difference in maturity rates, difference mortality rates and difference in habitat preferences between the male and female sexes may be the cause of unequal sex ratios. In addition to this, most probably related to vulnerability of the fishing gears that can be the cause for the deviation from 1:1 sex ratio (Berie, 2007; Gebremedhin *et al*., 2012) [4, 14].

The peak spawning season of *L. intermedius* was in the wet season (August). Comparable, studies were conducted (de Graaf *et al*., 2005) [9] in Lake Tana, (Gebremedhin *et al*., 2012) [14] in Arno-Garno Rivers, (Anteneh *et al*., 2007) [1] in Dirima and Megech Rivers, (Teshome *et al*., 2015) [35] in some tributaries rivers of Lake Tana reported that the peak-spawning season for the *L. intermedius* is through August to October.

According to FAO (1984) [12] length at first maturity of fish is considered as a minimum harvestable size of a given fish species. In the present study the average length at first sexual maturity for female *L. intermedius* was 32.4 cm FL, which is less than 37.5 cm FL reported by Gerber (*et al*., 2012) [15] for the *L. aeneus* in the middle Vaal River, South Africa. However, the length at first maturity of female fish in this study was longer than in Lake Tana (22.57 cm FL) (Anteneh *et al*., 2007) [1]. In the same way, the length at first maturity of male *L. intermedius* reported in this study (29.0 cm FL) is longer than that reported by (Gerber *et al*., 2012) as 25.4 cm FL. For combined sex, the size at first maturity of *L. intermedius* was 30.2 cm FL. However, it was greater than (Leveque and Daget, 1984) [22] in freshwater lake of Africa, (de Graaf *et al*., 2003) [9] in Lake Tana, (Tesfaye *et al*., 2016) [36] in Lake Koka reported as 28.5 cm FL, 26.5 cm FL and 28.1 cm FL length at maturity for the same species respectively. In conclusion, males mature at a younger age and smaller size than Females. The differences in spawning season and length at maturity between the populations of *L. intermedius* can be attributed to the fact that being related to the environmental conditions and recruitment success of fish (Gerber *et al*., 2012) [15]. Variations in biological factors, such as availability of foods, quality and quantity of food, feeding rate of fish that affects the spawning period and growth rate differences among the different *L. intermedius* stocks in the respective lakes (Suquet *et al*., 2005; Muluye *et al*., 2016) [34, 29]. For instance, spawning season of fish was peak during in the wet season. This might be associated with high abundance of food items like macrophytes and insects in the diet of African big barb in the wet season due to rainfall season of Ethiopia. In addition, the seasonal flooding can contribute in the water through bringing nutrients from the environment, and help in mixing autochthonous nutrients amongst the different strata of lake, which trigger the increasing of fish food items production (Mergeay *et al*., 2012; Okogwu, 2010) [25, 31].

In addition, physiological and biological factors of the fish affect the fish growth (maturity) (Zdanowski *et al*., 2001) [40]. The gonad development and rate of fish growth also affected by environmental factors, such as water temperature, oxygen concentration, salinity and photoperiod (Gerber *et al*., 2012; Zdanowski *et al*., 2001) [15, 40].

Many studies indicated that the interaction of both physical and chemical properties of the water (Deepak and Singh, 2014) [10], biological factors (Teshome *et al*., 2015) [35] and the pressure of overfishing (Mohammed and Uraguchi, 2013) [27] determine the size of fish in the water. For instance, biological factors, such as availability of fish in the water, fish behavior towards the fishing gear, shape, and external features of the fish, which depends on season, age, environment and other species, determine the size of fish in the catch (Kolding *et al*., 2003) [20]. In addition, human factors, such as fishing effort, gear type, mesh size and other factors (e.g. time of year, location, catch ability, quotas) decide the catch volume and size distribution of the catch (Mous *et al*., 2004) [28]. The environmental factors, such as water temperature (Davis and Parker, 1990) [8] and water salinity (Barton and Zitzow, 1995; Mous *et al*., 2004) [3, 28] also influence the size of the fish catch. In conclusion, size at first maturity of a given fish is a plastic trait that mainly depends on the genes and the environment in which they live as documented by (Tesfaye *et al*., 2016).

According to the FAO (1984) [12] report to conserve sustainable fish resource, commercial catching of fishes should be considered after reaching length at first sexual maturity. Therefore, length at first maturity of fishes is assumed as a minimum harvestable size of a given fish species (FAO, 1984) [12]. Based on the present study, *L. intermedius* were below 29.0 cm FL for male and 32.4 cm FL for female (length at first sexual maturity) should not be caught to sustainable fishery (Table 3). However, high proportions of *L. intermedius* caught (38.34%) were below length at first maturity (immature fish) (Table 3) as *L.*

intermedius starting from 20.1 cm FL were vulnerable to the mesh of the gill nets used by fishermen in Lake Koka. This is might be accidental capture of *L. intermedius* by the gill nets set to capture *Oreochromis niloticus* as reported in Lake Hawassa (Muluye *et al*., 2016) [36] and this is might be true for the present study. The smallest mesh size (6 cm) caught high amount of *L. intermedius* (31-34 cm FL) while 8 cm mesh sized gillnet caught a smallest amount of larger fish (34-37 cm FL) in Lake Koka (Tesfaye *et al*., 2016) [36]. In the line of this, fishermen most probably used 6 cm mesh size which resulted in immature fish harvesting. In other way, ≥8 cm mesh size is recommended for *L. intermedius* because of the fish should be caught after attainment of length at first maturity. The awareness of fishermen on the length at first sexual maturity is very limited. For instance, very few fishermen (1.3%) know the correct length at first sexual maturity of fish and (50.6%) of the fishermen did not know whether the catch fish is mature or immature as documented in Lake Hawassa (Muluye *et al*., 2016) [36] and this might be applicable for the present study. This leads to overfishing towards the sustainable use of the fish resource for the future generation to poverty alleviation. Accordingly, overfishing is resulted by poorly regulated high fishing effort by the commercial gillnet fishing during spawning season of adult barbs due to migration in river mouths (de Graaf *et al*., 2003) [9]. There was high immature fishing in the present study, when compared to Lake Tana's fishery. According to de Graaf *et al*. (2003) only (15%) were immature while (85%) of the large barbs were matured landed by the fishermen's gillnet in Lake Tana. In conclusion, awareness creation among fishermen as well as proper fishing regulations is urgently required to the continued fishing.

5. Conclusions

During the present study, it can be concluded that the peak spawning season of the *L. intermedius* was during the wet season (August). The smallest female fish with full ripe gonads was 25.6 cm FL while the smallest male fish was 25.0 cm FL in the lake. The 50% maturity length (L_{50}) was 32.4 cm FL for females and 29.0 cm FL for males. Based on this study, there was high immature fishing because of (38.34%) *L. intermedius* were below length at first sexual maturity and vulnerable to fishing gears for commercial fishery while (61.66%) were matured. Therefore, mesh size of the fishing gears needs to be widened and avoid fishing during the spawning season for protecting juveniles and mega spawners for sustainable fish resource utilization in Lake Koka.

6. Conflict of interest

The author declares that there is no conflict of interest.

7. Acknowledgements

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